Water quality in four regions of the Maryland Coastal Bays: assessing nitrogen source in relation to rainfall and brown tide.

Data Report

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Conclusions

Following on from a survey conducted in May of 2004, the current study was targeted to four small regions within the Coastal Bays, to assess in detail the nutrient inputs and sources within these regions. In that previous study, St Martins River is identified as a region with high nutrient inputs and overall poor water quality. St Martins River was included in the current study to further assess sources and inputs to this region. The 2004 study also identified Public Landing and Johnson's Bay as areas with poor water quality due to high total phosphorus, high turbidity and low dissolved oxygen – with no obviously apparent point of riverine source of this poor water quality. Similarly, the Chincoteague Island region showed relatively low water column total nitrogen, but high $\delta^{15}N$ (natural isotope abundance), suggesting possible human-derived sources of nitrogen to this area.

Regions identified as potentially problematic with regional $\delta^{15}N$ assessment, were spatially resolved with fine scale nutrient sampling.

The current detailed study was effective in clarifying that these four regions of the Maryland Coastal Bays do indeed show a range of water quality issues largely related to nutrient inputs, above concentrations suitable for maintaining key ecosystem services.

Oysters may provide a better integrated picture of nitrogen source than macroalgae

At the finer resolution presented in the current study, the longer term of integration provided by the oyster deployment (three months) was beneficial to determine patterns in nitrogen source. While four day deployments of the macroalgae were effective for broad spatial scales with a larger total range of values (Jones et al., 2004), at small spatial scales with only small variation the macroalgae did not clearly detect patterns. In the current study, deployed macroalgae were still effective at detecting patterns between regions (and in some cases within regions).

High water temperatures pose a threat to seagrass

Distinct seasonality was measured across all regions within the Coastal Bays, with in increase from a mean water temperature of 21.7 (±1.6, sd) in May up to a mean of 30.3 (±1.4, sd) in July. The high water temperatures were acute inshore within Johnsons Bay and in Chincoteague, both areas whith extensive seagrass meadows which could be negatively impacted by extended periods with water temperatures over 30°C.

Johnsons Bay shows evidence of local freshwater and nutrient inputs inshore

After rain in July, a clear signal of lower salinity water was observed inshore in Johnsons Bay, suggesting groundwater or overland flow to this area. This input of water was reflected in higher water column total nitrogen as well as elevated $\delta^{15}N$ in oyster tissue in the southern region of Johnsons Bay.

Public Landing shows evidence of local inputs of nitrogen and phosphorus

Higher water column total nitrogen and elevated $\delta^{15}N$ in Oyster tissue inshore and in the northern region of Public Landing suggests that there is a local source of this nitrogen, contributing to the poor water quality in this region of the Coastal Bays.

St Martins (a mini estuary) shows high total nutrient inputs and a flushing gradient.

The only possible local or point source of nutrients to St Martins River was near to Shell Gut Point, but in general, the large diffuse load coming from upstream overwhelms any smaller scale inputs.

Complex waterflows from the inlets around Chincoteague Island influence sources of nitrogen identified with macroalgal and oyster bioindicators.

In the northern, central and southern regions of the Chincoteague Island sampling region macroalgae and oyster bioindicators revealed a complex pattern of highly processed nitrogen, consistent with local but low concentration wastewater inflows.

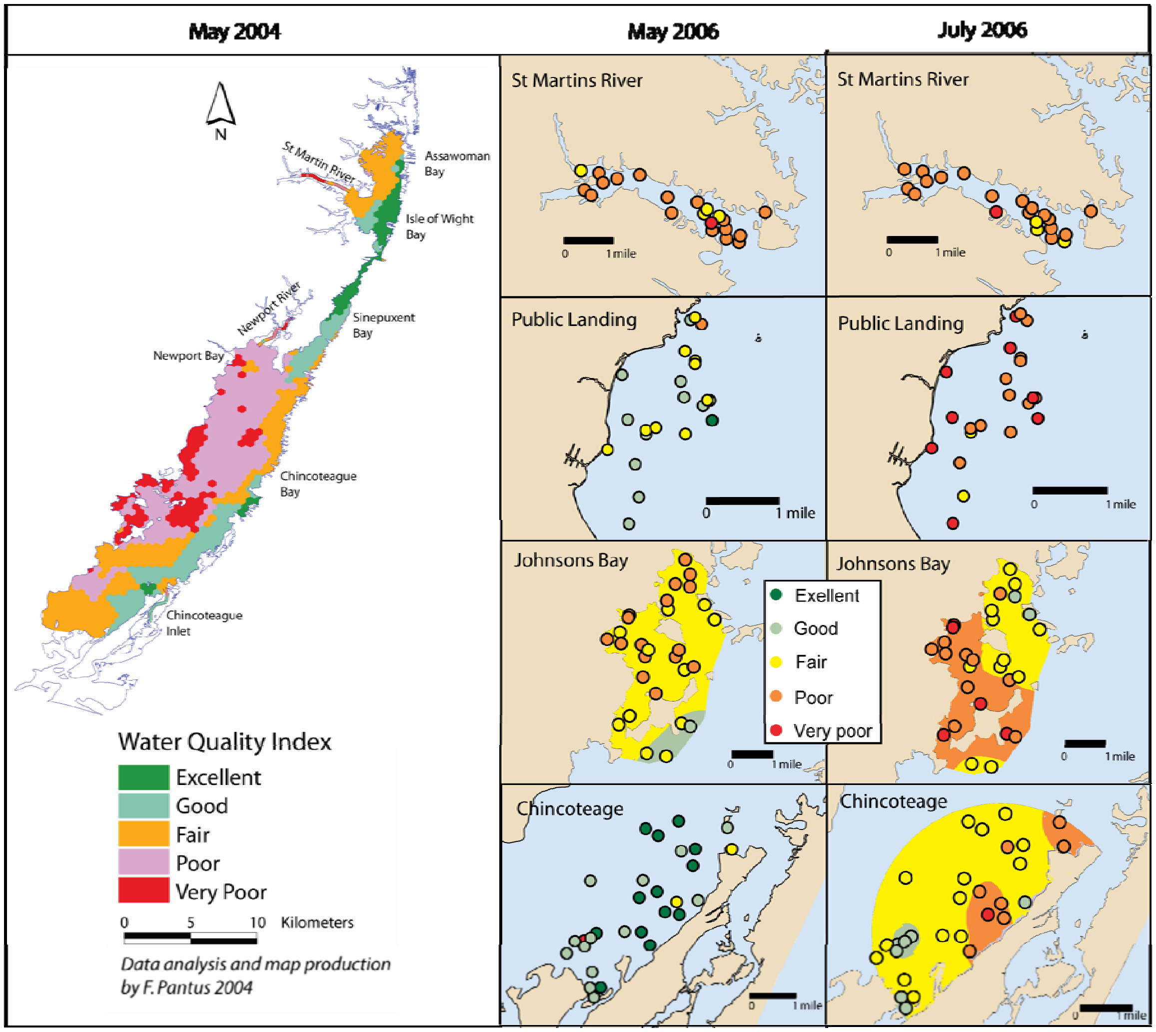

Figure 1: Water Quality Index before and after a rain event for four regions within the Maryland Coastal Bays.

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Introduction

Maryland's Coastal Bays are shallow water bodies (less than 3 m deep) that are uniform in depth (Figure 2), occurring between a small coastal watershed (175 sq. miles) and sandy barrier islands. Tidal exchange is limited, and restricted to the Ocean City and Chincoteague inlets. River input is low and groundwater is an important source of freshwater inflow. The Coastal Bays receive inputs from a range of nutrient sources, including wastewater treatment plants, septic systems, agricultural inputs, stormwater and urban runoff. Comparatively, Maryland's Coastal Bays have fewer human impacts than Chesapeake Bay, but the limited water exchange makes them more susceptible to nutrient increases.

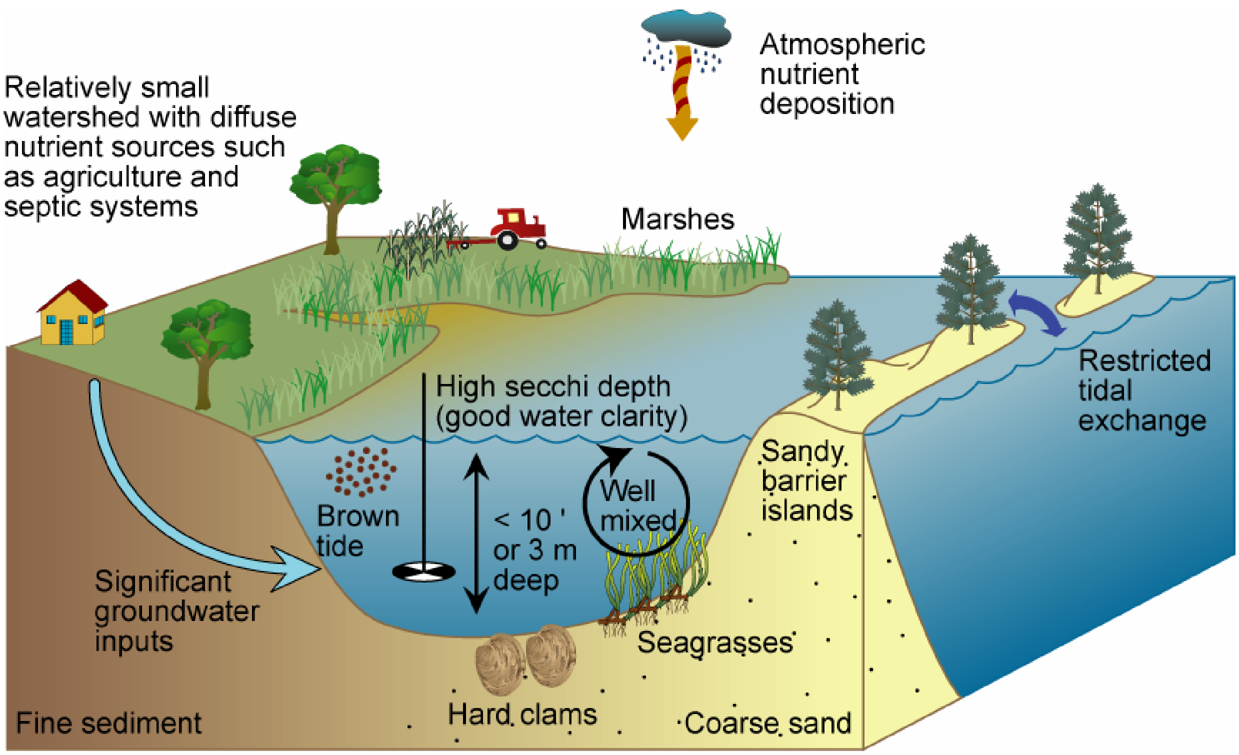


Figure 2: Conceptual diagram showing the key physical and biological processes within the Maryland Coastal Bays (after Wazniak *et al*., 2004)

An intensive study of the water quality of the Maryland Coastal Bays, carried out during July 2004, concluded that while water quality within St Martins River and Newport River was poor, there was also a large region of Chincoteague Bay with water quality below threshold values for maintenance of ecosystem services such as seagrass and fisheries (Figure 3; Jones et al., 2004). Low water quality resulted from high turbidity and water column total phosphorus as well as regions of low dissolved oxygen (Jones et al., 2004).

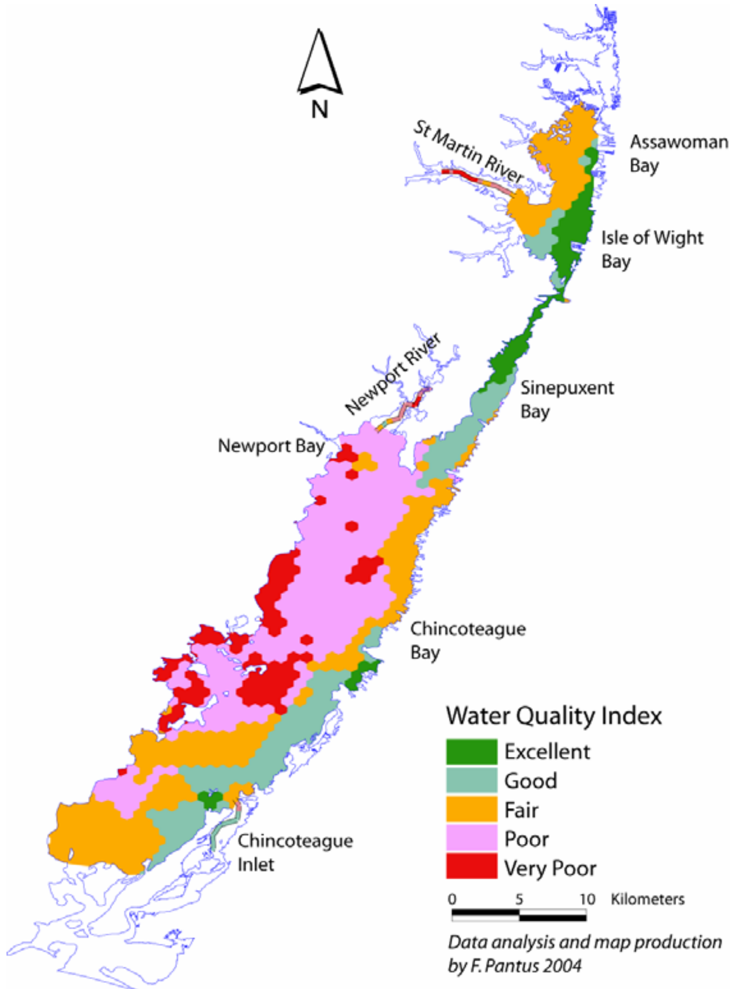


Figure 3: Integrated water quality index from an intensive survey during 2004 (after Jones et al., 2004)

A recent summary of long term data within the southern Coastal Bays of Maryland came to a similar conclusion, suggesting that even though water column nutrients and Chorophyll *a* are lower than they have been in the past, these trends have not only flattened out but in many cases are once again increasing (Figure 4). This raises the question of what is leading to these increases in nutrients, as while the northern Coastal Bays are showing extensive development, Chincoteague watershed is largely free from intensive urban development (Figure 5).

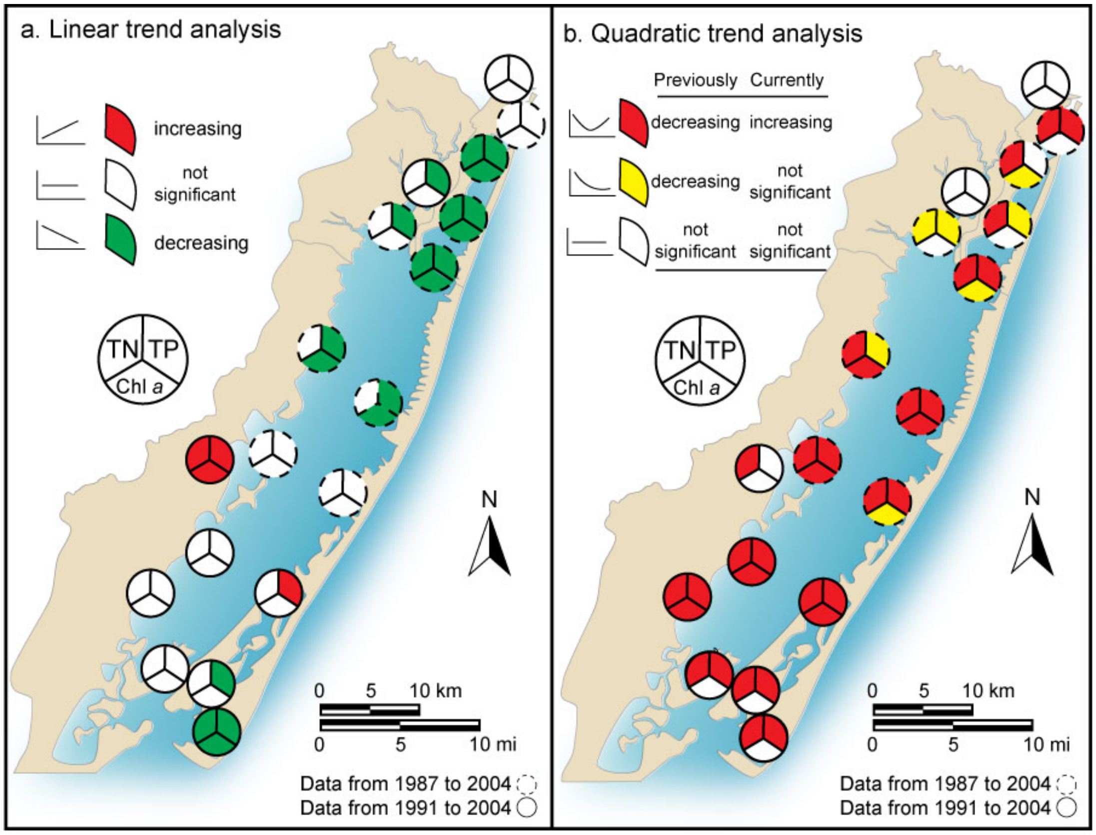


Figure 4: Summary of linear (a) and quadratic (b) trends in total nitrogen, total phosphorus and Chlorphyll *a* over more than a decade in the southern Coastal Bays (after Wazniak et al., 2006)

The slow flushing times (months) in the Coastal Bays result in a system where the water quality is strongly impacted by land use. The northern sections of the Coastal Bays are more heavily developed, particularly in the region of Ocean City, whereas the southern sections are predominantly agriculture and forest (Figure 5).

Determining the impacts and extent of sewage and septic derived nitrogen in marine systems with multiple inputs (both point and non-point source) is typically problematic, and it has been shown that physical and chemical water quality monitoring techniques are unable to determine the ecological impact of wastewater discharges. Biological indicators have long been used to determine ecological impacts of point source discharges (Worf, 1980; Kramer, 1994). The key feature of biological indicators is their ability to provide temporally and spatially integrated insights into the biological impacts of changes in anthropogenic activity. Unlike traditional chemical analyses of water column nutrients, these biological indicators measure the biologically available nutrients therefore providing more ecologically meaningful information.

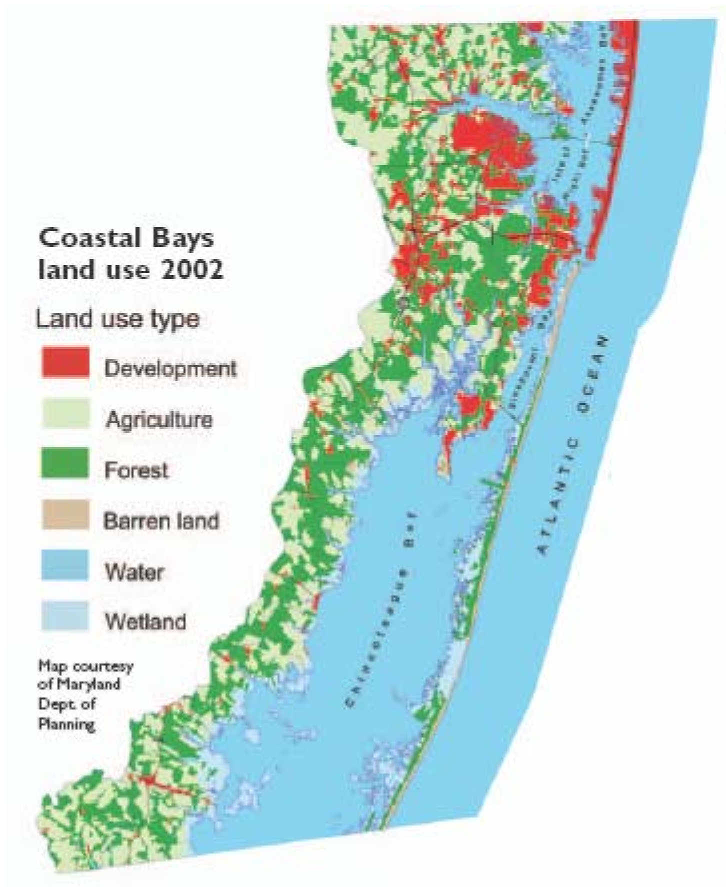


Figure 5: Land use map of the Maryland Coastal Bays (Map courtesy Maryland Department of Planning).

The study of Jones et al. (2004) documented patterns in total nitrogen consistent with nutrient inputs from the two main rivers (St Martins River and Newport River) gradually being diluted by ocean inputs through the Ocean City and Chincoteague inlets (Figure 6a). However, the use of macroalgae as a biological indicator of integrated $\delta^{15}N$ showed that some regions (eg Johnsons Bay and Chincoteague Island) with low concentration of total nitrogen have highly processed nitrogen (high $\delta^{15}N$ Figure 6b) which indicates possible local sources, perhaps of sewage nutrients or other effluent. The stable isotope analysis ($\delta^{15}N$) of aquatic plants has proven successful in identifying the location and extent of plumes from sewage treatment plants, aquaculture farms, septic outfalls and agriculture (Costanzo *et al.* 2001; Jones *et al.* 2001).

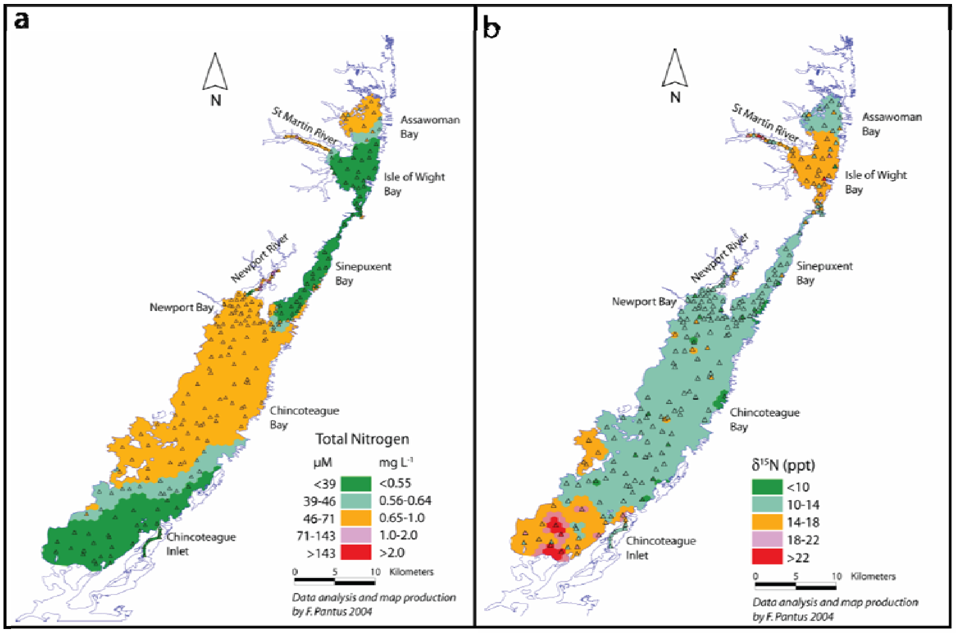


Figure 6: Comparison of total water column nitrogen (a) and $\delta^{15}N$ (b) throughout the Maryland Coastal Bays in June 2004 (after Jones *et al*., 2004).

All biological processing of nitrogen can result in changing the natural abundance ratio of nitrogen, including repeated nitrogen recycling by bacteria (Fourqurean et al., 1997), so this study aimed to identify whether regions in southern Chincoteague Bay and Johnsons Bay with elevated $\delta^{15}N$ have highly processed nitrogen inputs (eg from effluent) or whether there is little flushing and therefore high rates of recycling of nitrogen within these regions.

The project also aimed to assess the usefulness of oysters as a potential integrator of $\delta^{15}N$, as they have the potential to integrate over longer time periods (months) than deployed macroagae (4 days). The eastern oyster, (*Crassostrea virginica*) is potentially a simple yet powerful spatial and temporal indicator of nitrogen sources. When deployed in a spatial network along the coastal bays, oysters can provide spatially explicit baseline datasets of biologically important nitrogen sources to focus nutrient reduction strategies. Eastern oysters are euryhaline suspension filter feeders that derive nitrogen from a variety of spatially variable sources including microorganisms, phytoplankton, detritus and inorganic particles (Langdon and Newell 1996, Newell and Langdon 1996). Sydney rock oysters (*Saccostrea commercialis*) turn over nitrogen at different rates in different tissues and thus potentially provide a provide a long-, medium-, and short- term integrated history of nitrogen sources (Moore 2003). Analyzing the muscle, gills, and mantle, oysters provides this history for 1-2 weeks, 2-4 weeks, and > three months (Moore, 2003). This can be analyzed by $\delta^{15}N$ natural abundance.

The overall aim of this project was to conduct a comprehensive, spatially intensive survey of four regions of the Maryland Coastal Bays, St Martins River, Public Landing, Johnsons Bay and Chincoteague, analyzing stable nitrogen isotope ratios of ($\delta^{15}N$), together with traditional water quality parameters (dissolved oxygen, temperature, salinity, total nitrogen, total phosphorus and chlorophyll *a* concentration) to assess the sources and distribution of nutrients within these regions. These parameters were combined to produce a water quality index (WQI). Finally, bacteria counts were carried out to assess overall concentrations within Public Landing and Chincoteague, to assess whether bacterial source tracking might be used in the future to determine the sources of fecal bacteria and establish whether fecal bacteria and associated nutrients are being introduced into water bodies through human, wildlife, agricultural, or pet wastes.

Methodology

Study Region

The Maryland Coastal Bays comprise a series of shallow lagoons behind Fenwick and Assateague Islands. In May and July of 2006, an intensive field sampling program (248 sites) was conducted to measure a suite of water quality parameters and to determine the $\delta^{15}N$ isotopic signature of deployed macroalgae (*Gracilaria sp*) and oysters (*Crassostrea virginica*). Site locations were generated randomly using ArcView software, with the number of samples based on variability in spatial data collected in a previous survey (Jones *et al*., 2004). Four regions were targeted to obtain a more detailed understanding of sources of nitrogen within St Martins River, Public Landing, Johnsons Bay and along Chincoteague Island (Figure 7).

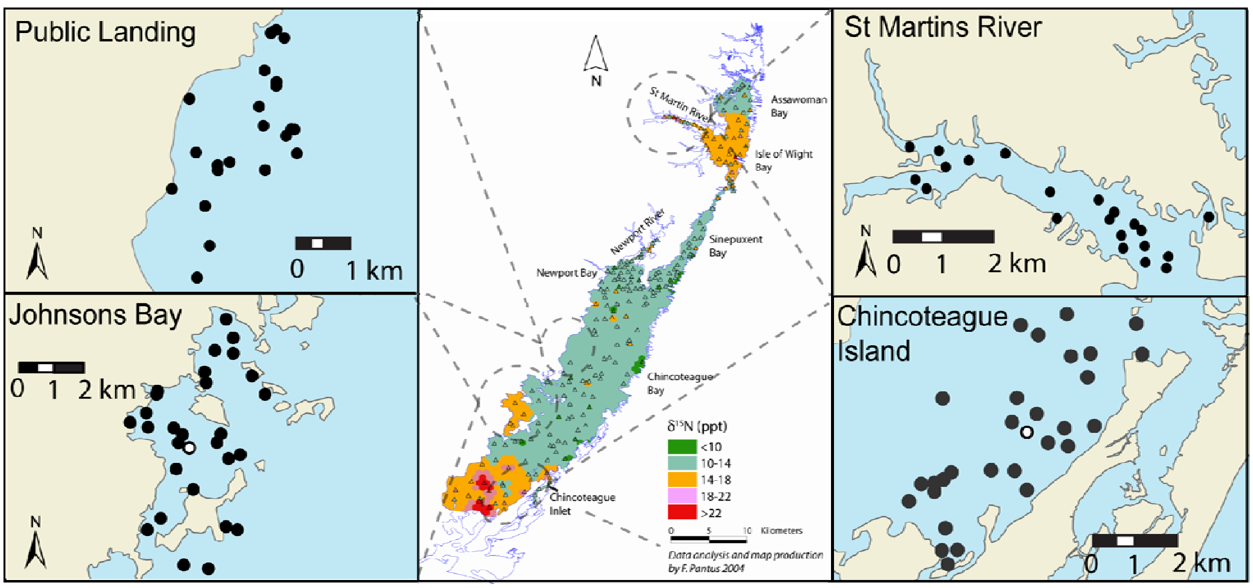


Figure 7: Map of the Maryland Coastal Bays showing the nitrogen isotope map from the 2004 survey which assisted in choosing the four regions sampled intensively in 2006: Public Landing (22 sites), Johnsons Bay (28 sites), St Martins River (21 sites) and Chincoteague Island (29 sites). The two continuous monitoring locations In Johnsons Bay and off Chincoteague Island are shown in white (Figure 7, Table 1). .

Table 1. Reporting region statistics detailing five regions with spatial predictions and three regions with linear predictions.

Reporting region	Extent	Unit	# sample sites	sample density	unit
St Martins River	6.97	km^2	21	3.0	samples/km^2
Public Landing	13.22	km^2	22	1.7	samples/km^2
Johnsons Bay	19.6	km^2	20	1.0	samples/km^2
Chincoteague Island	18.29	km^2	31	1.7	samples/km^2

Water quality sampling

Salinity, pH, temperature and dissolved oxygen (DO) were measured with a WTW water quality probe. Secchi depth was determined by lowering a 20 cm diameter Secchi disk through the water column until it was no longer possible to distinguish between the black and white quadrants.

Continuous monitoring

Two continuous monitoring stations were established for comparison to the once off spatial intensive sampling. Locations of continuous monitors were off Chincoteague Island (Lat 37.96331N, Long 75.35500W) and in Johnsons Bay (Lat 38.06611N, Long 75.34492W) (Figure 7).

Water column nutrients

Total nitrogen and total phosphorus were determined by collecting water samples in pre-rinsed containers, placed on ice and returned to the laboratory where they were frozen for subsequent analysis in accordance with the methods of Clesceri *et al.* (1989).

Chlorophyll a

Chlorophyll *a* concentrations were used as an indicator of phytoplankton biomass. At each site, Chlorophyll *a* concentration was determined by filtering a known volume of water through a Whatman GF/F filter which was immediately frozen. In the laboratory, the filter was ground in acetone to extract chlorophyll *a*, spectral extinction coefficients were determined on a fluorometer.

Microbial Source Tracking

At all sampling stations in Johnsons Bay and Chincoteague (May) and all stations in Public Landing and Johnsons Bay (July), 60 ml of surface water was collected. These were plated onto 'ColiPlate testkits' produced by Bluewater Biosciences and incubated at 35 °C for 24 hours, before reading.

Stable isotope technique

Gracilaria sp. (a red macroalgae) was collected from Greenbackville on the Maryland/Virginia border. Sub-samples were analyzed for their initial $\delta^{15}N$ isotopic signature. At each site, the macroalgae were incubated for four days in transparent, perforated chambers at half Secchi depth (Costanzo *et al*., 2001). Samples were oven dried to constant weight at 60 °C, ground and oxidized in a CN Biological Sample Converter. The resultant N_2 was analyzed by a continuous flow isotope ratio mass spectrometer. Total %N was determined, and the ratio of ^{15}N to ^{14}N was expressed as the relative difference between the sample and a standard (N_2 in air) using the following equation (Peterson & Fry, 1987):

$\delta^{15}N = (^{15}N/^{14}N \text{ (sample)} / ^{15}N/^{14}N \text{ (standard)} - 1) \times 1000$ (‰).

Nitrogen (N) occurs in two naturally stable forms, ^{15}N and ^{14}N, with the predominant form being ^{14}N (99.6%). The various sources of nitrogen often have distinguishable ^{15}N to ^{14}N ratios, thereby making it possible to identify the source of the nutrients (Heaton, 1986). Stable isotope ratios of nitrogen ($\delta^{15}N$) have been used widely in marine systems as tracers of discharged nitrogen from point and diffuse sources, including sewage effluent (Rau *et al.*, 1981; Heaton, 1986; Wada., 1980; Van Dover *et al.*, 1992; Macko & Ostrom, 1994; Cifuentes *et al.*, 1996; McClelland & Valiela, 1998). Plant $\delta^{15}N$ signatures have been used to identify nitrogen sources available for plant uptake (Heaton, 1986). Elevated $\delta^{15}N$ signatures in seagrass, mangroves and macroalgae have been attributed to plant assimilation of N from treated sewage effluent (Wada, 1980; Grice *et al.*, 1996; Udy & Dennison, 1997; Abal *et al.*, 1998, Carruthers et al., 2005). The elevated $\delta^{15}N$ signature subsequent to treatment of the sewage effluent is a result of isotopic fractionation during ammonia volatilization, nitrification and denitrification (McClelland & Valiela, 1998).

Oyster stable isotope analysis

Oysters were sourced from two locations in the Maryland Coastal Bays, near Ocean Pines, on St Martins River. These cultchless oysters, less than one year old, were initially grown as part of the Maryland Coastal Bays Oyster Gardening Program. Three oysters from a randomly selected source were placed in cages made from ¾" mesh, anchored by 3 bricks and suspended by surface buoys. Oysters from each source were randomly selected to be deployed on 22nd May in St Martins River and Johnson Bay and 23rd May in Public Landing and Chincoteague (see maps). Oyster cages were collected from Johnson Bay and St Martins on 13th July and from lower Chincoteage and Public Landing on 14th July. Samples were kept on ice until frozen at the laboratory until dissection. Shell length was measured and then mantle, gills, and adductor muscle were dissected out. Tissues were oven dried at 60°C for 48 hrs or until thoroughly dry and then ground with mortar and pestle. 1 mg subsamples were packed in tin capsules and sent to University California, Davis for stable isotope analysis.

Calculating Water Quality Index (WQI)

A water quality index was calculated for each region using the methods of Wazniak et al. (in press). Two metrics were included in the current analysis, temperature and nitrogen isotope ratio of deployed macroalgae (Table 2). Recent research is indicating that extended periods of warm water (>30 °C) may result in loss of seagrass due to reduction in oxygen concentrations in the vicinity of the apical meristem (Ken Moore and Jens Borum personal communications).

Table 2. Table of management objectives for the Maryland Coastal Bays together with water quality indicators and reference values to determine the status of the objectives (Wazniak *et al*., in press).

Management Objective	**Water Quality Indicator**	**Reference Value**
Maintain suitable fisheries habitat	Dissolved oxygen	DO > 5 mg L^{-1}
Maintain seagrass	Chlorophyll *a*	Chl *a* < 15 µg L^{-1}
Maintain seagrass	Total phosphorus	TP < 1.2 µM
Maintain seagrass	Total nitrogen	TN < 46 µM
Maintain seagrass	Water temperature	Temp<30 °C
Reduce sewage/septic inputs	Delta ^{15}N ($\delta^{15}N$)	$\delta^{15}N$ < 7 ‰

Spatial analysis

Measurements of physical parameters and water quality indicators were mapped using ESRI ArcMap. The NAD 1983 UTM Zone 18N Projected Coordinate System was selected to plot the data. Interpolation of the data was conducted by kriging, using the Spatial Analyst package and the advanced parameters from the semivariogram created by the Geostatistical Analyst. To determine the validity of kriged interpolations, the Cross Validation plot in the Geostatistical Analyst was employed. The resulting regression plot was analyzed with SAS 8.2 to determine if the slope significantly differed from zero, and thus had some measure of autocorrelation between the interpolated krig and original input data. Insignificant krigs were presented site by site without interpolation.

Findings

Continuous monitoring

The continuous monitoring data showed the extent of daily variations in temperature, dissolved oxygen, turbidity and Chlorophyll *a* as well as providing an effective comparison for the survey results (Figure 9, 10). Johnsons Bay had consistently higher turbidity and Chlorophyll *a* than Chincoteague (Table 3).

Rainfall

Rainfall was low before the May sampling, with a cumulative total for 2006 of 162mm by 22nd May. There was however several large rain events between late may and mid July such that cumulative total 2006 rainfall by 13th July was 380mm (Figure 8).

Salinity

Salinity in St Martins River had the largest range of all sites (24.9 – 28.9 in May and 24.3 – 28.2 in July), and this range was consistent between sampling events, however the lower salinity water was measured further downstream in July after heavy rainfall (Figs 8 and 11; table 4). Public Landing, Johnsons Bay and Chincoteague all had a reduction in salinity from approximately 31 in May to approximately 28 in July (Figure 11; table 4). Johnsons Bay showed a distinct onshore (ca 25) to offshore (ca 28) gradient in salinity in July, consistent with local freshwater inputs from groundwater or surface flow sources (Figure 11).

Temperature

Variation in surface water temperature between sites was 5-6 °C in both May (range 19.0 – 25.0°C) and July (range 27.9 – 33.7°C) (Figure 12). However, there was a large increase in water temperature across all sites during these months, from 21.7±1.6°C in May to 30.3±1.4°C (mean ± standard deviation) (Table 5). During July, 90% of the 21 sampling sites in St Martins River and 83% of 31 sites in Chincoteague were above the 30°C threshold for seagrass survival and while there is little seagrass in St Martins River, the sampling area near Chincoteague Island is amongst some of the most extensive *Zostera marina* meadows in the MD Coastal Bays.

Dissolved Oxygen (DO)

Public Landing and Chincoteague sites showed a large reduction in DO between May (8.10±0.26 and 8.17±2.04 mgl^{-1} respectively) and July (4.47±0.36 and 5.28±0.38 mgl^{-1} respectively) (mean

± standard deviation; table 6). Samples were taken at the bottom of the water column, however were once off samples taken during the day and the continuous monitoring data shows a daily variation of up to 4 mgl^{-1}, (Figures 9, 10), so these values are certainly a conservative estimate of DO. The relatively high concentration of DO in St Martins River versus Public Landing during July may be a result of the high phytoplankton populations in both which are shown by the high Chl *a* and low Secchi depths in these regions (Figures 14, 17), and that Public Landing was sampled in the morning (7:00-10:00am) while St Martins River was sampled in the afternoon (1:20-4:00pm), so DO may have still been low following night-time respiration in Public Landing, and elevated due to high photosynthesis in St Martins River.

Secchi depth

Mean Secchi depth decreased from a mean across all sites of 0.6±0.2 m in May to 0.4±0.1 m in July, the largest reduction being in the Chincoteague sampling region, reducing from 0.9±0.2 m in May to 0.5±0.1 m (Figure 14, Table 7). These high turbidity (low Secchi) readings in St Martins, Public Landing and Johnsons Bay, with lower turbidity in Chincoteague were consistent with the 2004 survey (Jones et al.,) and the increased turbidity in July suggests that it is later in the summer that the phytoplankton bloom reaches its maximum concentration (Figure 14).

Microbial Source Tracking

None of the samples (except positive controls) grew any bacteria colonies, suggesting that all sites had coliform and *E. coli* counts less than 5 cfu's (colony forming units) per 100ml.

Table 3. Summary data from continuous monitoring sites. Data is medians (standard deviations) and is taken from 19th May – 1st June and 12th July – 20th July, 2006.

	Chincoteague		Johnsons	
	May	July	May	July
Temperature (°C)	20.33 (2.30)	28.47 (1.25)	20.90 (2.51)	27.27 (1.08)
Salinity	32.22 (0.21)	28.00 (0.28)	32.85 (0.53)	30.92 (0.20)
DO (mg L^{-1})	7.11 (0.73)	6.91 (0.95)	7.39 (0.67)	6.55 (0.86)
Turbidity (ntu)	6.70 (3.69)	13.60 (6.93)	12.40 (3.51)	15.80 (47.88)
Chlorophyll a (µg L^{-1})	5.30 (4.40)	28.30 (5.18)	18.40 (6.05)	35.80 (12.38)

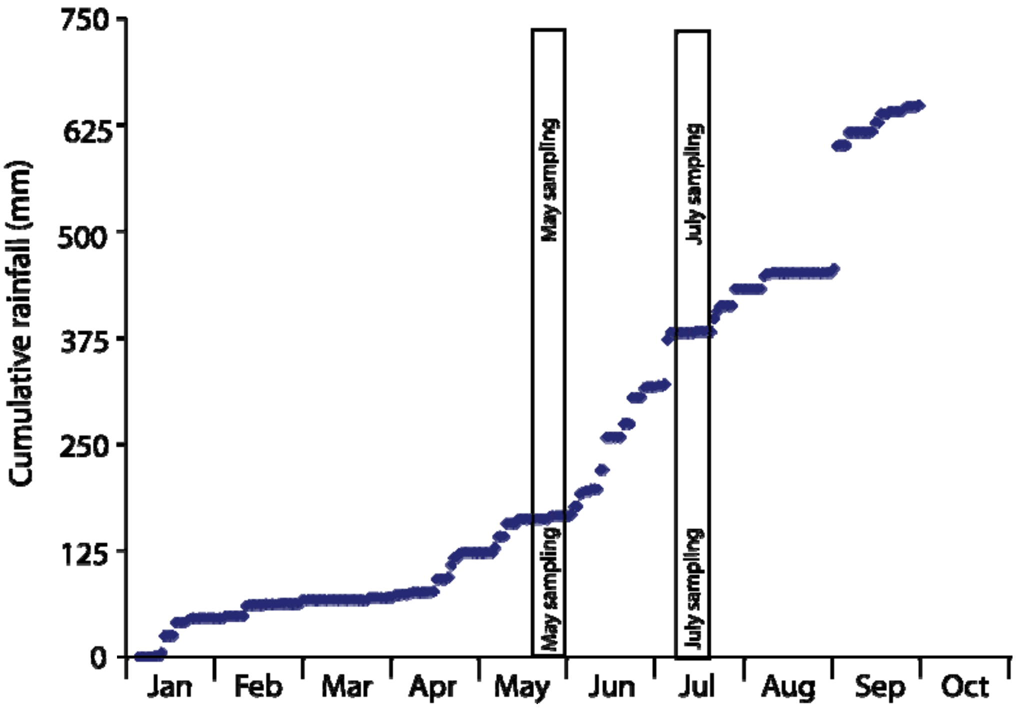


Figure 8: Rainfall data for Assateague Island, Maryland

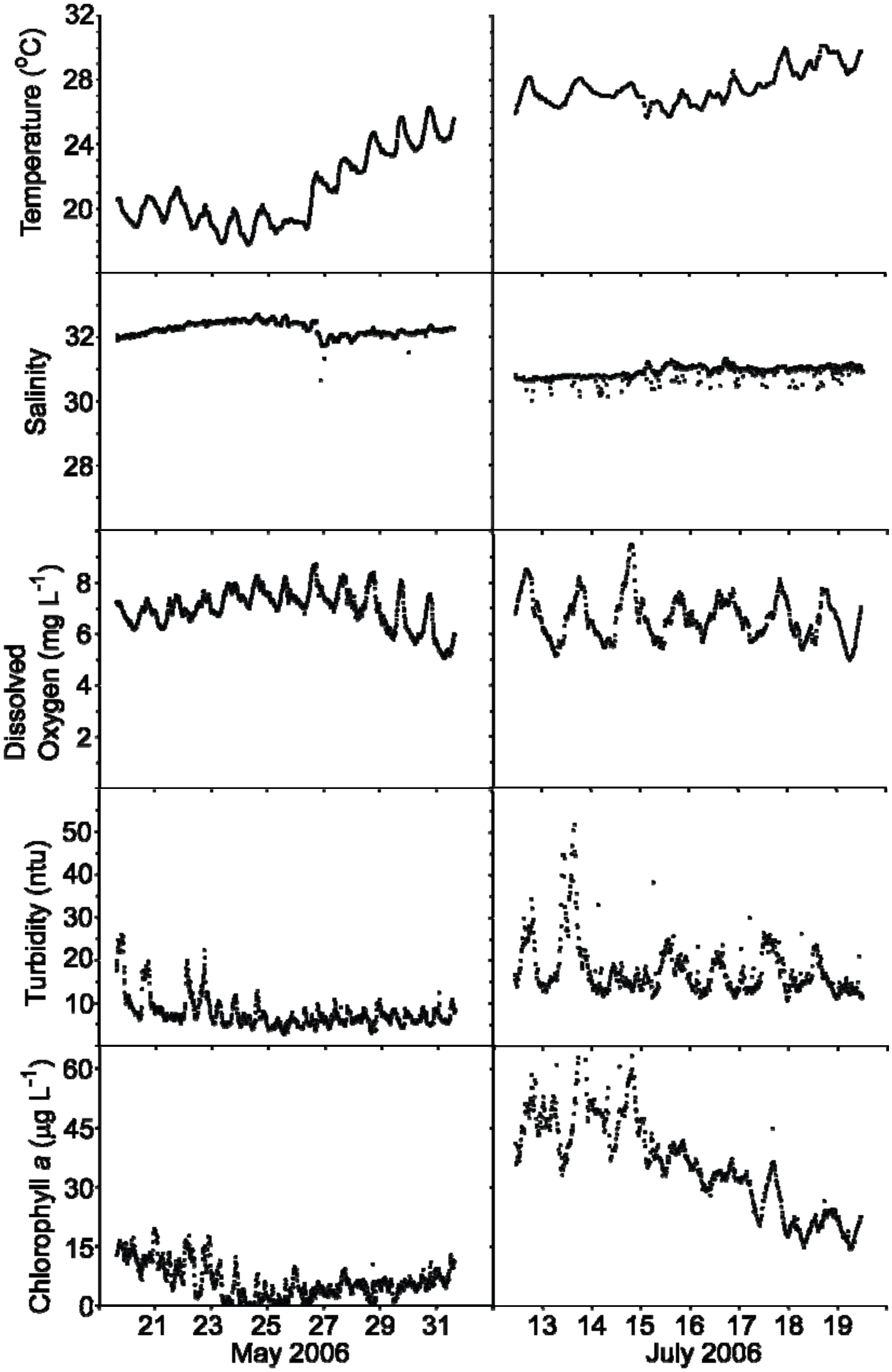


Figure 9: Data from Chincoteague Bay continuous monitoring site

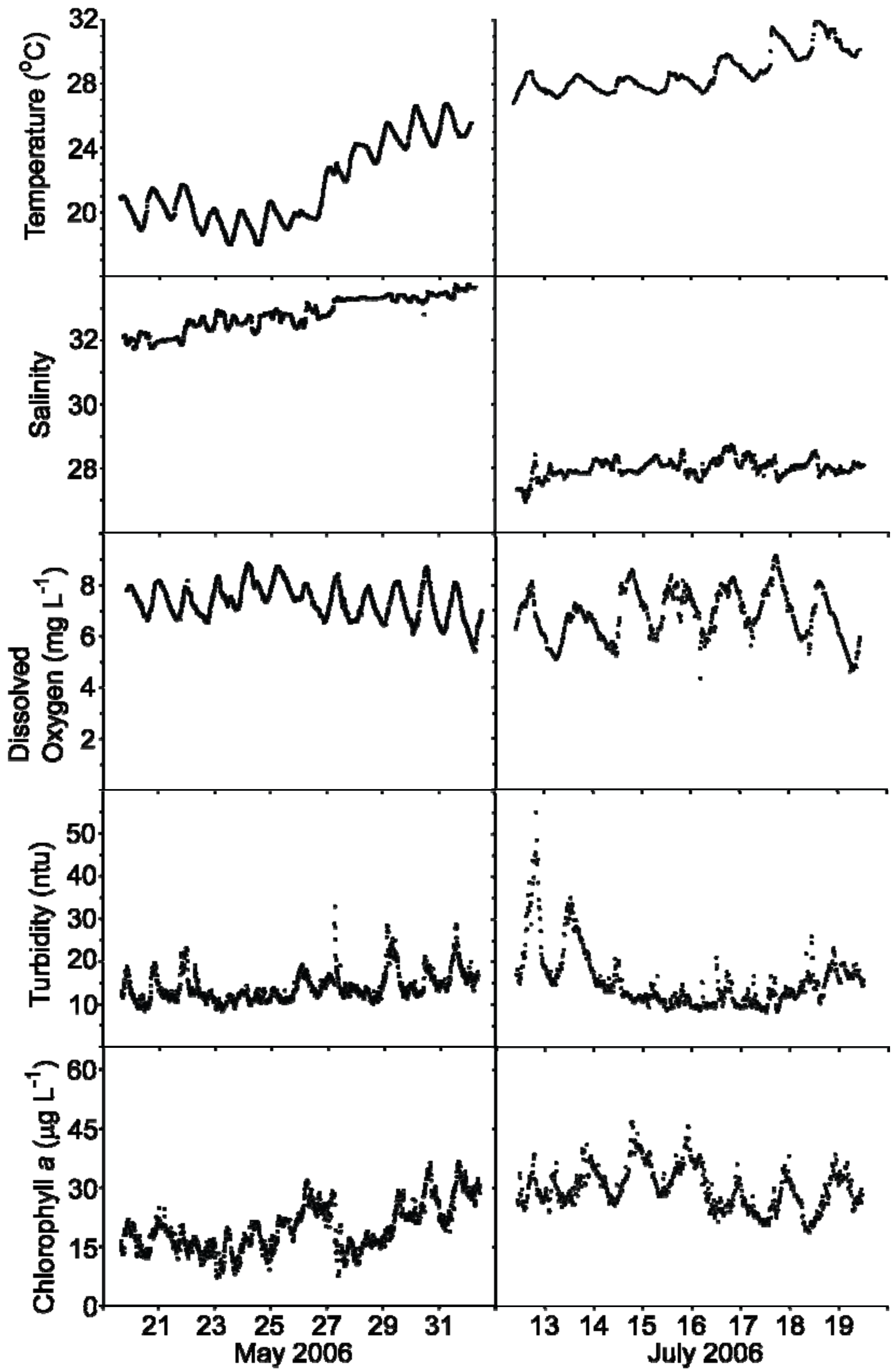


Figure 10: Data from Johnsons Bay continuous monitoring site

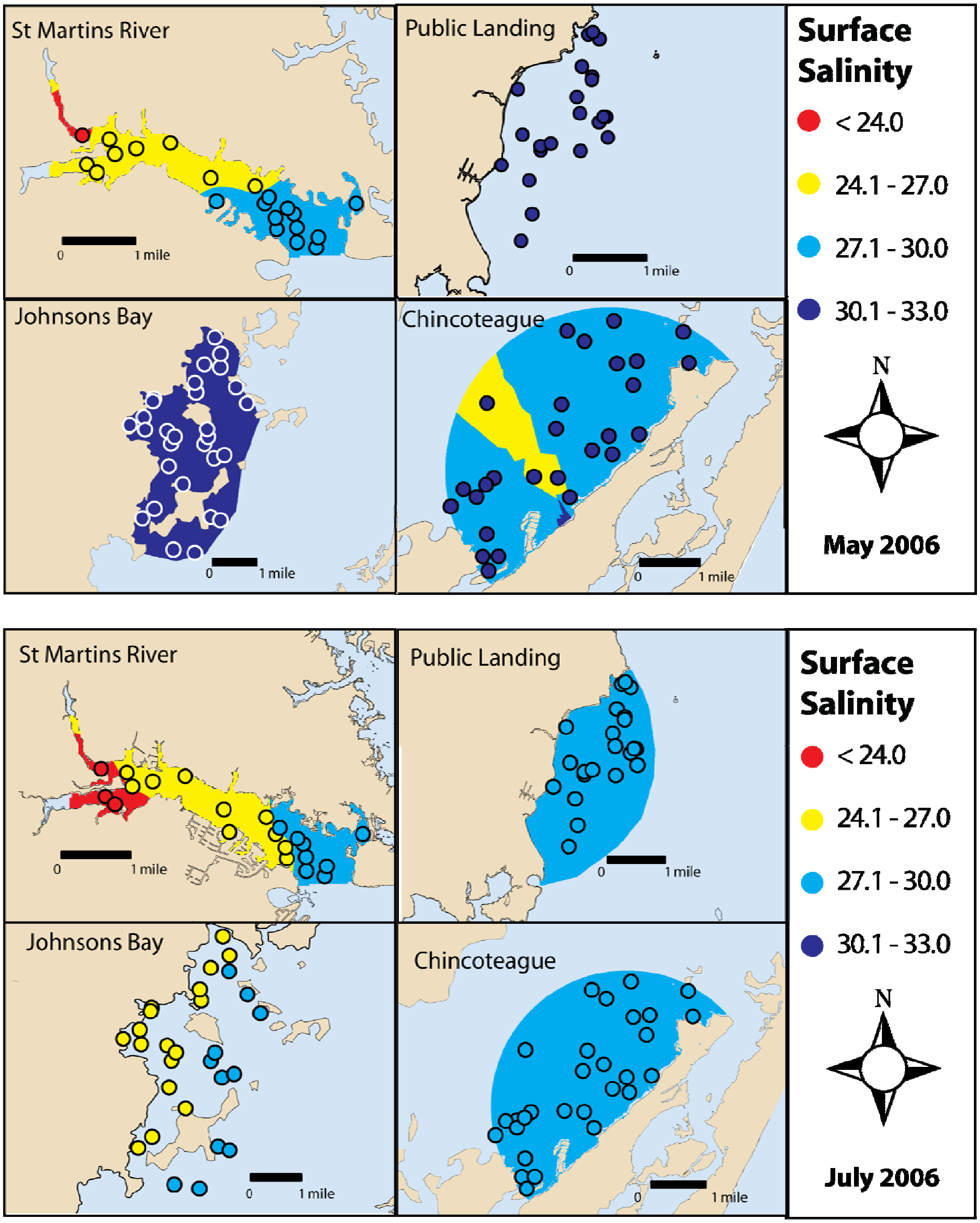


Figure 11: Surface salinity

Table 4. Surface salinity (mean±standard deviation)

	St Martins River	Public Landing	Johnson Bay	Chincoteague	Mean
May 06	26.9 (1.5)	30.4 (0.1)	31.6 (0.3)	31.3 (0.2)	**30.3 (1.9)**
July 06	26.0 (1.8)	28.5 (0.1)	26.6 (0.9)	29.7 (0.2)	**27.8 (1.8)**

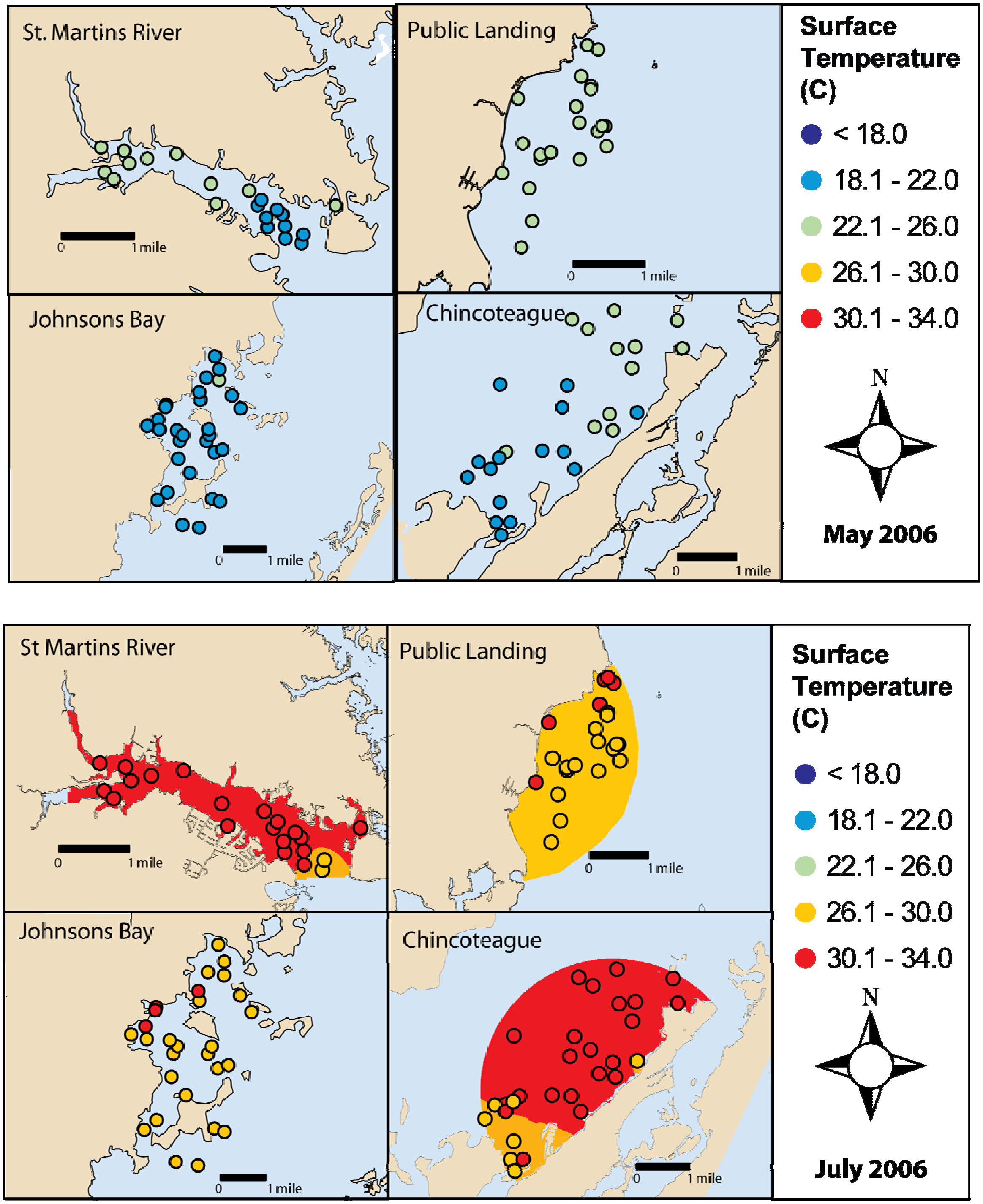
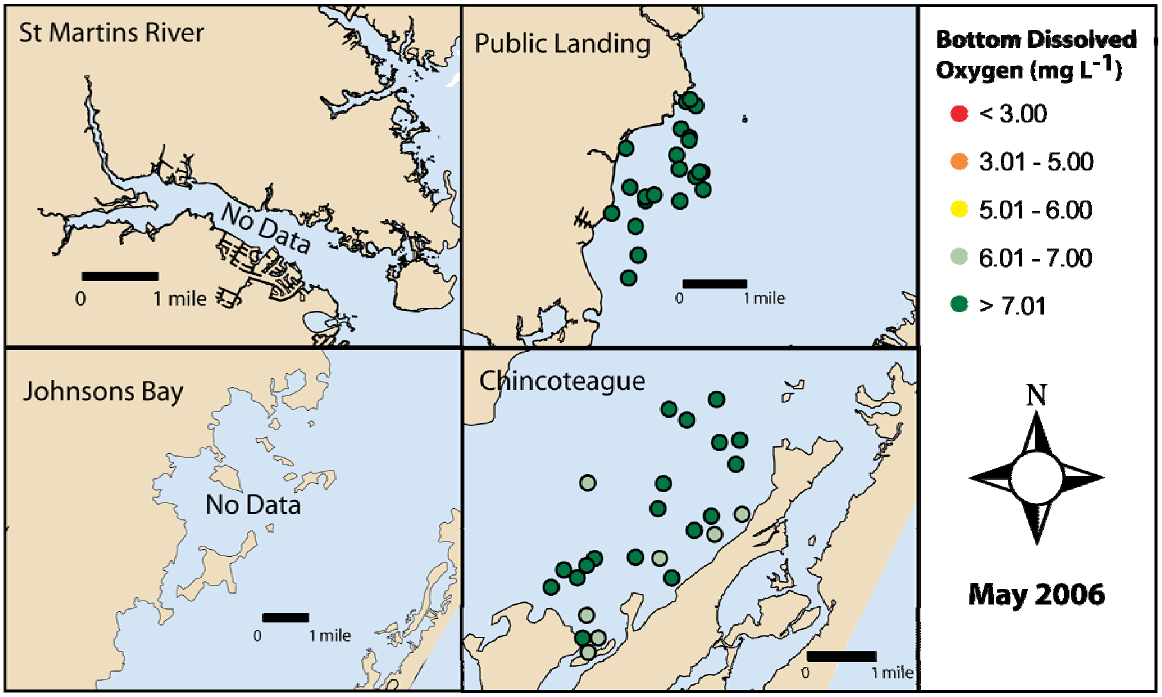


Figure 12: Surface water temperature (°C)

Table 5. Surface water temperature (°C) (mean±standard deviation)

	St Martins River	Public Landing	Johnson Bay	Chincoteague	Mean
May 06	22.5 (1.1)	23.1 (0.4)	20.3 (1.0)	19.9 (5.6)	**21.7 (1.6)**
July 06	31.6 (1.5)	29.8 (0.4)	29.3 (0.8)	30.6 (1.3)	**30.3 (1.4)**



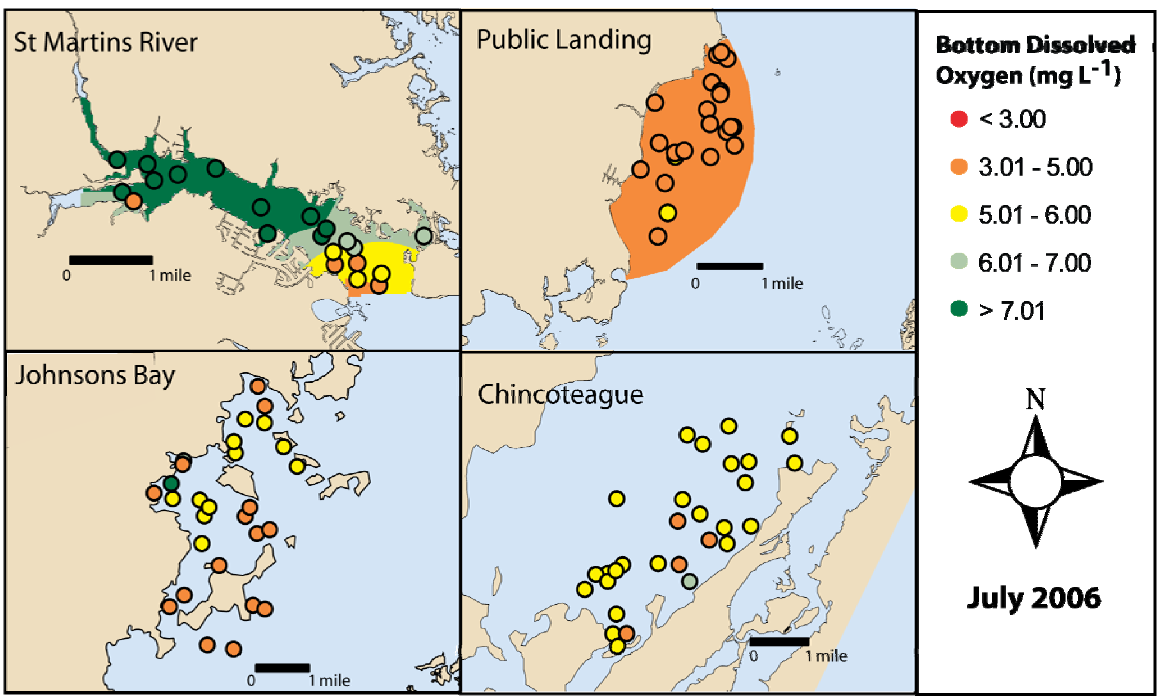


Figure 13: Bottom dissolved oxygen (DO) (mgl^{-1})

Table 6: Dissolved Oxygen (mgl^{-1}) (mean±standard deviation)

	St Martins River	Public Landing	Johnson Bay	Chincoteague	Mean
May 06		8.10 (0.26)		8.17 (2.04)	**8.14 (1.50)**
July 06	6.64 (1.55)	4.47 (0.36)	5.04 (0.80)	5.28 (0.38)	**5.32 (1.14)**

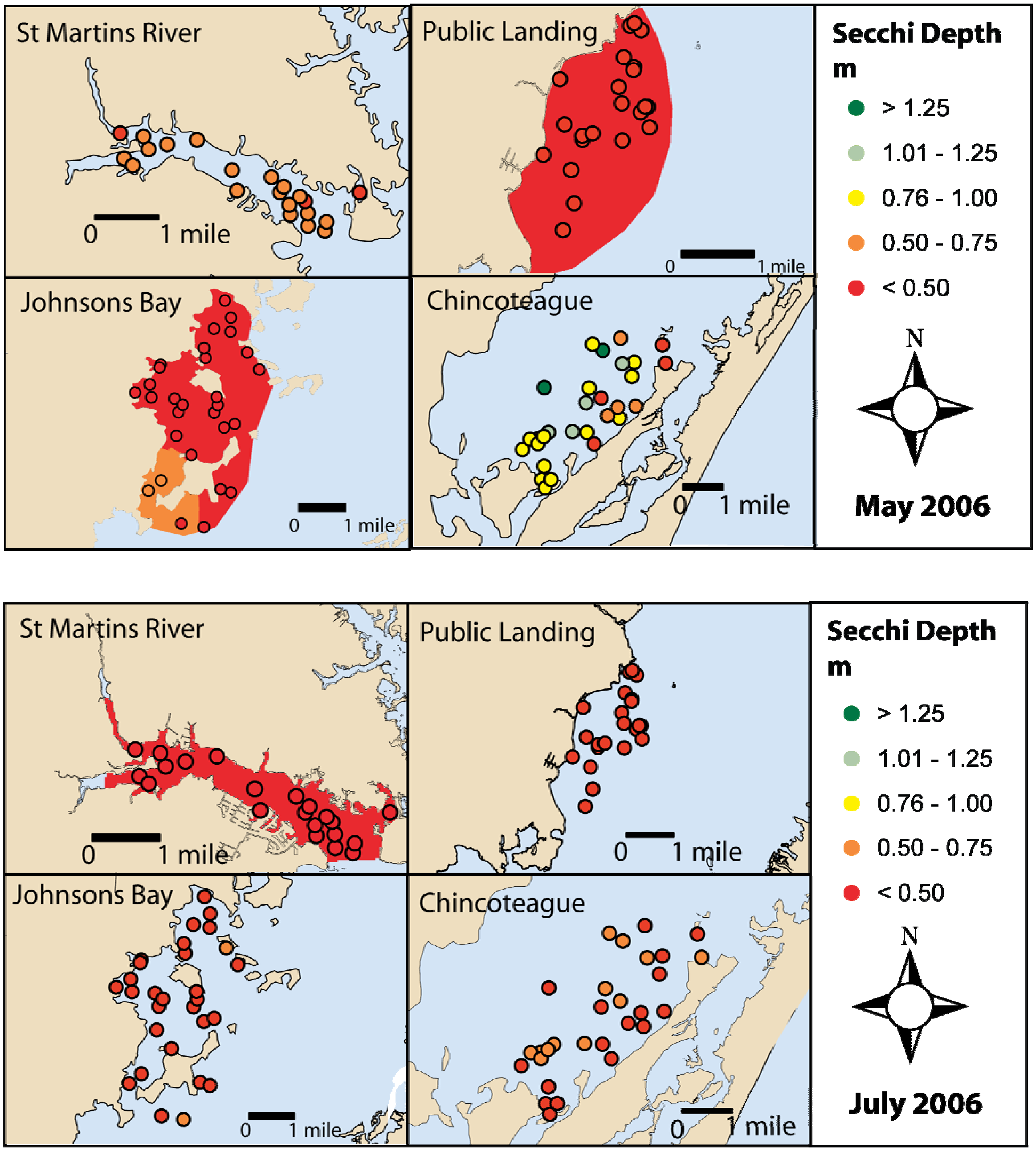


Figure 14: Secchi depth (m)

Table 7: Secchi depth (m) (mean±standard deviation)

	St Martins River	Public Landing	Johnson Bay	Chincoteague	Mean
May 06	0.6 (0.1)	0.4 (0.1)	0.4 (0.1)	0.9 (0.2)	**0.6 (0.2)**
July 06	0.3 (0.1)	0.4 (0.1)	0.4 (0.1)	0.5 (0.1)	**0.4 (0.1)**

Water column total nitrogen

During both May and July, Chincoteague was the only sampling region which was , on average, below the water column total nitrogen threshold of 46 μM (22.8±8.4 and 33.9±3.3μM respectively, mean±standard error) (Figure 15, table 9). Rainfall events resulting in only moderate reductions in salinity (Figure 8), resulted in large increases in total nitrogen concentration in surface waters of St Martins River (Figure 15). Johnsons Bay and Public Landing both show elevated total nitrogen concentrations in some inshore regions, suggesting local sources of nitrogen input to these regions and as these were observed also during May, it is likely that these are at least in part sourced from groundwater inflows (Figure 15).

Water column total phosphorus

All sampling sites for both May and July samplings were above the threshold value for water column total phosphorus of 1.2μM (Figure 16), however, there was still an increase from an overall mean of 2.59±0.77 μM in May to 4.42±1.04 μM in July (Table 10). Public Landing and Johnsons Bay had higher total phosphorus concentrations inshore, which is consistent with the total nitrogen measurements in indicating groundwater or overland nutrient inputs in these regions. During July, the slightly lower concentrations of total phosphorus in southern Chincoteague most likely reflect increased flushing from the southern ocean opening to Chincoteague Bay (Figure 16).

Water column chlorophyll a

Chlorophyll a concentration was low at all sites in May (<15 μgl^{-1}) (Figure 17). However, this was not consistent with high turbidity (low Secchi, Figure 14), high nutrients (Figure 15, 16) and high temperature (Figure 12). Further investigation revealed that the Phaeopigments were high at all sites for the May samples and, as Phaeopigments record degraded Chlorophyll *a*, this suggests that either there was a large number of decaying phytoplankton or, more likely, the Chlorophyll degraded in the samples (Table x, x). During July there was high to very high Chlorophyll a recorded in all sampling regions (15-50+ μgl^{-1}), suggesting phytoplankton blooms throughout the system (Figure 17). This is also consistent with the continuous monitoring data which were similar in July, but in Johnsons Bay (particularly) continuous monitoring data recorded Chl a concentrations from 10-30 μgl^{-1} while the survey values were all <15μgl^{-1} (Figure 10, 17).

Table 8: Surface water Phaeophytin pigments (μgl^{-1}) (mean±standard deviation)

	St Martins River	Public Landing	Johnson Bay	Chincoteague	Mean
May 06	30.45 (12.86)	46.93 (9.63)	36.43 (16.51)	19.99 (11.41)	**33.45 (12.60)**
July 06	11.96 (6.08)	13.42 (3.16)	11.63 (5.08)	9.28 (4.17)	**11.57 (4.62)**

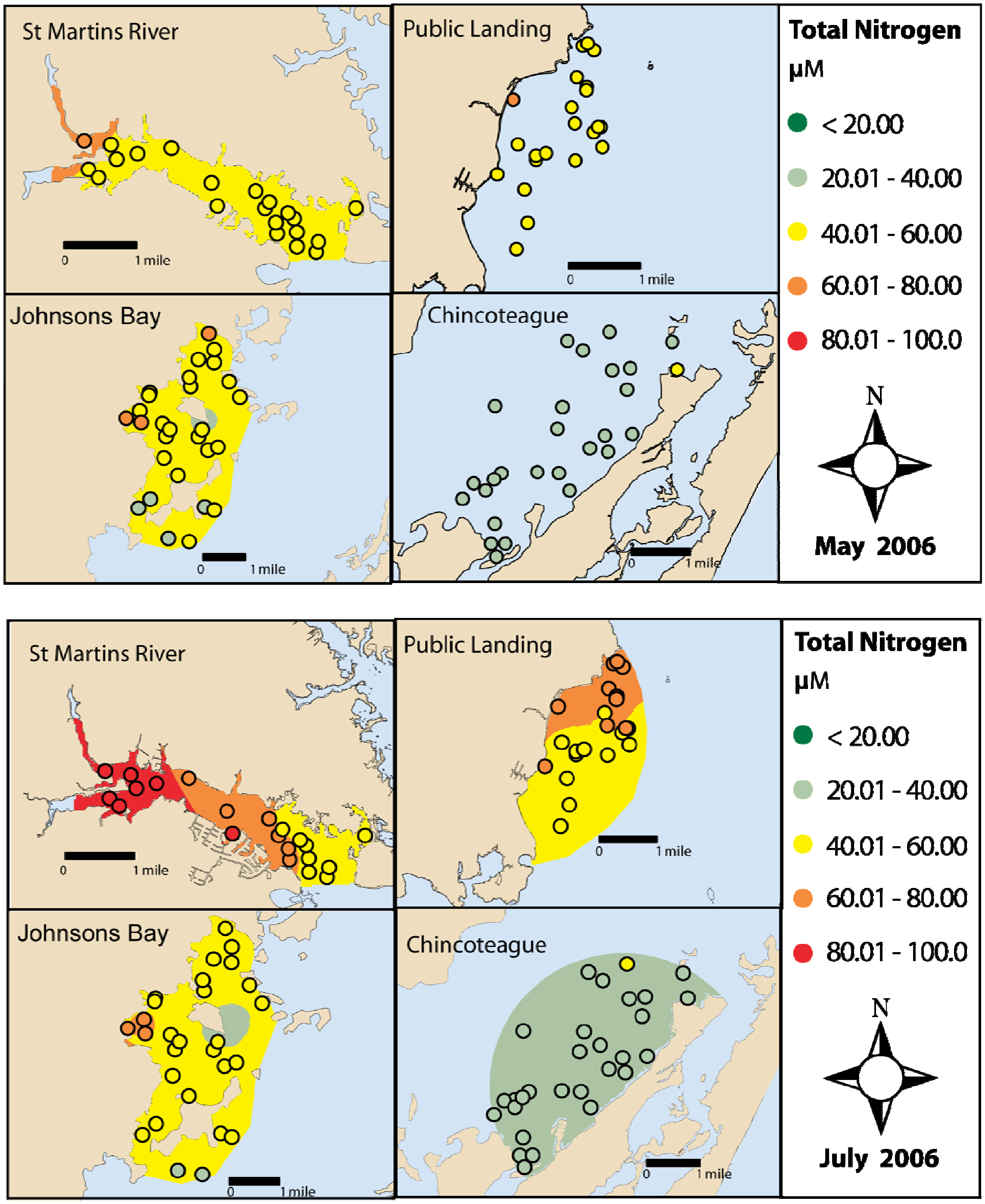


Figure 15: Surface water total nitrogen (µM)

Table 9: Surface water total nitrogen (µM) (mean±standard deviation)

	St Martins River	Public Landing	Johnson Bay	Chincoteague	Mean
May 06	54.6 (5.2)	50.9 (3.1)	49.7 (1.2)	22.8 (8.4)	**44.6 (13.7)**
July 06	69.9 (1.5)	58.7 (3.7)	50.7 (8.1)	33.9 (3.3)	**51.6 (15.7)**

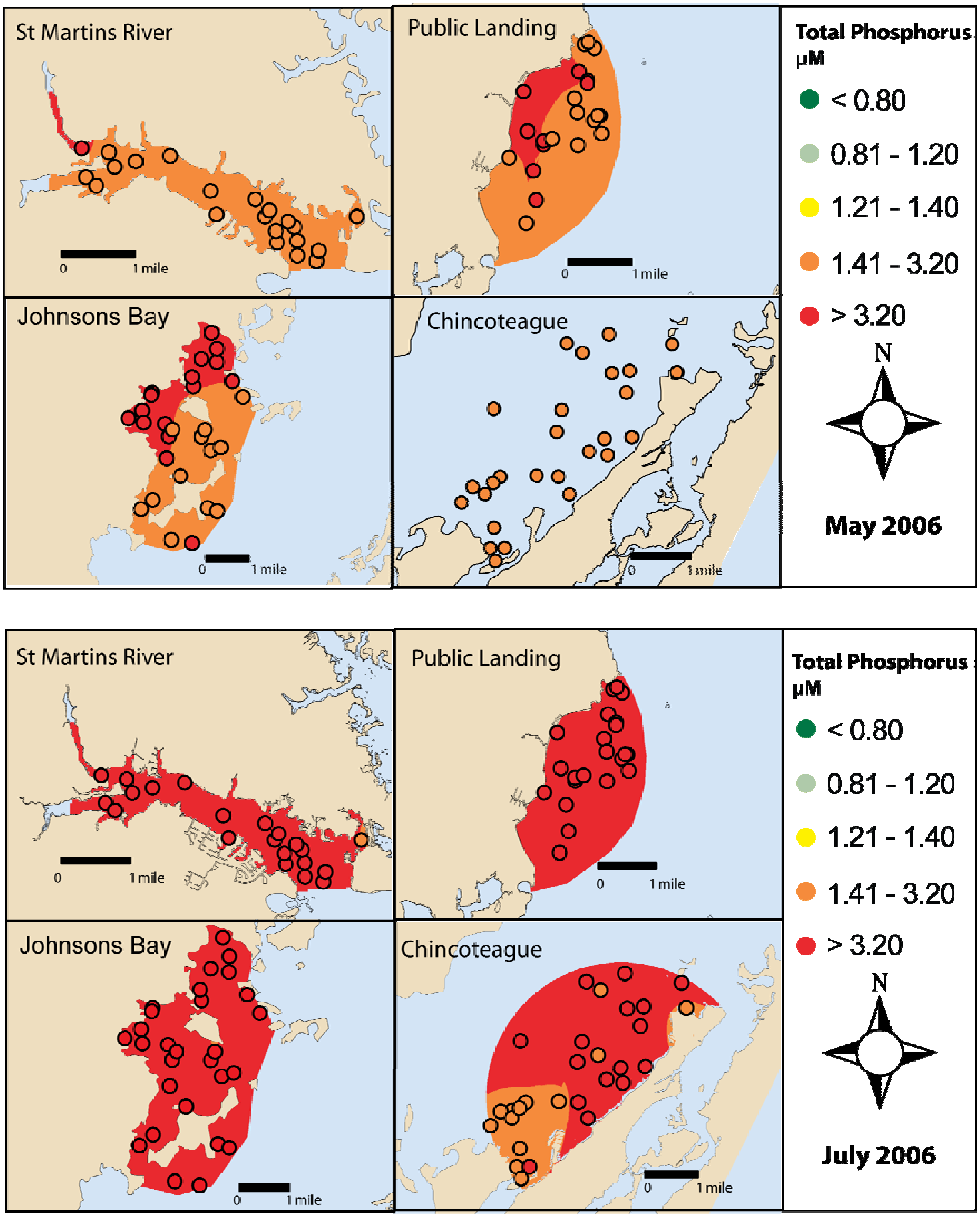


Figure 16: Surface water total phosphorus (µM)

Table 10: Surface water total phosphorus (µM) (mean±standard deviation)

	St Martins River	Public Landing	Johnson Bay	Chincoteague	Mean
May 06	2.39 (0.32)	3.11 (0.18)	3.27 (0.51)	1.61 (0.25)	**2.59 (0.77)**
July 06	4.69 (1.05)	4.79 (0.36)	5.14 (0.88)	3.26 (0.27)	**4.42 (1.04)**

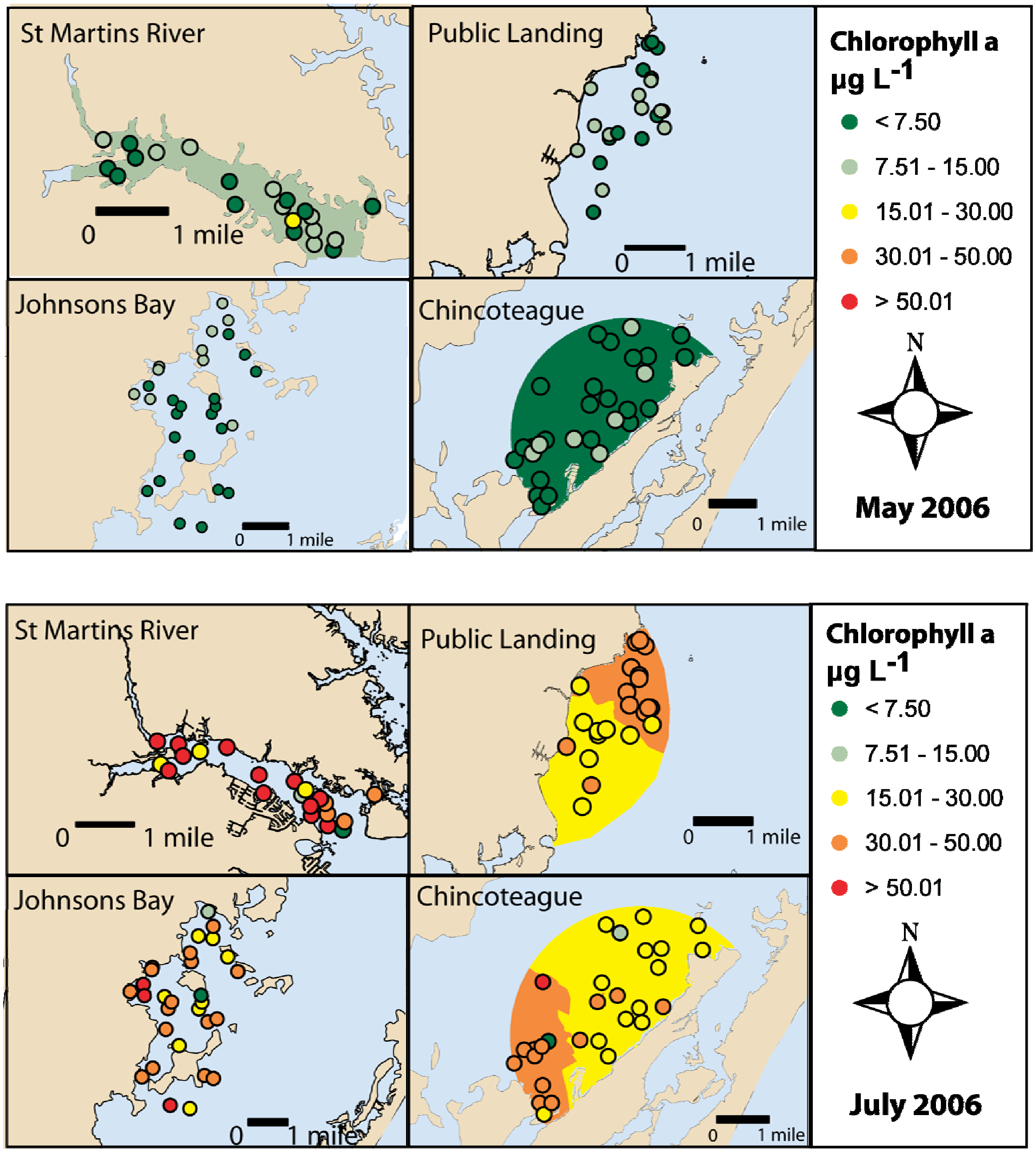


Figure 17: Surface water Chlorophyll a (µg l^{-1})

Table 11: Surface water Chlorophyll a (µg l^{-1}) (mean±standard deviation)

	St Martins River	Public Landing	Johnson Bay	Chincoteague	Mean
May 06	8.26 (3.98)	7.63 (2.27)	6.48 (2.98)	4.37 (6.22)	**7.2 (3.2)**
July 06	52.95 (29.07)	31.44 (6.46)	34.70 (11.94)	27.82 (9.32)	**35.8 (18.1)**

Bio-indicator Gracilaria %N

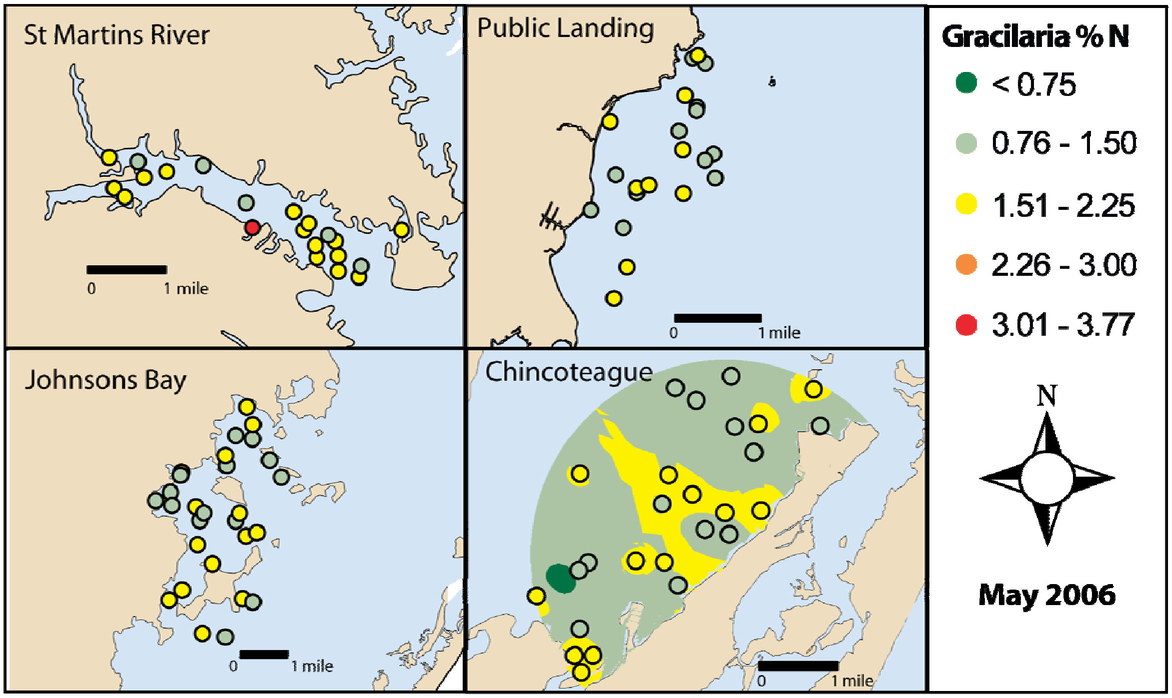
The tissue nitrogen measured in deployed *Gracilaria* for four days, closely reflected patterns in the surface water total nitrogen, with Chincoteague being lower in both May and July (ca 1.37% N, table x) than the other three sampling regions, which all showed an increase from May (global mean 1.49±0.46%) to June (global mean 1.49±0.46%) (Table 12). Patterns within each of the regions were less distinct, largely due to low variation at the scale of sampling (Figure 18). The initial values of %N in the *Gracilaria* used for deployment showed the same trend of being higher in July (2.75±0.13%) than May (1.47±0.20%), however, after the four day deployment, samples had both increased and decreased from the initial (Table 12).

Bio-indicator Gracilaria $\delta^{15}N$

The mean δ^{15}N over all sampling regions reduced from 7.33±1.15 ppt in May to 6.76±1.15 ppt in July (mean ± standard deviation), and while St Martins River and Johnsons Bay were slightly higher than the other regions in May, all regions were similar in the July sampling (Figure 19, Table 13). The only region to show clear spatial patterning in δ^{15}N was the July sampling in Chincoteague, where a northern, central and southern area of higher δ^{15}N (Figure 19). The lack of patterns may have resulted from the high initial value of the deployed gracilaria, or alternately may be reflecting processes within the coastal bays were mostly occurring at a larger scale when samples were taken, as evidenced by the uniformly high total phosphorus and Chlorophyll *a* concentrations.

Water quality index

A large decline in water quality, relative to threshold values to maintain fisheries and seagrass, was observed between May (overall mean water quality poor; 0.58±0.16) and July (mean water quality poor; 0.58±0.16), the largest declines in water quality between the two sampling periods being in Public Landing and Chincoteague (Figure 20, Table 14). In May, water quality was uniform throughout the St Martins River, Public Landing and Chincoteague regions however showed a distinct gradient in Johnsons Bay with water quality poor inshore and good offshore (Figure 20). In July, water quality was uniformly degraded to very degraded in St Martins River and Public Landing, while in Johnsons Bay the northern section had poor water quality and the southern section degraded to very degraded water quality and in Chincoteague water quality was generally poor with degraded areas in the north and centre of the sampling region and some good water quality to the south where there is higher flushing rates (Figure 20).



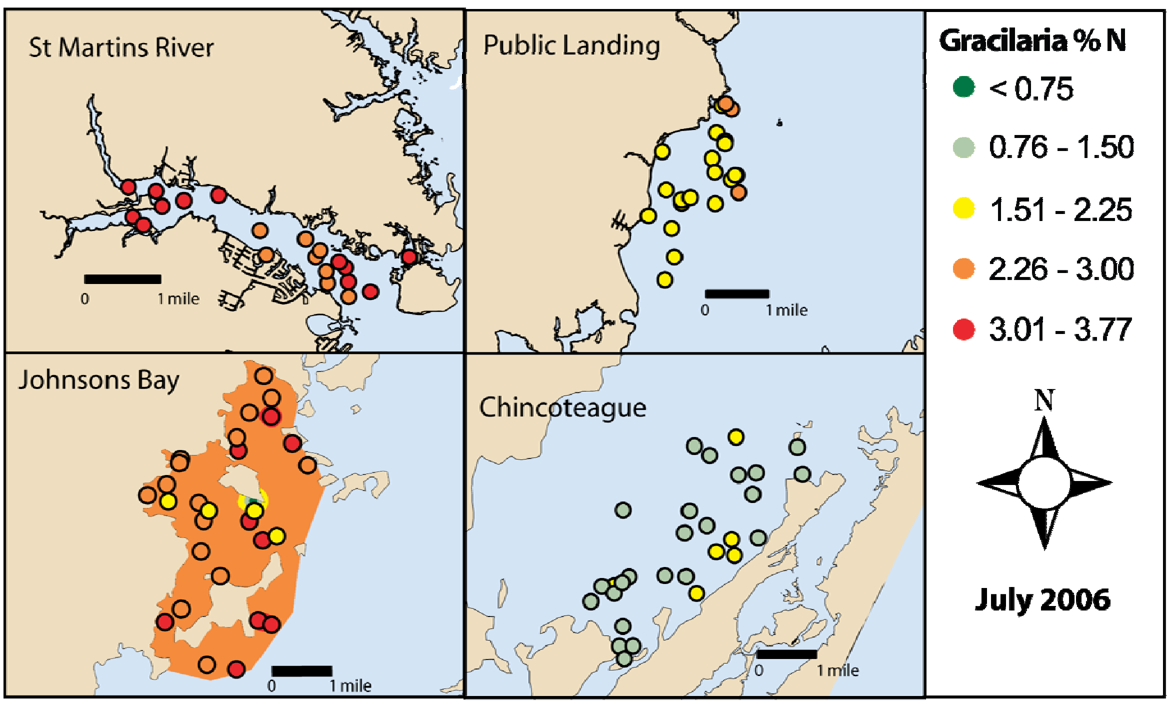
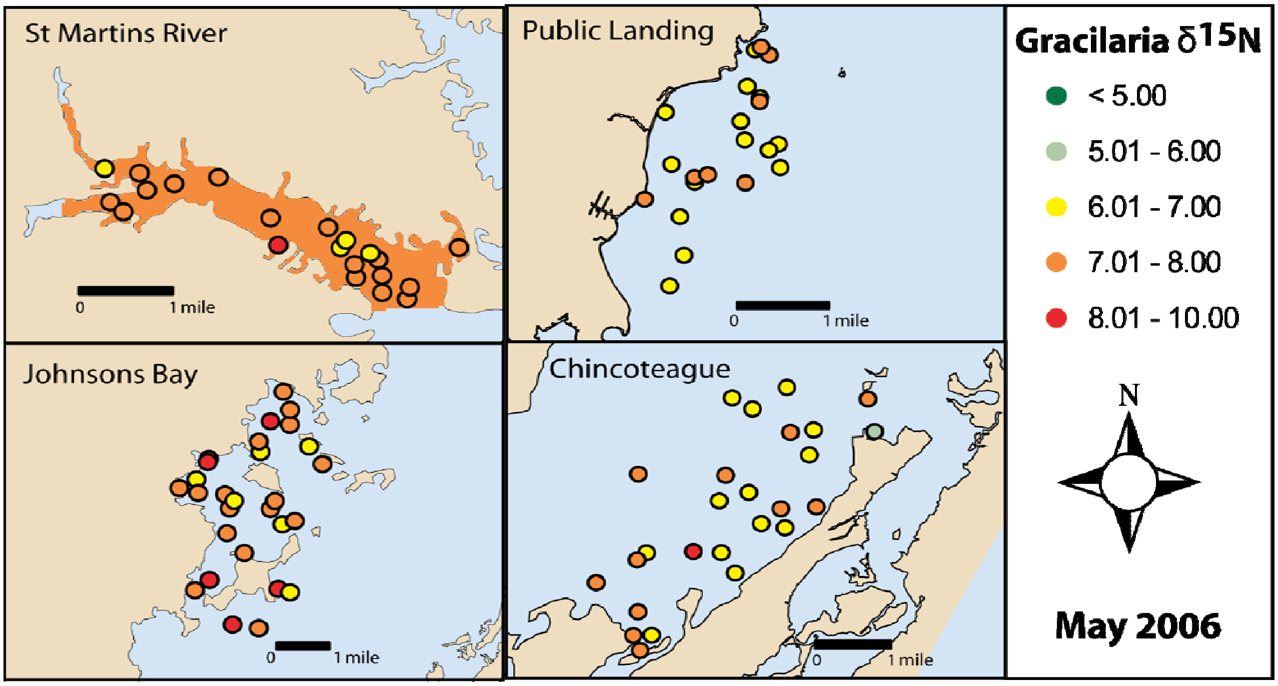


Figure 18: Deployed macroalgal tissue nitrogen, *Gracilaria* %N

Table 12: Deployed macroalgal tissue nitrogen, *Gracilaria* %N (mean±standard deviation)

	Initials	St Martins River	Public Landing	Johnson Bay	Chincoteague	Mean
May 06	1.47 (0.20)	1.79 (0.40)	1.40 (0.37)	1.46 (0.38)	1.38 (0.54)	**1.49 (0.46)**
July 06	2.75 (0.13)	2.90 (0.75)	1.94 (0.30)	2.72 (0.63)	1.36 (0.25)	**2.20 (0.82)**



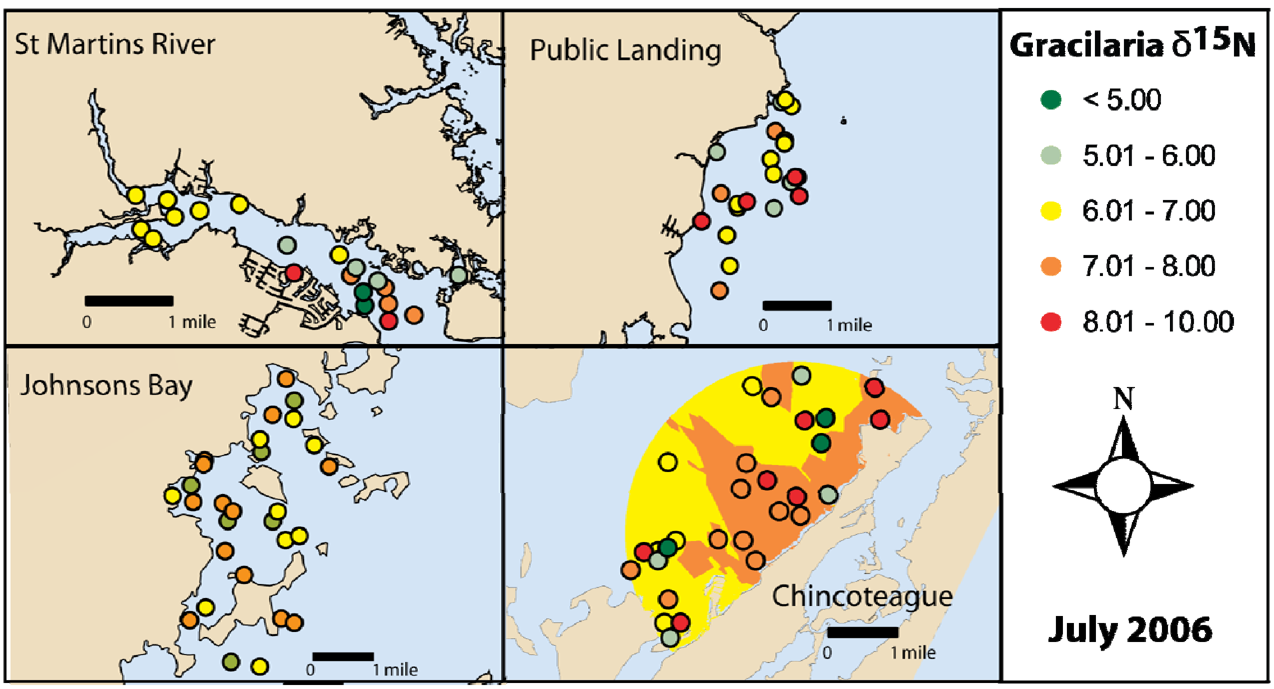


Figure 19: Natural nitrogen isotope abundance, *Gracilaria* $\delta^{15}N$ (ppt)

Table 13: Natural nitrogen isotope abundance, *Gracilaria* $\delta^{15}N$ (mean±standard deviation)

	Initials	St Martins River	Public Landing	Johnson Bay	Chincoteague	Mean
May 06	5.21 (0.26)	7.40 (0.41)	6.66 (1.50)	7.60 (2.33)	6.24 (2.19)	**7.33 (1.15)**
July 06	9.48 (1.09)	6.28 (1.30)	6.78 (0.93)	6.84 (0.85)	6.98 (1.34)	**6.76 (1.15)**

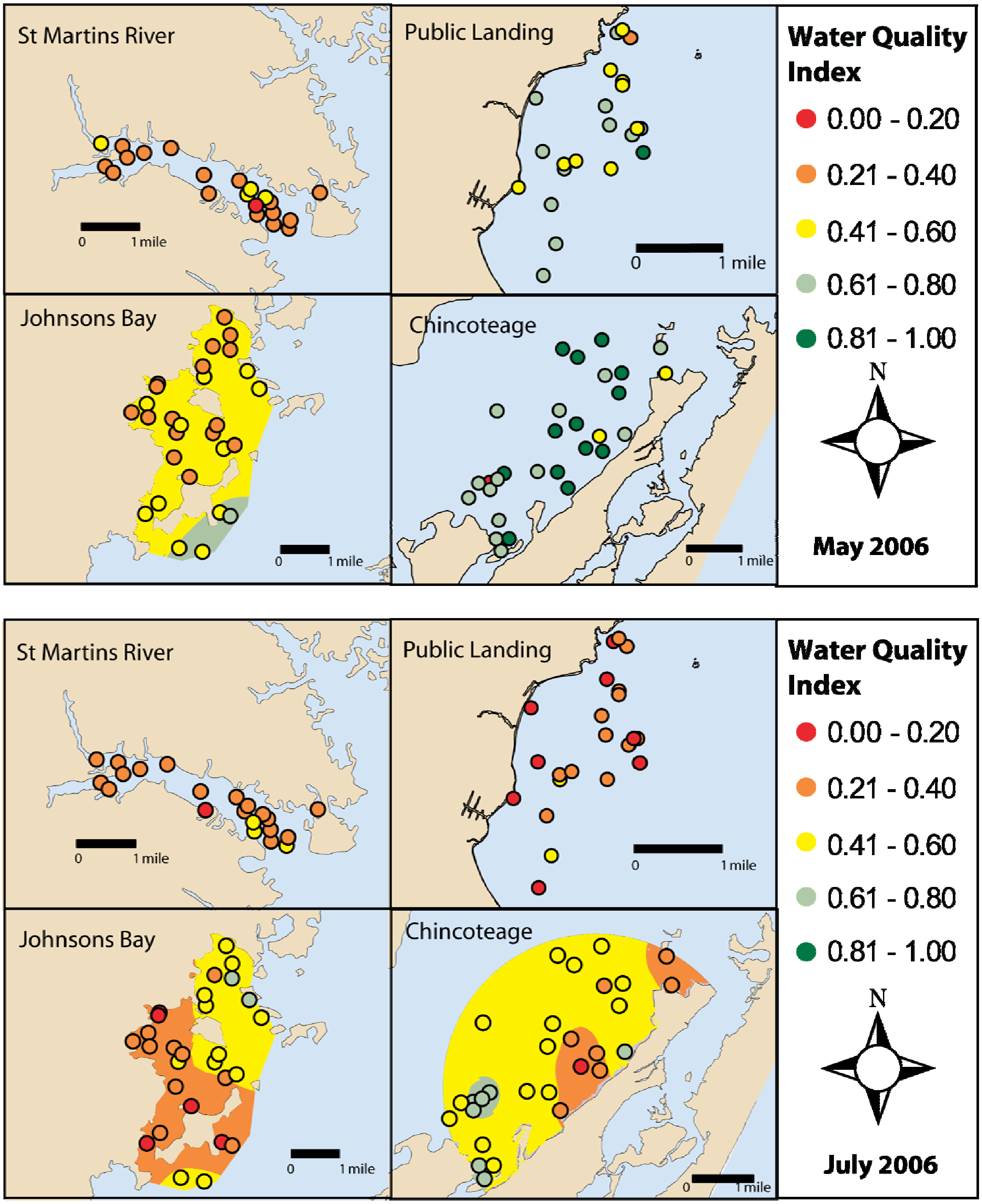


Figure 20: Integrated water quality index for all regions

Table 14: Integrated water quality index for all regions (mean±standard deviation)

	St Martins River	Public Landing	Johnson Bay	Chincoteague	Mean
May 06	0.43 (0.10)	0.61 (0.10)	0.49 (0.12)	0.75 (0.11)	**0.58 (0.16)**
July 06	0.35 (0.09)	0.27 (0.13)	0.39 (0.14)	0.49 (0.13)	**0.39 (0.15)**

Bio-indicator Oyster δ^{15}N muscle

Mean *Crassostrea* muscle tissue δ^{15}N over all sampling regions was 8.51±0.89 ppt after the deployment period, which was a mean increase of 0.34 ppt from the initial isotope values. Similar to the *Gracilaria* in May, St Martins River and Johnsons Bay were slightly higher than the other regions (Table 15). The southern portion of Johnson Bay showed higher isotope values than the northern portion. (Figure 21) Oyster mortalities make patterns in Public Landing and St Martins River difficult to determine.

Bio-indicator Oyster δ^{15}N gill

Gill tissue δ^{15}N were close to 1 ppt lower than those in the muscle, a pattern consistent with previous observations, and likely due to oyster physiology. The overall mean of 7.76 ± 0.88 is thus comparable to the muscle mean. A similar spatial pattern was found to that of the muscle, with an increasing gradient north to south in Johnson Bay. However, Public Landing had a higher mean of 7.88 ± 0.27 than St Martins River, with 7.75 ± 0.50. An increasing north to south gradient was also found in Chincoteague, though overall, it had the lowest mean of 7.41 ± 0.97.

Bio-indicator Oyster δ^{15}N mantle

Mantle, the shortest length integrator, had roughly the same mean isotope values as the gills, at 7.78 ± 0.96. Values in St Martin River and Chincoteague were very similar to those of the gill, but were higher than the gill in Public Landing and Johnson Bay. The north to south gradient in Johnsons Bay and Chincoteague can also be seen in the mantle (Figure 22).

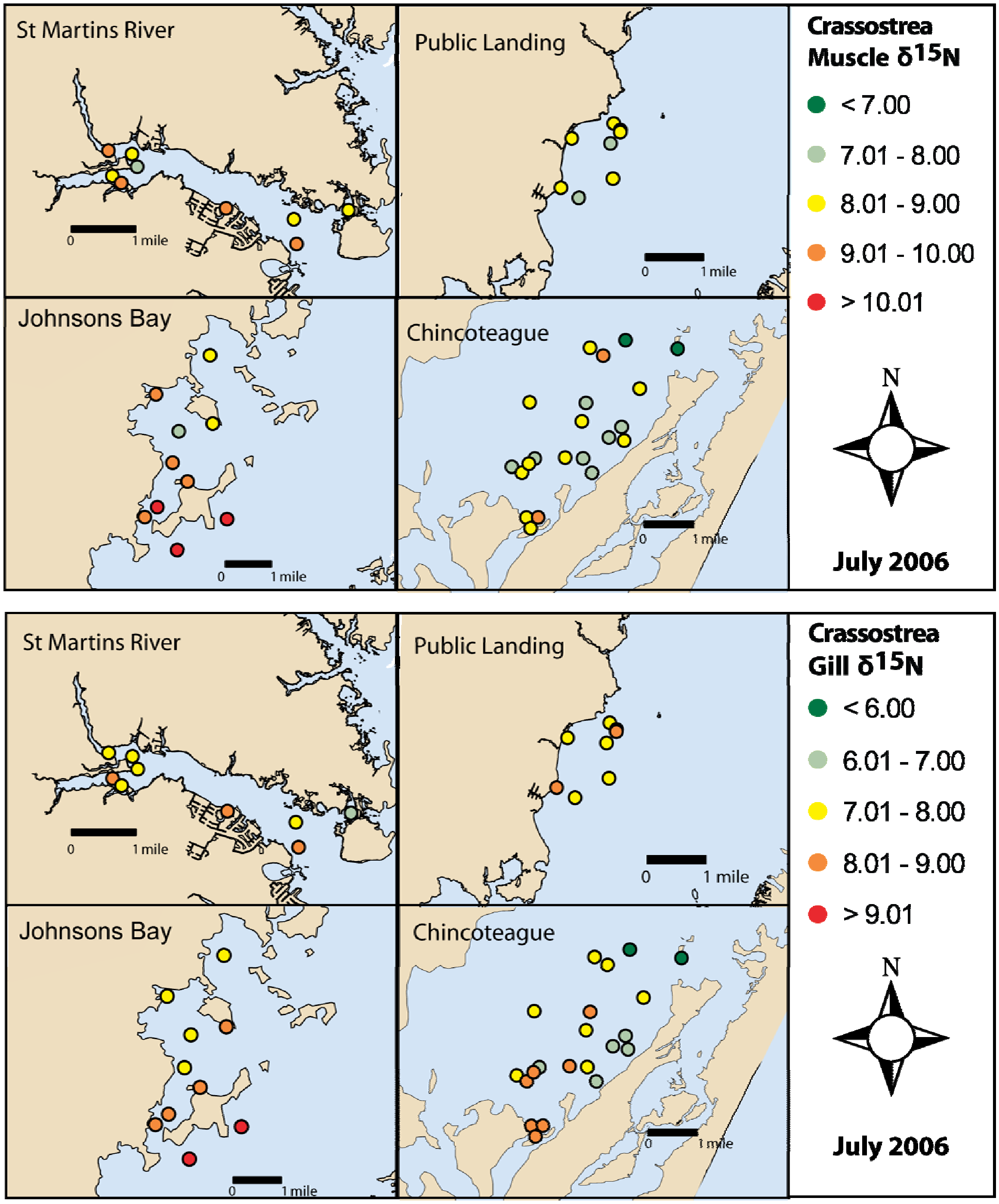


Figure 21: Natural nitrogen isotope abundance, *Crassostrea* $\delta^{15}N$ (ppt)

Table 15: Natural nitrogen isotope abundance, *Crassostrea* $\delta^{15}N$ (mean±standard deviation)

	St Martins River	Public Landing	Johnson Bay	Chincoteague	Mean
Muscle	8.75 (0.58)	7.89 (0.48)	8.53 (0.91)	8.05 (0.88)	**8.51 (0.89)**
Gill	7.75 (0.50)	7.88 (0.27)	8.40 (0.87)	7.41 (0.97)	**7.76 (0.88)**

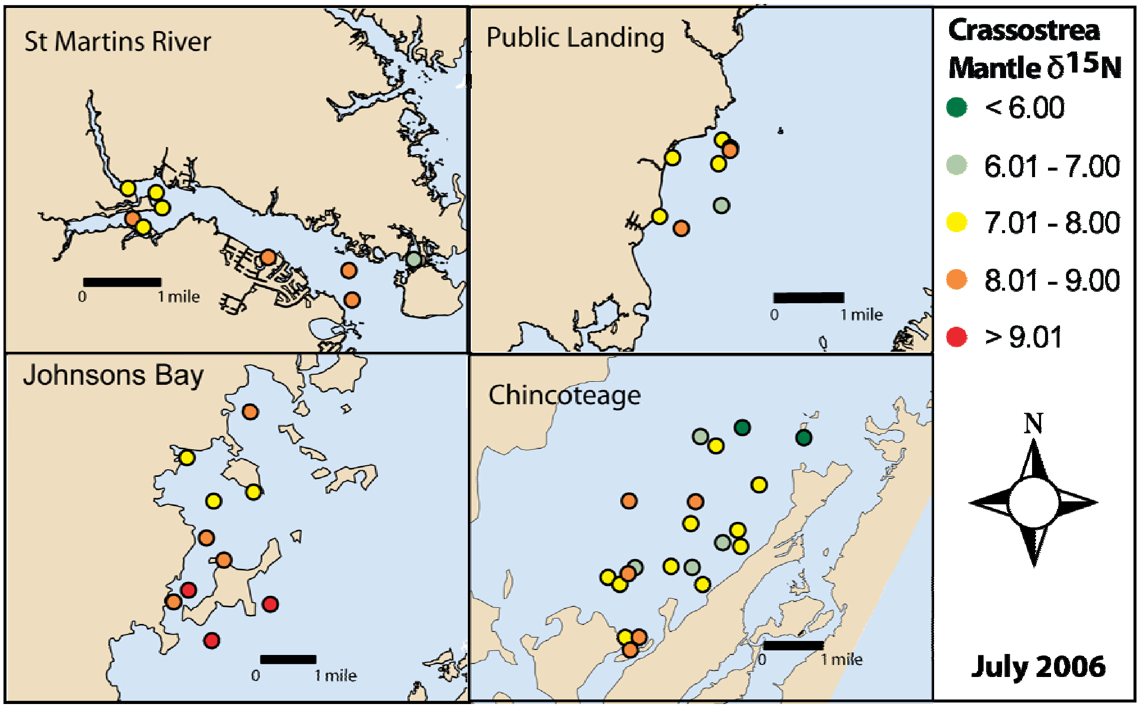


Figure 22: Natural nitrogen isotope abundance, *Crassostrea* $\delta^{15}N$ (ppt)

Table 16: Natural nitrogen isotope abundance, *Crassostrea* $\delta^{15}N$ (mean±standard deviation)

	St Martins River	Public Landing	Johnson Bay	Chincoteague	Mean
Mantle	7.71 (0.76)	8.44 (0.44)	9.30 (0.77)	7.39 (0.99)	**7.78 (0.96)**

Acknowledgments

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Appendix 1 – Survey data May 2006

			Surface				Bottom										
ID	Lat	Long	Temp	Salinity	pH	DO	Temp	Salinity	pH	DO	Secchi	Chl a	fya	Tot N (μM)	Tot P (μM)	%N	δ15N
CH1	37.98298	75.33997	22.4	31.4	7.9	7.5	22.4	31.4	6.8	7.9	0.8	4.6	32.1	26.6	1.8	1.6	7.0
CH10	37.98242	75.34555	22.2	31.3	7.9	8.0	22.2	31.3	7.9	7.9	1.1	2.8	13.6	23.2	1.6	1.3	7.5
CH11	37.96223	75.34678	22.4	31.3	7.9	7.3	21.9	31.4	7.9	6.8	0.9	5.2	25.1	26.5	1.6	1.2	6.8
CH12	37.98737	75.35465	23.0	31.3	7.9	7.7	22.9	31.3	7.9	7.8	1.2	3.6	18.0	26.0	1.7	1.3	6.8
CH14	37.97767	75.34098	22.5	31.4	7.9	7.1	22.2	31.4	7.9	7.3	0.8	7.7	30.2	26.1	1.7	1.2	6.4
CH15	37.93937	75.38305	18.9	31.2	7.7	7.4	18.9	31.2	7.7	7.1	0.8	7.3	27.7	22.5	1.6	1.9	7.9
CH16	37.94435	75.38198	19.2	31.2	7.7	7.2	19.2	31.3	7.7	7.0	1.0	6.4	30.7	21.7	1.5	1.5	7.2
CH17	37.98967	75.35960	22.7	31.3	7.8	7.2	22.5	31.3	7.9	7.2	1.0	4.8	15.0	25.4	1.7	1.5	6.5
CH18	37.95262	75.35868	21.7	31.2	nd	7.1	21.6	31.3	nd	7.4	0.5	8.3	31.9	25.6	1.7	1.4	6.8
CH19	37.98265	75.32533	23.9	32.3	8.1	nd	24.1	32.3	8.0	nd	0.5	nd	0.0	51.5	2.7	1.1	5.5
CH2	37.93622	75.38145	19.3	31.2	7.8	6.8	19.3	31.4	7.7	6.9	0.9	3.8	16.5	21.4	1.5	2.0	7.9
CH20	37.96788	75.36257	21.1	31.1	nd	13.2	20.9	31.2	nd	11.3	1.1	3.3	0	23.0	1.5	1.5	6.5
CH22	37.95693	75.36203	21.2	31.2	nd	7.0	20.9	31.2	nd	6.9	0.8	1.4	0.1	23.1	1.5	1.5	6.7
CH24	37.96968	75.35548	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	nd	nd	1.6	6.3
CH25	37.98950	75.32690	23.8	31.3	8.0	8.8	nd	nd	nd	nd	nd	5.8	0	23.1	1.5	1.7	7.1
CH26	37.95050	75.39208	20.1	31.0	7.8	7.8	20.2	31.0	7.8	7.6	0.8	3.0	0	20.2	1.5	2.0	7.5
CH27	37.95433	75.38858	20.5	31.0	7.8	9.1	20.4	31.0	7.8	8.7	1.0	1.1	1.9	20.7	1.4	nd	nd
CH28	37.97333	75.36107	21.2	31.0	nd	8.7	21.2	31.1	nd	8.5	1.0	0	6.3	20.4	1.5	1.6	7.0
CH29	37.96627	75.34775	22.4	31.3	7.8	7.1	21.9	31.4	7.9	7.4	0.7	nd	0.0	26.0	1.7	1.6	7.5
CH3	37.96312	75.35247	22.2	31.2	7.8	7.5	21.8	31.2	7.9	7.2	0.7	9.3	24.3	25.2	1.6	1.3	6.0
CH30	37.97348	75.38205	20.8	31.2	7.7	7.0	20.7	31.2	7.7	6.5	1.3	0	8.4	21.5	1.4	1.8	7.0
CH41	37.96667	75.33925	19.0	31.2	nd	7.8	22.5	31.2	8.0	6.9	0.7	6.0	nd	21.7	1.5	2.0	7.6
CH5	37.99192	75.34642	22.7	31.2	6.5	8.1	23.2	31.3	8.0	7.8	0.7	11.1	28.4	30.1	1.7	1.3	6.6
CH6	37.95682	75.38002	23.5	31.3	7.9	9.7	19.8	31.3	7.7	8.0	1.1	5.8	16.8	27.0	1.8	1.3	6.5
CH7	37.95260	75.38485	19.7	31.3	7.7	12.9	19.4	31.3	7.7	9.1	1.0	11.3	6.4	21.5	1.5	nd	nd
CH8	37.95532	75.38225	19.5	31.2	7.8	15.0	19.5	31.3	7.7	12.5	1.0	10.7	20.2	21.4	1.5	1.3	7.2
CH9	37.95715	75.36872	19.4	31.2	7.7	7.0	20.4	31.3	nd	15.6	1.1	10.7	21.7	21.0	1.5	2.0	8.1
CHS40	37.93942	75.37870	20.8	31.2	nd	6.9	19.2	31.2	nd	7.0	0.9		44.5	20.2	1.5	1.7	6.9
JB1	38.06702	75.33232	19.9	31.9	7.8	nd	19.9	31.9	7.8	nd	0.4	7.1	35.0	46.2	3.0	1.3	7.2
JB10	38.09378	75.33248	20.6	31.0	7.8	nd	20.5	31.0	7.8	nd	0.4	9.9	41.1	57.2	3.6	1.1	17.2
JB11	38.06948	75.33080	20.0	31.9	7.8	nd	20.0	31.9	7.8	nd	0.4	6.9	34.7	48.6	3.1	1.7	7.5
JB12	38.08440	75.33585	21.0	31.5	7.8	nd	21.0	31.5	7.8	nd	0.4	9.5	39.8	57.2	3.7	1.4	7.0
JB13	38.07332	75.36410	19.8	31.2	7.5	nd	19.8	31.2	7.7	nd	0.3	9.9	47.4	60.7	3.9	1.5	7.4
JB14	38.09282	75.32577	25.0	31.5	7.8	nd	20.4	31.5	7.8	nd	0.5	7.3	51.9	57.5	3.5	1.2	7.6
JB15	38.05350	75.34138	19.8	31.9	7.8	nd	19.7	32.0	7.8	nd	0.5	6.4	28.5	48.1	2.9	1.7	7.5

ID	Lat	Long	Surface Temp	Surface Salinity	Surface pH	Surface DO	Bottom Temp	Bottom Salinity	Bottom pH	Bottom DO	Secchi	Chl a	fya	Tot N (µM)	Tot P (µM)	%N	δ15N
JB16	38.06712	75.34653	19.8	31.7	7.7	nd	19.8	31.7	7.7	nd	0.4	6.2	37.6	56.6	3.5	1.4	7.3
JB17	38.04527	75.35350	19.5	32.0	7.6	nd	19.5	32.0	7.6	nd	0.6	2.8	12.0	38.8	2.1	2.2	8.1
JB18	38.03045	75.33627	19.6	31.7	7.8	nd	19.6	31.7	7.8	nd	0.5	3.9	17.9	44.4	3.2	1.5	7.9
JB2	38.04207	75.35852	19.6	32.0	7.6	nd	19.6	32.0	7.6	nd	0.6	2.6	12.0	37.7	2.3	1.9	7.8
JB20	38.10280	75.32807	20.6	30.9	7.8	nd	20.6	31.0	7.8	nd	0.3	11.7	39.2	60.6	3.8	1.5	7.2
JB21	38.03160	75.34532	19.5	31.9	7.7	nd	19.6	31.9	7.7	nd	0.5	3.0	12.7	39.6	2.6	1.6	8.2
JB22	38.09733	75.32565	20.4	31.3	7.8	nd	20.4	31.3	7.8	nd	0.2	8.7	36.6	55.5	3.6	1.7	7.8
JB23	38.04257	75.32952	19.9	32.1	7.7	nd	19.6	32.1	7.7	nd	0.5	3.6	27.9	38.6	2.4	2.1	8.2
JB24	38.06230	75.32818	19.9	31.9	7.8	nd	19.9	31.9	7.8	nd	0.3	4.6	36.4	46.3	2.9	1.7	6.9
JB25	38.08078	75.31430	19.9	31.8	7.8	nd	19.9	31.9	7.8	nd	0.5	4.6	44.2	45.3	3.2	1.4	7.9
JB26	38.07598	75.35812	21.4	31.6	7.8	nd	21.3	31.6	7.8	nd	0.5	0	95.9	57.5	3.8	1.4	6.9
JB27	38.06338	75.32387	19.9	32.0	7.7	nd	19.9	32.0	7.7	nd	0.4	12.1	34.9	47.2	2.9	1.5	7.8
JB28	38.08223	75.35387	21.2	31.6	7.8	nd	21.1	31.6	7.8	nd	0.4	13.1	43.7	58.4	4.0	1.6	7.7
JB3	38.04153	75.32540	19.6	31.7	7.9	nd	19.6	31.8	7.9	nd	0.4	3.6	17.2	44.4	3.0	1.1	6.4
JB4	38.07145	75.34815	19.8	31.3	7.7	nd	19.7	31.3	7.7	nd	0.4	3.4	19.9	57.2	3.6	1.6	7.4
JB5	38.08130	75.35423	21.3	31.6	7.8	nd	21.2	31.6	7.8	nd	0.4	8.1	45.4	57.6	3.8	1.3	8.8
JB6	38.05950	75.34743	19.8	31.8	7.6	nd	19.8	31.8	7.6	nd	0.5	6.0	42.1	56.1	3.3	1.6	8.0
JB7	38.08620	75.31900	20.1	31.4	7.8	nd	20.1	31.3	7.9	nd	0.5	6.4	39.0	52.2	3.2	1.2	7.0
JB8	38.08762	75.33642	20.7	31.1	7.8	nd	20.7	31.1	7.8	nd	0.4	8.7	47.1	56.9	3.6	1.6	7.8
JB9	38.06950	75.34493	19.7	31.9	7.7	nd	19.7	31.8	7.7	nd	0.5	6.7	31.0	52.5	3.1	1.1	6.6
JBS30	38.07183	75.35755	19.8	31.4	7.6	nd	19.8	31.4	7.6	nd	0.4	7.9	48.8	62.0	4.0	1.2	7.4
PL1	38.14750	75.26952	23.2	30.3	8.1	8.4	30.3	23.0	8.1	7.9	0.4	10.3	45.6	49.6	3.1	1.4	7.0
PL10	38.13995	75.28325	22.9	30.4	8.1	8.4	22.8	30.4	8.1	8.4	0.4	9.7	42.2	50.3	3.3	1.2	6.4
PL11	38.14425	75.26870	23.0	30.3	8.1	8.3	22.4	30.4	8.1	7.6	0.4	7.5	42.3	50.9	3.0	1.6	6.8
PL12	38.12412	75.28073	22.7	30.4	8.0	8.5	22.5	30.4	8.1	8.1	0.3	9.9	41.0	50.0	3.2	1.6	6.9
PL13	38.11877	75.28355	23.0	30.5	8.1	8.4	22.8	30.5	8.1	8.3	0.4	6.4	52.7	50.4	3.2	1.6	6.9
PL14	38.15995	75.26668	23.7	30.3	8.0	8.2	23.3	30.3	8.0	8.3	nd	4.8	64.5	52.9	3.1	1.2	6.8
PL15	38.15363	75.26825	23.6	30.4	8.1	8.1	23.3	30.3	8.0	7.7	0.4	nd	0.0	53.5	3.2	1.7	6.9
PL16	38.15907	75.26385	23.4	30.2	8.0	8.4	23.1	30.3	8.0	8.0	0.4	nd	0.0	50.0	3.0	1.5	7.7
PL17	38.13688	75.27862	22.6	30.3	8.0	8.1	22.1	30.3	8.1	8.1	0.4	6.2	54.2	51.9	3.2	1.4	6.9
PL18	38.14353	75.26205	23.1	30.3	8.1	8.4	22.6	30.3	8.1	8.4	0.3	4.0	51.6	49.8	3.0	1.3	6.8
PL19	38.16048	75.26555	nd	30.4	8.1	8.3	23.3	30.4	8.0	8.3	0.4	7.1	56.2	53.2	3.1	2.0	7.3
PL2	38.13770	75.27867	22.7	30.7	8.0	8.5	21.9	30.3	8.1	7.8	0.4	9.9	49.2	50.3	3.3	1.6	7.2
PL20	38.13085	75.28155	22.8	30.3	8.0	8.6	22.7	30.4	8.1	8.4	0.4	4.8	54.5	49.8	3.2	1.2	6.9
PL21	38.14247	75.26388	23.0	30.3	8.0	8.4	22.5	30.3	8.1	8.1	0.4	3.9	21.8	49.1	2.9	1.3	6.2
PL22	38.14905	75.28447	23.4	30.4	8.0	7.9	23.3	30.5	8.0	7.8	0.4	8.5	60.2	62.1	3.5	1.7	6.8
PL3	38.13388	75.28858	24.4	30.5	8.0	8.3	24.3	30.5	8.0	8.2	0.3	8.9	39.3	53.1	3.1	1.4	7.4

			Surface				Bottom										
ID	Lat	Long	Temp	Salinity	pH	DO	Temp	Salinity	pH	DO	Secchi	Chl a	fya	Tot N (µM)	Tot P (µM)	%N	δ15N
PL4	38.15162	75.26570	23.3	30.3	8.1	8.2	23.1	30.3	8.1	7.8	0.4	nd	0.0	51.5	3.2	1.2	6.8
PL5	38.13820	75.27607	22.8	30.3	8.1	8.5	22.4	30.3	8.0	8.5	0.3	6.7	46.1	48.1	2.9	1.6	7.3
PL6	38.14357	75.26278	22.8	30.3	8.1	8.4	22.7	30.3	8.0	8.0	0.3	8.3	44.0	48.4	3.0	nd	nd
PL7	38.15098	75.26577	23.4	30.3	8.0	8.3	23.2	30.3	8.1	8.2	0.4	10.3	48.2	51.8	3.2	1.2	7.1
PL8	38.13678	75.26853	22.7	30.4	8.0	8.4	22.2	30.4	8.1	8.3	0.5	6.7	43.1	47.1	2.8	1.6	7.7
PL9	38.13945	75.26163	22.9	30.3	8.0	8.4	22.7	30.4	8.1	8.3	0.4	10.9	35.3	45.6	2.7	1.2	6.8
SM1	38.41235	75.17388	24.3	24.9	7.7	nd	24.3	24.9	7.7	nd	0.6	5.1	40.0	57.4	2.7	1.5	7.4
SM10	38.40733	75.17957	23.9	25.1	7.7	nd	23.8	25.1	7.7	nd	0.6	6.8	49.7	58.0	2.6	1.7	7.6
SM11	38.39963	75.11118	23.4	28.9	7.6	nd	23.4	28.9	7.6	nd	0.4	3.6	17.6	47.0	1.8	2.2	7.7
SM12	38.39078	75.12132	21.3	28.8	7.6	nd	21.2	28.8	7.7	nd	0.7	5.4	33.3	47.1	2.2	1.7	7.3
SM13	38.41053	75.16702	23.6	25.1	7.7	nd	23.0	25.5	7.7	nd	0.6	9.1	26.2	57.9	2.5	1.7	7.1
SM14	38.39188	75.12618	21.7	28.5	7.6	nd	21.3	28.4	7.6	nd	0.7	8.3	27.4	58.7	2.3	1.6	7.8
SM15	38.39957	75.13437	21.8	27.7	7.6	nd	21.8	27.7	7.6	nd	0.6	9.3	23.2	49.8	2.2	1.8	6.7
SM16	38.40307	75.13685	22.1	26.7	7.6	nd	22.1	26.1	7.6	nd	0.7	8.9	19.7	57.1	2.4	2.1	7.7
SM17	38.39477	75.12627	21.4	28.4	7.5	nd	21.3	28.4	7.6	nd	0.6	9.7	20.9	50.0	2.2	2.2	7.5
SM18	38.39282	75.12080	21.4	28.6	7.7	nd	21.2	28.6	7.7	nd	0.6	12.7	22.0	46.9	2.1	1.5	7.5
SM19	38.41163	75.15837	23.0	25.6	7.7	nd	23.0	25.6	7.7	nd	0.7	11.0	17.2	56.5	2.5	1.4	7.4
SM2	38.39447	75.13135	21.7	28.3	7.5	nd	21.6	28.3	7.6	nd	0.6	5.2	40.6	50.3	2.3	2.0	7.4
SM20	38.39752	75.12698	21.7	27.8	7.6	nd	21.7	27.8	7.7	nd	0.5	11.7	16.2	53.1	2.1	1.8	7.8
SM3	38.40573	75.17702	23.8	25.1	7.7	nd	23.5	20.6	7.7	nd	0.6	3.9	49.2	57.3	2.5	1.5	7.4
SM31	38.40943	75.17240	23.4	25.4	7.8	nd	23.2	25.5	7.7	nd	0.7	6.6	18.7	57.5	2.5	2.1	7.5
SM4	38.40467	75.14813	22.5	26.6	7.6	nd	22.4	26.6	7.6	nd	0.6	6.9	29.4	56.5	2.5	1.3	7.2
SM5	38.40000	75.14665	22.2	27.6	7.4	nd	20.5	27.8	7.4	nd	0.7	4.6	33.7	57.1	2.6	3.2	8.3
SM6	38.41312	75.18072	24.8	23.6	7.8	nd	24.4	24.0	7.8	nd	0.5	14.3	66.1	69.3	3.5	1.6	6.9
SM7	38.39862	75.12857	21.8	27.7	7.6	nd	21.8	27.8	7.6	nd	0.6	5.4	32.0	52.0	2.2	1.4	6.4
SM9	38.40085	75.13327	22.0	27.3	7.6	nd	21.9	27.4	7.6	nd	0.6	5.4	23.1	56.1	2.3	1.6	7.0
SMS28	38.39673	75.13168	21.6	28.0	7.5	nd	21.5	28.0	7.6	nd	0.7	19.7	33.2	51.1	2.2	1.7	7.6

Appendix 2 – Survey data July 2006

			Surface				Bottom								
ID	Lat	Long	Temp	Salinity	pH	DO	Temp	Salinity	pH	DO	Secchi	Chl a	fya	Tot N (μM)	Tot P (μM)
CH1	37.98298	75.33997	31.3	29.6	8.0	6.7	31.3	29.6	8.0	5.4	0.4	17.1	9.3	35.5	3.3
CH10	37.98242	75.34555	31.9	29.7	8.0	7.3	31.8	29.7	8.0	5.4	0.6	20.2	6.1	33.3	3.3
CH11	37.96223	75.34678	31.5	29.5	8.0	6.8	31.4	29.5	8.0	5.4	0.4	28.6	13.8	39.5	3.7
CH12	37.98737	75.35465	32.6	29.6	8.1	8.2	32.6	29.6	8.1	5.4	0.6	14.4	3.1	31.7	3.1
CH14	37.97767	75.34098	31.2	29.6	7.9	6.5	31.2	29.6	7.9	5.4	0.4	19.9	12.7	34.5	3.4
CH15	37.93937	75.38305	29.0	30.0	7.8	5.7	28.9	30.0	7.8	5.4	0.4	31.8	9.0	31.5	3.1
CH16	37.94435	75.38198	27.9	30.0	7.8	5.5	27.8	30.0	7.8	5.4	0.4	33.9	4.7	30.2	3.0
CH17	37.98967	75.35960	32.7	29.6	8.2	8.6	32.7	29.6	8.2	5.4	0.6	26.2	9.2	33.5	3.3
CH18	37.95262	75.35868	30.5	29.7	7.9	6.8	30.1	29.6	7.9	6.8	0.5	22.6	10.3	35.8	3.4
CH19	37.98265	75.32533	32.5	29.6	8.0	6.1	32.5	29.6	8.0	5.4	0.7	17.9	6.2	35.8	3.0
CH2	37.93622	75.38145	27.9	30.0	7.8	5.3	27.9	30.0	7.8	5.4	0.4	29.2	8.7	32.4	3.1
CH20	37.96788	75.36257	30.7	29.6	7.9	5.9	28.8	29.5	7.8	4.2	0.5	31.0	13.7	34.6	3.4
CH22	37.95693	75.36203	30.2	29.7	7.8	5.5	28.8	29.7	7.8	4.9	0.4	29.8	7.9	32.8	3.4
CH23	37.95453	75.38487	30.3	29.7	7.8	5.6	28.4	29.8	7.8	5.3	0.6	33.2	7.1	29.1	2.8
CH24	37.96968	75.35548	30.8	29.5	7.9	5.8	29.7	29.6	7.9	5.4	0.6	32.0	16.8	33.9	3.2
CH25	37.98950	75.32690	32.0	29.4	8.1	7.8	32.0	29.4	8.1	5.4	0.4	17.1	8.6	38.2	3.7
CH26	37.95050	75.39208	29.4	30.0	7.8	5.5	28.7	30.0	7.8	5.3	0.5	41.3	3.2	30.6	3.1
CH27	37.95433	75.38858	30.0	29.8	7.8	5.5	28.5	29.9	7.8	5.2	0.6	37.1	7.2	29.5	3.0
CH28	37.97333	75.36107	30.6	29.5	7.9	5.5	28.8	29.6	7.9	5.0	0.6	25.2	8.2	34.5	3.5
CH29	37.96627	75.34775	31.2	29.6	8.0	6.8	31.2	29.6	8.0	5.4	0.4	27.8	18.1	35.6	3.6
CH3	37.96312	75.35247	30.4	29.4	7.9	5.1	30.0	29.4	7.9	4.8	0.5	29.0	11.4	37.1	3.4
CH30	37.97348	75.38205	30.8	29.7	7.9	6.4	30.7	29.7	7.9	5.4	0.4	50.2	20.1	37.4	4.0
CH41	37.96667	75.33925	28.1	30.0	7.8	5.3	28.0	29.9	7.8	5.4	0.4	37.7	5.9	32.3	3.2
CH5	37.99192	75.34642	32.2	29.5	8.1	7.0	31.9	29.5	8.1	5.4	0.4	20.2	12.7	44.4	3.5
CH6	37.95682	75.38002	32.3	29.6	8.2	7.8	32.3	29.6	8.2	5.4	0.6	3.2	6.3	34.7	3.1
CH7	37.95260	75.38485	30.2	29.6	7.8	5.6	28.4	29.8	7.8	5.1	0.6	32.4	6.4	32.3	3.1
CH8	37.95532	75.38225	29.7	30.0	7.8	5.5	28.5	30.0	7.8	5.4	0.6	30.2	7.7	29.9	2.8
CH9	37.95715	75.36872	30.3	29.6	7.8	5.5	28.3	29.9	7.8	5.2	0.6	31.2	7.1	30.8	2.9
CHS40	37.93942	75.37870	30.4	29.7	7.8	5.8	28.5	29.7	7.8	5.0	0.5	36.7	7.8	32.2	3.2
JB1	38.06702	75.33232	29.1	27.1	7.9	8.9	28.5	27.5	7.8	4.4	0.5	25.4	12.1	48.1	5.0
JB10	38.09378	75.33248	29.1	26.0	7.9	6.1	29.0	25.9	7.9	5.7	0.4	27.8	10.6	50.3	4.6
JB11	38.06948	75.33080	29.2	27.2	7.9	5.2	28.5	27.4	7.7	3.6	0.4	29.4	9.9	45.7	4.8
JB12	38.08440	75.33585	29.9	26.0	7.8	6.1	29.5	26.0	7.8	5.6	0.4	36.1	7.1	50.4	4.7
JB13	38.07332	75.36410	28.8	25.1	7.9	4.9	28.7	25.1	7.9	4.6	0.3	46.5	20.1	65.9	7.2
JB14	38.09282	75.32577	29.8	27.1	7.9	5.3	29.0	27.0	7.8	5.1	0.5	23.0	5.8	45.1	4.2

			Surface				Bottom					Surface			Bottom
ID	Lat	Long	Temp	Salinity	pH	DO	Temp	Salinity	pH	DO	Secchi	Chl a	fya	Tot N (μM)	Tot P (μM)
JB15	38.05350	75.34138	28.5	26.9	7.8	4.1	28.5	26.9	7.8	4.4	0.5	28.8	11.4	49.6	5.6
JB16	38.06712	75.34653	28.6	25.9	8.0	5.7	28.5	25.9	8.0	5.6	0.5	39.7	16.9	54.9	5.6
JB17	38.04527	75.35350	28.4	26.6	7.9	4.6	28.4	26.5	7.8	4.5	0.3	42.3	15.4	51.0	5.5
JB18	38.03045	75.33627	28.6	28.4	7.9	4.8	28.5	28.4	7.8	4.9	0.6	23.6	6.8	33.8	3.7
JB2	38.04207	75.35852	28.9	26.7	7.9	4.8	28.6	26.8	7.9	4.7	0.3	38.3	15.2	48.6	5.1
JB20	38.10280	75.32807	29.6	25.6	7.8	6.3	28.7	25.9	7.7	4.5	0.4	9.7	0.8	60.0	5.5
JB21	38.03160	75.34532	28.6	28.0	7.8	4.8	28.6	28.0	7.8	4.7	0.5	58.8	15.8	36.1	3.6
JB22	38.09733	75.32565	29.8	26.0	7.9	5.8	28.7	26.8	7.8	4.6	0.3	30.6	9.8	49.0	4.4
JB23	38.04257	75.32952	28.7	27.5	7.8	4.8	28.6	27.5	7.8	4.7	0.4	31.8	12.9	49.0	5.0
JB24	38.06230	75.32818	29.0	27.6	7.9	5.1	28.6	27.6	7.8	4.6	0.4	31.0	12.1	47.7	5.0
JB25	38.08078	75.31430	29.2	27.6	7.9	5.3	28.9	27.7	7.9	5.3	0.5	40.1	0	43.3	4.2
JB26	38.07598	75.35812	31.2	25.3	7.9	7.3	29.8	25.6	8.0	7.8	0.2	64.5	18.8	70.2	6.8
JB27	38.06338	75.32387	28.8	27.6	7.9	5.3	28.5	27.8	7.8	4.4	0.4	30.4	9.1	45.9	4.8
JB28	38.08223	75.35387	31.2	25.4	7.9	6.4	30.0	25.3	7.9	6.4	0.4	35.1	11.0	57.3	6.1
JB3	38.04153	75.32540	28.7	27.8	7.8	4.6	28.6	27.8	7.8	4.5	0.4	32.6	5.4	41.1	4.3
JB4	38.07145	75.34815	28.7	26.0	8.0	5.7	28.7	26.0	8.0	5.7	0.4	18.2	8.8	54.3	5.7
JB5	38.08130	75.35423	31.1	25.2	7.9	6.8	28.9	25.6	7.7	4.3	0.3	41.9	12.7	57.6	6.0
JB6	38.05950	75.34743	28.4	26.2	7.9	5.3	28.4	26.3	7.9	5.2	0.4	37.3	15.2	52.0	5.5
JB7	38.08620	75.31900	29.3	27.2	7.9	5.2	28.7	27.2	7.8	5.1	0.6	19.7	4.4	42.3	4.0
JB8	38.08762	75.33642	30.5	25.8	7.9	6.1	28.9	26.2	7.8	5.4	0.5	44.5	7.1	53.8	4.9
JB9	38.06950	75.34493	28.6	26.2	8.0	5.9	28.6	26.2	8.0	5.7	0.4	32.2	17.0	52.4	5.5
JBS30	38.07183	75.35755	28.8	25.4	7.9	5.3	28.8	25.5	7.9	5.3	0.4	52.4	21.8	64.5	6.6
OJB11	38.07203	75.33123	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
PL1	38.14750	75.26952	29.8	28.6	7.9	5.0	29.5	28.6	7.9	4.5	0.4	35.1	14.9	59.2	4.5
PL10	38.13995	75.28325	30.0	28.5	nd	4.5	30.0	28.5	nd	4.6	0.4	28.0	12.0	56.7	4.9
PL11	38.14425	75.26870	29.7	28.7	7.9	5.1	29.4	28.7	7.9	4.7	0.3	35.1	13.8	60.9	4.6
PL12	38.12412	75.28073	29.1	28.3	7.8/9	5.3	29.0	28.3	7.9	5.1	0.4	31.6	10.4	53.1	4.8
PL13	38.11877	75.28355	29.0	28.2	7.9	5.0	29.0	28.2	7.9	4.9	0.4	26.8	12.2	50.3	4.5
PL14	38.15995	75.26668	30.4	28.5	7.9	5.0	29.6	28.5	7.9	4.4	0.4	39.7	18.7	62.6	4.7
PL15	38.15363	75.26825	30.2	28.5	7.9	4.8	29.6	28.5	7.8	4.0	0.3	37.1	18.2	62.1	4.7
PL16	38.15907	75.26385	30.3	28.5	7.9	5.1	29.5	28.6	7.9	4.4	0.4	40.3	17.2	62.2	4.7
PL17	38.13688	75.27862	29.4	28.4	nd	5.2	29.5	28.4	nd	5.1	0.3	27.2	11.1	54.1	4.8
PL18	38.14353	75.26205	29.6	28.7	nd	4.9	29.3	28.7	nd	4.5	0.4	32.4	13.0	58.1	4.6
PL19	38.16048	75.26555	30.2	28.5	7.9	4.8	29.6	28.5	7.9	4.3	0.3	39.5	18.5	63.5	4.9
PL2	38.13770	75.27867	29.5	28.4	nd	4.8	29.5	28.4	nd	4.7	0.3	24.6	11.0	54.9	4.7

			Surface				Bottom								
ID	Lat	Long	Temp	Salinity	pH	DO	Temp	Salinity	pH	DO	Secchi	Chl a	fya	Tot N (μM)	Tot P (μM)
PL20	38.13085	75.28155	30.0	28.5	7.9	4.8	29.9	28.5	7.9	4.7	0.4	27.0	15.5	56.9	5.1
PL21	38.14247	75.26388	29.6	28.7	nd	4.9	29.4	28.7	nd	4.5	0.4	34.7	14.7	59.2	4.7
PL22	38.14905	75.28447	30.3	28.5	7.8	4.2	30.3	28.5	7.8	4.1	0.4	17.9	6.9	65.8	5.9
PL3	38.13388	75.28858	30.2	28.5	7.9	4.2	30.2	28.5	7.9	4.1	0.4	32.0	12.0	60.4	5.7
PL4	38.15162	75.26570	30.0	28.5	7.9	4.7	29.4	28.5	7.8	3.8	0.4	37.5	15.3	60.8	4.6
PL5	38.13820	75.27607	29.5	28.6	nd	5.1	29.5	28.6	nd	5.0	0.4	22.6	9.2	56.7	4.7
PL6	38.14357	75.26278	29.7	28.7	nd	4.9	29.4	28.7	nd	4.5	0.4	33.4	10.8	60.3	4.7
PL7	38.15098	75.26577	29.7	28.6	7.8	4.5	29.4	28.6	7.8	3.7	0.4	39.7	15.8	61.9	4.8
PL8	38.13678	75.26853	29.2	28.6	nd	5.0	29.2	28.6	nd	4.4	0.5	22.0	10.5	55.2	4.5
PL9	38.13945	75.26163	29.3	28.7	7.9	4.7	29.1	28.7	7.9	4.5	0.4	27.4	13.5	56.8	4.5
SM1	38.41235	75.17388	33.5	24.3	8.1	10.1	32.4	24.5	8.0	8.5	0.2	112.3	13.5	86.9	6.0
SM10	38.40733	75.17957	33.6	22.7	8.1	9.5	30.7	22.9	8.0	7.1	0.2	19.4	4.3	97.1	6.4
SM11	38.39963	75.11118	31.7	28.0	7.7	6.8	31.7	28.0	7.7	6.7	0.4	47.4	4.0	55.9	3.2
SM12	38.39078	75.12132	29.2	28.1	7.8	6.3	27.0	28.2	7.7	4.4	0.4	5.6	26.5	49.5	3.3
SM13	38.41053	75.16702	33.1	24.4	8.0	9.2	29.9	25.5	7.8	8.1	0.3	18.8	0	83.8	5.7
SM14	38.39188	75.12618	30.1	27.6	7.9	6.8	27.8	28.2	7.8	5.0	0.4	51.2	13.2	56.0	3.9
SM15	38.39957	75.13437	30.8	26.6	7.9	7.3	30.7	26.5	7.9	7.4	0.3	11.5	2.7	64.0	4.1
SM16	38.40307	75.13685	31.0	26.8	7.9	7.7	30.9	26.8	7.9	7.5	0.3	53.8	11.2	62.2	4.0
SM17	38.39477	75.12627	30.2	27.6	7.9	6.9	28.0	28.0	7.8	4.8	0.4	40.3	11.7	57.1	3.9
SM18	38.39282	75.12080	29.4	28.2	7.8	6.3	27.5	28.3	7.7	5.2	0.3	44.7	10.0	51.7	4.3
SM19	38.41163	75.15837	32.7	25.4	8.0	9.5	31.5	25.5	7.9	8.6	0.3	50.3	5.5	77.4	5.4
SM2	38.39447	75.13135	30.2	26.6	7.8	7.0	27.8	27.8	7.7	3.5	0.4	51.6	11.9	63.5	4.1
SM20	38.39752	75.12698	30.3	27.7	7.8	7.0	29.5	27.6	7.8	6.4	0.4	46.1	13.0	54.8	3.7
SM3	38.40573	75.17702	33.4	22.2	8.2	10.3	30.3	23.6	7.8	4.8	0.3	93.8	17.0	96.7	6.2
SM31	38.40943	75.17240	33.7	24.2	8.1	9.8	33.7	24.2	8.0	9.5	0.3	98.3	16.8	88.4	6.1
SM4	38.40467	75.14813	31.6	25.6	8.0	8.9	29.0	27.1	7.8	7.5	0.4	73.5	12.7	72.2	4.8
SM5	38.40000	75.14665	33.4	24.6	7.9	7.7	30.6	24.9	7.8	7.6	0.3	66.1	19.5	80.1	5.2
SM6	38.41312	75.18072	33.3	23.5	8.0	9.3	32.1	23.6	8.0	7.5	0.2	95.0	20.1	90.9	6.4
SM7	38.39862	75.12857	30.7	27.5	7.8	7.0	29.6	27.7	7.8	6.6	0.4	51.6	11.7	57.6	4.0
SM9	38.40085	75.13327	30.7	27.3	7.9	7.9	30.4	27.3	7.8	7.3	0.4	26.2	4.6	58.0	3.7
SMS28	38.39673	75.13168	31.3	26.6	7.9	7.5	28.3	27.6	7.8	5.4	0.4	54.6	9.6	64.2	4.2

ID	Lat	Long	*Gracilaria* %N	*Gracilaria* δ15N	*Crassostrea* Muscle %N	*Crassostrea* Muscle δ15N	*Crassostrea* Gill %N	*Crassostrea* Gill δ15N	*Crassostrea* Mantle %N	*Crassostrea* Mantle δ15N
CH1	37.98298	75.33997	1.1	4.0	0.0	0.0	0.0	0.0	0.0	0.0
CH10	37.98242	75.34555	1.0	8.4	nd	nd	nd	nd	nd	nd
CH11	37.96223	75.34678	1.6	8.0	11.6	8.9	7.6	6.9	8.0	7.4
CH12	37.98737	75.35465	1.3	7.4	12.4	9.2	7.9	7.7	8.5	7.8
CH14	37.97767	75.34098	1.5	4.9	11.0	8.3	6.9	7.4	7.5	7.8
CH15	37.93937	75.38305	1.5	6.6	13.0	8.8	8.8	8.9	9.5	7.9
CH16	37.94435	75.38198	1.2	7.3	nd	nd	nd	nd	nd	nd
CH17	37.98967	75.35960	1.3	6.2	12.7	8.5	8.4	7.1	7.6	6.9
CH18	37.95262	75.35868	1.5	7.6	12.0	7.4	8.3	6.5	8.9	7.1
CH19	37.98265	75.32533	1.3	8.7	nd	nd	nd	nd	nd	nd
CH2	37.93622	75.38145	1.2	5.1	12.2	8.6	8.2	8.0	8.3	8.7
CH20	37.96788	75.36257	1.3	7.0	12.6	8.1	7.9	7.6	8.1	7.1
CH22	37.95693	75.36203	1.3	7.3	12.0	7.9	7.8	7.8	8.5	7.0
CH23	37.95453	75.38487	1.5	6.8	nd	nd	nd	nd	nd	nd
CH24	37.96968	75.35548	1.4	8.1	nd	nd	nd	nd	nd	nd
CH25	37.98950	75.32690	1.2	9.1	11.2	6.5	7.8	5.5	6.9	5.1
CH26	37.95050	75.39208	1.2	8.0	nd	nd	nd	nd	nd	nd
CH27	37.95433	75.38858	1.1	8.4	11.2	7.8	8.2	7.1	7.2	7.3
CH28	37.97333	75.36107	1.5	7.3	11.1	7.2	8.0	8.1	8.2	8.0
CH29	37.96627	75.34775	2.0	8.7	10.5	7.2	7.1	6.4	8.1	7.8
CH3	37.96312	75.35247	1.9	7.6	12.6	7.2	8.2	7.0	7.0	6.5
CH30	37.97348	75.38205	1.1	6.9	12.2	8.1	8.6	7.7	9.7	8.4
CH41	37.96667	75.33925	1.4	5.6	nd	nd	nd	nd	nd	nd
CH5	37.99192	75.34642	1.9	5.3	11.1	6.5	7.8	5.3	7.1	5.2
CH6	37.95682	75.38002	1.2	6.4	11.6	7.1	7.3	6.6	7.1	6.5
CH7	37.95260	75.38485	1.4	5.4	10.4	8.3	7.5	8.5	6.2	7.8
CH8	37.95532	75.38225	1.2	4.5	10.7	8.6	7.1	8.4	7.2	8.6
CH9	37.95715	75.36872	1.3	7.7	10.6	8.9	5.7	8.2	6.4	7.6
CHS40	37.93942	75.37870	1.0	8.4	10.5	10.0	7.6	8.8	7.0	8.9
JB1	38.06702	75.33232	3.1	5.3	nd	nd	nd	nd	nd	nd
JB10	38.09378	75.33248	3.0	7.0	14.1	8.6	10.3	7.8	9.8	8.3
JB11	38.06948	75.33080	2.0	6.1	nd	nd	nd	nd	nd	nd
JB12	38.08440	75.33585	3.1	5.9	nd	nd	nd	nd	nd	nd
JB13	38.07332	75.36410	2.5	7.0	nd	nd	nd	nd	nd	nd
JB14	38.09282	75.32577	3.7	6.8	nd	nd	nd	nd	nd	nd
JB15	38.05350	75.34138	2.8	7.3	12.6	9.1	9.0	8.6	8.5	8.2
JB16	38.06712	75.34653	2.6	5.4	nd	nd	nd	nd	nd	nd
JB17	38.04527	75.35350	3.0	6.4	14.0	10.2	8.6	8.8	10.9	9.1
JB18	38.03045	75.33627	3.1	6.9	nd	nd	nd	nd	nd	nd
JB2	38.04207	75.35852	3.1	7.5	12.5	9.7	7.7	8.5	8.2	8.7
JB20	38.10280	75.32807	2.7	7.5	nd	nd	nd	nd	nd	nd
JB21	38.03160	75.34532	2.8	5.2	11.8	10.3	8.6	9.5	9.2	9.6
JB22	38.09733	75.32565	2.9	5.8	nd	nd	nd	nd	nd	nd
JB23	38.04257	75.32952	3.2	8.0	nd	nd	nd	nd	nd	nd
JB24	38.06230	75.32818	3.2	6.7	nd	nd	nd	nd	nd	nd
JB25	38.08078	75.31430	2.8	7.3	nd	nd	nd	nd	nd	nd
JB26	38.07598	75.35812	2.9	5.8	nd	nd	nd	nd	nd	nd
JB27	38.06338	75.32387	2.2	6.1	nd	nd	nd	nd	nd	nd
JB28	38.08223	75.35387	2.8	7.3	nd	nd	nd	nd	nd	nd
JB3	38.04153	75.32540	3.1	7.6	12.4	10.3	11.0	10.2	11.3	10.4
JB4	38.07145	75.34815	2.6	7.8	nd	nd	nd	nd	nd	nd

			Gracilaria		*Crassostrea*					
ID	**Lat**	**Long**	**%N**	**δ15N**	**Muscle %N**	**Muscle δ15N**	**Gill %N**	**Gill δ15N**	**Mantle %N**	**Mantle δ15N**
JB5	38.08130	75.35423	2.8	8.0	12.8	9.1	8.4	7.3	9.9	8.0
JB6	38.05950	75.34743	2.9	7.9	12.0	9.1	7.6	7.6	10.5	8.2
JB7	38.08620	75.31900	3.0	6.9	nd	nd	nd	nd	nd	nd
JB8	38.08762	75.33642	3.0	6.4	nd	nd	nd	nd	nd	nd
JB9	38.06950	75.34493	2.1	7.8	11.6	7.8	8.1	7.6	8.2	7.2
JBS30	38.07183	75.35755	2.1	7.9	nd	nd	nd	nd	nd	nd
OJB11	38.07203	75.33123	nd	nd	12.7	8.8	8.4	8.1	7.3	7.6
PL1	38.14750	75.26952	1.9	6.6	11.8	7.7	8.0	7.7	8.3	7.9
PL10	38.13995	75.28325	1.5	7.7	nd	nd	nd	nd	nd	nd
PL11	38.14425	75.26870	1.9	6.5	nd	nd	nd	nd	nd	nd
PL12	38.12412	75.28073	1.7	6.3	nd	nd	nd	nd	nd	nd
PL13	38.11877	75.28355	1.8	7.7	nd	nd	nd	nd	nd	nd
PL14	38.15995	75.26668	2.1	5.8	nd	nd	nd	nd	nd	nd
PL15	38.15363	75.26825	1.9	7.6	11.4	8.7	9.0	7.9	8.3	7.8
PL16	38.15907	75.26385	2.3	6.1	nd	nd	nd	nd	nd	nd
PL17	38.13688	75.27862	2.1	6.6	nd	nd	nd	nd	nd	nd
PL18	38.14353	75.26205	1.8	5.5	nd	nd	nd	nd	nd	nd
PL19	38.16048	75.26555	2.7	6.7	nd	nd	nd	nd	nd	nd
PL2	38.13770	75.27867	2.2	6.9	nd	nd	nd	nd	nd	nd
PL20	38.13085	75.28155	1.8	6.3	12.4	7.9	10.4	7.9	11.2	8.3
PL21	38.14247	75.26388	2.2	5.8	nd	nd	nd	nd	nd	nd
PL22	38.14905	75.28447	1.6	5.9	12.1	9.0	8.0	7.8	7.5	7.5
PL3	38.13388	75.28858	1.6	8.1	13.0	8.7	8.9	8.1	8.8	7.9
PL4	38.15162	75.26570	2.2	6.3	12.5	8.7	9.4	8.3	11.0	8.1
PL5	38.13820	75.27607	1.8	8.2	nd	nd	nd	nd	nd	nd
PL6	38.14357	75.26278	1.7	8.3	nd	nd	nd	nd	nd	nd
PL7	38.15098	75.26577	1.7	6.9	12.9	8.6	9.5	8.2	11.6	8.6
PL8	38.13678	75.26853	1.7	5.1	11.0	8.1	7.7	7.4	8.0	6.9
PL9	38.13945	75.26163	2.4	8.2	nd	nd	nd	nd	nd	nd
SM1	38.41235	75.17388	3.3	6.1	13.6	8.7	9.3	7.6	9.5	7.5
SM10	38.40733	75.17957	3.3	6.0	13.4	8.7	7.8	8.1	5.2	8.2
SM11	38.39963	75.11118	3.1	5.6	12.9	8.2	7.1	6.8	6.7	6.3
SM12	38.39078	75.12132	nd	nd	nd	nd	nd	nd	nd	nd
SM13	38.41053	75.16702	3.5	6.8	nd	nd	nd	nd	nd	nd
SM14	38.39188	75.12618	2.9	8.2	13.3	9.6	8.0	8.5	7.5	8.7
SM15	38.39957	75.13437	2.3	7.5	nd	nd	nd	nd	nd	nd
SM16	38.40307	75.13685	2.4	6.1	nd	nd	nd	nd	nd	nd
SM17	38.39477	75.12627	3.3	7.3	nd	nd	nd	nd	nd	nd
SM18	38.39282	75.12080	3.1	7.2	nd	nd	nd	nd	nd	nd
SM19	38.41163	75.15837	3.0	6.8	nd	nd	nd	nd	nd	nd
SM2	38.39447	75.13135	2.5	2.5	nd	nd	nd	nd	nd	nd
SM20	38.39752	75.12698	3.0	7.2	12.7	8.7	8.2	7.8	9.4	8.4
SM3	38.40573	75.17702	3.6	6.0	13.1	9.1	7.3	7.9	7.0	7.9
SM31	38.40943	75.17240	3.8	6.8	12.7	7.5	8.0	7.3	8.2	7.1
SM4	38.40467	75.14813	2.7	5.3	nd	nd	nd	nd	nd	nd
SM5	38.40000	75.14665	2.8	8.4	12.8	9.1	8.2	8.4	9.4	8.4
SM6	38.41312	75.18072	3.1	6.4	12.1	9.1	7.7	7.6	7.0	7.0
SM7	38.39862	75.12857	3.3	5.5	nd	nd	nd	nd	nd	nd
SM9	38.40085	75.13327	2.7	5.1	nd	nd	nd	nd	nd	nd
SMS28	38.39673	75.13168	3.0	4.7	nd	nd	nd	nd	nd	nd