NOAA Technical Report, OAR AOML-38

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Atlantic Oceanographic and Meteorological Laboratory
Miami, Florida

February 2010

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / Office of Oceanic and Atmospheric Research

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February 2010

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List of Acronyms

ADCP	Acoustic Doppler current profiler
AOML	Atlantic Oceanographic and Meteorological Laboratory
BC	Boca Raton
BR	Broward
BRI	Boca Raton Inlet
CFU	Colony-forming units
CTD	Conductivity-temperature-depth
EDT	Eastern Daylight Time
EPA	Environmental Protection Agency
FACE	Florida Area Coastal Environment
HW	Hollywood
MC	Miami-Dade Central
MGD	Millions of gallons per day
MN	Miami-Dade North
NH_4	Ammonia-N
N+N	Nitrate + nitrite-N
NO_2	Nitrite-N
NO_3	Nitrate
NOAA	National Oceanic and Atmospheric Administration
P	Orthophosphate
PCR	Polymerase chain reaction
PEI	Port Everglades Inlet
qPCR	Quantitative polymerase chain reaction
RSMAS	Rosenstiel School of Marine and Atmospheric Science
SC	South Central
Si	Silica

Executive Summary

In October 2006, a cruise of the Florida Area Coastal Environment (FACE) program was conducted aboard the NOAA RV *Nancy Foster*. The cruise visited coastal sites in the vicinity of six treated wastewater boils in south Florida. The outfalls included in this study were those for the South Central (SC), Boca Raton (BC), Broward (BR), Hollywood (HW), Miami-Dade North (MN), and Miami-Dade Central (MC) wastewater treatment plants. The outfall terminus locations were determined by the ship's multi-beam instrumentation. The boils and associated down-current plumes were studied to produce a data set of ocean currents, ocean chemistry, and microbiology.

Seawater was analyzed for Nitrate + Nitrite-N (N+N), Nitrite-N (NO_2), Ammonia-N (NH_4), Orthophosphate-P (P), and Silica (Si). Samples were collected by a conductivity-temperature-depth (CTD) rosette at three depths—near-surface, mid-depth, and near-bottom—and from three transects—inshore of the boil, approximately in line with the boil, and further offshore of the boil. The CTD data indicated a tendency toward better defined and deeper thermoclines at the 20-30 m depth in the deeper (more offshore) casts. The thermocline showed a tendency to shoal at 10-20 m and become less well defined in more inshore casts.

Overall, surface samples showed the highest nutrient concentrations versus samples taken at other depths; surface samples taken nearest the boil showed the highest nutrient concentrations in comparison to other samples collected in the vicinity of the outfall. The only exception was Si, which had a maximum observed concentration at an inlet sampling site.

The outfall plume was found to be dynamic, irregular, and mainly at the surface. Evidence of the plume was unequivocally observed below the surface only in casts very near the boil. In general, the plume, as tracked by salinity deficit, remained at the surface in the upper 10 m of the water column No unequivocal evidence of downward movement of the plume could be seen in downcurrent casts (i.e., as in increases in bottom sample concentrations).

Dilutions on the order of 10 within 300 m of the boil were calculated and thereafter concentrations became similar to ambient waters. In general, the lowest concentrations were observed in the deepest near-bottom samples, and near-bottom nutrient concentrations at the outfall were similar to those in the surrounding areas. The average and maximum dilution values ($C_{boil\ surf}/C$) were as follows: N+N: avg 10, max 56; NH_4: avg 76, max 1305; P: avg 20, max 125; and Si: avg 35, max 502.

Samples were analyzed for a variety of microbes, and the detection frequency was higher for the southern boils compared to the northern boils. Viable enterococci and *Bacteroides* were low (≤5 CFU/100 ml). *Staphylococcus aureus*, *Cryptosporidium, Giardia*, human-specific enterococci, human-specific *Bacteroides*, *Salmonella* spp., norovirus, enterovirus, and coliphage MS2 were detected in some outfall samples. *Campylobacter jejuni* and *Escherichia coli* 0157:H7 were not detected in any of the samples.

1. Introduction

Management of water use and wastewater treatment plant effluent is vital to coastal populations and ecosystems, including fast-growing Florida. Both the benefits and impacts of human activities need to be considered within the context of the coastal ecosystem. However, such an endeavor requires a solid understanding of the ecosystem, including baseline chemical and microbiological concentrations, dilution of wastewater treatment plant effluent plumes into the coastal ocean, the location and influence of inlet plumes, and the characterization of ocean currents in the receiving waters. In coastal south Florida, these parameters have yet to be adequately characterized.

The Florida Area Coastal Environment (FACE) project originated as a NOAA response to south Florida government agencies and water and sewer authorities in need of ecosystem data to make better-informed decisions regarding the competing uses of coastal resources. The FACE program is a multi-year partnership of NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML) and other federal agencies, state and county ecosystem management agencies, county governments, municipal water and sewer authorities, and environmentally-concerned citizen groups. In 2006, the FACE program conducted a research cruise aboard the NOAA RV *Nancy Foster* to obtain near-synoptic oceanographic, chemical, and biological measurements from the six treated-wastewater outfalls off of Florida's southeastern coast.

2. Objectives

The primary objective of this FACE cruise was to produce a data set of ocean currents, ocean chemistry, and microbiology from the six treated-wastewater outfall sites and their associated down-current plumes. The outfalls included in this study were those for the South Central (SC), Boca Raton (BC), Broward (BR), Hollywood (HW), Miami-Dade North (MN), and Miami-Dade Central (MC) wastewater treatment plants.

The outfalls discharge effluent from facilities that provide secondary treatment and basic disinfection through the use of chlorine (EPA, 2003b). The Miami-Dade Central and Miami-Dade North sites have the highest flow rates, and the effluent is discharged through multi-port diffusers (5 for MC, 12 for MN). The other four outfalls discharge effluent through single ports. Some outfall information is provided in Tables 1 and 2; the outfalls are listed in order from south to north (i.e., Miami-Dade Central is the southernmost outfall) (Figure 1). The reader is referred to EPA (2003b) and Koopman *et al.* (2006) and the references therein for a detailed review of the outfalls and information regarding effluent limitations and monitoring requirements.

Table 1. Overview of the wastewater treatment plant outfalls in the FACE study area.[1]

Name (Abbreviation)	Latitude	Longitude	Outflow (MGD)[2]	Discharge Depth (m)	Pipe Length (km)
Miami-Dade Central (MC)	25°27.715'N	80°5.158'W	104.6	30.5	5.7
Miami-Dade North (MN)	25°55.203'N	80°5.176'W	80.6	32.9	3.6
Hollywood (HW)	26°01.147'N	80°5.156'W	39.5	28.3	3.1
Broward (BR)	26°15.083'N	80°3.724'W	36.5	32.6	2.2
Boca Raton (BC)	26°21.016'N	80°3.243'W	10.7	27.4	1.6
South Central (SC)[3]	26°27.715'N	80°2.525'W	12.3	27.4	1.6

[1]Pipe end locations were derived from the multi-beam studies reported in this report; other data are from Koopman *et al.* (2006).
[2]Millions of gallons per day.
[3]The South Central wastewater treatment plant is located in Delray Beach and sometimes goes by this name (EPA, 2003b) or by the name Boynton-Delray (Koopman *et al.,* 2006).

Table 2. Calculated daily nutrient fluxes from the wastewater treatment plant outfalls in the FACE study area[1] (nr = not reported).

Outfall	TN[2] kg/day [N]	NH_4 kg/day [N]	N+N kg/day [N]	TP kg/day [P]
Miami-Dade Central (MC)	6652	nr	nr	634
Miami-Dade North (MN)	5339	nr	nr	519
Hollywood (HW)	2482	1779	179	164
Broward (BR)	2045	nr	nr	180
Boca Raton (BC)	685	425	134	28
South Central (SC)	871	545	191	79

[1]Mass output computed from concentrations and averaged monthly flows from Koopman *et al.* (2006).
[2]Nutrient nomenclature is discussed in section 6, Analytical Methods.

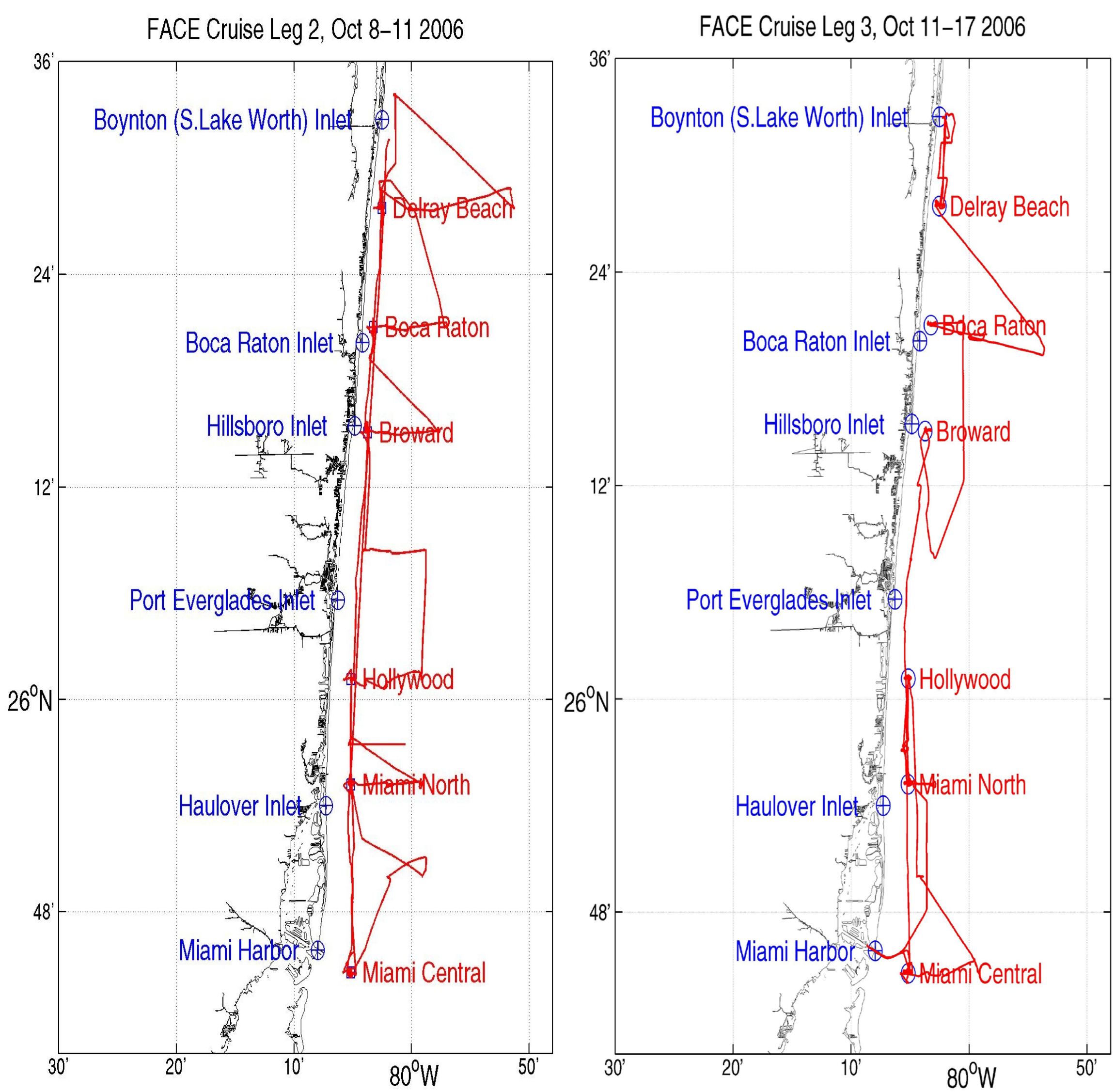

Figure 1. Cruise track maps for Legs 2 (left) and 3 (right) of the 2006 RV *Nancy Foster* FACE cruise. Major inlets are shown in blue; wastewater treatment plant names and outfall terminus locations are given in red.

3. Participating Scientists

The science team members aboard the 2006 RV *Nancy Foster* FACE cruise are given in Table 3.

Table 3. Science personnel for the 2006 FACE cruise on the RV *Nancy Foster*.

Name	Title	Legs	Affiliation
Bishop, Joseph	Scientist	1, 2, 3	AOML
Carsey, Thomas	Scientist	1, 2, 3	AOML
Casanova, Hector	Scientist	1, 2, 3	NOAA Corps[1]
Drayer, Courtney	Scientist	1, 2, 3	UM (RSMAS)
Featherstone, Charles	Scientist	1, 2, 3	AOML
Fischer, Charles	Scientist	2, 3	AOML
Goodwin, Kelly	Scientist	3	AOML
Saied, Amel	Scientist	3	UM (RSMAS)
Sinigalliano, Christopher	Scientist	3	AOML
Stamates, Jack	Scientist	1, 2, 3	AOML

[1]Stationed at AOML.

4. Operations

The 2006 RV *Nancy Foster* FACE cruise consisted of three legs which are described below. Figures 1 and 2 show the locations of sample collections and the locations of ocean outfalls and inlets.

4.1 Leg 1

Scientific equipment was loaded on the RV *Nancy Foster* on Friday, October 6, 2006 at the Miami Coast Guard Station located at the Port of Miami. All scientific equipment was configured and checked to ensure that all systems were properly functioning. An open house was hosted onboard the RV *Nancy Foster* on Saturday, October 7, 2006.

4.2 Leg 2

The northward leg began on Sunday, October 8, 2006. The ship departed the Miami Coast Guard Station at 9:00 a.m. and proceeded to ~25°46’N, 80°8’W to test the conductivity-temperature-depth (CTD) system. The ship’s multi-beam system was used to map each of the outfall pipes, beginning with the Miami Central (MC) site. Upon arrival at the Boynton Inlet vicinity, the Shipek® bottom sampler was employed at the South Central (SC) outfall location for seafloor sediment sampling. The sampling regimen was as follows: samples were obtained at 10 km east, 5 km east, 2 km east, 1 km west, and 1 km north of each outfall. Samples were obtained ~100 m south, at the boil, and at 50, 100, and 200 m north of the outfall, nominally, for a total of 10 samples per outfall. Samples were obtained at additional sites between the Hollywood and Broward outfalls, near the latitude of the Port Everglades Inlet (PE1-PE4).

4.3 Leg 3

The southward leg began on October 12, 2006. The ship initiated an examination of each of the six treated-wastewater outfall plumes, beginning with the South Central outfall plume. Each plume was examined using the following procedure: (1) the ship determined the location of

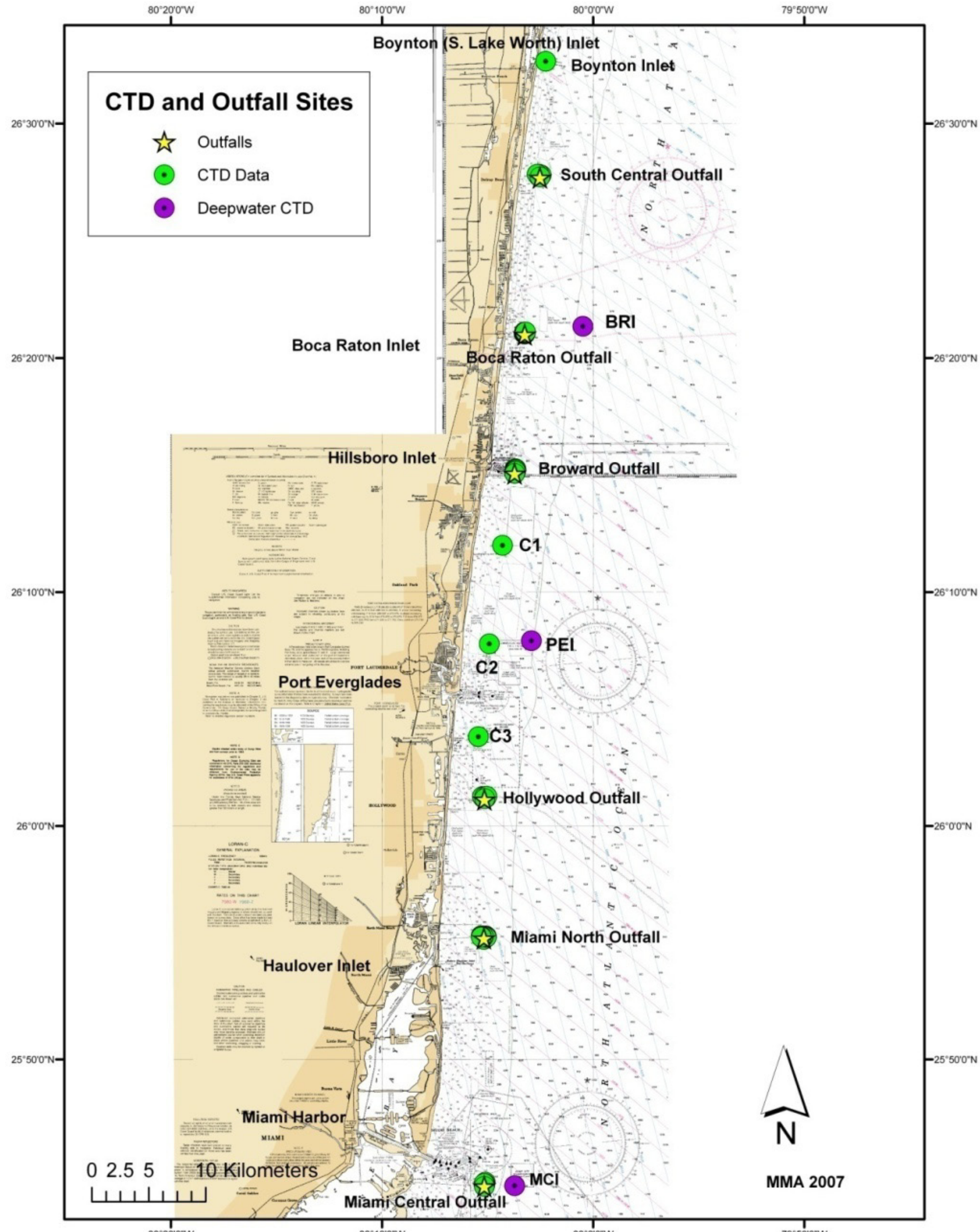

Figure 2. Map of the CTD water sampling sites, outfalls, and inlets during the 2006 RV *Nancy Foster* FACE cruise. Sites BRI, PEI, and MCI were deeper water CTD cast sites. Sites C1, C2, and C3 were intermediary sites to provide data between the Hollywood and Broward sites.

the boil using salinity-deficit measurements and visual information and stopped for an acoustic Doppler current profile (ADCP) measurement; (2) the ship deployed a V-Fin (a tow body equipped with a CTD) at the boil and maneuvered to turn points east and west criss-crossing the plume, with increments of approximately 100 yards, and continued northward until the plume could no longer be detected; and (3) the ship deployed the CTD system at nine sites determined by the V-Fin results, three sets of three crossings of the plume at ~100 yards separation. The ship operated in the vicinity of each plume for a minimum of 24-36 hours. The ship returned to the Miami Coast Guard Station on October 19, 2006. A plot of Legs 2 and 3 of the cruise is given in Figure 1. Table 4 provides a summary of the daily activities during the cruise.

Table 4. Daily activity log for the 2006 RV *Nancy Foster* FACE cruise.

Leg	Day	October	Day	Activity
Leg 2	Sunday	8	281	Test of CTD, multi-beam at all outfalls going north
	Monday	9	282	Shipek at SC, Shipek at BC (deep water)
	Tuesday	10	283	Shipek at BR, PE1, PE2, PE3, PE4, and HW
	Wednesday	11	284	Shipek at HW, MM1, MM2; transit to Boynton Inlet
Leg 3	Thursday	12	285	ADCP, CTD at Boynton; V-Fin, and CTD at SC
	Friday	13	286	V-Fin and CTD at BC
	Saturday	14	287	V-Fin and CTD at BR; CTD at C1-C2-C3
	Sunday	15	288	CTD at HW, Shipek samples; CTD at MC
	Monday	16	289	CTD at MC
	Tuesday	17	290	V-Fin and CTD at HW
	Wednesday	18	291	V-Fin and CTD at MN, return

5. Sampling Methods

5.1 Water Sampling

Most outfall boils could be identified visually by changes in the appearance of the ocean surface. A V-Fin, which is a tow body equipped with a CTD (Endeco/YSI), was employed to help locate the boil and the accompanying plume. The V-Fin was attached to the ship's A-frame and towed behind the ship in a criss-crossing track designed to intercept the surface expression of the outfall plume. It was expected that the plume could be detected by a deficit in salinity (because the plume is fresh water) and possibly in temperature. The mean location of the plume was derived by the V-Fin and used to fix the location of sites which were subsequently sampled by CTD-rosette casts and analyzed for a variety of parameters. The V-Fin data time stamp had to be adjusted by 1.75 minutes to bring that data into conformity with the ship's time. This factor was applied to all V-Fin data sets reported in this document. Times are given in Eastern Daylight Time (EDT).

Sampling was performed at a series of stations, creating a transect grid with stations running north to south and from offshore to inshore. A Seabird 911 CTD and 12, 2-L Niskin bottles were lowered by crane from the RV *Nancy Foster* to acquire a profile of temperature and salinity and to collect discrete water samples at three depths (surface, mid, and near bottom).

Discrete water samples were collected for the following parameters: (1) nutrients; (2) pH; (3) chlorophyll-*a* and phaeopigments; (4) microbiology; and (5) ^{15}N isotopes. The locations of the CTD casts are shown in Figure 3 (right panel). Once the CTD and Niskin bottles were on board, sample water was withdrawn from the appropriate Niskin bottle and placed in the corresponding sample storage container. Samples were either stored on board for later analysis at AOML or analyses were carried out immediately in the laboratory on the RV *Nancy Foster*.

5.2 Sediment Sampling

Sediment samples were collected using a Teflon-coated Shipek® sediment sampler (Model #214WA140). The exact location of sample collection was chosen to avoid hard-bottom areas. The Shipek unit was lowered to the seafloor by the ship's winch and cable, which was operated by the ship's deck department. Once the Shipek reached the seafloor, the sampler closed and collected approximately 0.5 to 1 L of sediment. The Shipek was then brought on board, and sediment was placed in the ship's refrigerated storage area for subsequent ^{15}N isotope analysis. The sediment sampling locations are shown in Figure 3 (left panel).

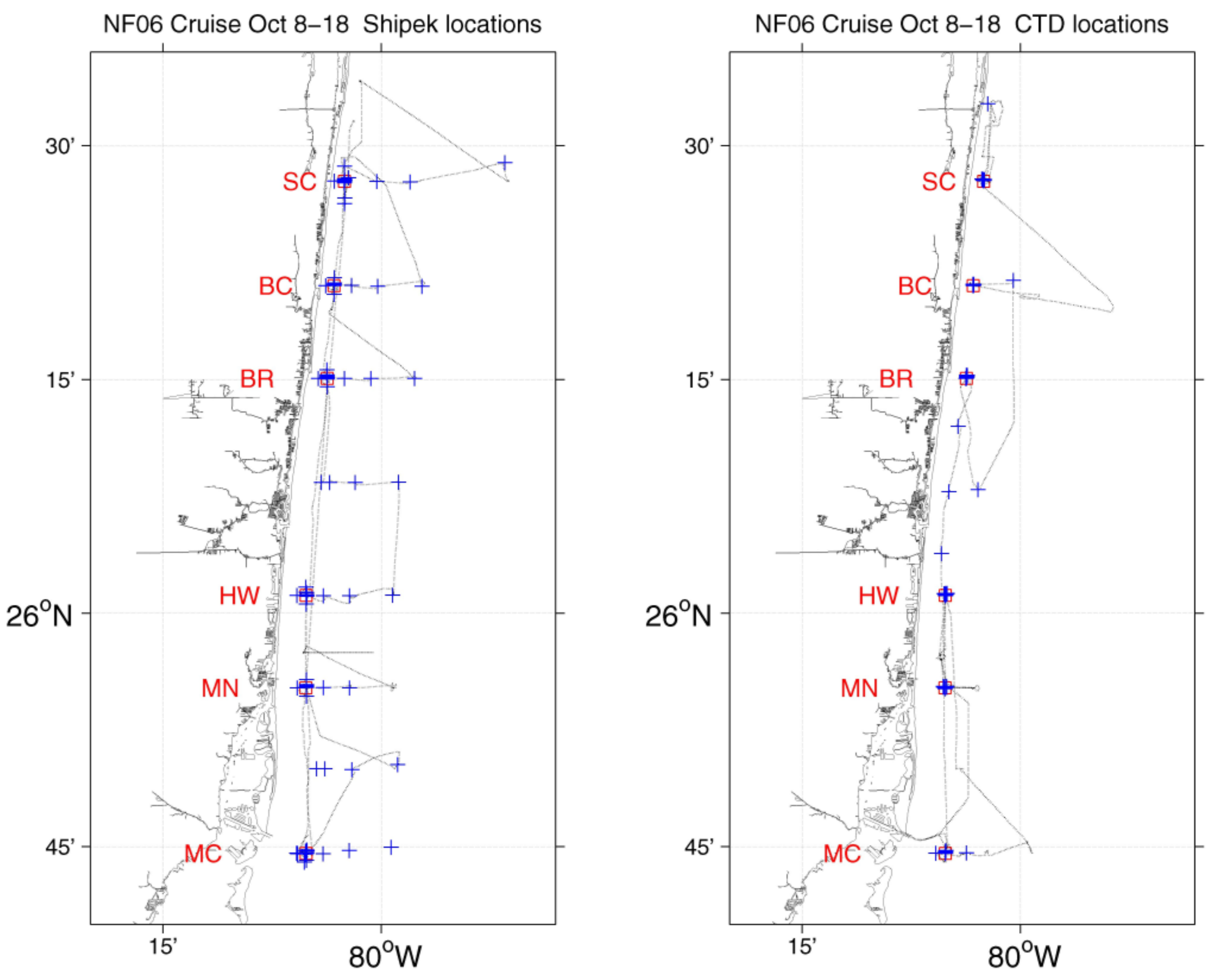

Figure 3. Map of the Shipek sampling sites and Leg 2 track (left panel) and the CTD cast sites and Leg 3 track (right panel). Sampling locations are denoted by + symbols and outfall pipe ends are denoted by squares (see Table 1 for outfall abbreviations).

5.3 Acoustic Doppler Current Profiler (ADCP)

A RDI 600-kHz ADCP (Teledyne RD Instruments, Poway, California) was attached to a line and lowered off the side of the RV *Nancy Foster* for approximately 10-15 minutes. The ADCP was brought back on board and the data downloaded and processed immediately to determine the current direction and velocity of each outfall plume. The instrument was deployed 10 times during the cruise.

The data from the dipped ADCP were processed by using the RDI quality control parameters to identify the data that had sufficient three- or four-beam solutions to be stable, had sufficient correlation, and to also assure that the bottom was not influencing the data. Each ensemble was screened to look for evidence of the ship's propulsion in the data. If there were any ensembles that significantly deviated in the upper water column, those ensembles were eliminated from the average.

The means, minima, maxima, and standard deviations of the data that passed the above-mentioned quality-control procedures were used for data analysis. The ADCP data consisted of east-west (**u**) and north-south (**v**) current vector components. The current direction was defined as the direction toward which the water was flowing. Positive values for the **u** component were directed east. Positive values for the **v** component were directed north. The magnitude was the speed of the current in a depth bin, for that measurement interval. The direction in degrees indicated the direction the current was flowing towards, where 360 degrees indicated flow that was due north and 180 degrees indicated flow that was due south.

6. Analytical Methods

6.1 Nutrient Analysis

All water samples were filtered through 0.45-µm glass fiber filters using a 50-ml syringe. The filter was washed before use by passing 50 ml of sample water through the filter. Sample tubes were rinsed three times with filtered sample water, shaking with the cap in place after each rinse. Filtered water was collected in two 8 ml polystyrene test tubes, one for Ammonia-N analysis and the other for Nitrate + Nitrite-N, Nitrite-N, Orthophosphate-P, and Silica analysis. Ammonia samples were preserved by the addition of 0.2% (v/v) chloroform. All samples were analyzed on board the RV *Nancy Foster* after collection using the following EPA methods.

EPA Method 349.0 (MDL = 0.02 µM, 0.003 mg N/L) was used to determine the concentration of ammonia (NH_4) in water samples (Zhang *et al.,* 1997b). This method uses automated gas segmented continuous flow colorimetry. Ammonia in solution reacts with alkaline phenol and NADTT at 60°C to form indophenol blue in the presence of sodium nitroferricyanide as a catalyst. The absorbance of indophenol blue at 640 nm is linearly proportional to the concentration of ammonia in the sample.

EPA Method 353.4 (MDL = 0.005 µM, 0.0001 mg N/L) was used to determine the concentration of nitrate and nitrite (denoted "N+N") in water samples (Zhang *et al.,* 1997a). This method uses automated gas segmented continuous flow colorimetry. Samples are passed through a copper-coated cadmium reduction column, and nitrate is reduced to nitrite in a buffer solution. The concentration of nitrite is then determined by diazotizing with sulfanilamide and coupling with N-1-naphthylethylenediamine dihydrochloride to form a color azo dye. The absorbance measured at 540 nm is linearly proportional to the concentration of nitrite + nitrate in the sample. Nitrate (NO_3^-) concentrations are obtained by subtracting nitrite (NO_2^-) values, which have been separately determined without the cadmium reduction procedure, from the nitrite + nitrate values.

EPA Method 365.5 (MDL = 0.02 μM, 0.0007 mg P/L) was used to determine the concentration of orthophosphate (denoted "P") in water samples (Zimmermann and Keefe, 1997; Zhang *et al.,* 2001). This method uses automated calorimetric and continuous flow analysis for the determination of low-level orthophosphate concentrations. Ammonium molybdate and antimony potassium tartrate react in an acidic medium with dilute solutions of phosphate to form an antimony-phosphomolybdate complex. This complex is reduced to an intensely blue-colored complex by ascorbic acid. The absorbance measured at 800 nm is proportional to the phosphate concentration in the sample.

EPA Method 366.0 (MDL = 0.04 μM, 0.001 mg Si/L) was used to determine the concentration of silica (denoted "Si") in water samples (Zhang and Berberian, 1997). This method uses automated gas segmented continuous flow colorimetry for the analysis of dissolved silicate concentration. In this method, β-molybdosilicic acid is formed by reaction of the silicate contained in the sample with molybdate in acidic solution. The β-molybdosilicic acid is then reduced by ascorbic acid to form molybdenum blue. The absorbance of the molybdenum blue, measured at 660 nm, is linearly proportional to the concentration of silicate in the sample.

6.2 pH Analysis

The pH was determined spectrophotometrically following the methods of Clayton and Byrne (1993) and Mosley *et al.* (2004). A sulfonephthalein dye, *m*-cresol purple, was added to the sample, and absorbance readings were measured at wavelengths of 434 nm, 578 nm, and 725 nm. Temperature and salinity were recorded for each sample. The following equations were used to calculate the pH of each sample:

$$pH = pK'a\,(mCP) + \log\,[(R - 0.0069)/(2.222 - R*0.133)],$$

where

$$pK'a\,(mCP) = 8.6353 - 0.3238S^{1/2} + 0.0807S - 0.01157S^{3/2} + 0.000694S^2,$$

where S is the salinity, R is the ratio of the two absorbance peaks of the indicator *m*-cresol purple (*m*CP) (wavelengths of 578 and 434 nm) dye after a baseline correction at 725 nm (i.e., $R = {}_{578}A/{}_{434}A$), and p*K*'a (*m*CP) is the acid dissociation constant of the indicator *m*-cresol purple dye (MDL = 0.001 pH units).

6.3 Chlorophyll-*a* and Phaeopigment Analysis

Water samples were filtered through 25 cm, 0.45-μm glass fiber filters using a filter apparatus either attached to a hand pump or a vacuum pump. An aliquot of 200 ml of sample water was filtered. The filter was folded in half by forceps and placed in a 2-ml polypropylene vial. A duplicate from the same sample was filtered and placed in the same vial. Chlorophyll-*a* was extracted using a 60:40 mixture of acetone and dimethyl sulfoxide (Shoaf and Lium, 1976; Kelble *et al.,* 2005). The amount of phaeopigments was determined by examining the difference between the acidified and unacidified fluorescence of the chlorophyll-*a* sample. Concentrations (mg/m^{-3}) were calibrated via comparison to spectrophotometrically-determined concentrations using a Turner Designs model TD-700 fluorometer (MDL = 0.05 µg/L).

6.4 Stable Isotope Analysis

Isotope analysis of sediment and algal samples was carried out by P. Swart and C. Drayer of the Stable Isotope Laboratory at the University of Miami's Rosenstiel School of Marine and Atmospheric Science (RSMAS). The results are described in Swart and Drayer (2007) and are reviewed in Section 17.5 of this report.

6.5 Microbiological Analysis

Water at mid and bottom depths was collected via CTD Niskin bottles. Surface water from the outfall boils was collected by a bucket, except for *Cryptosporidium* and *Giardia* analysis. In these cases, water was sampled via the ship's flow-through system using a flow meter and flow controller connected to a cartridge housing (graciously supplied by H. Solo-Gabriele) containing a Filta-Max foam filter (IDEXX, Inc.). The RV *Nancy Foster* was equipped with bow thrusters that allowed the ship to stay on the boil while 200 L of water was obtained. Sediment samples were collected by Shipek, as described in section 5.2. Surface water samples were collected by bucket from inlet sites to compare results with surface water taken from the boils.

6.5.1 Culture analysis

Selective and differential media were used to analyze samples for viable enterococci, *Escherichia coli*, *Bacteroides* species, and *Staphylococcus aureus*. Viable enterococci were enumerated using two methods: (1) membrane filtration with incubation on mEI agar according to EPA Method 1600 (EPA, 2002a); and (2) the EPA-approved Enterolert™ chromogenic substrate assay (IDEXX, Inc.). Viable *E. coli* were enumerated by membrane filtration and incubation on mTEC agar using EPA Method 1603 (EPA, 2002b). Viable *Bacteroides* spp. were enumerated by membrane filter method incubated on BBE agar under anaerobic conditions (Baums *et al.,* 2007). Viable *Staphylococcus aureus* were enumerated by membrane filtration method incubated on CHROMagar™ Staph aureus (Goodwin and Pobuda, 2009). Water samples (800-2100 ml) processed by membrane filtration used 0.45-µm cellulose nitrate membrane filters (Whatman).

6.5.2 Immunofluoresecent analysis

Cryptosporidium oocysts and *Giardia* cysts were concentrated from 200 L samples as described above in section 6.5. The oocysts and cysts were recovered using the EPA-approved Filta-Max® system according to the manufacturer's instructions (IDEXX, Inc.). The Filta-Max wash station and sample concentration equipment was graciously supplied by H. Solo-Gabriele. The protists were enumerated by immunomagnetic separation and immunofluorescent microscopy according to EPA Method 1623 (EPA, 2001). Analysis was conducted by the National Environmental Laboratory Accreditation Program-certified facilities of BSC Labs, Inc., in Miami, Florida.

6.5.3 Viral analysis

Samples were collected, filtered, eluted, and shipped on ice to the NOAA laboratory in Charleston, South Carolina for analysis of enteric viruses. Briefly, 1.2-3 L of water were filtered through ViroCap positively-charged aluminum fiber filters (Scientific Methods, Inc., Granger, Indiana). The viruses were then eluted using 2 mL of Optima RE solution (Scientific Methods, Inc.) with the addition of 0.01% Tween. The eluate was frozen and shipped, then thawed for extraction of viral RNA. Extraction followed either the CEFAS protocol (Lees *et al.,* 1994) or the Qiagen MIDI extraction kit per manufacturer's instructions. Both protocols were performed on each sample for the sake of comparison. Extracts were then analyzed for viruses using the reverse-transcriptase polymerase chain reaction (RT-PCR) process. Assays for detection of norovirus and enterovirus were performed as described in Jothikumar *et al.* (2005) and Gregory *et al.* (2006), respectively. Norovirus analysis included individual assays for genogroups I and II. The MS2 assay is currently unpublished. Given the lack of quantitative controls used for these assays, results were reported as the presence or absence of each virus. The minimum detection limit for the MS2 assay was 5 genomes per reaction, and the detection limit for norovirus and enterovirus was 25 genomes per reaction.

In addition to that described above, norovirus and enterovirus were analyzed by quantitative polymerase chain reaction (qPCR) at AOML using kits by Cepheid, Inc., as described in Sinigalliano *et al.* (2007).

6.5.4 PCR analysis

In general, 1.5 L of water was filtered onto 0.2-µm Supor-200 filters (Pall Corporation) for the purpose of total deoxyribonucleic acid (DNA) extraction. Crude DNA lysates were obtained from filters, while onboard the ship by bead-beating (Haughland *et al.,* 2005) in a Qiagen AE buffer with a Qbiogene FastPrep bead beating instrument at speed 6.5 for a total of 40 s. The lysates were diluted to 1:5 with a fresh AE buffer and stored at -80°C until analysis.

An aliquot (5 µL) of each 1:5 dilution was utilized as template DNA in 50-µL PCR reactions according to the following: 5-µL Finzyme 10X buffer; 1.25-µL dNTPs (10 mM); 1.5-µL BSA (10 mg/mL); 2.5-µL forward primer (10 µM); 2.5-µL reverse primer (10 µM); 0.75-µL Finzyme; Hotstart Taq Polymerase. Cycling conditions were as follows: 94°C denaturation for 10 min; 30 cycles of 94°C for 30 s; 58°C for 30 s; 72°C for 30 s, followed by a 70°C extension for 8 min; hold at 4°C.

The lysates were analyzed for the presence of the following fecal indicators, pathogens, and markers of fecal pollution, as described in LaGier *et al.* (2007):

- enterococci (23S rRNA gene)
- human-specific enterococci (*esp* gene)
- *Campylobacter jejuni* (*hipO* gene)
- *Salmonella* spp. (IpaB gene)
- *Escherichia coli* strain 0157:H7 (*rfb* gene)
- *Staphylococcus aureus* (*clfA* gene)
- human adenovirus (*Hexon* gene)

In addition to standard positive and negative controls, samples were also tested for the presence of amplifiable DNA and for PCR inhibition using primers that amplify a universal region of the bacterial 16S rRNA gene (Unifor/Unirev primer set; Zheng *et al.,* 1996).

DATA SUMMARY

7. Miami-Dade Central Outfall

7.1 Outfall Description

The Miami-Dade Central ocean outfall is located approximately 5.7 km offshore Virginia Key, Florida, at a depth of 30.5 meters. An average discharge flow rate of 105 MGD (millions of gallons per day) has been reported (Koopman *et al.,* 2006). Figure 4 shows the seafloor in the vicinity of the outfall as recorded by the ship's multi-beam instrumentation. Analysis of these data resulted in a determination of the location of the outfall terminus at 25°44.569'N, 80°5.158'W (25.74282°N, 80.08597°W). Table 5 lists the CTD sample stations and sample depths, as shown in Figure 5. Table 6 lists the sediment sample locations and depths, also shown in Figure 5.

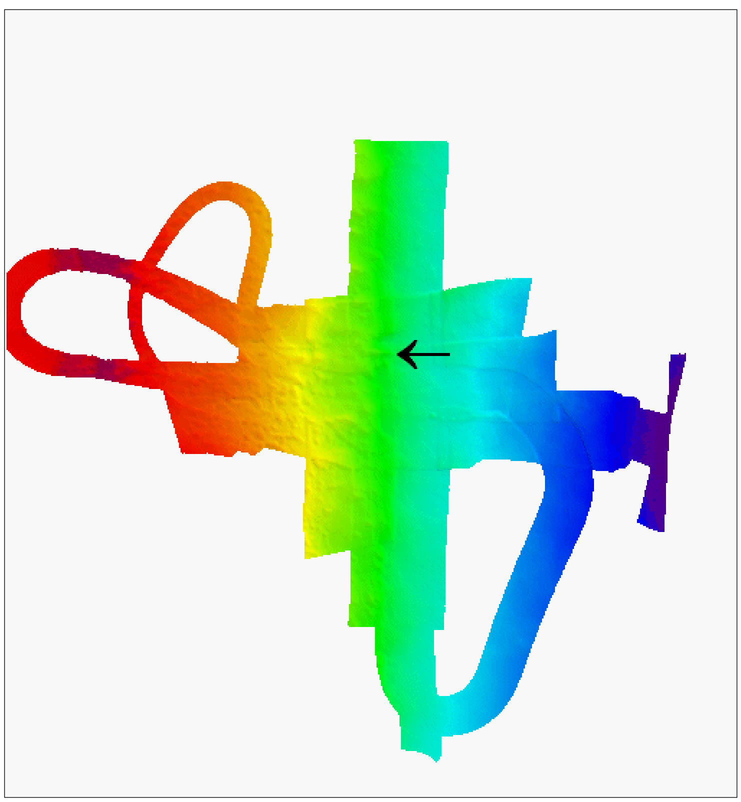

Figure 4. Multi-beam view of the seafloor in the vicinity of the Miami-Dade Central outfall. The location of the outfall pipe end is marked by an arrow.

Table 5. CTD sample locations for the Miami-Dade Central outfall.

Station	Date	Latitude	Longitude	Distance to Pipe End (m)	Depth (m)	Station	Date	Latitude	Longitude	Distance to Pipe End (m)	Depth (m)
MC1a	16-Oct	25.7457	-80.0852	14.59	0.0	MC6a	16-Oct	25.7443	-80.0860	164.97	0.0
MC1b	16-Oct	25.7457	-80.0852	14.59	17.2	MC6b	16-Oct	25.7443	-80.0860	164.97	15.4
MC1c	16-Oct	25.7457	-80.0852	14.59	34.3	MC6c	16-Oct	25.7443	-80.0860	164.97	30.8
MC2a	16-Oct	25.7436	-80.0856	94.53	0.0	MC7a	16-Oct	25.7444	-80.0862	177.60	0.0
MC2b	16-Oct	25.7436	-80.0856	94.53	16.6	MC7b	16-Oct	25.7444	-80.0862	177.60	14.5
MC2c	16-Oct	25.7436	-80.0856	94.53	33.2	MC7c	16-Oct	25.7444	-80.0862	177.60	29.0
MC3a	16-Oct	25.7435	-80.0858	77.80	0.0	MC8a	16-Oct	25.7448	-80.0856	223.57	0.0
MC3b	16-Oct	25.7435	-80.0858	77.80	16.1	MC8b	16-Oct	25.7448	-80.0856	223.57	16.3
MC3c	16-Oct	25.7435	-80.0858	77.80	32.1	MC8c	16-Oct	25.7448	-80.0856	223.57	32.5
MC4a	16-Oct	25.7435	-80.0859	76.28	0.0	MC9a	16-Oct	25.7448	-80.0861	220.94	0.0
MC4b	16-Oct	25.7435	-80.0859	76.28	15.8	MC9b	16-Oct	25.7448	-80.0861	220.94	14.7
MC4c	16-Oct	25.7435	-80.0859	76.28	31.5	MC9c	16-Oct	25.7448	-80.0861	220.94	29.4
MC5a	16-Oct	25.7443	-80.0858	165.78	0.0	MC10a	16-Oct	25.7427	-80.0859	329.68	0.0
MC5b	16-Oct	25.7443	-80.0858	165.78	16.2	MC10b	16-Oct	25.7427	-80.0859	329.68	15.7
MC5c	16-Oct	25.7443	-80.0858	165.78	32.3	MC10c	16-Oct	25.7427	-80.0859	329.68	31.3

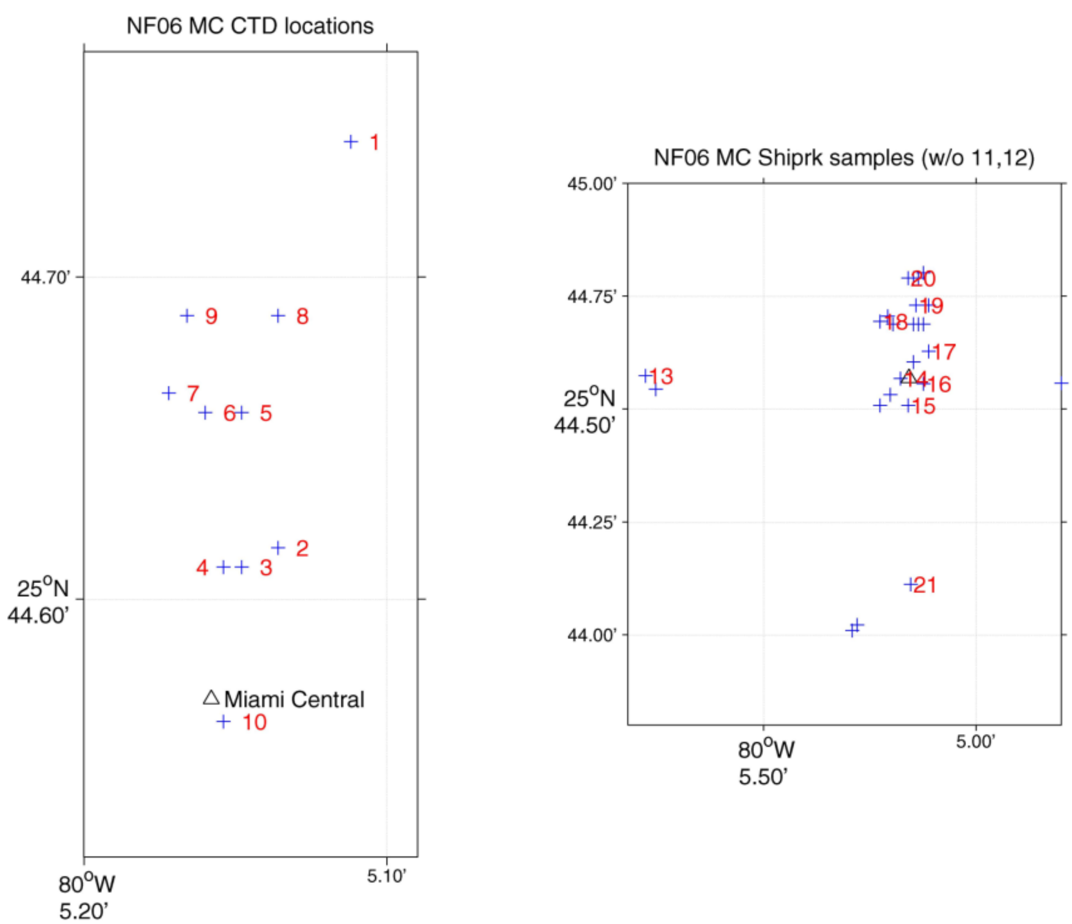

Figure 5. Location of the CTD (left panel) and Shipek sediment (right panel) sample sites for the Miami-Dade Central outfall study. Station 10 was the boil; stations to the left are closer to shore (and thus more shallow). The location of the outfall pipe end is denoted by a triangle.

Table 6. Sediment sample locations for the Miami-Dade Central (MC) outfall and Miami Mid (MM) transect.

Station	Date	Latitude	Longitude	Depth (m)	Station	Date	Latitude	Longitude	Depth (m)
MC10	15-Oct	25.7495	-79.9887	350.0	MC19	15-Oct	25.7455	-80.0857	32.5
MC11	15-Oct	25.7458	-80.0369	251.7	MC19a	15-Oct	25.7448	-80.0858	32.5
MC12	15-Oct	25.7424	-80.0667	116.7	MC19b	16-Oct	25.7448	-80.0856	32.9
MC13	15-Oct	25.7429	-80.0963	14.1	MC19c	16-Oct	25.7448	-80.0854	32.5
MC13b	15-Oct	25.7424	-80.0959	14.1	MC19d	16-Oct	25.7448	-80.0854	33.2
MC14a	15-Oct	25.7428	-80.0863	31.0	MC19e	16-Oct	25.7455	-80.0852	33.2
MC14b	15-Oct	25.7337	-80.0880	19.8	MC20a	16-Oct	25.7465	-80.0860	29.1
MC14c	15-Oct	25.7335	-80.0882	18.6	MC20b	16-Oct	25.7465	-80.0858	30.6
MC15a	15-Oct	25.7418	-80.0860	31.3	MC20c	16-Oct	25.7465	-80.0856	7.4
MC15b	15-Oct	25.7418	-80.0871	23.7	MC20d	16-Oct	25.7467	-80.0854	32.6
MC15c	15-Oct	25.7422	-80.0867	26.5	MC21a	16-Oct	25.7352	-80.0859	29.9
MC16	15-Oct	25.7426	-80.0854	34.3	MC21b	16-Oct	25.7352	-80.0859	29.9
MC17a	15-Oct	25.7438	-80.0852	34.4	MM1a	11-Oct	25.8335	-79.9853	294.1
MC17b	15-Oct	25.7434	-80.0858	32.8	MM1b	11-Oct	25.8379	-79.9813	287.7
MC18a	15-Oct	25.7449	-80.0871	24.1	MM2	11-Oct	25.8326	-80.0338	245.9
MC18b	15-Oct	25.7448	-80.0866	20.0	MM3	15-Oct	25.8335	-80.0743	95.0
MC18c	15-Oct	25.7451	-80.0868	20.0	MM4	15-Oct	25.8334	-80.0646	149.0

7.2 Nutrients

A total of 30 nutrient samples were collected during the CTD operations around the Miami-Dade Central outfall. These results are listed in Table 7 for concentrations in µM and in Table 8 for concentrations in mg/L. These results are also presented graphically in Figure 6. Station MC10 was the closest site to the outfall. The other sites were located north of the outfall (Figure 5). Sites 2, 3, and 4 created an offshore-to-onshore transect closest to the outfall. Sites 5, 6, and 7 created the next offshore-to-onshore transect north of the outfall. Sites 8 and 9 were the next sites north and, finally, site 1 was the station located the farthest north and offshore, approximately 330 m from the outfall pipe (Table 5).

In general, the lowest nutrient concentrations were observed in the bottom samples, and the highest concentrations were observed in the near-surface samples collected in the boil. Site 2 showed lower concentrations than shoreward sites 3 and 4 (Figure 5). Site 2 showed similar nutrient concentrations to site 1 despite the fact that site 1 was nearly three times farther north, indicating that site 2 was outside the immediate plume. Near-surface concentrations of P were 0.4 µM at site 2. This same concentration was also observed at sites MC8 and MC9; therefore, the concentration of P decreased nine-fold within ~220 m north of the outfall (3.6 µM P at the boil, MC10). A similar decrease (7-10 fold) was seen for the other analytes over this same distance. Although the V-Fin data (see section 7.6) revealed a signature of the plume north of the boil, ADCP data of the Miami-Dade Central outfall suggested that the current direction was not stable during this time period.

Table 7. Nutrient results in µM for the Miami-Dade Central outfall (see Figure 5 for location map; BDL = below detection limit).

Station	Depth (m)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)	Station	Depth (m)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)
MC1a	1.8	0.57	0.32	4.01	0.47	1.01	MC6a	1.8	0.57	0.36	10.68	0.58	1.60
MC1b	16.1	0.05	BDL	0.35	0.11	0.25	MC6b	12.0	0.28	0.15	4.64	0.24	0.87
MC1c	32.2	0.07	BDL	0.58	0.12	0.17	MC6c	25.5	0.08	0.01	0.16	0.12	0.14
MC2a	1.7	0.53	0.31	5.37	0.40	1.20	MC7a	1.5	0.48	0.29	8.92	0.47	1.36
MC2b	12.8	0.55	0.33	5.61	0.44	1.11	MC7b	11.5	0.13	0.05	1.79	0.13	0.41
MC2c	27.3	0.04	BDL	0.29	0.08	0.17	MC7c	27.8	0.07	BDL	0.24	0.01	0.17
MC3a	3.1	1.00	0.61	10.97	0.70	2.00	MC8a	1.6	0.38	0.22	7.77	0.40	1.25
MC3b	11.9	0.79	0.49	9.08	0.62	1.63	MC8b	12.6	0.01	BDL	0.11	0.11	0.17
MC3c	25.7	0.05	BDL	0.23	0.14	0.12	MC8c	26.0	0.13	0.02	0.16	0.08	0.25
MC4a	2.1	1.26	0.80	15.94	1.00	2.62	MC9a	1.8	0.27	0.16	6.41	0.36	1.11
MC4b	13.4	0.14	0.05	1.61	0.21	0.39	MC9b	11.5	0.14	0.07	3.19	0.26	0.66
MC4c	25.5	0.05	BDL	0.11	BDL	0.06	MC9c	23.9	0.12	0.01	0.32	0.10	0.20
MC5a	1.6	0.66	0.41	11.42	0.57	1.73	MC10a	2.6	2.23	1.58	66.32	3.55	8.07
MC5b	12.5	0.03	BDL	0.13	0.09	0.14	MC10b	12.2	0.57	0.37	15.94	1.48	2.11
MC5c	25.9	0.19	0.01	0.11	0.02	0.17	MC10c	25.9	0.16	0.02	1.12	0.30	0.31

Table 8. Nutrient results in mg/L for the Miami-Dade Central outfall (see Figure 5 for location map; BDL = below detection limit).

Station	Depth (m)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)	Station	Depth (m)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)
MC1a	1.8	0.008	0.004	0.056	0.015	0.028	MC6a	1.8	0.008	0.005	0.150	0.018	0.045
MC1b	16.1	0.001	BDL	0.005	0.003	0.007	MC6b	12.0	0.004	0.002	0.065	0.007	0.024
MC1c	32.2	0.001	BDL	0.008	0.004	0.005	MC6c	25.5	0.001	BDL	0.002	0.004	0.004
MC2a	1.7	0.007	0.004	0.075	0.012	0.034	MC7a	1.5	0.007	0.004	0.125	0.014	0.038
MC2b	12.8	0.008	0.005	0.079	0.014	0.031	MC7b	11.5	0.002	0.001	0.025	0.004	0.011
MC2c	27.3	0.001	BDL	0.004	0.002	0.005	MC7c	27.8	0.001	BDL	0.003	BDL	0.005
MC3a	3.1	0.014	0.009	0.154	0.022	0.056	MC8a	1.6	0.005	0.003	0.109	0.012	0.035
MC3b	11.9	0.011	0.007	0.127	0.019	0.046	MC8b	12.6	BDL	BDL	0.002	0.003	0.005
MC3c	25.7	0.001	BDL	0.003	0.004	0.003	MC8c	26.0	0.002	BDL	0.002	0.002	0.007
MC4a	2.1	0.018	0.011	0.223	0.031	0.073	MC9a	1.8	0.004	0.002	0.090	0.011	0.031
MC4b	13.4	0.002	0.001	0.023	0.007	0.011	MC9b	11.5	0.002	0.001	0.045	0.008	0.018
MC4c	25.5	0.001	BDL	0.002	BDL	0.002	MC9c	23.9	0.002	BDL	0.004	0.003	0.006
MC5a	1.6	0.009	0.006	0.160	0.018	0.048	MC10a	2.6	0.031	0.022	0.928	0.110	0.226
MC5b	12.5	BLD	BDL	0.002	0.003	0.004	MC10b	12.2	0.008	0.005	0.223	0.046	0.059
MC5c	25.9	0.003	BDL	0.002	0.001	0.005	MC10c	25.9	0.002	BLD	0.016	0.009	0.009

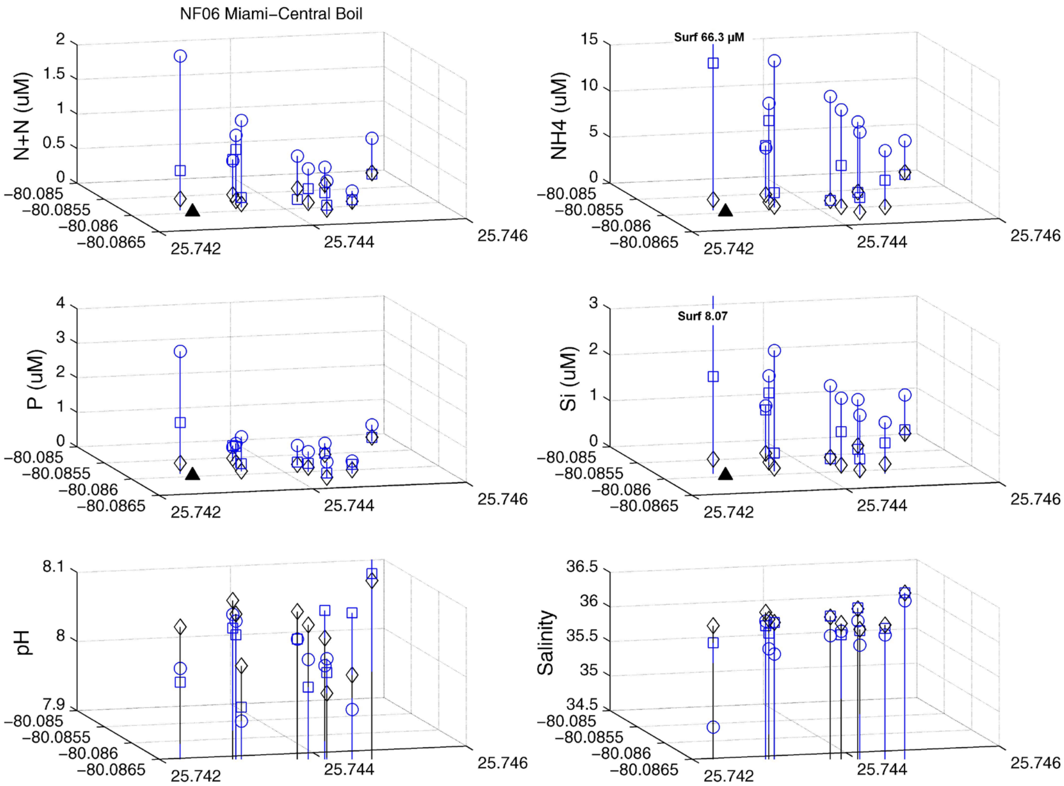

Figure 6. Three-dimensional presentation of nutrient results, pH, and salinity from CTD casts around the Miami-Dade Central outfall. Concentrations are denoted by the height on the vertical axis. Circles indicate concentrations obtained from the surface samples. Squares indicate concentrations from the mid-level samples, and diamonds indicate concentrations from the bottom-most samples. The filled black triangles denote the location of the outfall terminus. Latitudes and longitudes are plotted in Cartesian space and do not indicate true geographic accuracy. The concentration of NH_4 in the surface sample was 66.3 µM, and the concentration of Si was 8.07 µM; the vertical scale was chosen so that the other sample concentrations would be better viewed. See Appendix 1 for tabulated data.

7.3 Chlorophyll and pH

A total of 30 chlorophyll and pH samples were collected during CTD operations around the Miami-Dade Central outfall. Table 9 list the results for the chlorophyll and pH samples collected along with the temperature and salinity data for each depth sampled. No obvious relationship between the outfall and chlorophyll-*a* or phaeopigments was observed.

7.4 CTD Casts

A total of 10 CTD casts were conducted at the Miami-Dade Central outfall on October 16, 2006. At each station, a water sample was obtained near the bottom, at mid depth, and near the surface. MC1 had no profile information due to a failure of the CTD. Figures 7-15 show the temperature, salinity, and oxygen saturation for each station. The plots suggest that a thermocline existed at a depth of 15-25 m only in the deeper, more offshore casts (MC2, MC5, MC8). Unfortunately, no ADCP measurements were made from the ship on October 16th. ADCP data from instrumentation on the Gulf Stream Reef (Figures 105 and 106) indicated a northerly current regime. Water depths ranged from ~29 m (MC7) to ~32 m (MC8).

Table 9. Temperature, salinity, pH, chlorophyll-*a*, and phaeopigment results for the Miami-Dade Central outfall.

Station	Depth (m)	Temperature (°C)	Salinity (PSU)	pH	Chlorophyll-*a* (μg/L)	Phaeopigments (μg/L)
MC1a	1.8	28.62	36.01	8.29	0.488	0.105
MC1b	16.1	28.64	36.12	8.09	0.475	0.110
MC1c	32.2	28.56	36.12	8.08	0.578	0.128
MC2a	1.7	28.66	36.00	8.06	0.416	0.096
MC2b	12.8	28.62	35.94	8.04	0.429	0.093
MC2c	27.3	28.59	36.13	8.08	0.526	0.123
MC3a	3.1	28.64	35.70	8.06	0.428	0.097
MC3b	11.9	28.65	35.93	8.04	0.596	0.121
MC3c	25.7	28.57	36.12	8.07	0.429	0.099
MC4a	2.1	28.63	35.67	7.92	0.429	0.099
MC4b	13.4	28.59	36.13	7.94	0.507	0.123
MC4c	25.5	28.57	36.13	8.00	0.545	0.126
MC5a	1.6	28.63	35.85	8.03	0.422	0.105
MC5b	12.5	28.65	36.14	8.03	0.403	0.093
MC5c	25.9	28.52	36.12	8.07	0.590	0.151
MC6a	1.8	28.64	36.01	8.01	0.399	0.096
MC6b	12.0	28.63	35.96	7.97	0.434	0.094
MC6c	25.5	28.56	36.12	8.06	0.550	0.133
MC7a	1.5	28.61	35.90	8.02	0.461	0.116
MC7b	11.5	28.62	36.11	8.00	0.451	0.095
MC7c	27.8	28.61	36.13	7.97	0.447	0.104
MC8a	1.6	28.64	35.95	7.98	0.411	0.089
MC8b	12.6	28.65	36.14	8.06	0.397	0.091
MC8c	26.0	28.52	36.12	8.02	0.662	0.206
MC9a	1.8	28.62	35.98	7.94	0.431	0.110
MC9b	11.5	28.64	36.07	8.08	0.386	0.107
MC9c	23.9	28.55	36.12	7.99	0.523	0.138
MC10a	2.6	28.63	34.65	8.00	0.461	0.128
MC10b	12.2	28.63	35.87	7.98	0.448	0.122
MC10c	25.9	28.53	36.12	8.06	0.527	0.173

In this and the following discussion, we consider that the outfall plume consists of non-saline water and is, therefore, buoyant. We then employ the salinity decrease (deficit compared to the ambient waters) to track the outfall plume. The caveat is that salinity deficit waters may have other sources, including rain or an inlet plume, so that care must be exercised in interpreting the data. The CTD data from MC10, the station just south of the outfall, showed evidence of the plume at the surface (~5 m). The subsequent casts showed the plume maintaining a depth of 10-12 m above the irregular thermocline seen at 15-20 feet. Just north of the boil, sample MC3 showed the plume had broken up into two streams at 2-11 m and 15-21 m depths, respectively. The plume was well confined to the surface in most of the remaining casts (MC4, MC7, MC9, MC12, MC13). The data were insufficiently regular for a clear description of horizontal or vertical spreading of the plume.

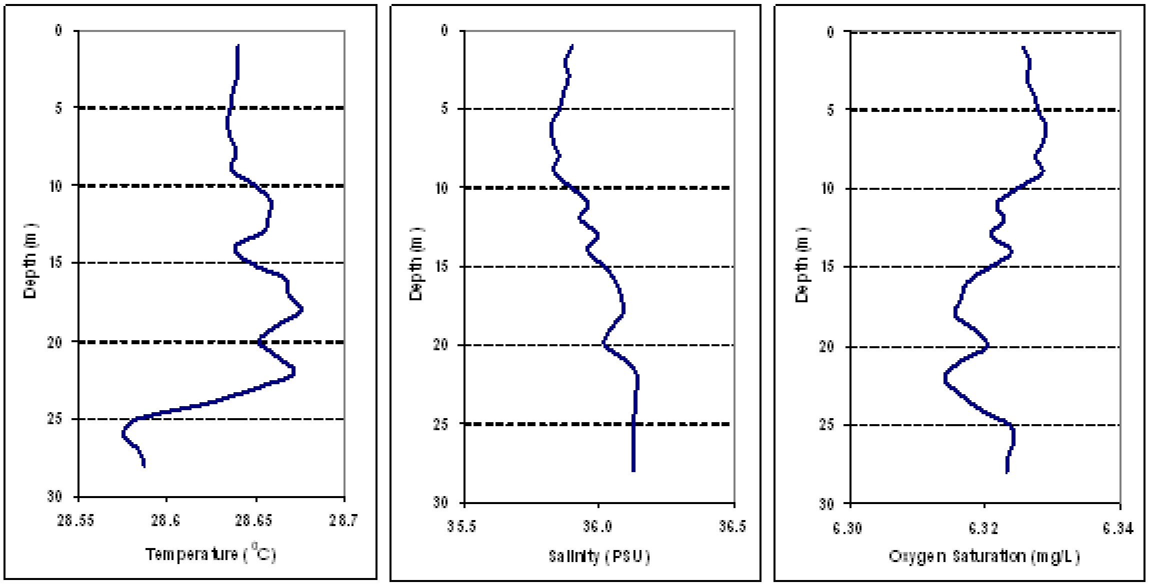

Figure 7. Temperature, salinity, and oxygen concentration profiles at station MC2.

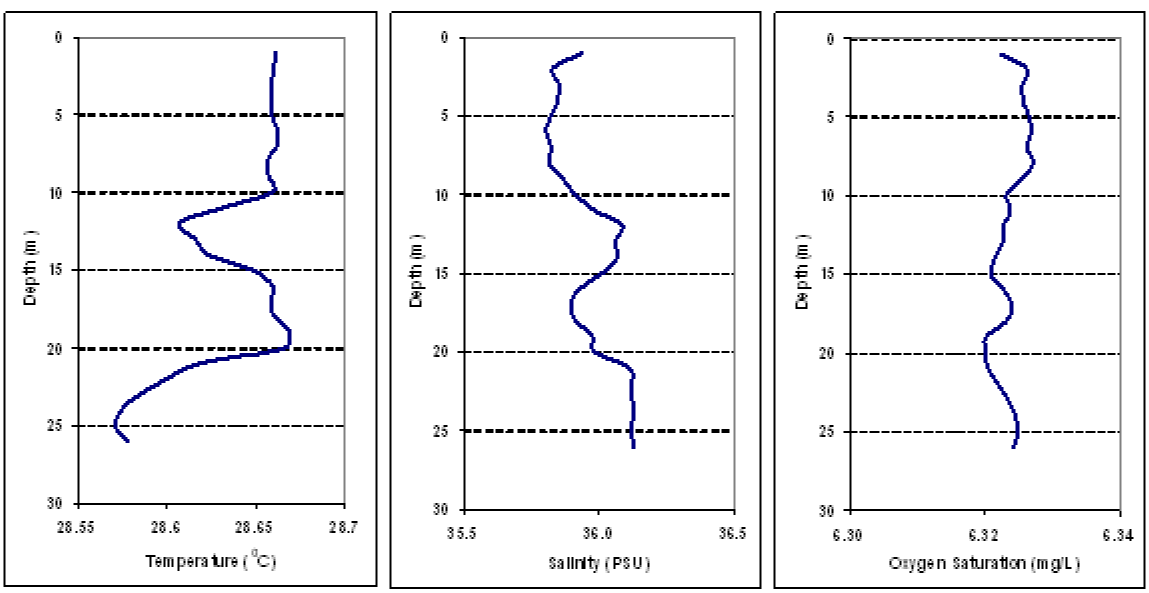

Figure 8. Temperature, salinity, and oxygen concentration profiles at station MC3.

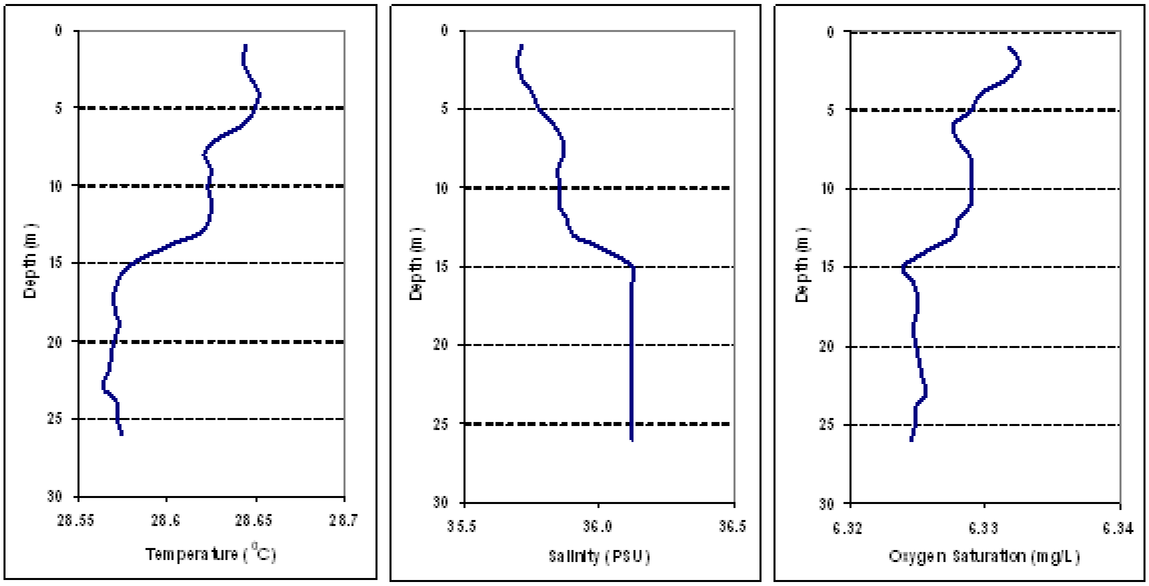

Figure 9. Temperature, salinity, and oxygen concentration profiles at station MC4.

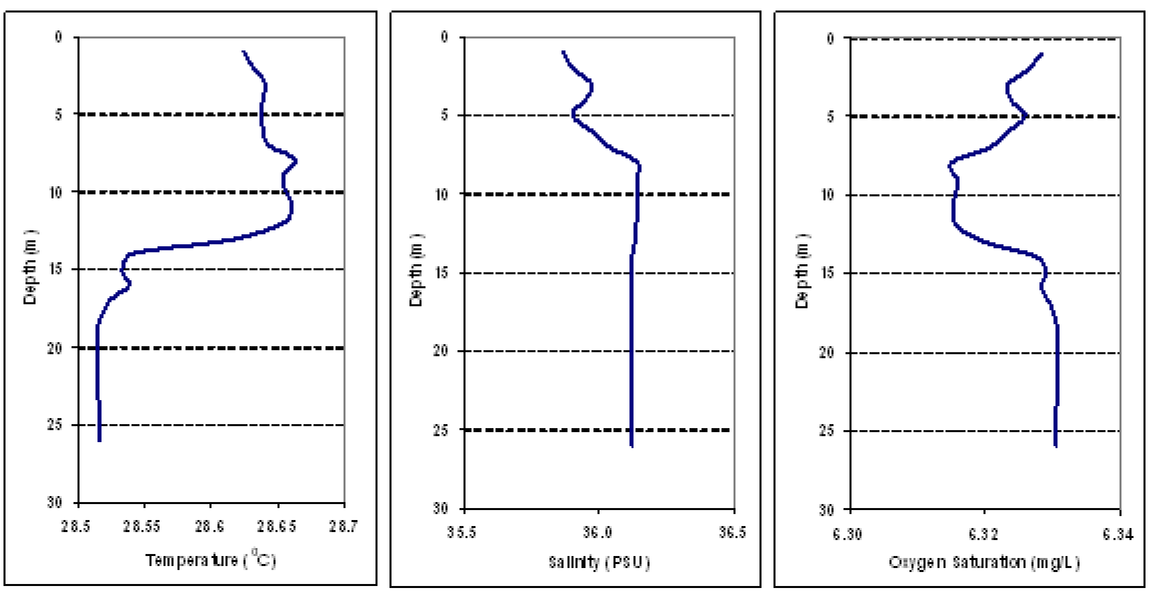

Figure 10. Temperature, salinity, and oxygen concentration profiles at station MC5.

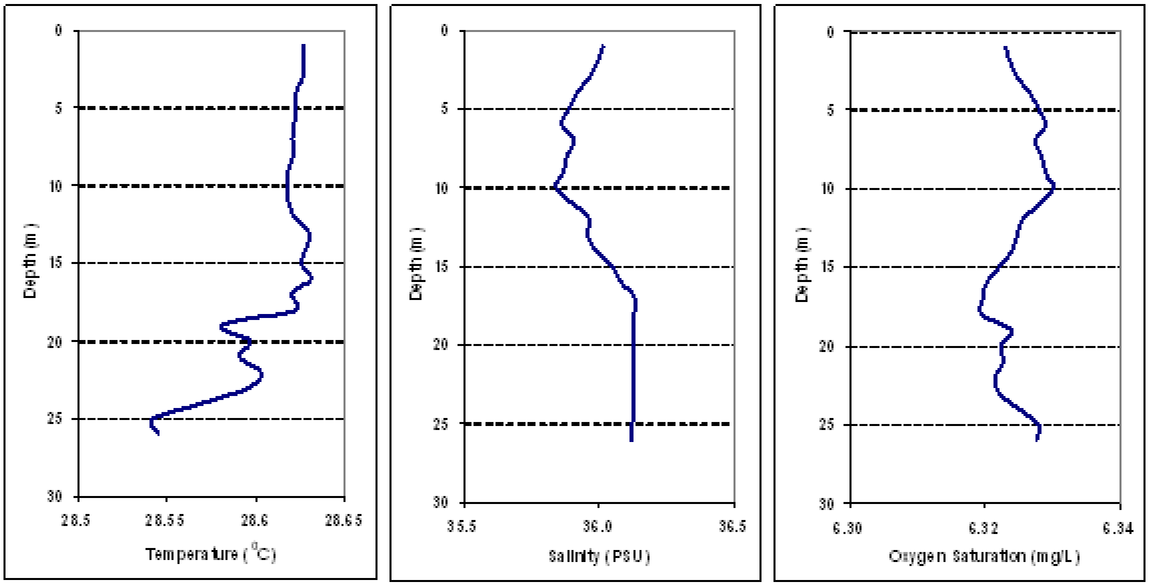

Figure 11. Temperature, salinity, and oxygen concentration profiles at station MC6.

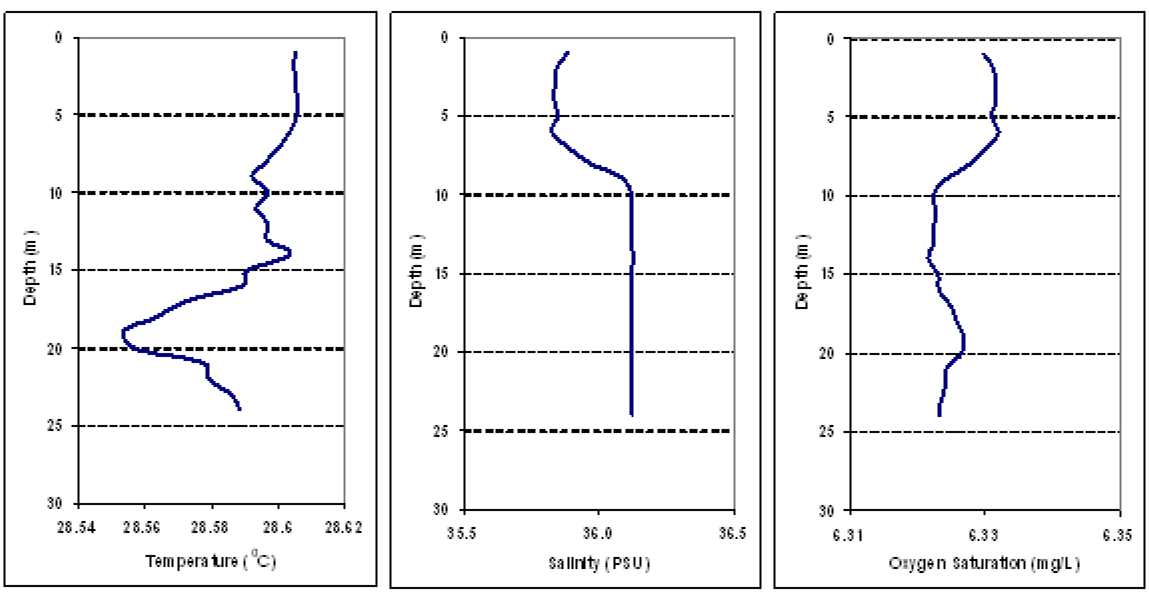

Figure 12. Temperature, salinity, and oxygen concentration profiles at station MC7.

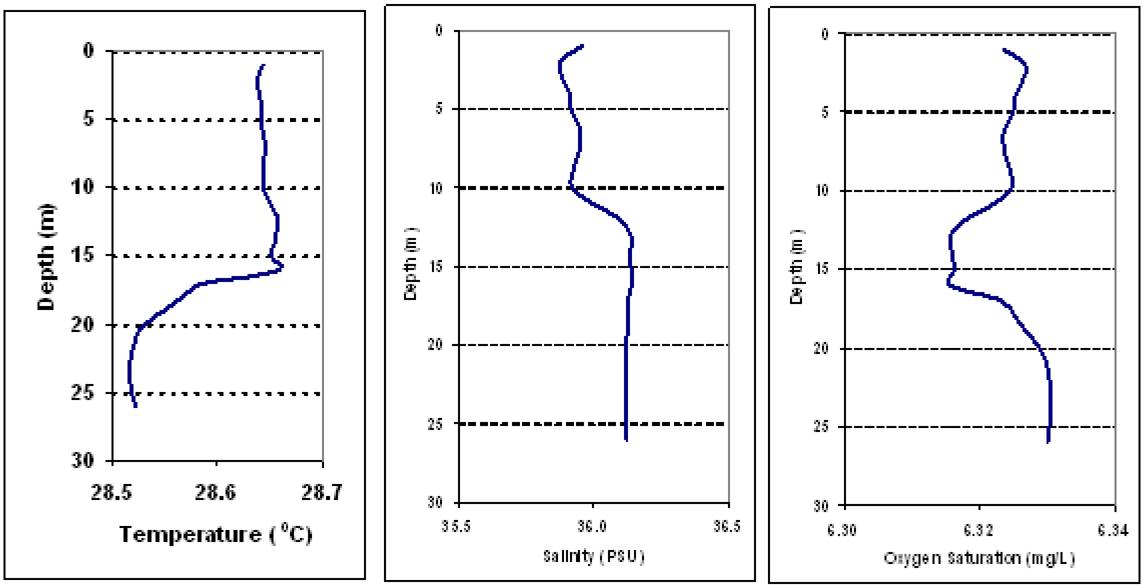

Figure 13. Temperature, salinity, and oxygen concentration profiles at station MC8.

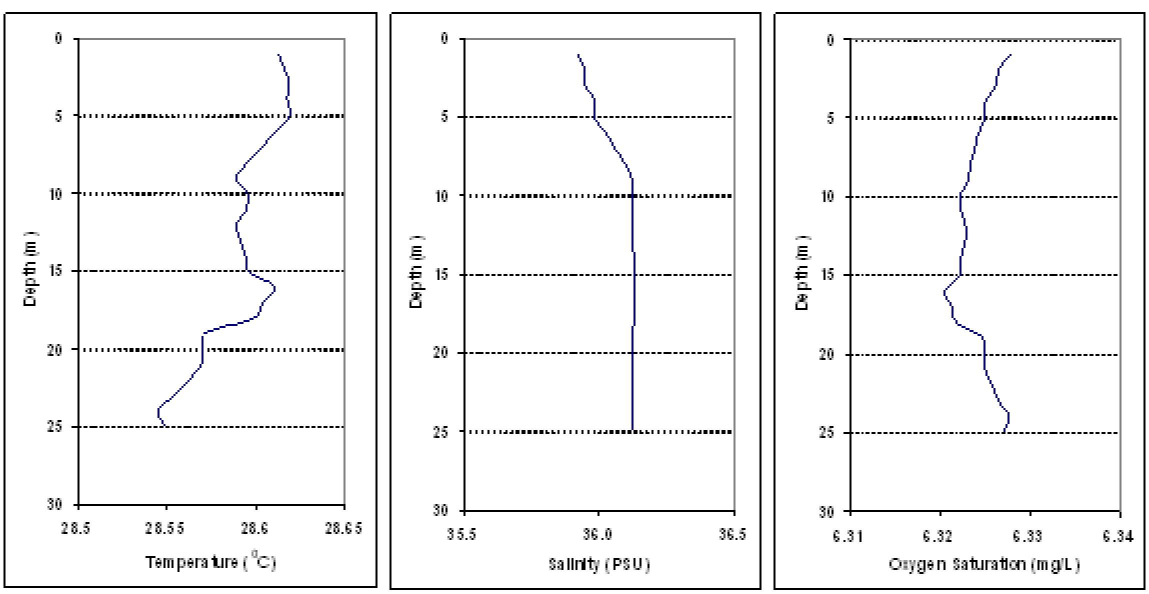

Figure 14. Temperature, salinity, and oxygen concentration profiles at station MC9.

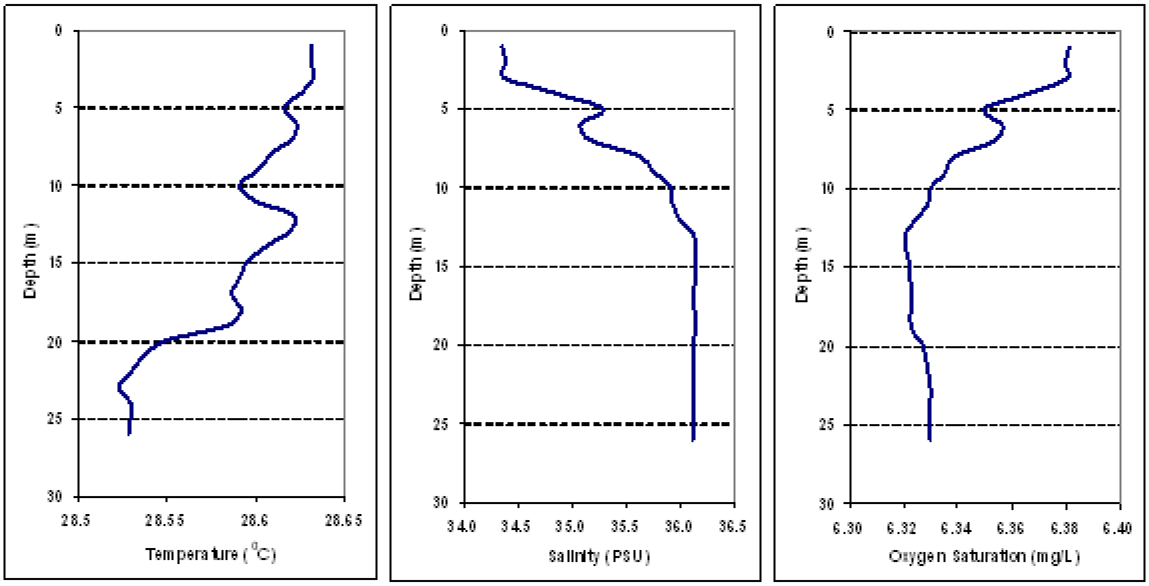

Figure 15. Temperature, salinity, and oxygen concentration profiles at station MC10.

7.5 Current Velocity and Direction

A RDI ADCP was dipped at the Miami-Dade Central outfall on October 8, 2006 to obtain current direction and velocity. Table 10 lists the current data obtained from the Miami-Dade Central outfall, while Figure 16 graphically depicts the data. On this date (October 8th), the current was towards the southwest with the magnitude decreasing with depth, ranging from 21.6 cm/s at 4 m to 17.1 cm/s at 10 m. However, water samples were not collected until October 16th, and on this date the current was towards the north (see V-Fin data below).

Table 10. Current velocity and direction[1] for the Miami-Dade Central outfall on October 8, 2006 at 10:00 EDT.

Depth (m)	U (cm/s)	V (cm/s)	Magnitude (cm/s)	Direction (Degree)
4	-16.2	-14.3	21.6	228.6
6	-11.9	-16.9	20.7	215.1
8	-9.9	-15.7	18.5	212.2
10	-8.1	-15.7	17.1	208.3

[1]**U**: east-west current vector component, positive to the east; **V**: north-south component, positive to the north; magnitude: speed of the current; direction: 360 degrees towards due north.

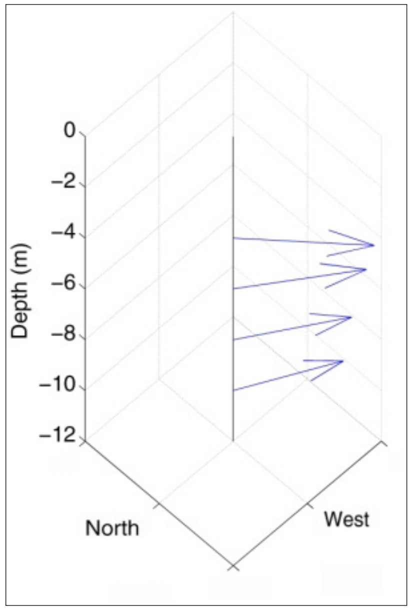

Figure 16. Plot of current vectors versus depth for the Miami-Dade Central outfall on October 8, 2006 at 10:00 EDT. Arrow lengths represent relative velocity (see Table 10 for values).

7.6 V-Fin

On October 16, 2006, the V-Fin was deployed to help locate the surface expression of the Miami-Dade Central plume (Figure 17). Ocean current measurements (i.e., ADCP) were not made on this day, but the mean current direction for the area was to the north (EPA, 2003b; also see ADCP data in section 18.1). V-Fin operations took place north of the outfall location. Figure 18 shows the track over the outfall plume and the salinity and temperature traces from the V-Fin instrumentation. Data where the plume was sampled can be readily discerned in the salinity data. Those data have been highlighted in differing colors in Figure 18. The data clearly indicate that the plume was moving northward. The temperature deficit was absent to minimal when the plume was encountered.

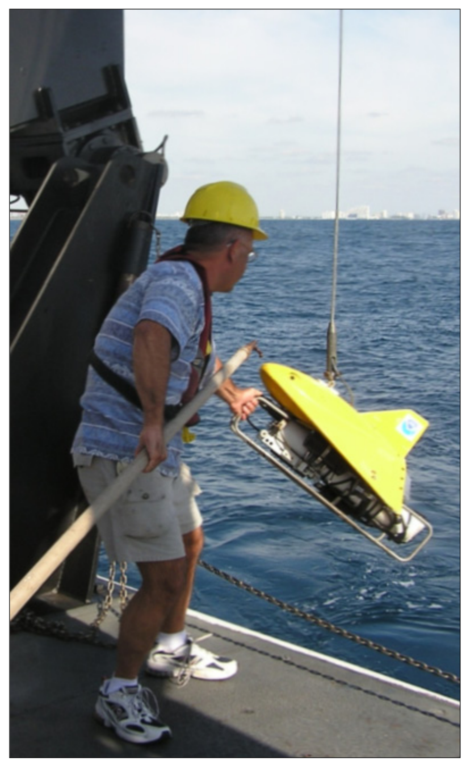

Figure 17. V-Fin instrument being deployed from the aft of the RV *Nancy Foster.*

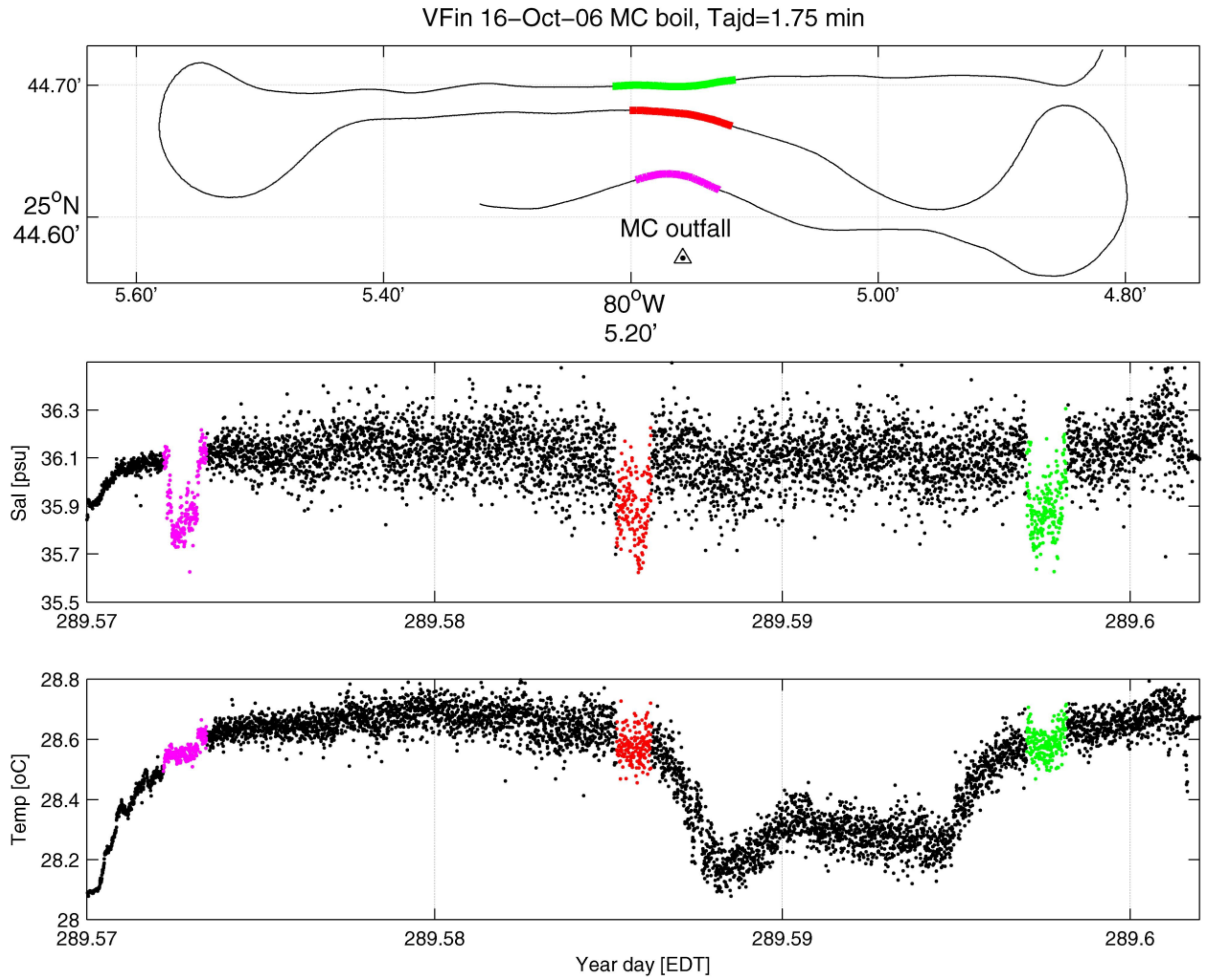

Figure 18. Top panel: Track of the V-Fin instrument on October 16, 2006 as it passed over the Miami-Dade Central outfall plume. The middle and bottom panels show changes in salinity and temperature as the plume was traversed. Plume indications as determined by salinity deficit are highlighted in magenta, red, and green.

8. Miami-Dade North Outfall

8.1 Outfall Description

The Miami-Dade North ocean outfall is located approximately 3.6 km offshore of the northern section of Miami Beach at a depth of 32.9 meters and has an average discharge flow rate of 80 MGD. Figure 19 shows the outfall pipe as recorded by the ship's multi-beam system. From these data, a location of 25°55.203'N, 80°5.176'W (25.92005°N, 80.08627°W) was determined (Table 1). Table 11 lists the CTD sample stations and sample depths; Table 12 lists the sediment sample locations and depths. These values are graphically shown in Figure 20. Cast MN1 and sample MN2 (boil sample only) were obtained on the evening of October 17th; the surface current was southwesterly (see section 8.2). The other casts took place on October 18th; the current was then northerly.

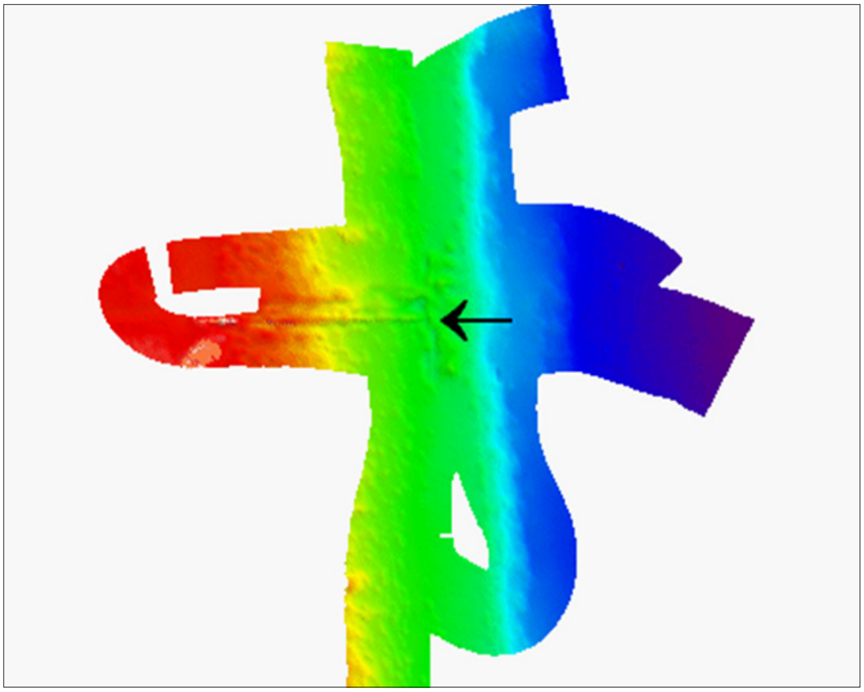

Figure 19. Multi-beam view of the seafloor in the vicinity of the Miami-Dade North outfall. The location of the outfall pipe end is marked by an arrow.

Table 11. CTD sample locations for the Miami-Dade North outfall.

Station	Date	Latitude	Longitude	Distance to Pipe End (m)	Depth (m)	Station	Date	Latitude	Longitude	Distance to Pipe End (m)	Depth (m)
MN1a	17-Oct	25.9192	-80.0863	94.57	0	MN7a	18-Oct	25.9212	-80.0867	135.02	0
MN1b	17-Oct	25.9192	-80.0863	94.57	15	MN7b	18-Oct	25.9212	-80.0867	135.02	15
MN1c	17-Oct	25.9192	-80.0863	94.57	31	MN7c	18-Oct	25.9212	-80.0867	135.02	30
MN2a	17-Oct	25.9196	-80.0863	50.15	0	MN8a	18-Oct	25.9217	-80.0868	191.07	0
MN3a	18-Oct	25.9217	-80.0848	234.90	0	MN8b	18-Oct	25.9217	-80.0868	191.07	14
MN3b	18-Oct	25.9217	-80.0848	234.90	19	MN8c	18-Oct	25.9217	-80.0868	191.07	29
MN4a	18-Oct	25.9212	-80.0843	234.60	0	MN9a	18-Oct	25.9218	-80.0884	288.76	0
MN4b	18-Oct	25.9212	-80.0843	234.60	19	MN9b	18-Oct	25.9218	-80.0884	288.76	10
MN4c	18-Oct	25.9212	-80.0843	234.60	38	MN9c	18-Oct	25.9218	-80.0884	288.76	20
MN5a	18-Oct	25.9207	-80.0844	200.19	0	MN10a	18-Oct	25.9213	-80.0883	246.31	0
MN5b	18-Oct	25.9207	-80.0844	200.19	19	MN10b	18-Oct	25.9213	-80.0883	246.31	10
MN5c	18-Oct	25.9207	-80.0844	200.19	38	MN10c	18-Oct	25.9213	-80.0883	246.31	21
MN6a	18-Oct	25.9210	-80.0868	118.34	0	MN11a	18-Oct	25.9209	-80.0883	224.24	0
MN6b	18-Oct	25.9210	-80.0868	118.34	14	MN11b	18-Oct	25.9209	-80.0883	224.24	14
MN6c	18-Oct	25.9210	-80.0868	118.34	28	MN11c	18-Oct	25.9209	-80.0883	224.24	27

Table 12. Sediment sample locations for the Miami-Dade North outfall.

Station	Date	Latitude	Longitude	Depth (m)
MN10	11-Oct	25.9202	-79.9863	253.0
MN10b	11-Oct	25.9194	-79.9889	257.0
MN10c	11-Oct	25.9233	-79.9871	257.0
MN11	11-Oct	25.9202	-80.0364	255.6
MN12	11-Oct	25.9203	-80.0664	140.9
MN13	11-Oct	25.9202	-80.0962	15.3
MN14a	11-Oct	25.9114	-80.0863	28.4
MN14b	11-Oct	25.9114	-80.0863	28.4
MN14c	11-Oct	25.9112	-80.0859	29.7
MN15	11-Oct	25.9112	-80.0862	30.6
MN16a	11-Oct	25.9202	-80.0862	27.6
MN16b	11-Oct	25.9202	-80.0858	32.6
MN16c	11-Oct	25.9203	-80.0858	32.7
MN17a	11-Oct	25.9210	-80.0864	30.6
MN17b	11-Oct	25.9220	-80.0857	32.1
MN17c	11-Oct	25.9220	-80.0857	32.1
MN18	11-Oct	25.9211	-80.0857	34.0
M18b	11-Oct	25.9211	-80.0857	34.0
MN19a	11-Oct	25.9228	-80.0858	33.4
MN19b	11-Oct	25.9228	-80.0858	33.4
MN19c	11-Oct	25.9228	-80.0859	36.9
MN20	11-Oct	25.9237	-80.0856	34.8
MN21	11-Oct	25.9291	-80.0856	35.5

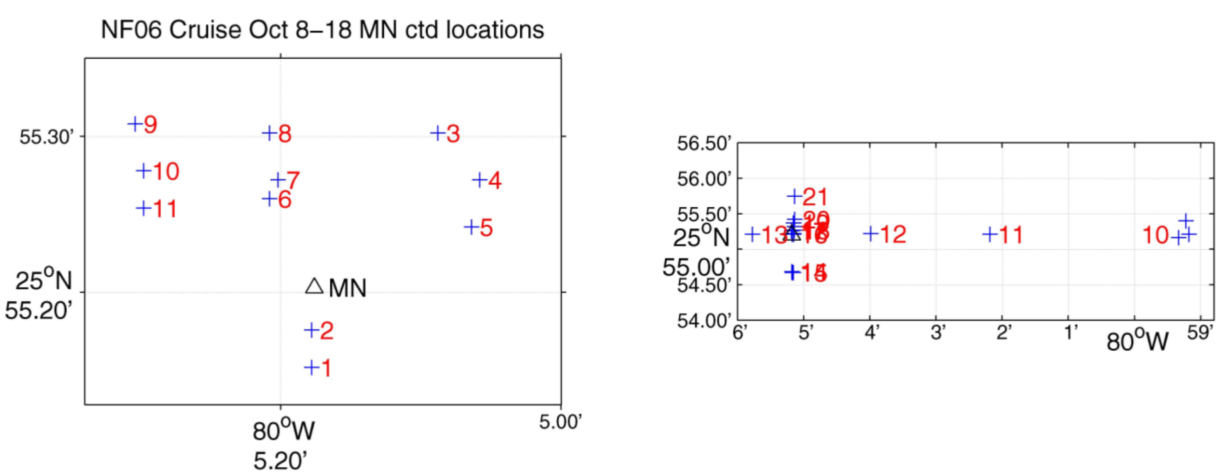

Figure 20. Location of the CTD (left panel) and Shipek sediment (right panel) sample sites for the Miami-Dade North outfall study. The location of the outfall pipe end is denoted by a triangle. CTD casts at MN1 and MN2 were obtained during southerly ocean flow.

8.2 Nutrients

A total of 31 nutrient samples were collected during the CTD operations around the Miami-Dade North outfall. These results are listed in Table 13 for concentrations in µM and in Table 14 for concentrations in mg/L. A graphic presentation of these results is also given in Figure 21. For Miami-Dade North, the closest station to the outfall was site 2, located about 50 m south of the outfall. Site 1 was also located to the south. These samples were obtained on the evening of October 17th (16:42 and 17:15 EDT, respectively) with the current going south. Note the very high concentrations of N+N (site 1) and NH_4 (site 2) in Tables 13 and 14. The current profile measured at 19:00 ETD was eastward (see Table 18 and Figure 35). The other samples were taken the next day on October 18th, north of the outfall, as the current had turned to the north by that time (see Table 19 and Figure 36). Sites 8, 7, and 6 created a north-to-south transect inshore of the outfall. Sites 9, 10, and 11 created the most shoreward north-to-south transect. Sites 3, 4, and 5 created the most offshore north-to-south transect, with site 3 located the farthest north and offshore from the outfall (235 m).

As seen with Miami-Dade Central, near-surface samples generated the highest nutrient concentrations, and lowest concentrations were observed in samples collected near the bottom. There was a general trend of lower concentrations for samples farther from the outfall. The highest concentrations were observed near the boil at MN2 and at MN1. At a distance of 45 m (MN2 to MN1), all the analytes were diluted two-fold, except for P which was diluted nine-fold. Within ~70 m north of the boil (MN2-MN6), all of the analytes were diluted four-fold. Except for MN1 and MN2, these samples were taken while the current was flowing north (October 18). At MN8, 191 m north of the outfall, larger dilutions were observed ranging from 22-fold for N+N to 180-fold for NO_2; P was below detection at this site. NH_4 concentrations were also below detection at MN8; however, the most shoreward (MN9) and offshore (MN3) sites both showed concentrations around 3 µM.

Table 13. Nutrient results in µM for the Miami-Dade North outfall (see Figure 20 for location map; BDL = below detection limit).

Station	Depth (m)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)	Station	Depth (m)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)
MN1a	1.4	29.00	1.00	12.85	0.78	3.24	MN7a	1.5	0.68	0.44	6.20	BDL	1.53
MN1b	15.8	1.71	0.49	4.79	0.24	1.71	MN7b	13.6	0.10	0.03	BDL	BDL	0.13
MN1c	28.1	0.26	0.14	0.02	0.03	0.62	MN7c	26.2	0.12	0.01	BDL	BDL	0.10
MN2	24.3	2.81	1.77	26.10	1.71	5.78	MN8a	1.5	0.13	0.01	BDL	BDL	0.10
MN3a	1.4	0.37	0.23	2.66	0.13	0.90	MN8b	13.6	0.11	0.01	BDL	BDL	0.10
MN3b	15.9	0.08	0.02	BDL	BDL	0.36	MN8c	25.4	0.19	0.02	0.12	BDL	0.21
MN3c	33.5	0.14	0.02	BDL	BDL	0.11	MN9a	1.5	0.35	0.22	2.52	BDL	1.77
MN4a	1.2	0.21	0.12	1.36	0.06	0.44	MN9b	8.6	0.34	0.20	3.12	BDL	1.34
MN4b	19.4	0.06	0.01	BDL	BDL	0.17	MN9c	16.7	0.24	0.03	BDL	BDL	0.18
MN4c	34.1	0.10	0.01	BDL	BDL	0.11	MN10a	1.4	0.08	0.04	BDL	BDL	1.24
MN5a	1.4	0.58	0.39	5.08	2.00	1.14	MN10b	8.5	0.05	0.03	BDL	BDL	0.91
MN5b	15.6	0.04	0.02	BDL	BDL	0.11	MN10c	17.0	0.21	0.02	BDL	BDL	0.29
MN5c	33.2	0.11	0.03	BDL	BDL	0.11	MN11a	1.4	0.07	0.01	BDL	BDL	1.29
MN6a	2.8	0.76	0.50	6.02	0.42	1.63	MN11b	9.3	BDL	BDL	BDL	BDL	0.02
MN6b	10.9	0.11	0.04	BDL	0.04	0.27	MN11c	18.0	0.14	0.02	BDL	BDL	0.05
MN6c	23.6	0.30	0.04	BDL	0.06	0.25							

Table 14. Nutrient results in mg/L for the Miami-Dade North outfall (see Figure 20 for location map; BDL = below detection limit).

Station	Depth (m)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)	Station	Depth (m)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)
MN1a	1.4	0.406	0.014	0.180	0.024	0.091	MN7a	1.5	0.010	0.006	0.087	BDL	0.043
MN1b	15.8	0.024	0.007	0.067	0.008	0.048	MN7b	13.6	0.001	BDL	BDL	BDL	0.004
MN1c	28.1	0.004	0.002	BDL	0.001	0.017	MN7c	26.2	0.002	BDL	BDL	BDL	0.003
MN2	24.3	0.039	0.025	0.365	0.053	0.162	MN8a	1.5	0.002	BDL	BDL	BDL	0.003
MN3a	1.4	0.005	0.003	0.037	0.004	0.025	MN8b	13.6	0.002	BDL	BDL	BDL	0.003
MN3b	15.9	0.001	BDL	BDL	BDL	0.010	MN8c	25.4	0.003	BDL	0.002	BDL	0.006
MN3c	33.5	0.002	BDL	BDL	BDL	0.003	MN9a	1.5	0.005	0.003	0.035	BDL	0.050
MN4a	1.2	0.003	0.002	0.019	0.002	0.012	MN9b	8.6	0.005	0.003	0.044	BDL	0.038
MN4b	19.4	0.001	BDL	BDL	BDL	0.005	MN9c	16.7	0.003	BDL	BDL	BDL	0.005
MN4c	34.1	0.001	BDL	BDL	BDL	0.003	MN10a	1.4	0.001	0.001	BDL	BDL	0.035
MN5a	1.4	0.008	0.005	0.071	0.062	0.032	MN10b	8.5	0.001	BDL	BDL	BDL	0.025
MN5b	15.6	0.001	BDL	BDL	BDL	0.003	MN10c	17.0	0.003	BDL	BDL	BDL	0.008
MN5c	33.2	0.002	BDL	BDL	BDL	0.003	MN11a	1.4	0.001	BDL	BDL	BDL	0.036
MN6a	2.8	0.011	0.007	0.084	0.013	0.046	MN11b	9.3	BDL	BDL	BDL	BDL	0.001
MN6b	10.9	0.002	0.001	BDL	0.001	0.008	MN11c	18.0	0.002	BDL	BDL	BDL	0.001
MN6c	23.6	0.004	0.001	BDL	0.002	0.007							

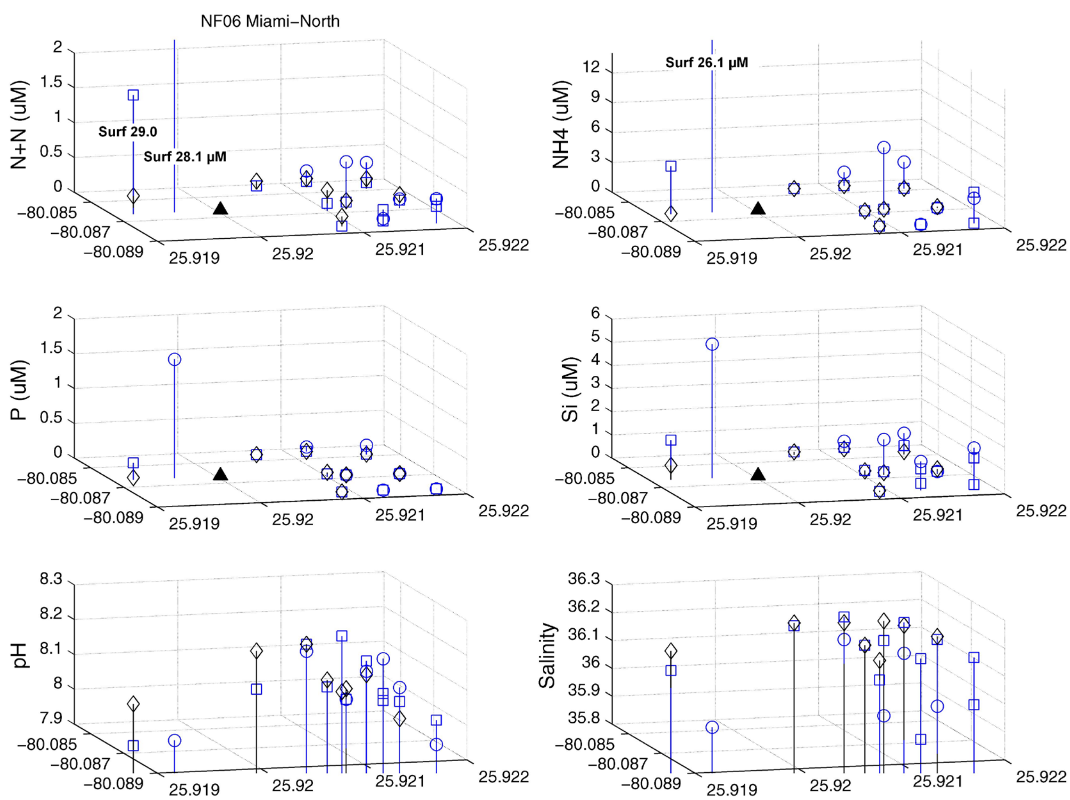

Figure 21. Three-dimensional presentation of nutrient results, pH, and salinity from CTD casts around the Miami-Dade North outfall. The format follows that of Figure 6. See Appendix 1 for tabulated data.

8.3 Chlorophyll and pH

A total of 31 chlorophyll and pH samples were collected during CTD operations around the Miami-Dade North outfall. Table 15 lists the results for the chlorophyll and pH samples collected along with the temperature and salinity data for each depth sampled. Higher chlorophyll-*a* concentrations were observed for the more shoreward stations.

8.4 CTD Casts

A total of 11 CTD casts were conducted at the Miami-Dade North outfall on October 17 and 18. As with other casts, water samples were obtained near the bottom, at mid depth, and near the surface. Figures 22-32 show the temperature, salinity, and oxygen saturation for each station. The thermocline was observed in the inner (MN11, MN10, MN9) and center (MN6, MN7, MN8) casts at 8-10 m. In the outer casts (MN5, MN4, MN3), the thermocline was deeper at 23-33 m.

Table 15. Temperature, salinity, pH, chlorophyll-*a*, and phaeopigment results for the Miami-Dade North outfall.

Station	Depth (m)	Temperature (°C)	Salinity (PSU)	pH	Chlorophyll-*a* (µg/L)	Phaeopigments (µg/L)
MN1a	1.4	28.51	35.62	7.92	0.778	0.200
MN1b	15.8	28.49	36.07	7.90	0.517	0.188
MN1c	28.1	28.49	36.14	8.02	0.845	0.279
MN2	24.3	28.53	35.86	7.91	0.642	0.189
MN3a	1.4	28.56	36.04	8.04	0.402	0.124
MN3b	15.9	28.56	36.15	8.07	0.468	0.141
MN3c	33.5	28.47	36.14	8.03	0.405	0.126
MN4a	1.2	28.57	36.08	8.09	0.398	0.124
MN4b	19.4	28.60	36.16	8.11	0.390	0.112
MN4c	34.1	28.51	36.14	8.11	0.408	0.164
MN5a	1.4	28.58	35.94	8.08	0.412	0.120
MN5b	15.6	28.58	36.14	7.99	0.384	0.115
MN5c	33.2	28.56	36.15	8.10	0.414	0.122
MN6a	2.8	28.56	35.87	8.04	0.560	0.112
MN6b	10.9	28.55	36.15	8.06	0.396	0.117
MN6c	23.6	28.53	36.15	8.08	0.430	0.119
MN7a	1.5	28.67	35.89	8.02	0.437	0.122
MN7b	13.6	28.64	36.16	8.02	0.530	0.136
MN7c	26.2	28.70	36.23	8.05	0.422	0.123
MN8a	1.5	28.78	35.92	8.05	0.417	0.128
MN8b	13.6	28.63	36.16	N/A	0.492	0.129
MN8c	25.4	28.61	36.17	7.96	0.433	0.139
MN9a	1.5	28.60	35.66	7.93	0.825	0.218
MN9b	8.6	28.78	35.98	8.00	0.687	0.177
MN9c	16.7	28.60	36.15	8.03	0.486	0.113
MN10a	1.4	28.58	35.70	8.18	0.874	0.265
MN10b	8.5	28.70	35.86	8.06	0.776	0.219
MN10c	17.0	28.65	36.15	8.08	0.479	0.156
MN11a	1.4	28.57	35.69	8.15	0.900	0.256
MN11b	9.3	28.93	36.08	8.25	0.594	0.169
MN11c	18.0	28.65	36.15	8.09	0.523	0.149

The plume could be seen in the salinity, oxygen, and temperature profiles in the two sites south of the outfall, most strongly at 15 m (MN1, MN2), when the current was southerly. The remaining casts were taken while the current was flowing north. As with the Miami-Dade Central casts, the plume was observed as irregular boluses. A signature of the plume was observed at MN11, the closest station to the outfall of the inshore sites, centered at ~6 m. At all the outer (MN5, MN4, MN3) and middle (MN6, MN7, MN8) casts, the plume was clearly seen in the salinity signal at 5-9 m depth and less distinctly in the temperature and oxygen data. The seawater depth increased from ~20 m (MN9) to 38 m (MN4).

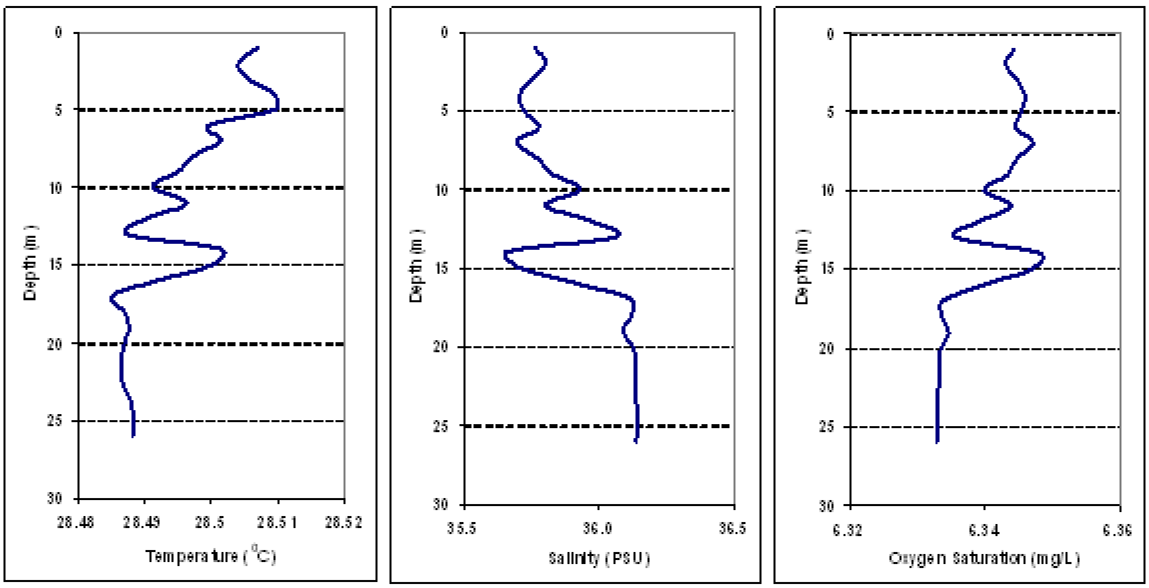

Figure 22. Temperature, salinity, and oxygen concentration profiles at station MN1 on October 17, 2006.

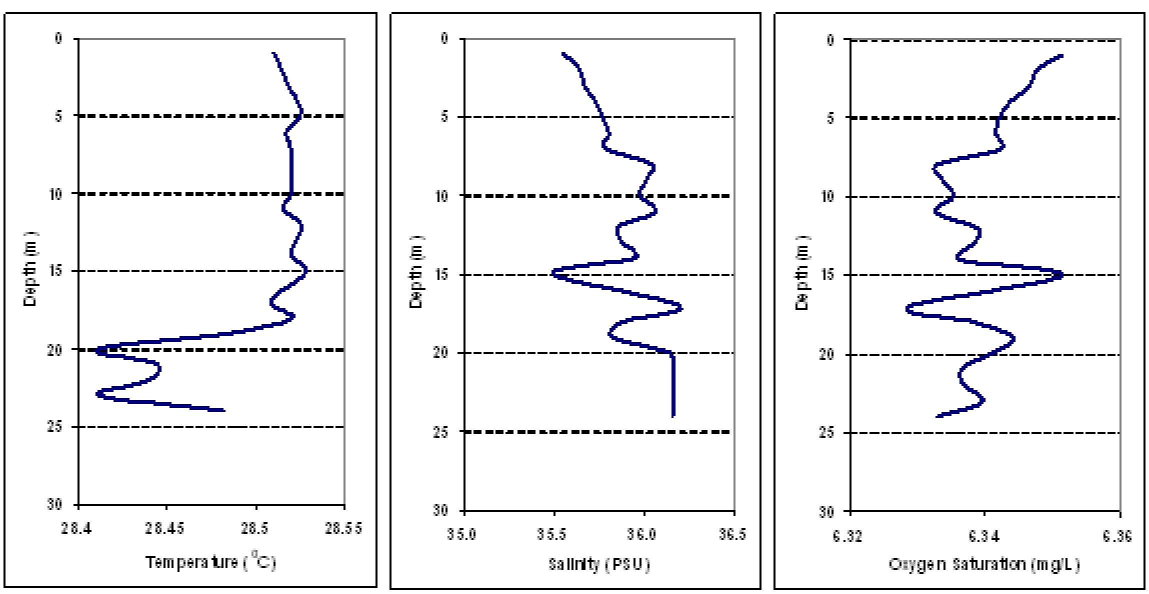

Figure 23. Temperature, salinity, and oxygen concentration profiles at station MN2 on October 17, 2006.

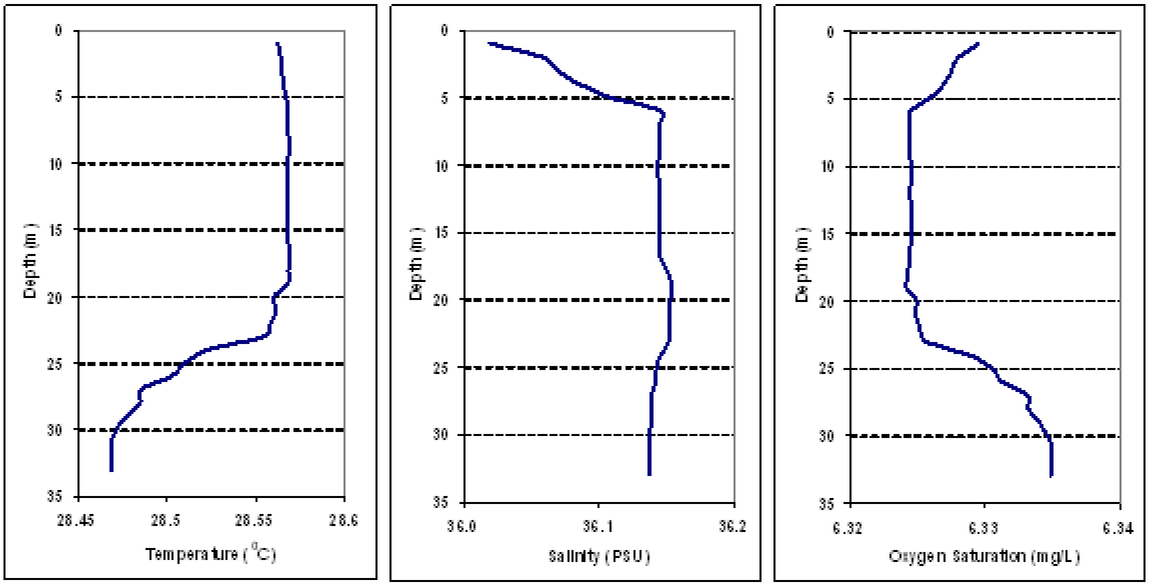

Figure 24. Temperature, salinity, and oxygen concentration profiles at station MN3 on October 18, 2006.

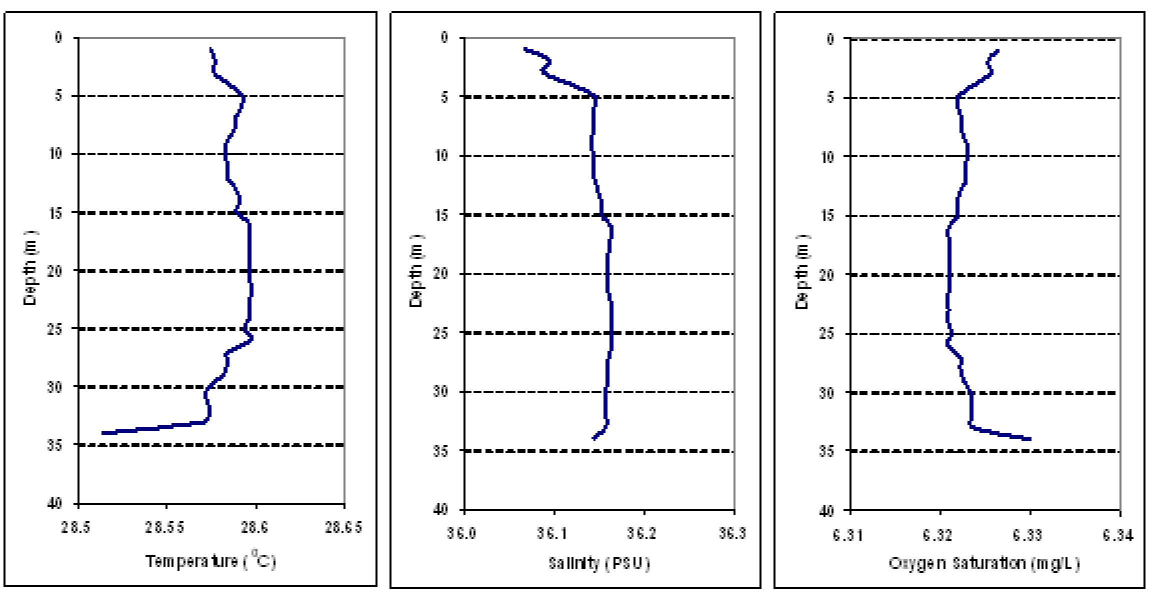

Figure 25. Temperature, salinity, and oxygen concentration profiles at station MN4 on October 18, 2006.

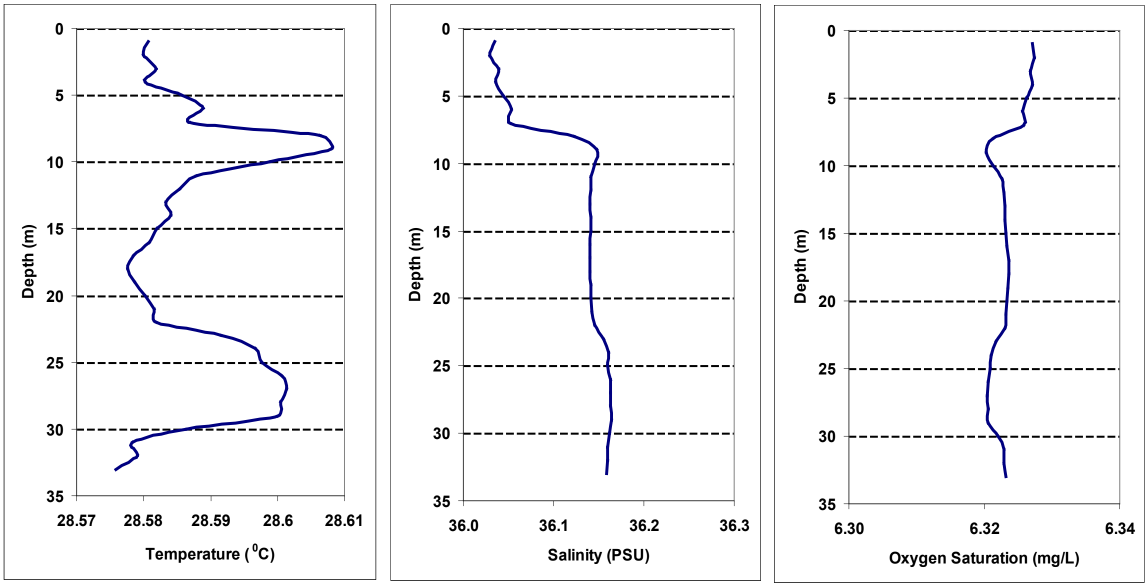

Figure 26. Temperature, salinity, and oxygen concentration profiles at station MN5 on October 18, 2006.

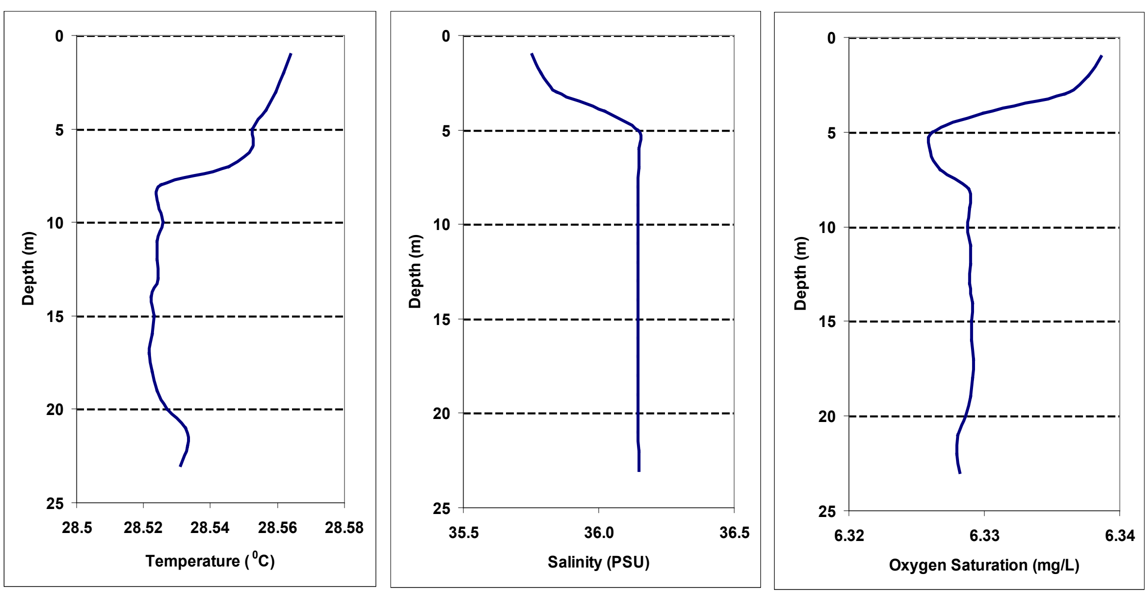

Figure 27. Temperature, salinity, and oxygen concentration profiles at station MN6 on October 18, 2006.

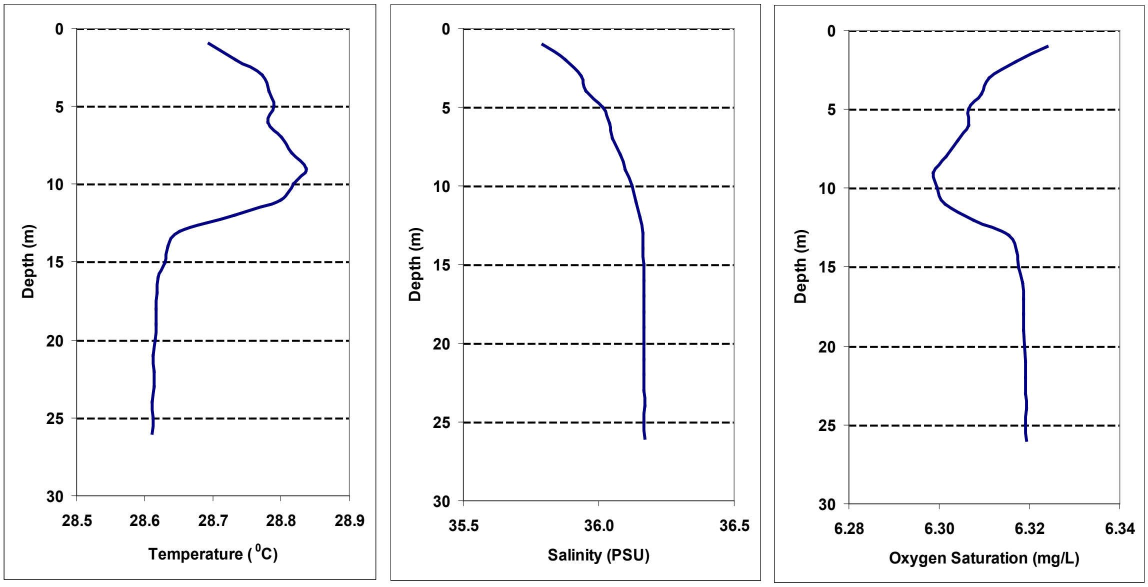

Figure 28. Temperature, salinity, and oxygen concentration profiles at station MN7 on October 18, 2006.

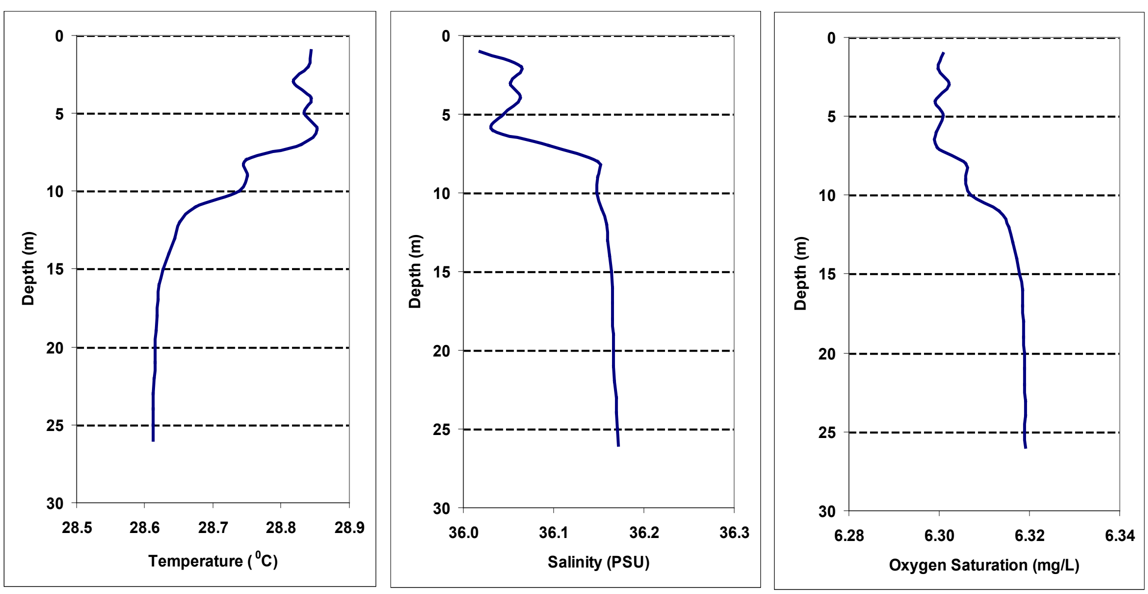

Figure 29. Temperature, salinity, and oxygen concentration profiles at station MN8 on October 18, 2006.

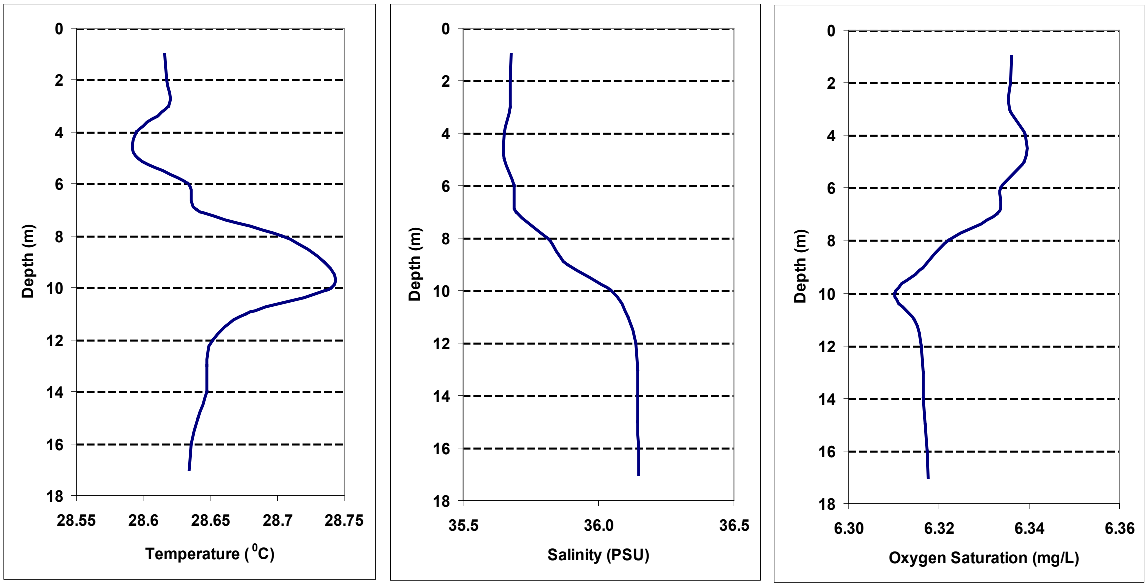

Figure 30. Temperature, salinity, and oxygen concentration profiles at station MN9 on October 18, 2006.

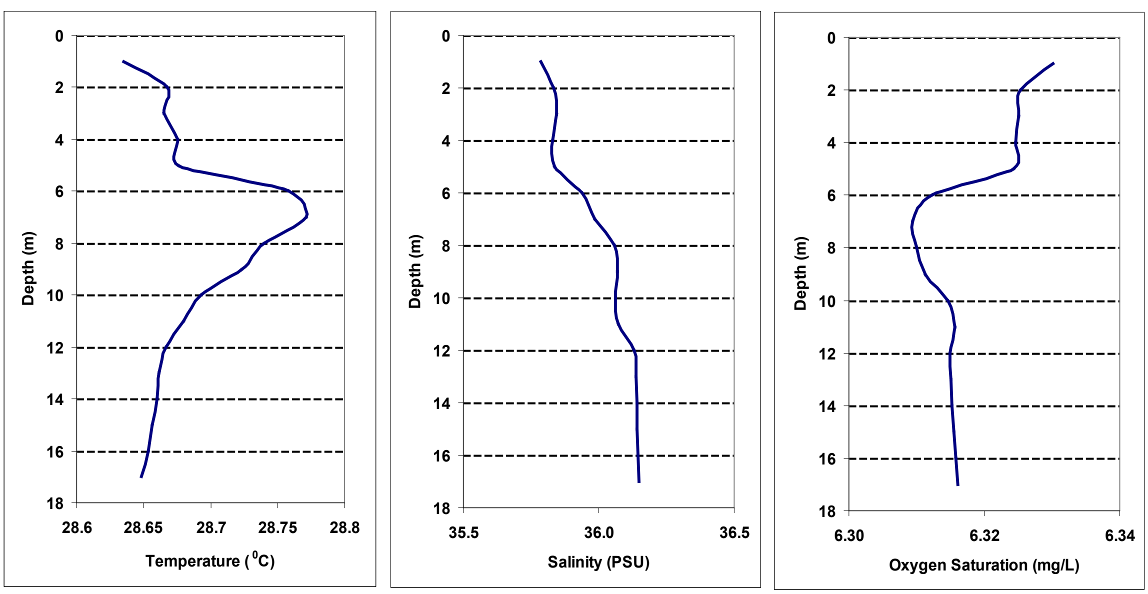

Figure 31. Temperature, salinity, and oxygen concentration profiles at station MN10 on October 18, 2006.

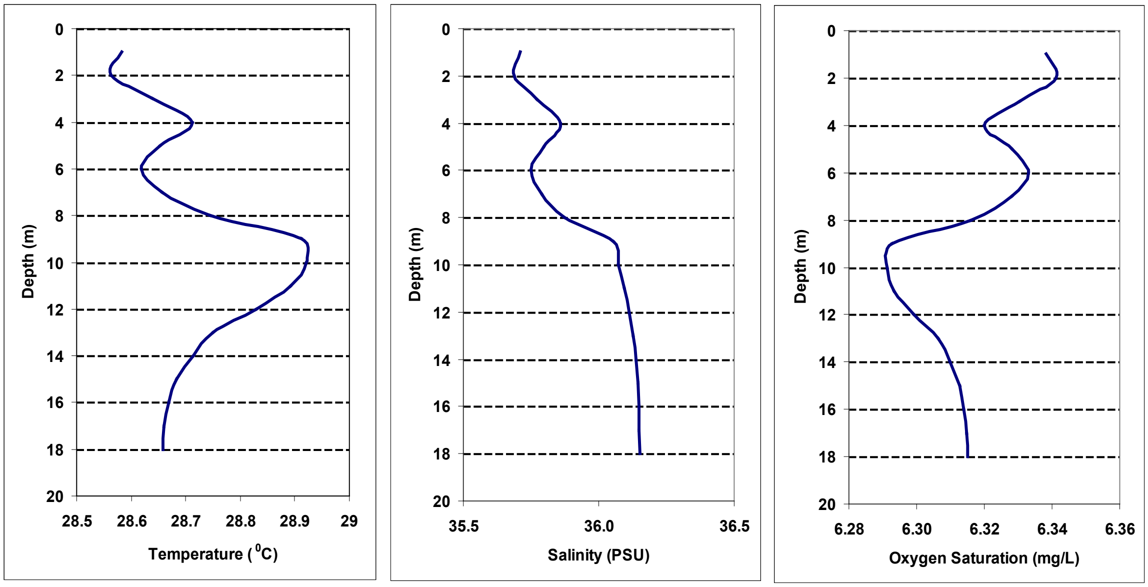

Figure 32. Temperature, salinity, and oxygen concentration profiles at station MN11 on October 18, 2006.

The above plots show that the plume was at a somewhat lower temperature than the surrounding waters. The salinity data from MN1 and MN2 (boil samples) were consistent with an irregular, rising plume of lower density (~35.4 PSU) water. At MN6, salinity data indicated that the plume was confined to the upper 5 m and, while irregular, stayed within 5-10 m for the remaining stations. Similar but less evident trends were seen in temperature and oxygen saturation.

8.5 Current Velocity and Direction

A RDI ADCP was dipped at the Miami-Dade North outfall to obtain current direction and velocity. A total of four dips were performed at this site. Tables 16-19 list the current vector data obtained from the Miami-Dade North outfall, while Figures 33-36 graphically depict the data. During the first sampling (October 11th, 14:00 EDT; Table 16, Figure 33), shear was observed in the water column with the current to the south from near the surface to 20 m with a shift to the north-northwest below. The current magnitude was ~6 cm/s at both the top and bottom of the water column, with a minimum of 0.22 cm/s at 20 m, which was the inflection point for the change in current direction. This shear was not observed during the second sampling (October 11th, 20:20 EDT), and the mean direction of flow was to the south, ranging from 6-11 cm/s (Table 17, Figure 34). When the site was sampled again (October 17, 19:00 EDT), the current was stronger (39 cm/s maximum), with a flow to the east and a maximum magnitude at 14 m (Table 18, Figure 35). On the final day of sampling (October 18, 07:40 EDT), the flow was to the north, ranging from 8 cm/s at 8 m to 12 cm/s at 14 m (Table 19, Figure 36).

Table 16. Current velocity and direction for the Miami-Dade North outfall on October 11, 2006 at 14:00 EDT (see Table 10 for further explanation).

Depth (m)	U (cm/s)	V (cm/s)	Magnitude (cm/s)	Direction (Degree)
4	0.9	-6.1	6.12	171.3
6	0.6	-3.7	3.74	170.6
8	1.6	-3.9	4.26	157.6
10	2.0	-4.0	4.47	154.2
12	1.7	-2.7	3.19	148.1
14	1.0	-2.2	2.42	154.9
16	0.9	-1.3	1.61	144.5
18	0.5	-1.0	1.12	151.4
20	0.1	0.2	0.22	31.0
22	-0.9	1.9	2.11	335.6
24	-2.7	4.0	4.79	326.3
26	-3.5	4.5	5.67	322.2
28	-4.2	4.2	5.87	315.0

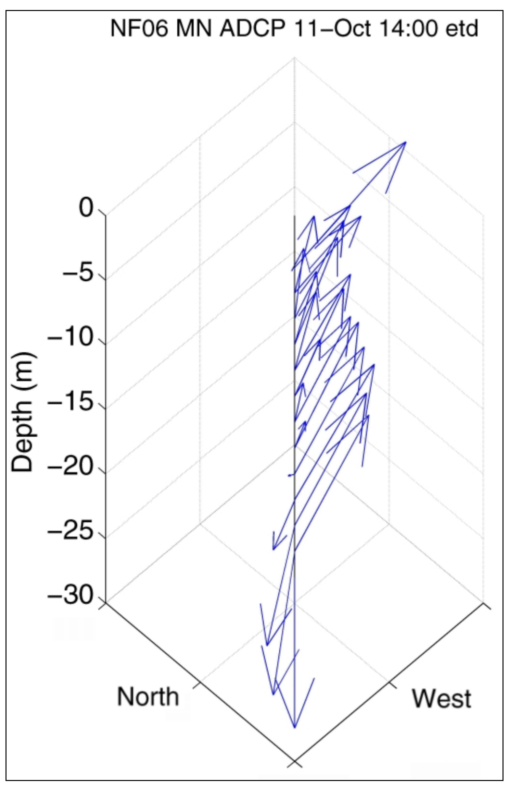

Figure 33. Plot of current vectors versus depth for the Miami-Dade North outfall on October 11, 2006 at 14:00 EDT. Arrow lengths represent relative velocity (see Table 16 for values).

Table 17. Current velocity and direction for the Miami-Dade North outfall on October 11, 2006 at 20:20 EDT (see Table 10 for further explanation).

Depth (m)	U (cm/s)	V (cm/s)	Magnitude (cm/s)	Direction (Degree)
4	0.8	-5.7	5.8	172.2
6	3.2	-4.9	5.8	147.2
8	3.3	-4.1	5.3	141.6
10	2.9	-4.8	5.6	149.3
12	2.6	-7.5	8.0	160.8
14	3.5	-7.8	8.6	156.2
16	3.1	-8.0	8.6	158.7
18	3.8	-9.4	10.1	158.0
20	3.6	-9.7	10.4	159.7
22	3.6	-10.6	11.2	161.1
24	3.8	-10.1	10.8	159.5
26	3.9	-10.4	11.1	159.5

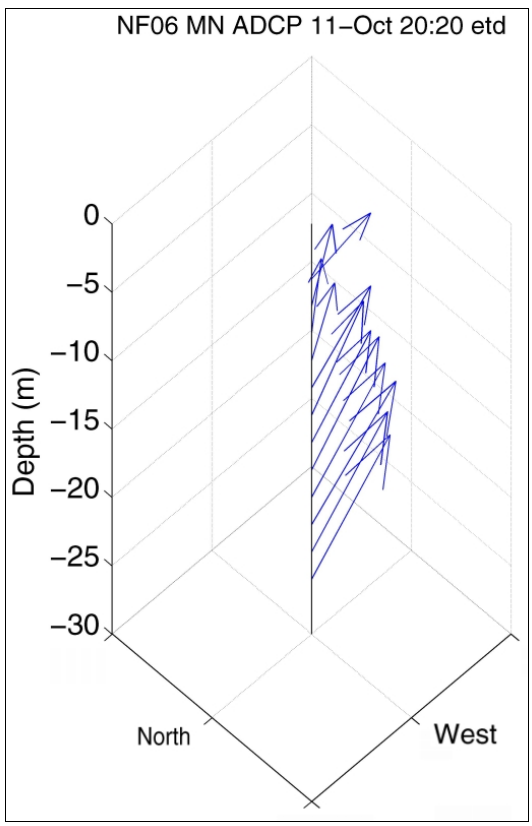

Figure 34. Plot of current vectors versus depth for the Miami-Dade North outfall on October 11, 2006 at 20:20 EDT. Arrow lengths represent relative velocity (see Table 17 for values).

Table 18. Current velocity and direction for the Miami-Dade North outfall on October 17, 2006 at 19:00 EDT (see Table 10 for further explanation).

Depth (m)	U (cm/s)	V (cm/s)	Magnitude (cm/s)	Direction (Degree)
4.25	17.2	-18.2	25.0	136.6
6.25	16.7	-11.4	20.2	124.3
8.25	17.6	-4.0	18.1	102.9
10.25	21.0	-4.5	21.5	102.1
12.25	31.7	-7.7	32.6	103.6
14.25	40.1	-7.6	40.8	100.8
16.25	38.4	-7.3	39.1	100.7
18.25	38.7	-6.3	39.2	99.2
20.25	34.5	-5.9	35.0	99.7
22.25	22.4	0.1	22.4	89.8
24.25	16.0	1.5	16.1	84.5
26.25	13.0	-4.9	13.9	110.7

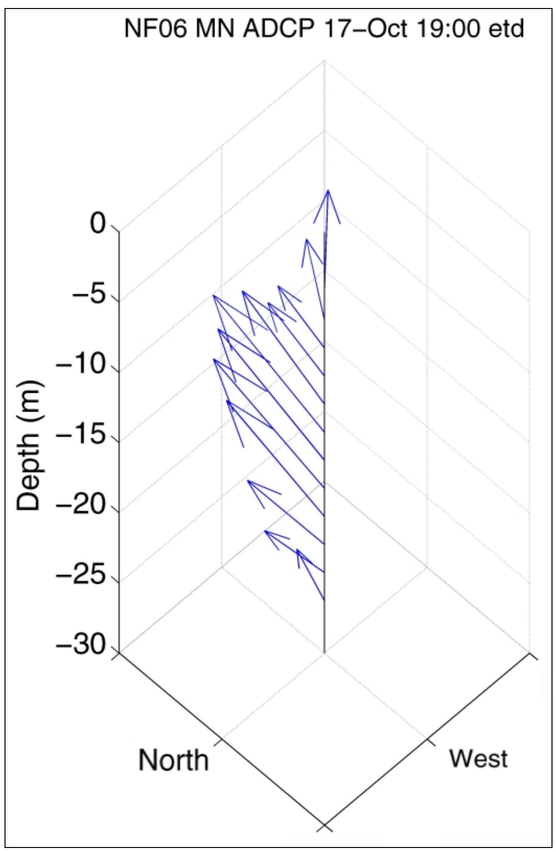

Figure 35. Plot of current vectors versus depth for the Miami-Dade North outfall on October 17, 2006 at 19:00 EDT. Arrow lengths represent relative velocity (see Table 18 for values).

Table 19. Current velocity and direction for the Miami-Dade North outfall on October 18, 2006 at 07:40 EDT (see Table 10 for column descriptions).

Depth (m)	U (cm/s)	V (cm/s)	Magnitude (cm/s)	Direction (Degree)
4.3	-4.2	9.0	9.9	334.8
6.3	-4.3	7.4	8.6	329.7
8.3	-3.5	7.7	8.4	335.6
10.3	-2.1	9.3	9.5	347.1
12.3	-2.6	11.0	11.3	346.7
14.3	-3.4	11.9	12.4	344.2
14.3	-2.7	11.8	12.1	347.3
16.3	-2.8	11.0	11.3	345.5
18.3	-2.5	11.6	11.9	348.1
20.3	-2.7	11.3	11.6	346.8
22.3	-3.1	11.3	11.7	344.7
24.3	-2.6	11.5	11.8	347.1
26.3	-1.8	11.4	11.6	351.3
28.3	-1.6	9.0	9.1	350.2

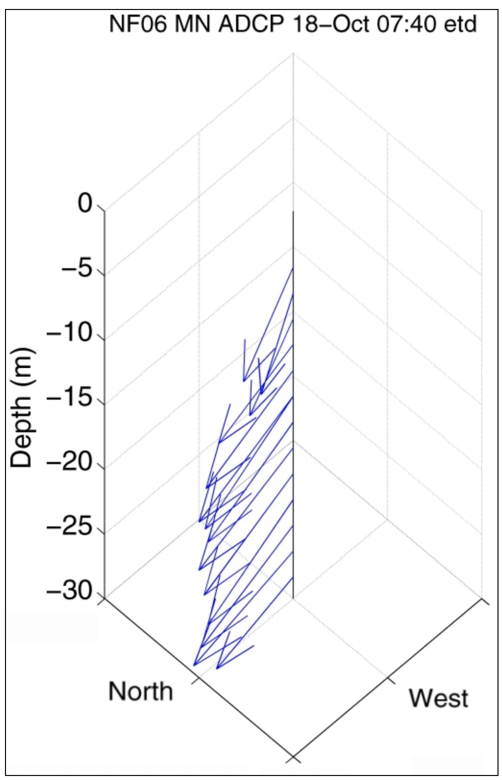

Figure 36. Plot of current vectors versus depth for the Miami-Dade North outfall on October 18, 2006 at 07:40 EDT. Arrow lengths represent relative velocity (see Table 19 for values).

8.6 V-Fin

No V-Fin data were collected.

9. Hollywood Outfall

9.1 Outfall Description

The Hollywood ocean outfall is located approximately 3.1 km offshore of the southern section of Broward County at a depth of 28.3 meters and has an average discharge flow rate of 40 MGD. Figure 37 shows the outfall pipe as recorded by the ship's multi-beam system. From these data, a location of 26°1.147'N, 80°5.156'W (26.019117°N, 80.089533°W) was determined. Table 20 lists the CTD sample stations and sample depths. Table 21 lists the sediment sample locations and depths. These values are shown graphically in Figure 38.

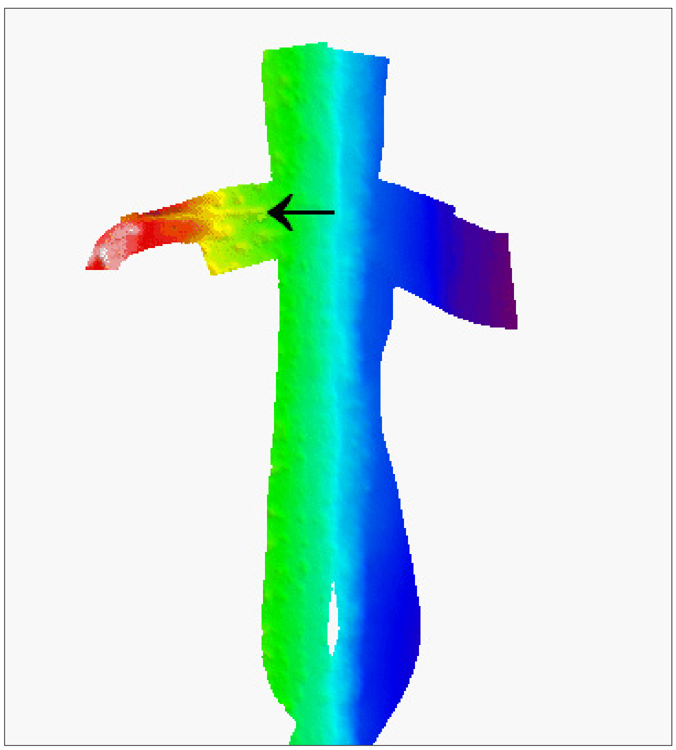

Figure 37. Multi-beam view of the seafloor in the vicinity of the Hollywood outfall. The location of the outfall pipe end is marked by an arrow.

Table 20. CTD sample locations for the Hollywood outfall.

Station	Date	Latitude	Longitude	Distance to Pipe End (m)	Depth (m)	Station	Date	Latitude	Longitude	Distance to Pipe End (m)	Depth (m)
HW1a	17-Oct	26.0203	-80.0868	157.52	0	HW6b	17-Oct	26.0207	-80.0871	211.16	8
HW1b	17-Oct	26.0203	-80.0868	157.52	10	HW6c	17-Oct	26.0207	-80.0871	211.16	16
HW1c	17-Oct	26.0203	-80.0868	157.52	20	HW7a	17-Oct	26.0211	-80.0874	264.79	0
HW2a	17-Oct	26.0203	-80.0856	135.73	0	HW7b	17-Oct	26.0211	-80.0874	264.79	7.7
HW2b	17-Oct	26.0203	-80.0856	135.73	14	HW7c	17-Oct	26.0211	-80.0874	264.79	15
HW2c	17-Oct	26.0203	-80.0856	135.73	28	HW8a	17-Oct	26.0212	-80.0856	234.04	0
HW3a	17-Oct	26.0203	-80.0846	187.26	0	HW8b	17-Oct	26.0212	-80.0856	234.04	14
HW3b	17-Oct	26.0203	-80.0846	187.26	17	HW8c	17-Oct	26.0212	-80.0856	234.04	28
HW3c	17-Oct	26.0203	-80.0846	187.26	34	HW9a	17-Oct	26.0213	-80.0840	310.26	0
HW4a	17-Oct	26.0208	-80.0845	235.69	0	HW9b	17-Oct	26.0213	-80.0840	310.26	19
HW4b	17-Oct	26.0208	-80.0845	235.69	17	HW9c	17-Oct	26.0213	-80.0840	310.26	37
HW4c	17-Oct	26.0208	-80.0845	235.69	35	HW10a	17-Oct	26.0197	-80.0856	72.92	0
HW5a	17-Oct	26.0207	-80.0857	177.60	0	HW10b	17-Oct	26.0197	-80.0856	72.92	14
HW5b	17-Oct	26.0207	-80.0857	177.60	13	HW10c	17-Oct	26.0197	-80.0856	72.92	29
HW5c	17-Oct	26.0207	-80.0857	177.60	27	HW11	17-Oct	26.0186	-80.0861	59.82	25
HW6a	17-Oct	26.0207	-80.0871	211.16	0						

Table 21. Sediment sample locations for the Hollywood outfall.

Station	Date	Latitude	Longitude	Depth (m)
HW10	10-Oct	26.0193	-79.9869	262.0
HW11	10-Oct	26.0189	-80.0363	234.0
HW12	10-Oct	26.0189	-80.0663	135.8
HW13	10-Oct	26.0190	-80.0966	26.0
HW14	10-Oct	26.0280	-80.0863	22.7
HW14b	10-Oct	26.0280	-80.0863	22.7
HW15	10-Oct	26.0227	-80.0862	22.9
HW16	10-Oct	26.0219	-80.0860	24.3
HW16b	10-Oct	26.0219	-80.0862	24.0
HW16c	10-Oct	26.0219	-80.0862	23.0
HW16d	10-Oct	26.0219	-80.0858	26.4
HW17	10-Oct	26.0210	-80.0860	25.2
HW17b	10-Oct	26.0210	-80.0856	28.1
HW18	10-Oct	26.0201	-80.0855	28.5
HW19	10-Oct	26.0192	-80.0855	29.0
HW19a	10-Oct	26.0192	-80.0855	29.0
HW19b	10-Oct	26.0192	-80.0853	29.8
HW19c	10-Oct	26.0191	-80.0853	29.8
HW19d	10-Oct	26.0191	-80.0853	29.8
HW20	10-Oct	26.0182	-80.0854	29.4
HW21	10-Oct	26.0100	-80.0859	28.5
HW21b	10-Oct	26.0100	-80.0860	28.1

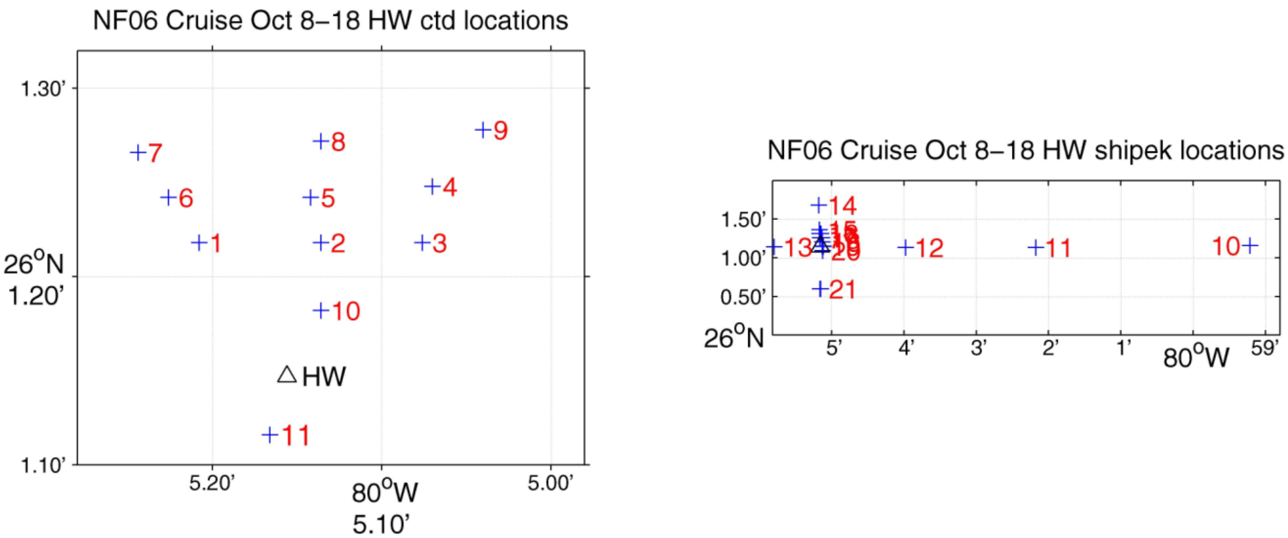

Figure 38. Location of the CTD (left panel) and Shipek sediment (right panel) sample sites for the Hollywood outfall study. The location of the outfall pipe end is denoted by a triangle.

9.2 Nutrients

A total of 31 nutrient samples were collected during the CTD operations around the Hollywood outfall on October 17, 2006. These results are listed in Table 22 for concentrations in µM and in Table 23 for concentrations in mg/L. A graphic presentation of these results is provided in Figure 39. Station HW11 was the site closest to the outfall, located 60 m south of the outfall. Station HW10 was located 73 m north of the outfall. The other sites sampled were all north of the outfall (Figure 38), with sites 10, 2, 5, and 8 creating a south-to-north transect most in line with the outfall. Sites 1, 6, and 7 created the most inshore south-to-north transect, while sites 3, 4, and 9 created the most offshore south-to-north transect. Site 9 was located the farthest north and offshore from the outfall (310 m). The current was northwest at the surface and north below (see below).

Elevated concentrations were observed at HW11 but, at HW10, P was below detection, Si was reduced six-fold, and the other analytes were reduced eight- to ten-fold. Within 234 m north of the outfall (HW8), the concentration reduction had increased to nine-fold for Si and nine- to 14-fold for the other analytes. In comparison, the farthest site (HW9) showed a 24-fold reduction for Si and a 200-fold dilution for NH_4 and N+N. Both P and NO_2 were below detection. For HW11, only deep (28.5 m) samples were reported.

Table 22. Nutrient results in µM for the Hollywood outfall (see Figure 38 for location map; BDL = below detection limit).

Station	Depth (m)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)	Station	Depth (m)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)
HW1ab	2.6	0.25	0.03	0.55	0.13	0.63	HW6b	9.4	0.21	0.01	BDL	BDL	0.40
HW1bb	6.8	0.20	0.02	0.01	0.04	0.57	HW6c	13.5	0.19	0.01	BDL	BDL	0.38
HW1cb	16.3	0.24	0.02	0.20	BDL	0.54	HW7a	1.3	0.23	0.03	BDL	BDL	0.43
HW2a	1.5	0.59	0.32	2.03	0.08	0.87	HW7b	7.1	0.21	0.02	0.06	BDL	0.38
HW2b	11.4	0.70	0.42	1.97	0.04	1.01	HW7c	12.3	0.18	0.02	BDL	BDL	0.32
HW2c	22.9	0.25	BDL	0.06	BDL	0.43	HW8a	1.2	0.64	0.34	2.20	BDL	0.96
HW3a	2.3	1.26	0.81	3.31	0.09	1.54	HW8b	12.3	0.16	0.03	0.12	BDL	0.43
HW3b	15.3	0.08	BDL	BDL	BDL	0.40	HW8c	24.6	0.15	0.01	0.07	BDL	0.49
HW3c	31.6	0.09	BDL	BDL	BDL	0.35	HW9a	1.5	0.03	BDL	0.15	BDL	0.35
HW4a	1.7	0.08	BDL	BDL	BDL	0.52	HW9b	18.7	0.03	BDL	BDL	BDL	0.35
HW4b	18.7	0.13	BDL	0.33	BDL	0.49	HW9c	35.6	0.13	0.01	0.11	BDL	0.32
HW4c	32.4	0.19	0.02	0.10	BDL	0.43	HW10a	1.5	0.77	0.46	3.17	BDL	1.32
HW5a	1.4	0.23	0.09	0.59	BDL	0.52	HW10b	13.8	0.16	0.01	0.54	BDL	0.40
HW5b	12.2	0.18	0.04	0.36	BDL	0.43	HW10c	25.8	0.12	0.01	0.23	BDL	0.40
HW5c	24.1	0.26	0.02	BDL	BDL	0.38	HW11	35.8	5.95	4.56	30.22	0.83	8.26
HW6a	1.5	0.18	0.01	BDL	BDL	0.38							

Table 23. Nutrient results in mg/L for the Hollywood outfall (see Figure 38 for location map; BDL = below detection limit).

Station	Depth (m)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)	Station	Depth (m)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)
HW1ab	2.6	0.004	BDL	0.008	0.004	0.018	HW6b	9.4	0.003	BDL	BDL	BDL	0.011
HW1bb	6.8	0.003	BDL	BDL	0.001	0.016	HW6c	13.5	0.003	BDL	BDL	BDL	0.011
HW1cb	16.3	0.003	BDL	0.003	BDL	0.015	HW7a	1.3	0.003	BDL	BDL	BDL	0.012
HW2a	1.5	0.008	0.004	0.028	0.002	0.024	HW7b	7.1	0.003	BDL	0.001	BDL	0.011
HW2b	11.4	0.010	0.006	0.028	0.001	0.028	HW7c	12.3	0.003	BDL	BDL	BDL	0.009
HW2c	22.9	0.004	BDL	0.001	BDL	0.012	HW8a	1.2	0.009	0.005	0.031	BDL	0.027
HW3a	2.3	0.018	0.011	0.046	0.003	0.043	HW8b	12.3	0.002	BDL	0.002	BDL	0.012
HW3b	15.3	0.001	BDL	BDL	BDL	0.011	HW8c	24.6	0.002	BDL	0.001	BDL	0.014
HW3c	31.6	0.001	BDL	BDL	BDL	0.010	HW9a	1.5	BDL	BDL	0.002	BDL	0.010
HW4a	1.7	0.001	BDL	BDL	BDL	0.015	HW9b	18.7	BDL	BDL	BDL	BDL	0.010
HW4b	18.7	0.002	BDL	0.005	BDL	0.014	HW9c	35.6	0.002	BDL	0.002	BDL	0.009
HW4c	32.4	0.003	BDL	0.001	BDL	0.012	HW10a	1.5	0.011	0.006	0.044	BDL	0.037
HW5a	1.4	0.003	0.001	0.008	BDL	0.015	HW10b	13.8	0.002	BDL	0.008	BDL	0.011
HW5b	12.2	0.003	0.001	0.005	BDL	0.012	HW10c	25.8	0.002	BDL	0.003	BDL	0.011
HW5c	24.1	0.004	BDL	BDL	BDL	0.011	HW11	35.8	0.083	0.064	0.423	0.026	0.231
HW6a	1.5	0.003	BDL	BDL	BDL	0.011							

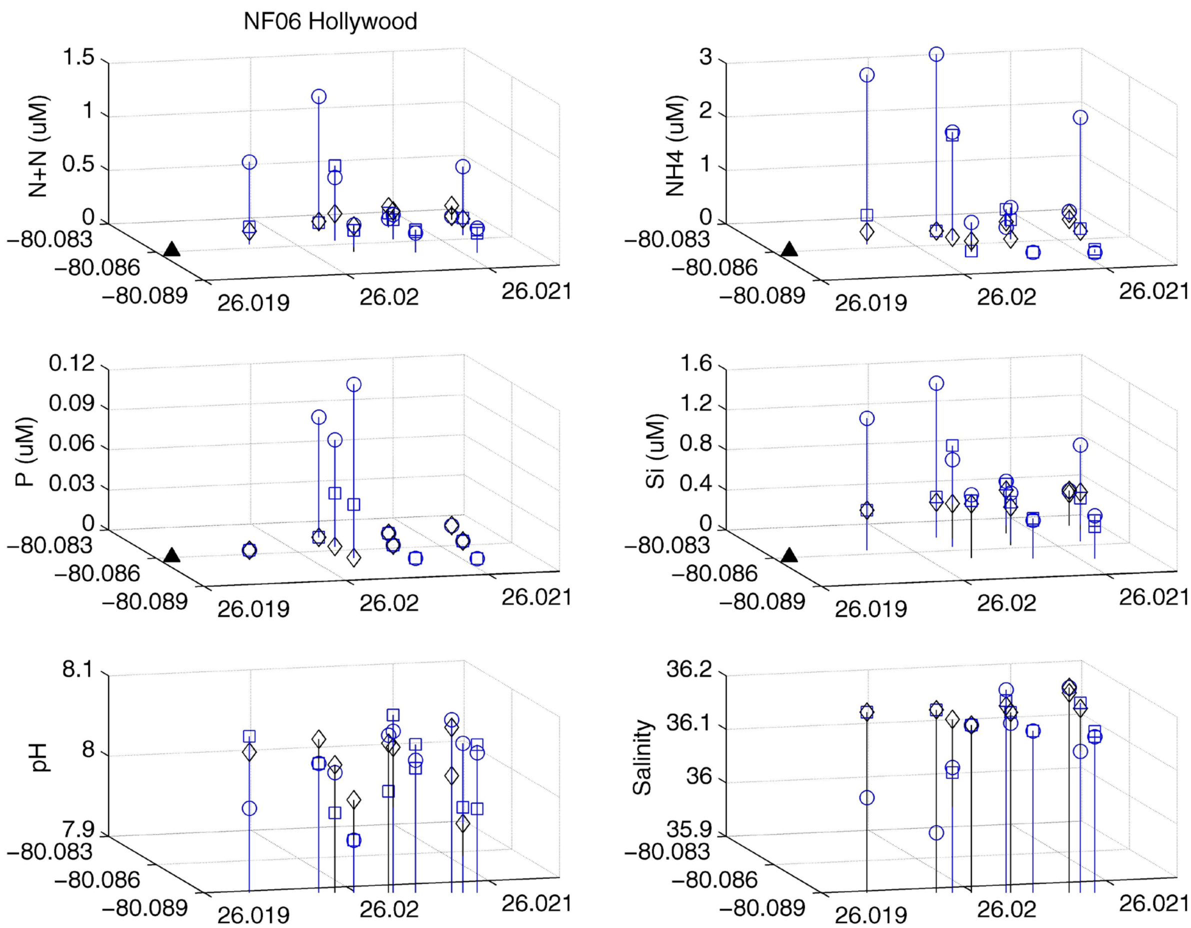

Figure 39. Three-dimensional presentation of nutrient results, pH, and salinity from CTD casts around the Hollywood outfall. The format follows that of Figure 6. See Appendix 1 for tabulated data.

9.3 Chlorophyll and pH

A total of 31 chlorophyll and pH samples were collected during CTD operations around the Hollywood outfall. Table 24 lists the results for the chlorophyll and pH samples collected along with the temperature and salinity data for each depth sampled. Chlorophyll concentrations appeared to be slightly higher at the stations of the most inshore transect.

9.4 CTD Casts

A total of 11 CTD casts were conducted at the Hollywood outfall on October 17, 2006. At each station, a water sample was obtained from near the bottom, at mid depth, and near the surface. Figures 40-50 show the temperature, salinity and oxygen saturation for each station. The depth of the casts increased from 12-17 m for the inner casts (HW1, HW6, HW7), to 23-26 m for the middle casts (HW11, HW10, HW2, HW5, HW8), to 33-36 m for the outer casts (HW3, HW4, HW9). The thermocline was poorly defined in the inner casts, but was observed at 5-8 m in the middle casts and at 15-20 m in the outer casts.

The plume evidently rose to the surface rapidly, already confined to the upper 8 m in casts HW10 and HW11, the two stations closest to the outfall, but was not evident in the salinity deficits in any of the inner casts. The current was to the northwest at the surface and north below (see discussion in section 9.5). The plume was clearly noted in middle casts HW2, HW5, and HW8, but was confined to the upper 5-10 m of water. Of the outer casts, the plume was clearly noted in HW3 at about the 12-m depth, was less defined in HW4 in the upper 20 m of water, and barely notable in HW9 down to about 27 m.

Table 24. Temperature, salinity, pH, chlorophyll-*a*, and phaeopigment results for the Hollywood outfall.

Station	Depth (m)	Temperature (°C)	Salinity (PSU)	pH	Chlorophyll-*a* (µg/L)	Phaeopigments (µg/L)
HW1ab	2.6	28.61	36.16	7.93	0.406	0.114
HW1bb	6.8	28.61	36.16	7.93	0.409	0.111
HW1cb	16.3	28.61	36.16	7.98	0.430	0.118
HW2a	1.5	28.59	36.06	8.00	0.475	0.129
HW2b	11.4	28.60	36.05	7.95	0.480	0.125
HW2c	22.9	28.59	36.15	8.01	0.460	0.120
HW3a	2.3	28.60	35.92	8.00	0.494	0.115
HW3b	15.3	28.29	36.15	8.00	0.509	0.122
HW3c	31.6	28.59	36.15	8.03	0.493	0.124
HW4a	1.7	28.69	36.18	8.03	0.335	0.076
HW4b	18.7	28.60	36.16	7.96	0.473	0.068
HW4c	32.4	28.56	36.15	8.02	0.483	0.108
HW5a	1.4	28.65	36.14	8.05	0.373	0.081
HW5b	12.2	28.62	36.16	8.07	0.371	0.091
HW5c	24.1	28.61	36.16	8.03	0.397	0.095
HW6a	1.5	28.60	36.15	8.03	0.439	0.103
HW6b	9.4	28.59	36.15	8.02	0.462	0.101
HW6c	13.5	28.59	36.15	8.05	0.453	0.098
HW7a	1.3	28.54	36.14	8.04	0.507	0.117
HW7b	7.1	28.55	36.14	7.97	0.480	0.107
HW7c	12.3	28.59	36.15	8.05	0.550	0.094
HW8a	1.2	28.66	36.08	8.03	0.365	0.086
HW8b	12.3	28.65	36.17	7.95	0.357	0.082
HW8c	24.6	28.73	36.16	7.93	0.394	0.096
HW9a	1.5	28.76	36.17	8.04	0.177	0.058
HW9b	18.7	28.72	36.17	8.03	0.238	0.059
HW9c	35.6	28.59	36.16	7.97	0.470	0.098
HW10a	1.5	28.73	36.01	7.96	0.333	0.046
HW10b	13.8	28.75	36.17	8.05	0.244	0.064
HW10c	25.8	28.67	36.17	8.03	0.384	0.096
HW11	35.8	28.71	13.78	7.93	0.214	0.065

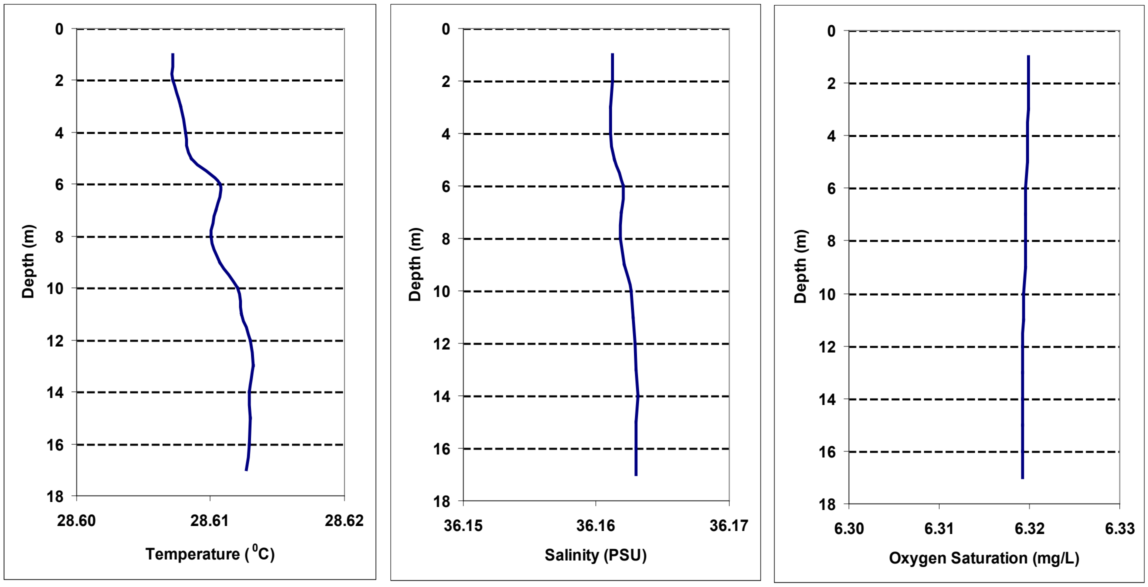

Figure 40. Temperature, salinity, and oxygen concentration profiles at station HW1.

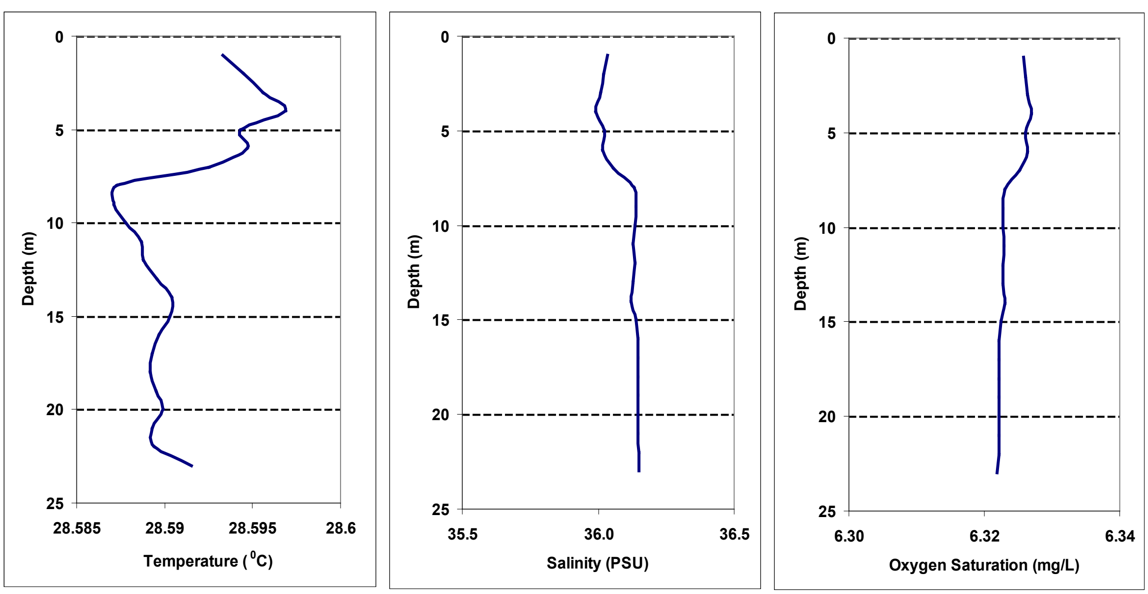

Figure 41. Temperature, salinity, and oxygen concentration profiles at station HW2.

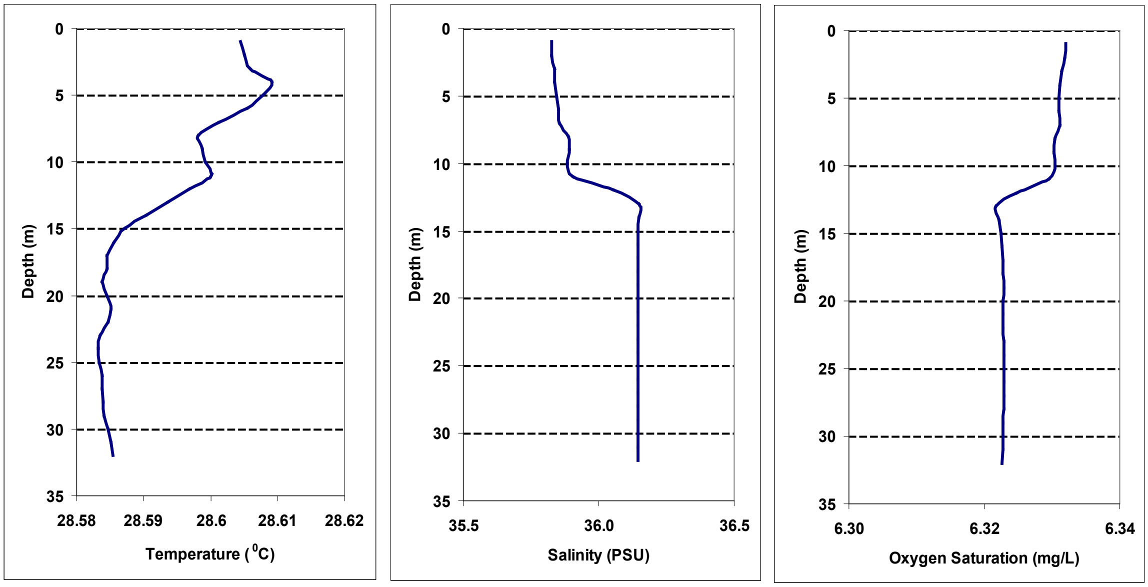

Figure 42. Temperature, salinity, and oxygen concentration profiles at station HW3.

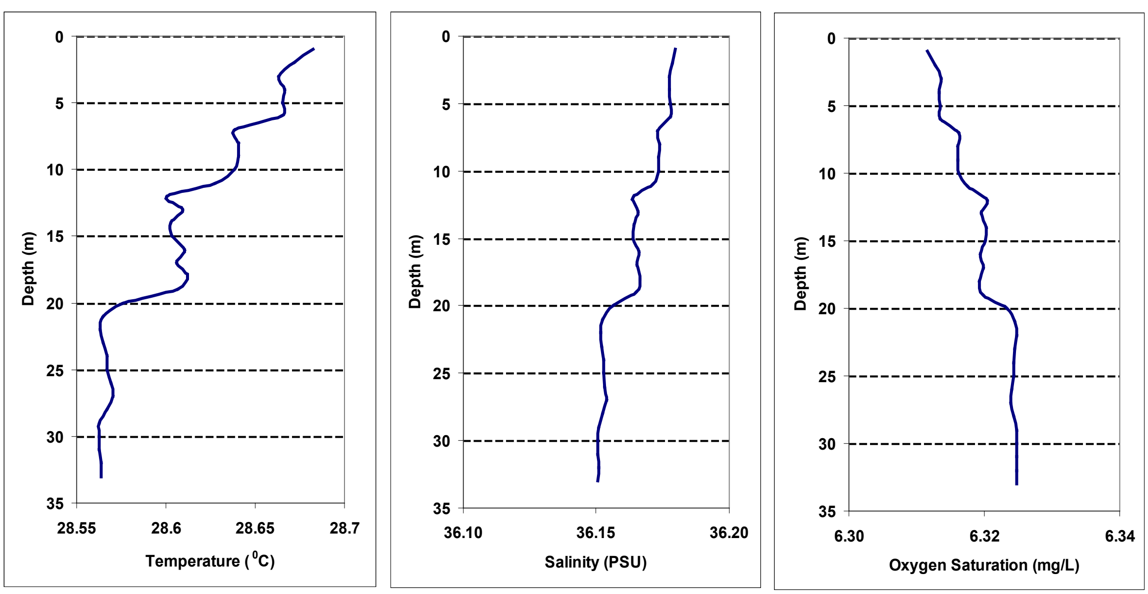

Figure 43. Temperature, salinity, and oxygen concentration profiles at station HW4.

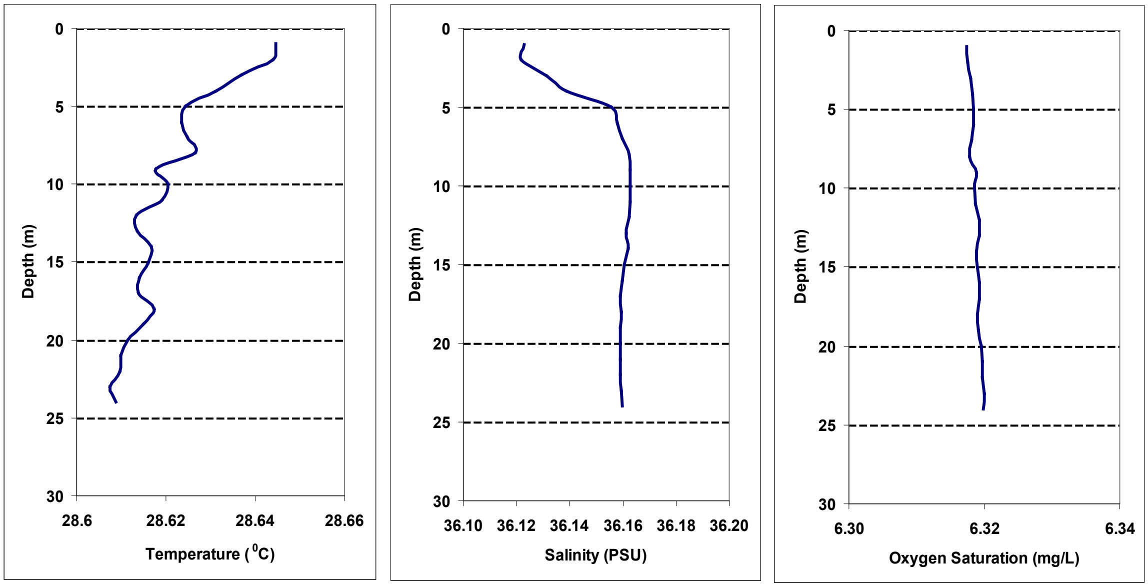

Figure 44. Temperature, salinity, and oxygen concentration profiles at station HW5.

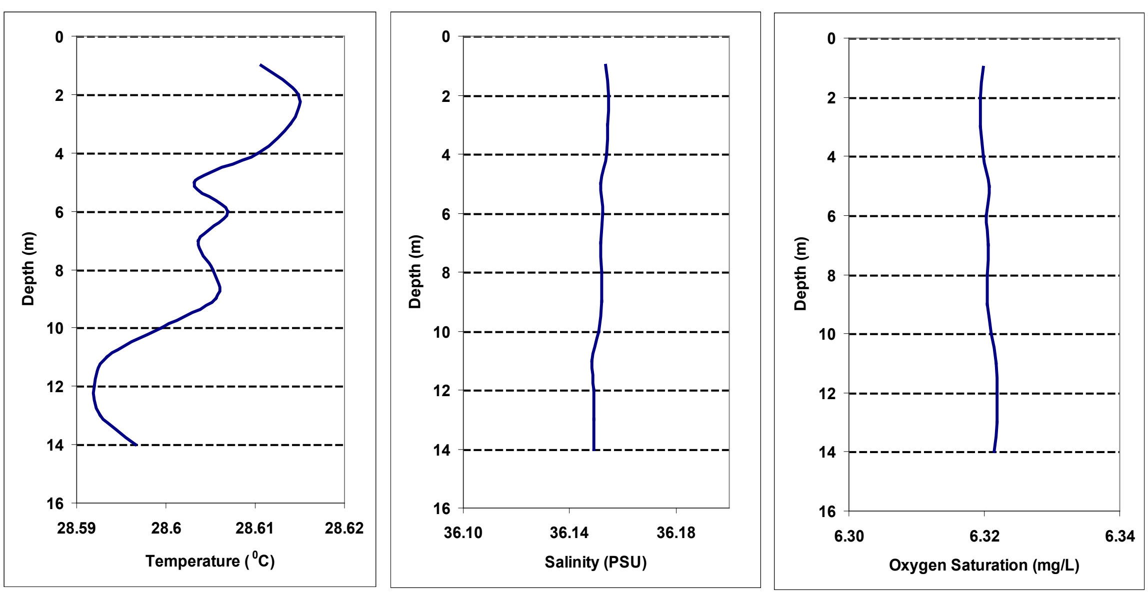

Figure 45. Temperature, salinity, and oxygen concentration profiles at station HW6.

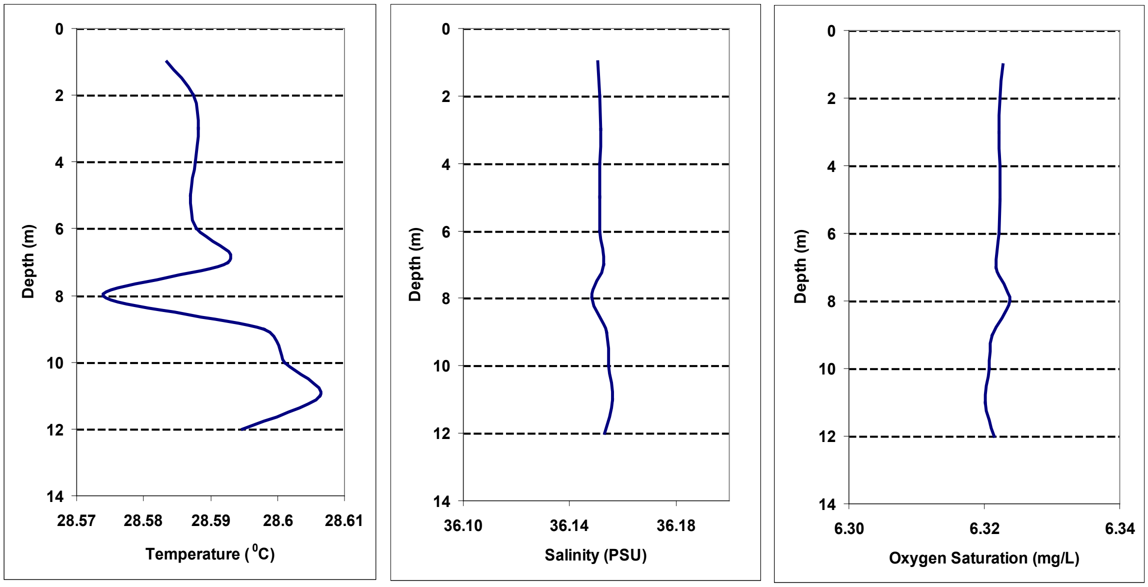

Figure 46. Temperature, salinity, and oxygen concentration profiles at station HW7.

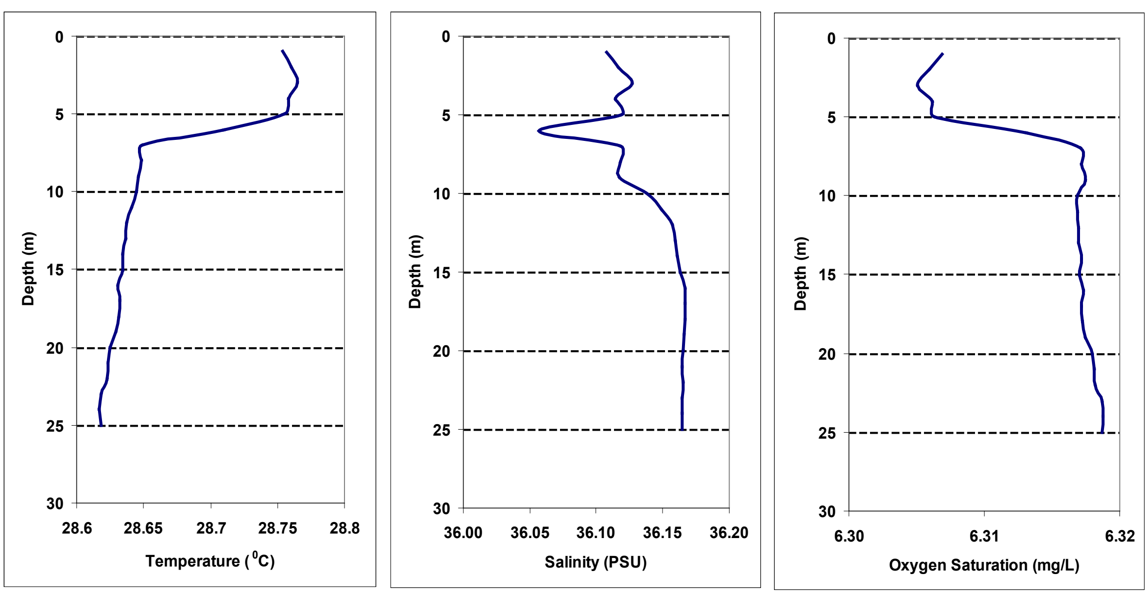

Figure 47. Temperature, salinity, and oxygen concentration profiles at station HW8.

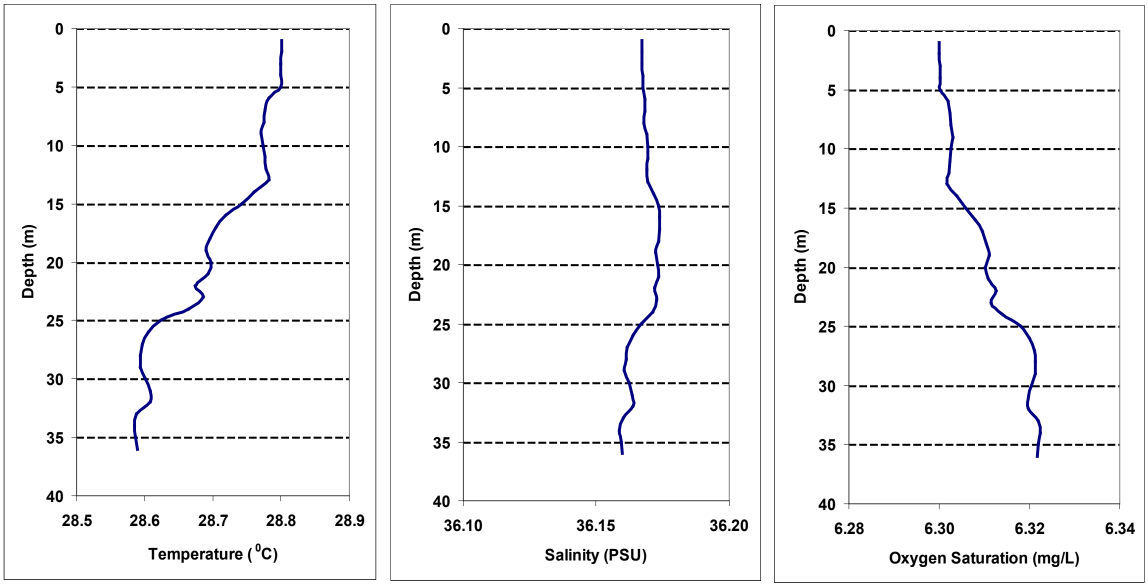

Figure 48. Temperature, salinity, and oxygen concentration profiles at station HW9.

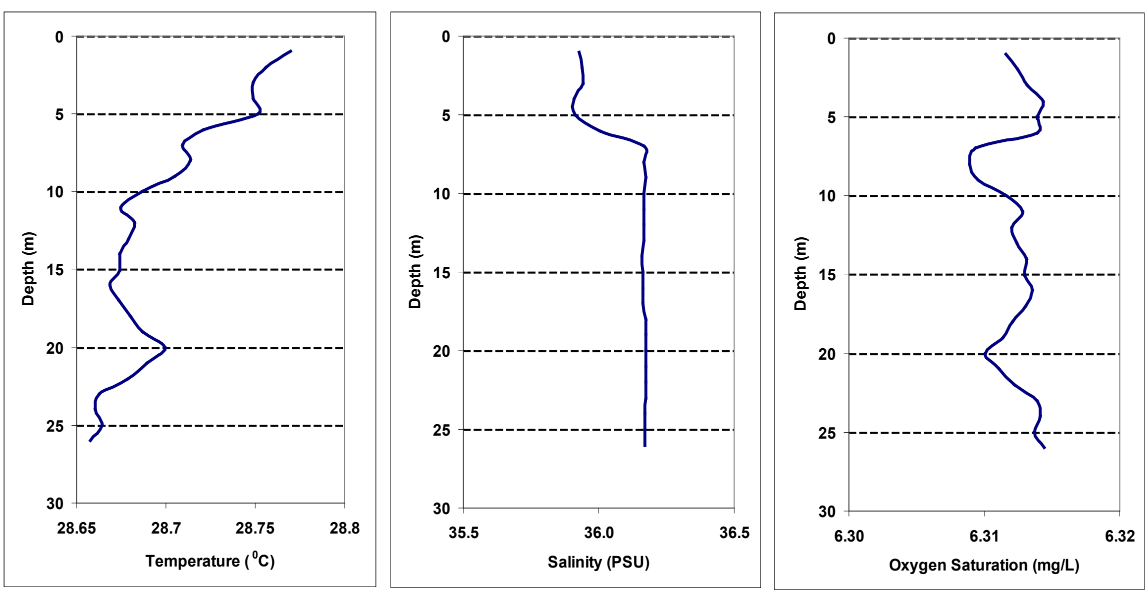

Figure 49. Temperature, salinity, and oxygen concentration profiles at station HW10.

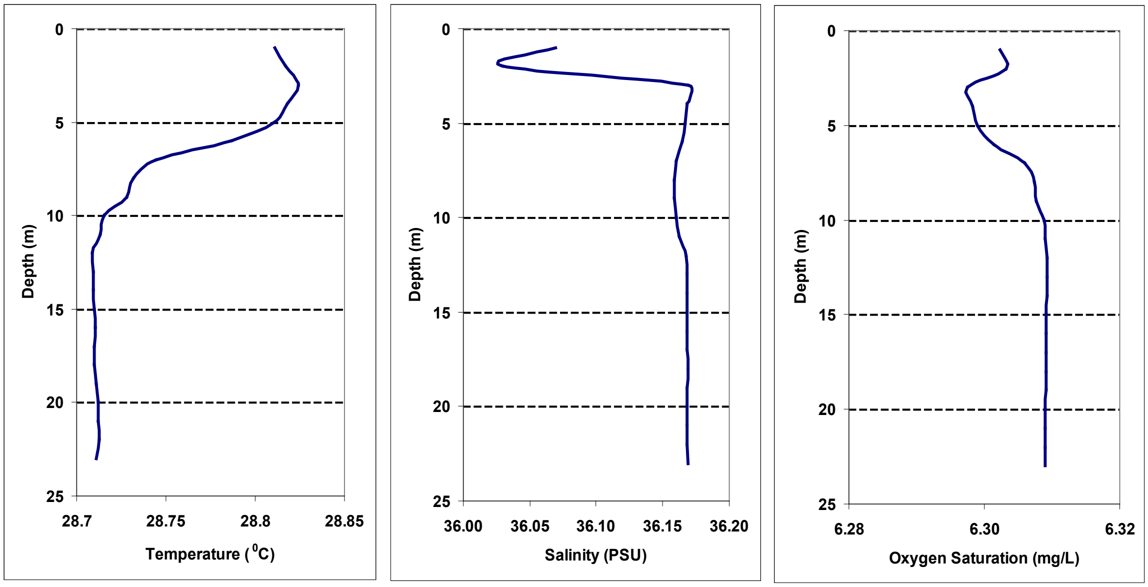

Figure 50. Temperature, salinity, and oxygen concentration profiles at station HW11.

9.5 Current Velocity and Direction

A RDI ADCP was dipped at the Hollywood outfall to obtain current direction and velocity. Two dips were performed at this site. Tables 25 and 26 list the current data obtained from the Hollywood outfall, while Figures 51 and 52 graphically depict the data. On the first sampling (October 10, 21:00 EDT), the current was to the south, decreasing with depth from 37 cm/s near the surface to 23 cm/s near the bottom. The current below 11 m had reversed to the north on the second sampling (October 17, 08:30 EDT), with flows to the northwest at more shallow depths.

Table 25. Current velocity and direction for the Hollywood outfall on October 10, 2006 at 21:00 EDT (see Table 10 for column descriptions).

Depth (m)	U (cm/s)	V (cm/s)	Magnitude (cm/s)	Direction (Degree)
4.25	-6.8	-36.9	37.5	190.4
6.25	-5.0	-34.8	35.2	188.1
8.25	-5.5	-32.8	33.2	189.5
10.25	-4.1	-31.2	31.5	187.4
12.25	-3.2	-29.6	29.7	186.2
14.25	-1.1	-28.4	28.4	182.2
16.25	1.2	-26.8	26.9	177.5
18.25	1.6	-24.1	24.2	176.3
20.25	1.5	-22.8	22.9	176.3

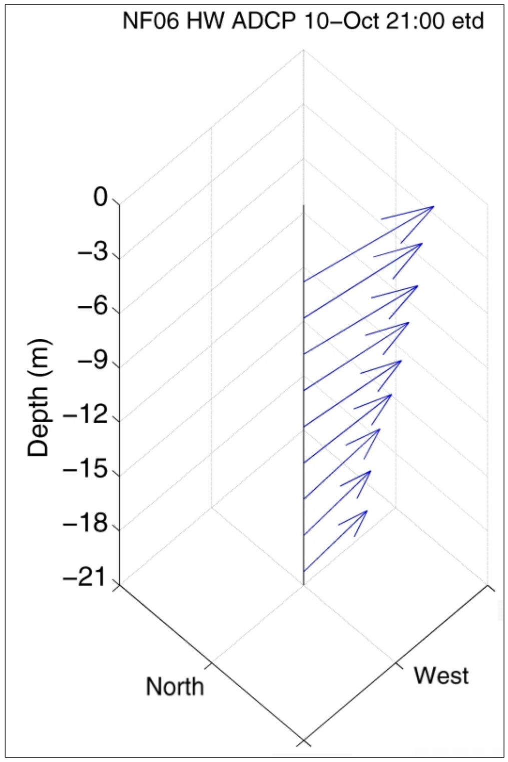

Figure 51. Plot of current vectors versus depth for the Hollywood outfall on October 10, 2006 at 21:00 EDT. Arrow lengths represent relative velocity (see Table 25 for values).

Table 26. Current velocity and direction for the Hollywood outfall on October 17, 2006 at 08:30 EDT (see Table 10 for column descriptions).

Depth (m)	U (cm/s)	V (cm/s)	Magnitude (cm/s)	Direction (Degree)
4.6	-19.6	10.0	22.0	297.0
6.6	-17.9	10.5	20.8	300.4
8.6	-13.4	13.6	19.1	315.2
10.6	-8.2	17.5	19.3	335.0
12.6	-4.1	22.2	22.6	349.7
14.6	-3.0	25.4	25.6	353.3
16.6	-2.1	27.0	27.0	355.6

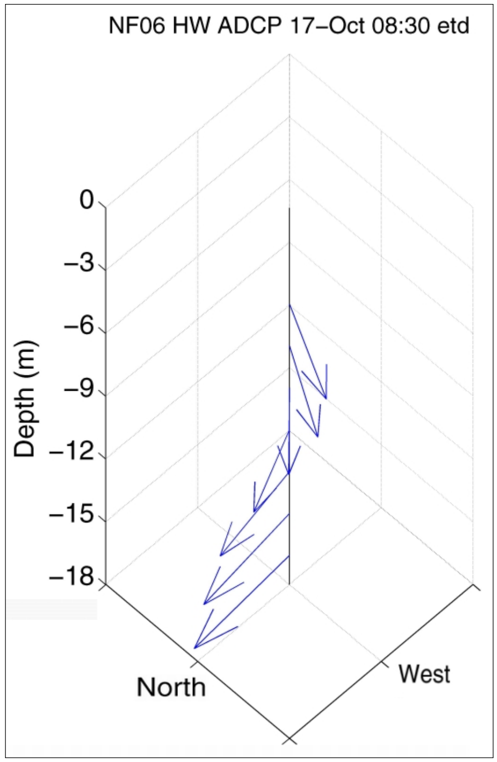

Figure 52. Plot of current vectors versus depth for the Hollywood outfall on October 17, 2006 at 08:30 EDT. Arrow lengths represent relative velocity (see Table 26 for values).

9.6 V-Fin

A V-Fin was lowered via A-frame behind the ship to criss-cross the Hollywood outfall to obtain additional information on the salinity and temperature to determine the location of the plume. Figure 53 shows the track over the outfall plume, as well as the salinity and temperature deficits encountered when the plume was sampled. The areas indicating the plume have been highlighted in differing colors.

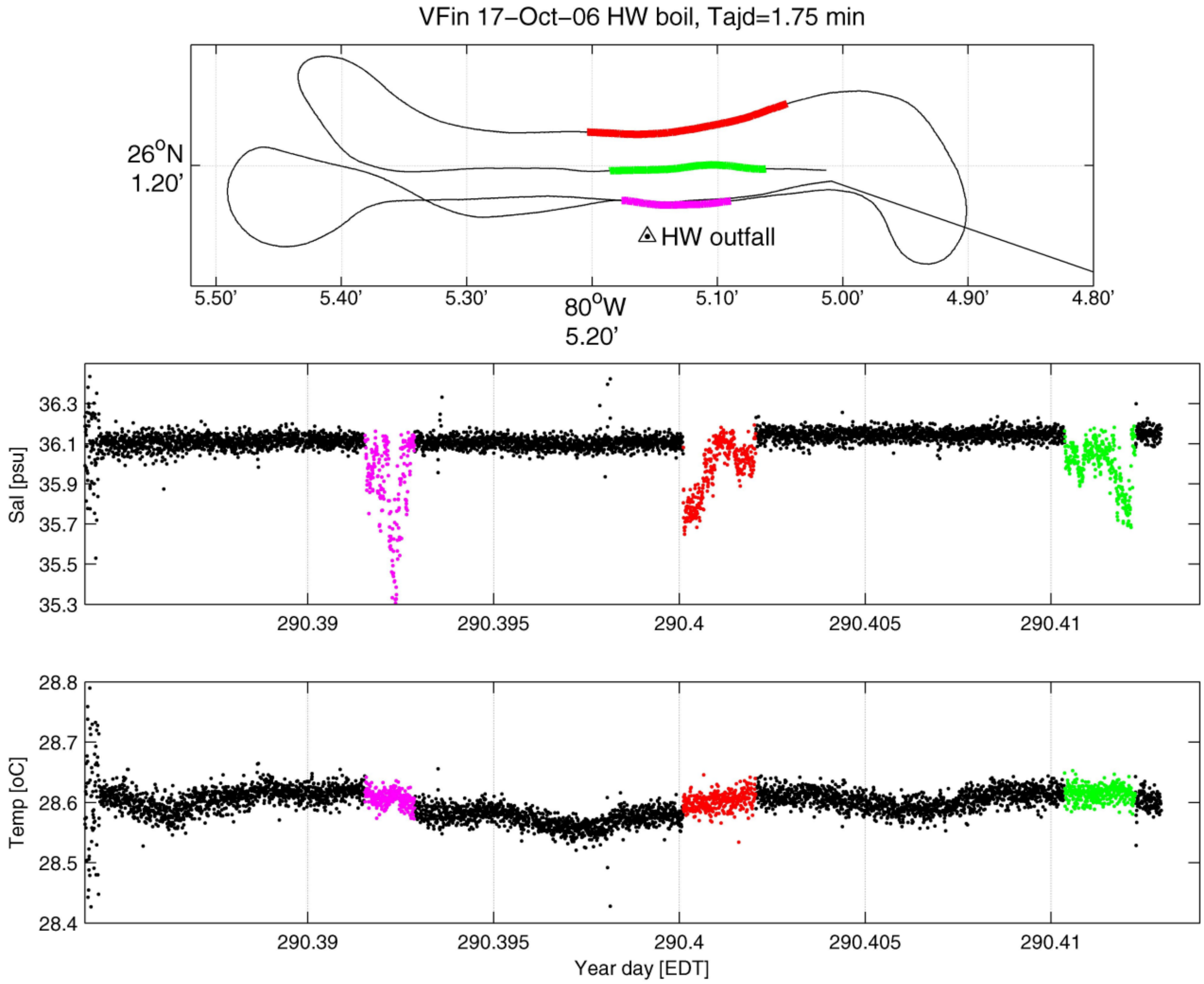

Figure 53. Top panel: Track of the V-Fin instrument on October 17, 2006 as it passed over the Hollywood outfall plume. The middle and bottom panels show changes in salinity and temperature as the plume was traversed. Plume indications as determined by salinity deficit are highlighted in magenta, red, and green. No temperature deficit was found.

10. Broward Outfall

10.1 Outfall Description

The Broward ocean outfall is located approximately 2.2 km offshore from the northern section of Broward County at a depth of 32.6 meters and has an average discharge flow rate of 36 MGD. Figure 54 shows the outfall pipe as recorded by the ship's multi-beam system. From these data, a location of 26°15.083'N, 80°3.724'W (26.25138°N, 80.062067°W) was determined. Table 27 lists the CTD sample stations and sample depths, while Table 28 lists the sediment sample locations and depths. These data are shown graphically in Figure 55.

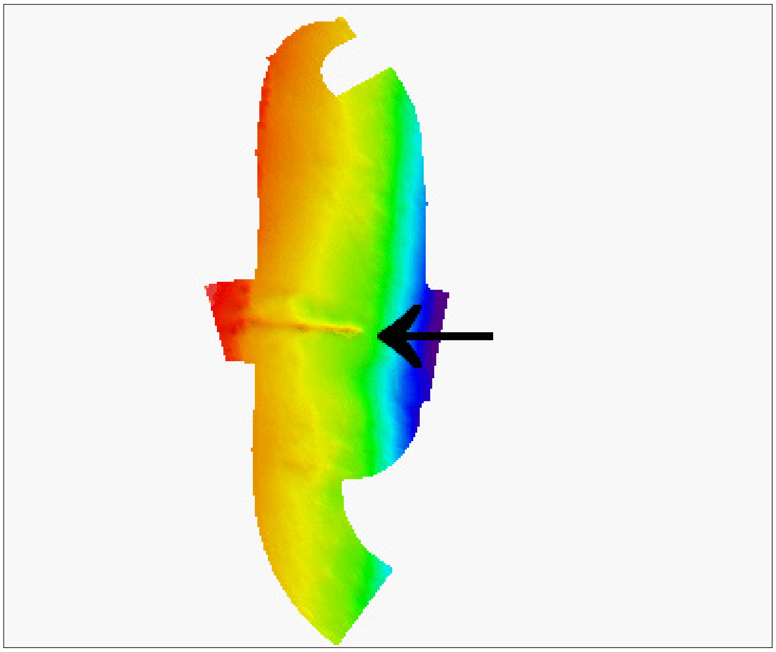

Figure 54. Multi-beam view of the seafloor in the vicinity of the Broward outfall. The outfall is clearly visible as a yellow line and is marked by an arrow.

Table 27. CTD sample locations for the Broward outfall.

Station	Date	Latitude	Longitude	Distance to Pipe End (m)	Depth (m)	Station	Date	Latitude	Longitude	Distance to Pipe End (m)	Depth (m)
BR1a	14-Oct	26.2524	-80.0618	116.1	0	BR7a	14-Oct	26.2529	-80.0620	168.8	0
BR1b	14-Oct	26.2524	-80.0618	116.1	16.8	BR7b	14-Oct	26.2529	-80.0620	168.8	16.2
BR1c	14-Oct	26.2524	-80.0618	116.1	33.5	BR7c	14-Oct	26.2529	-80.0620	168.8	32.4
BR2a	14-Oct	26.2547	-80.0613	376.6	0	BR8a	14-Oct	26.2545	-80.0610	362.5	0
BR2b	14-Oct	26.2547	-80.0613	376.6	17.5	BR8b	14-Oct	26.2545	-80.0610	362.5	19.4
BR2c	14-Oct	26.2547	-80.0613	376.6	35	BR8c	14-Oct	26.2545	-80.0610	362.5	38.8
BR3a	14-Oct	26.2538	-80.0615	274.6	0	BR9a	14-Oct	26.2537	-80.0611	275.0	0
BR3b	14-Oct	26.2538	-80.0615	274.6	17.6	BR9b	14-Oct	26.2537	-80.0611	275.0	19.2
BR3c	14-Oct	26.2538	-80.0615	274.6	35.2	BR9c	14-Oct	26.2537	-80.0611	275.0	38.4
BR4a	14-Oct	26.2529	-80.0616	174.9	0	BR10a	14-Oct	26.2529	-80.0613	185.2	0
BR4b	14-Oct	26.2529	-80.0616	174.9	17.3	BR10b	14-Oct	26.2529	-80.0613	185.2	18.9
BR4c	14-Oct	26.2529	-80.0616	174.9	34.5	BR10c	14-Oct	26.2529	-80.0613	185.2	37.8
BR5a	14-Oct	26.2546	-80.0618	358.7	0	BR11a	14-Oct	26.2514	-80.0619	16.7	0
BR5b	14-Oct	26.2546	-80.0618	358.7	16.3	BR11b	14-Oct	26.2514	-80.0619	16.7	17.1
BR5c	14-Oct	26.2546	-80.0618	358.7	32.6	BR11c	14-Oct	26.2514	-80.0619	16.7	34.2
BR6a	14-Oct	26.2538	-80.0618	270.0	0	BR12	14-Oct	26.2512	-80.0619	28.4	31
BR6b	14-Oct	26.2538	-80.0618	270.0	16.5	BR13	14-Oct	26.2512	-80.0623	30.2	29
BR6	14-Oct	26.2538	-80.0618	270.0	32.9	BR14	14-Oct	26.2513	-80.0622	14.4	28

Table 28. Sediment sample locations for the Broward outfall.

Station	Date	Latitude	Longitude	Depth (m)
BR10	10-Oct	26.2514	-79.9617	246.0
BR11	10-Oct	26.2514	-80.0120	198.8
BR12	10-Oct	26.2513	-80.0420	37.7
BR13	10-Oct	26.2514	-80.0720	16.5
BR14	10-Oct	26.2423	-80.0620	40.7
BR15b	10-Oct	26.2506	-80.0620	33.9
BR15c	10-Oct	26.2506	-80.0620	33.9
BR15d	10-Oct	26.2507	-80.0621	33.9
BR15e	10-Oct	26.2507	-80.0618	36.7
BR16	10-Oct	26.2514	-80.0621	31.0
BR16b	10-Oct	26.2516	-80.0620	33.8
BR16c	10-Oct	26.2516	-80.0621	33.8
BR17	10-Oct	26.2522	-80.0621	32.9
BR18	10-Oct	26.2532	-80.0622	32.3
BR19a	10-Oct	26.2541	-80.0621	32.8
BR19b	10-Oct	26.2541	-80.0619	32.8
BR20	10-Oct	26.2549	-80.0621	32.6
BR21	10-Oct	26.2604	-80.0622	31.0
BR21b	10-Oct	26.2604	-80.0622	31.0

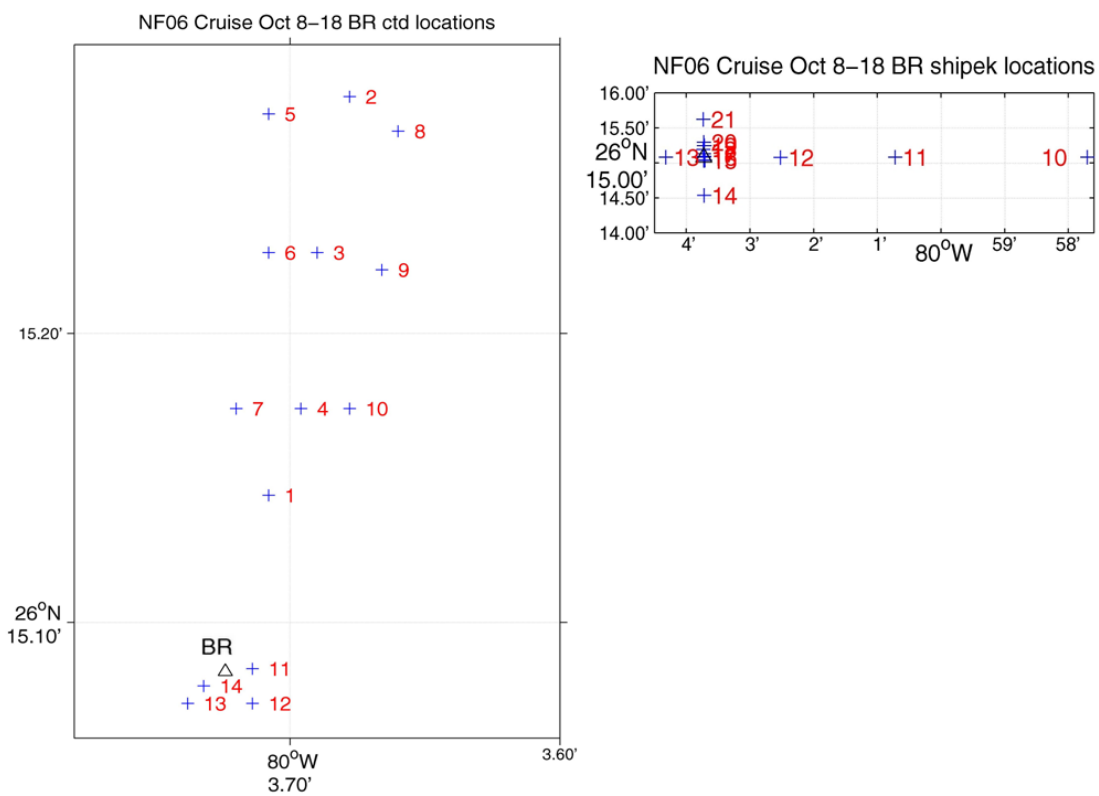

Figure 55. Location of the CTD (left panel) and Shipek sediment (right panel) sample sites for the Broward outfall study. The location of the outfall pipe end is denoted by a triangle.

10.2 Nutrients

A total of 33 nutrient samples were collected during CTD operations around the Broward outfall. These results are listed in Table 29 for concentrations in µM and in Table 30 for concentrations in mg/L. A graphic presentation of these results is shown in Figure 56. Station BR11, located 17 m east of the outfall, was sampled as near as possible to the visual boil; the analytical results indicated that the boil had moved when the bottles were opened. The highest concentrations for most analytes were from station BR1, the next closest station, located 116 m north of the outfall; we consider these values as "boil" values. The next closest stations were BR7, BR4, and BR10, located between 170 m and 185 m north of the outfall in a transect running inshore to offshore. The next set of stations was 270-275 m north of the outfall (BR6, BR3, BR9) and the next set was 359-377 m north of the outfall (BR5, BR2, BR8), with site 2 being the farthest north and site 8 the most offshore. Sites BR12, BR13, and BR14 were attempted, but no nutrient data were obtained.

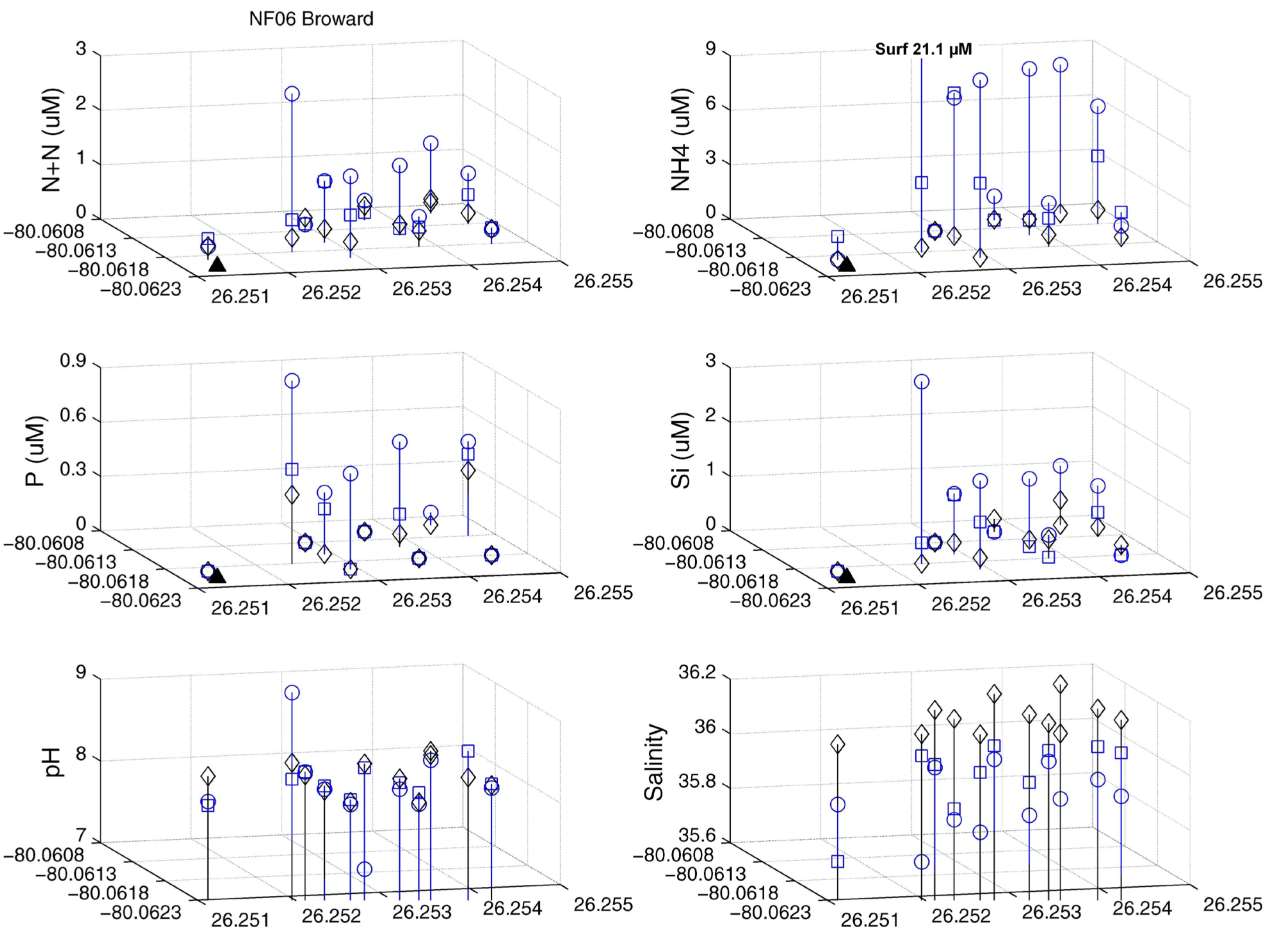

Figure 56. Three-dimensional presentation of nutrient results, pH, and salinity from CTD casts around the Broward outfall. The surface concentration of NH_4 at the boil was 21.1 µM. CTD casts 12, 13, and 14 are not shown. The format follows that of Figure 6. See Appendix 1 for tabulated data.

Table 29. Nutrient results in µM for the Broward outfall (see Figure 55 for location map; BDL = below detection limit).

Station	Depth (m)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)	Station	Depth (m)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)
BR1a	1.5	2.91	2.22	21.09	1.01	3.35	BR6c	27.2	0.29	0.09	0.66	BDL	0.35
BR1b	13.7	0.59	0.38	3.82	0.52	0.38	BR7a	1.1	1.50	1.05	9.79	0.53	1.63
BR1c	27.9	0.26	0.05	0.24	0.38	BDL	BR7b	14.7	0.78	0.50	4.10	BDL	0.87
BR2a	1.2	0.93	0.66	6.49	0.52	0.92	BR7c	29.0	0.29	0.06	BDL	BDL	0.21
BR2b	13.8	0.54	0.33	3.75	0.45	0.43	BR8a	1.2	1.29	0.91	8.20	0.07	1.09
BR2c	29.5	0.20	0.02	0.78	0.36	0.16	BR8b	17.0	0.20	0.04	BDL	BDL	BDL
BR3a	1.4	1.28	0.95	9.17	0.58	1.25	BR8c	34.1	0.26	0.07	BDL	BDL	0.46
BR3b	14.4	0.12	0.01	0.82	0.18	BDL	BR9a	1.2	0.36	0.21	1.33	BDL	BDL
BR3c	29.5	0.20	0.02	0.88	0.07	0.13	BR9b	19.4	0.14	0.03	BDL	BDL	BDL
BR4a	1.1	1.13	0.82	7.97	0.34	1.11	BR9c	34.4	0.26	0.07	0.03	BDL	0.24
BR4b	15.0	1.12	0.80	8.24	0.25	1.09	BR10a	1.2	0.12	0.03	BDL	BDL	BDL
BR4c	30.3	0.25	0.06	0.36	BDL	0.21	BR10b	16.6	0.13	0.05	BDL	BDL	BDL
BR5a	1.3	0.26	0.06	0.98	BDL	BDL	BR10c	33.9	0.24	0.03	BDL	BDL	BDL
BR5b	13.3	0.29	0.14	1.73	BDL	BDL	BR11a	1.2	0.24	0.07	BDL	BDL	BDL
BR5c	27.2	0.27	0.07	0.36	BDL	0.19	BR11b	15.9	0.39	0.22	1.28	BDL	BDL
BR6a	1.3	0.55	0.29	2.42	BDL	0.43	BR11c	30.2	0.25	0.08	BDL	BDL	BDL
BR6b	13.1	0.36	0.15	1.55	BDL	0.02							

Table 30. Nutrient results in mg/L for the Broward outfall (see Figure 55 for location map; BDL = below detection limit).

Station	Depth (m)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)	Station	Depth (m)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)
BR1a	1.5	0.041	0.031	0.295	0.031	0.094	BR6c	27.2	0.004	0.001	0.009	BDL	0.010
BR1b	13.7	0.008	0.005	0.053	0.016	0.011	BR7a	1.1	0.021	0.015	0.137	0.017	0.046
BR1c	27.9	0.004	0.001	0.003	0.012	BDL	BR7b	14.7	0.011	0.007	0.057	BDL	0.024
BR2a	1.2	0.013	0.009	0.091	0.016	0.026	BR7c	29.0	0.004	0.001	BDL	BDL	0.006
BR2b	13.8	0.008	0.005	0.053	0.014	0.012	BR8a	1.2	0.018	0.013	0.115	0.002	0.031
BR2c	29.5	0.003	BDL	0.011	0.011	0.004	BR8b	17.0	0.003	0.001	BDL	BDL	BDL
BR3a	1.4	0.018	0.013	0.128	0.018	0.035	BR8c	34.1	0.004	0.001	BDL	BDL	0.013
BR3b	14.4	0.002	BDL	0.011	0.006	BDL	BR9a	1.2	0.005	0.003	0.019	BDL	BDL
BR3c	29.5	0.003	BDL	0.012	0.002	0.004	BR9b	19.4	0.002	BDL	BDL	BDL	BDL
BR4a	1.1	0.016	0.011	0.112	0.010	0.031	BR9c	34.4	0.004	0.001	BDL	BDL	0.007
BR4b	15.0	0.016	0.011	0.115	0.008	0.031	BR10a	1.2	0.002	BDL	BDL	BDL	BDL
BR4c	30.3	0.004	0.001	0.005	BDL	0.006	BR10b	16.6	0.002	0.001	BDL	BDL	BDL
BR5a	1.3	0.004	0.001	0.014	BDL	BDL	BR10c	33.9	0.003	BDL	BDL	BDL	BDL
BR5b	13.3	0.004	0.002	0.024	BDL	BDL	BR11a	1.2	0.003	0.001	BDL	BDL	BDL
BR5c	27.2	0.004	0.001	0.005	BDL	0.005	BR11b	15.9	0.005	0.003	0.018	BDL	BDL
BR6a	1.3	0.008	0.004	0.034	BDL	0.012	BR11c	30.2	0.004	0.001	BDL	BDL	BDL
BR6b	13.1	0.005	0.002	0.022	BDL	0.001							

Table 31. Temperature, salinity, pH, chlorophyll-*a*, and phaeopigment results for the Broward outfall.

Station	Depth (m)	Temperature (°C)	Salinity (PSU)	pH	Chlorophyll-*a* (µg/L)	Phaeopigments (µg/L)
BR1a	1.5	28.87	35.65	9.24	0.940	0.166
BR1b	13.7	28.91	36.04	8.18	1.050	0.137
BR1c	27.9	28.79	36.12	8.38	0.649	0.157
BR2a	1.2	28.86	35.85	N/A	0.772	0.193
BR2b	13.8	28.88	35.97	8.18	0.804	0.112
BR2c	29.5	28.80	36.11	7.86	0.459	0.125
BR3a	1.4	28.87	35.76	7.85	0.774	0.243
BR3b	14.4	28.89	35.88	7.93	1.408	0.490
BR3c	29.5	28.78	36.13	7.98	0.452	0.035
BR4a	1.1	28.84	35.77	7.94	0.850	0.185
BR4b	15.0	28.82	35.81	7.98	0.732	0.146
BR4c	30.3	28.69	36.14	7.92	0.380	0.060
BR5a	1.3	28.86	35.86	7.97	1.209	0.355
BR5b	13.3	28.81	36.02	8.02	0.779	0.140
BR5c	27.2	28.67	36.14	8.00	0.397	0.112
BR6a	1.3	28.77	36.00	7.81	0.869	0.185
BR6b	13.1	28.79	36.04	7.95	0.692	0.149
BR6c	27.2	28.61	36.14	7.83	0.317	0.105
BR7a	1.1	28.84	35.78	7.94	0.699	0.226
BR7b	14.7	28.80	36.00	8.00	0.511	0.130
BR7c	29.0	28.68	36.14	7.97	0.391	0.113
BR8a	1.2	28.90	35.74	7.94	1.001	0.403
BR8b	17.0	28.93	35.98	8.00	1.148	0.385
BR8c	34.1	28.57	36.16	8.05	0.345	0.077
BR9a	1.2	29.02	35.91	6.69	1.072	0.438
BR9b	19.4	28.95	35.96	7.93	1.107	0.364
BR9c	34.4	28.60	36.15	7.98	0.482	0.121
BR10a	1.2	29.07	35.92	8.01	1.093	0.556
BR10b	16.6	28.97	35.93	8.01	1.210	0.725
BR10c	33.9	28.69	36.13	7.97	0.579	0.107
BR11a	1.2	29.02	35.89	8.00	1.811	1.039
BR11b	15.9	28.89	35.68	7.95	1.137	0.448
BR11c	30.2	28.77	36.11	8.31	0.628	0.148

10.3 Chlorophyll and pH

A total of 33 chlorophyll and pH samples were collected during CTD operations around the Broward outfall. Table 31 lists the results for the chlorophyll and pH samples collected along with the temperature and salinity data for each depth sampled.

10.4 CTD casts

A total of 14 CTD casts were conducted at the Broward outfall on October 14, 2006. No chemical data were obtained for BR12, BR13, and BR14. For the remaining stations, water samples were obtained near the bottom, at mid depth, and at the surface. CTD data from all 14 casts are shown in Figures 57-70. The wind was strong and from the south during this time. Seawater depth varied from ~32 m (BR7) to 39 m (BR8). A poorly-defined thermocline was noted in the mid casts (BR1, BR4, BR3, BR2) at 13-20 m depth and at 27-30 m depth in the offshore casts (BR10, BR9, BR8).

The plume was clearly visible via oxygen saturation and salinity deficit in BR11 and BR13, taken 17 m east and 29 m south of the outfall pipe, respectively, but it was difficult to discern in the more inshore casts (BR7, BR6, BR5). The plume was more evident in the center samples (BR4, BR3, BR2) and deep casts (BR10, BR9, BR8) in the upper 20 m or so. The plume was noted in BR2, still in the upper ~13 m of water; this site is 377 m north of the outfall.

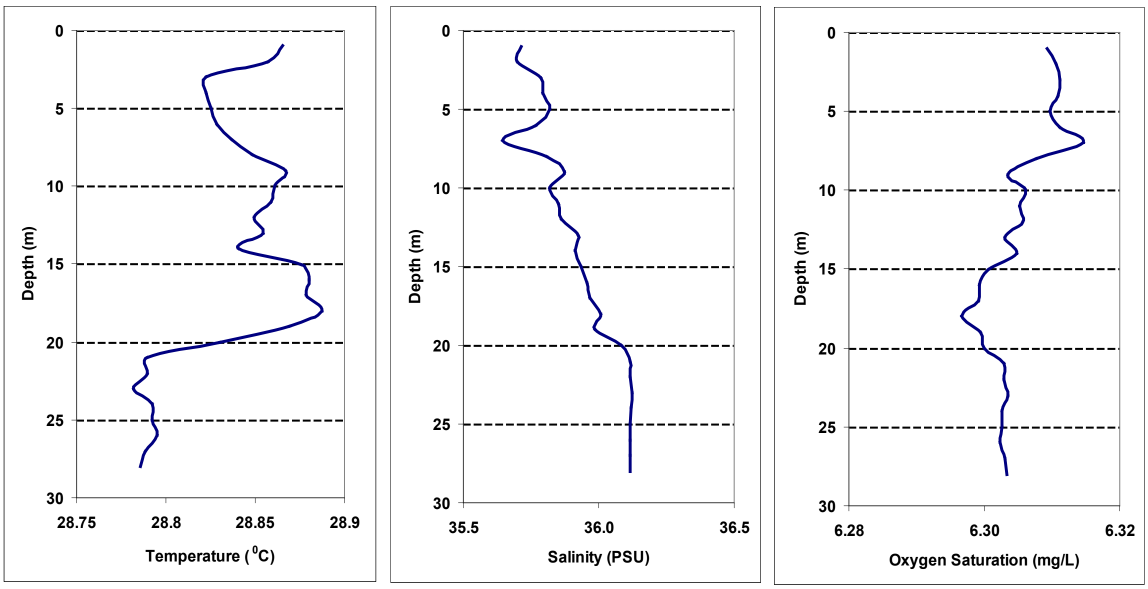

Figure 57. Temperature, salinity, and oxygen concentration profiles at station BR1.

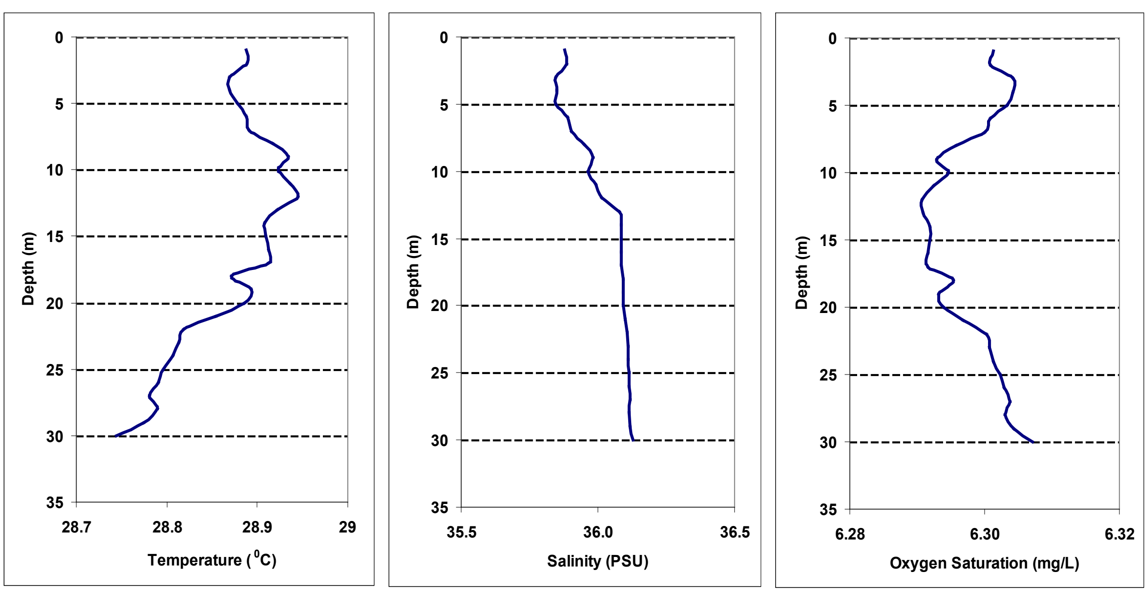

Figure 58. Temperature, salinity, and oxygen concentration profiles at station BR2.

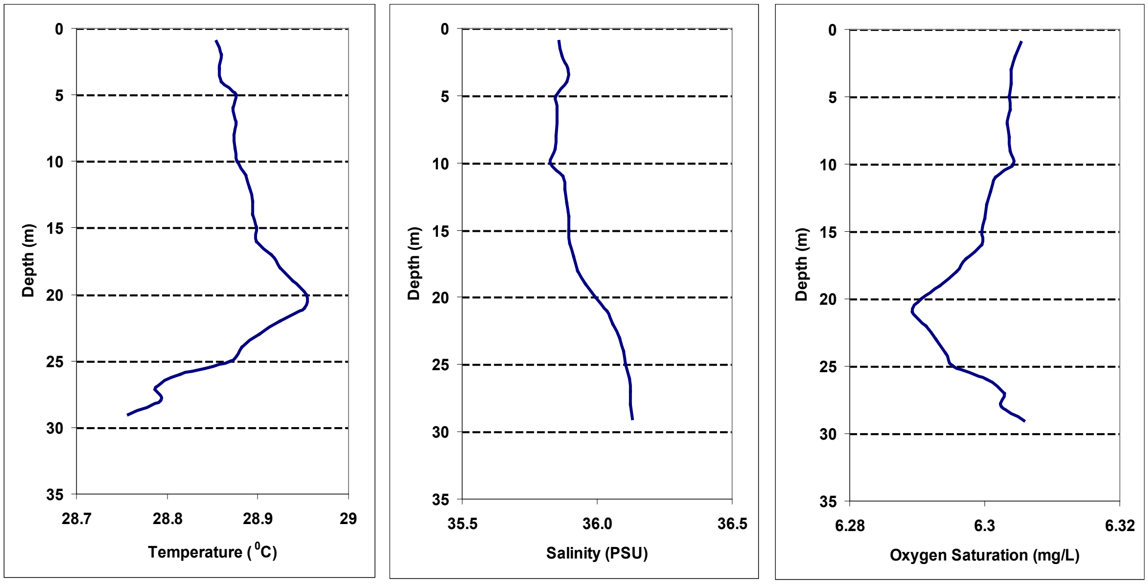

Figure 59. Temperature, salinity, and oxygen concentration profiles at station BR3.

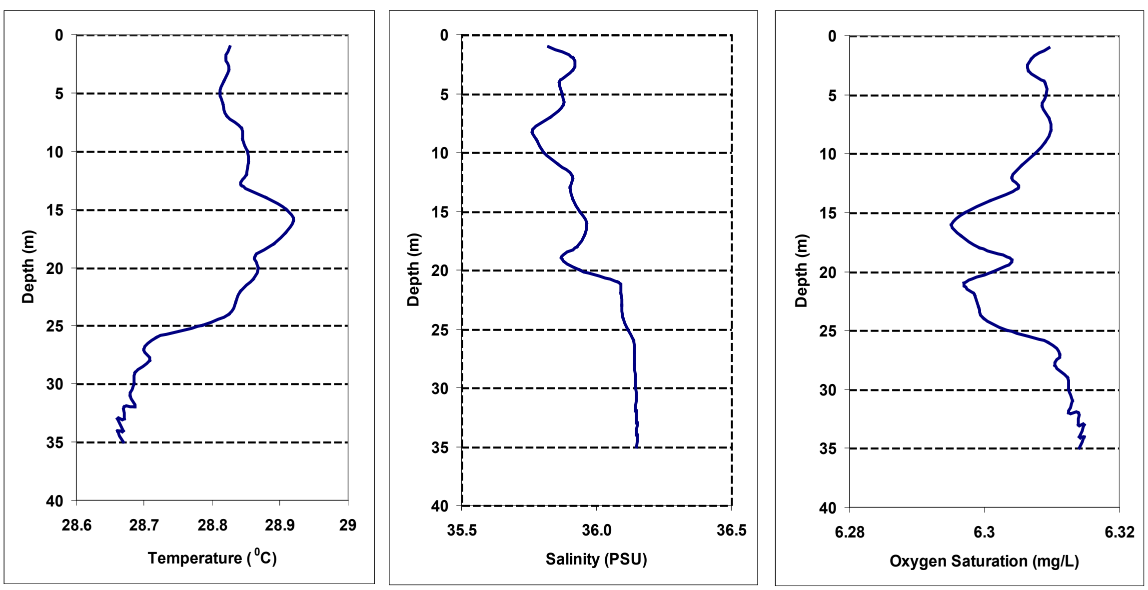

Figure 60. Temperature, salinity, and oxygen concentration profiles at station BR4.

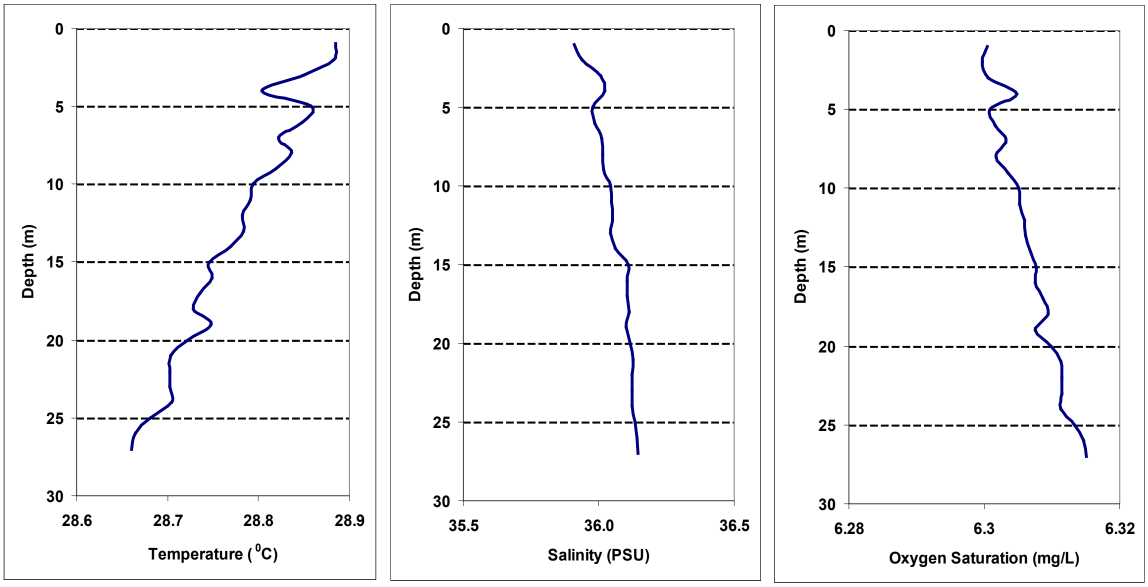

Figure 61. Temperature, salinity, and oxygen concentration profiles at station BR5.

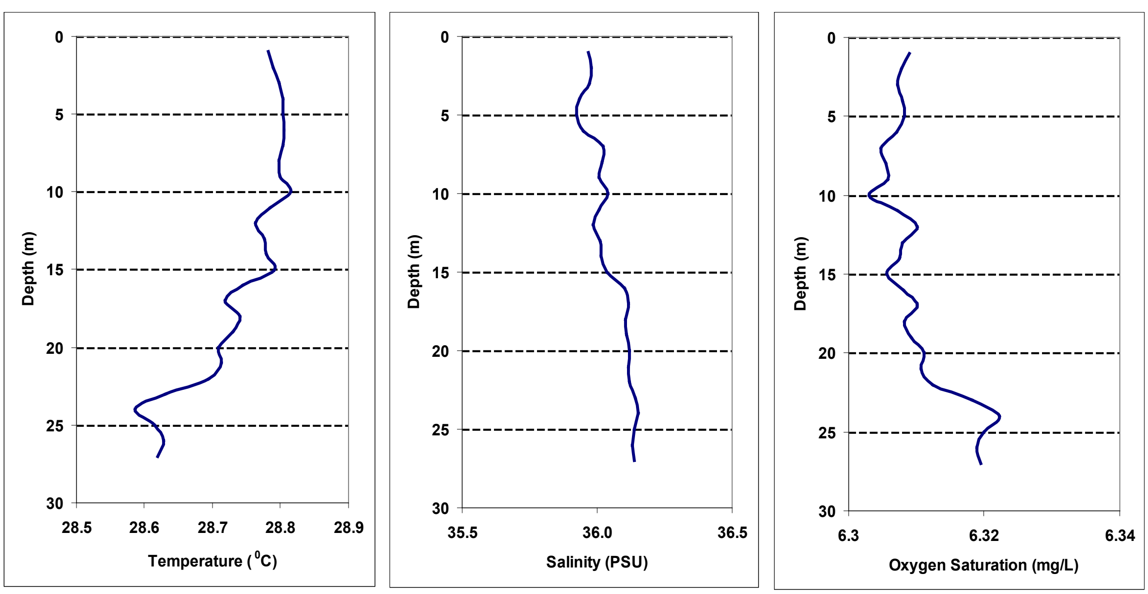

Figure 62. Temperature, salinity, and oxygen concentration profiles at station BR6.

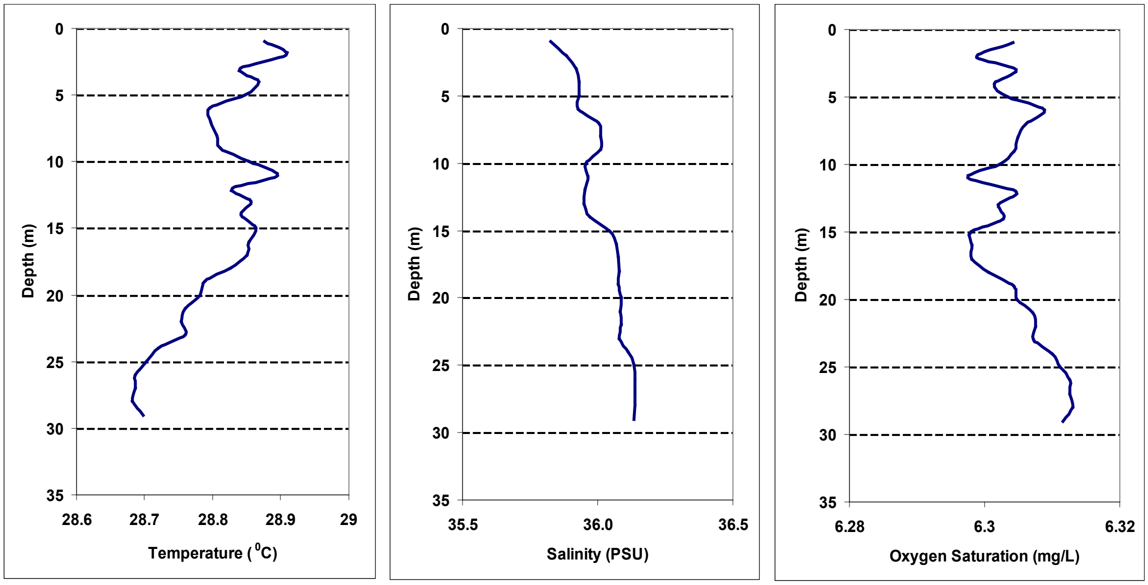

Figure 63. Temperature, salinity, and oxygen concentration profiles at station BR7.

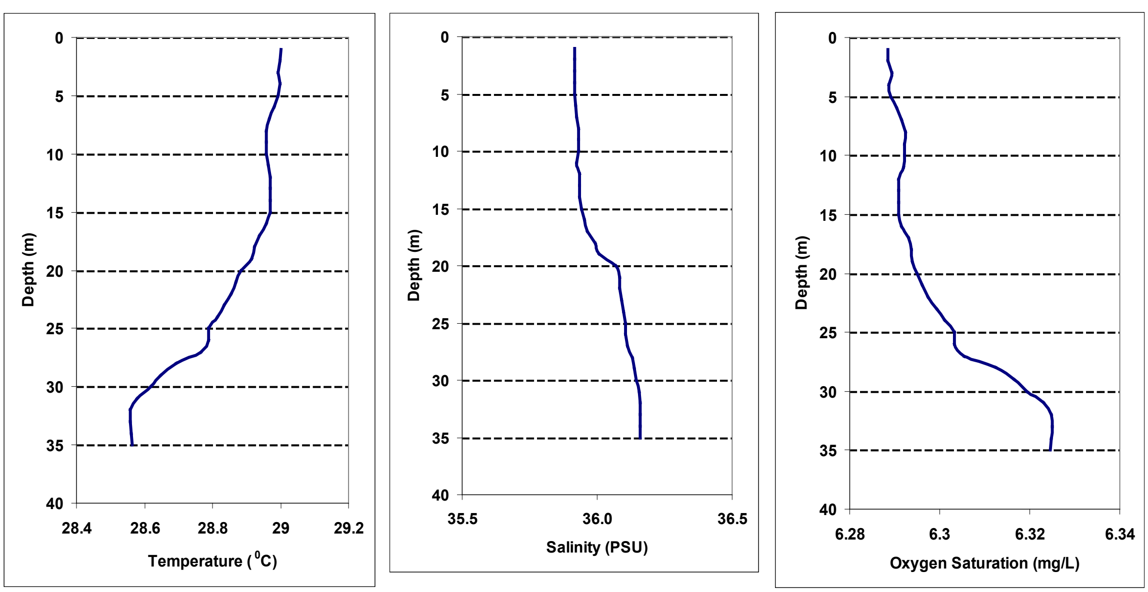

Figure 64. Temperature, salinity, and oxygen concentration profiles at station BR8.

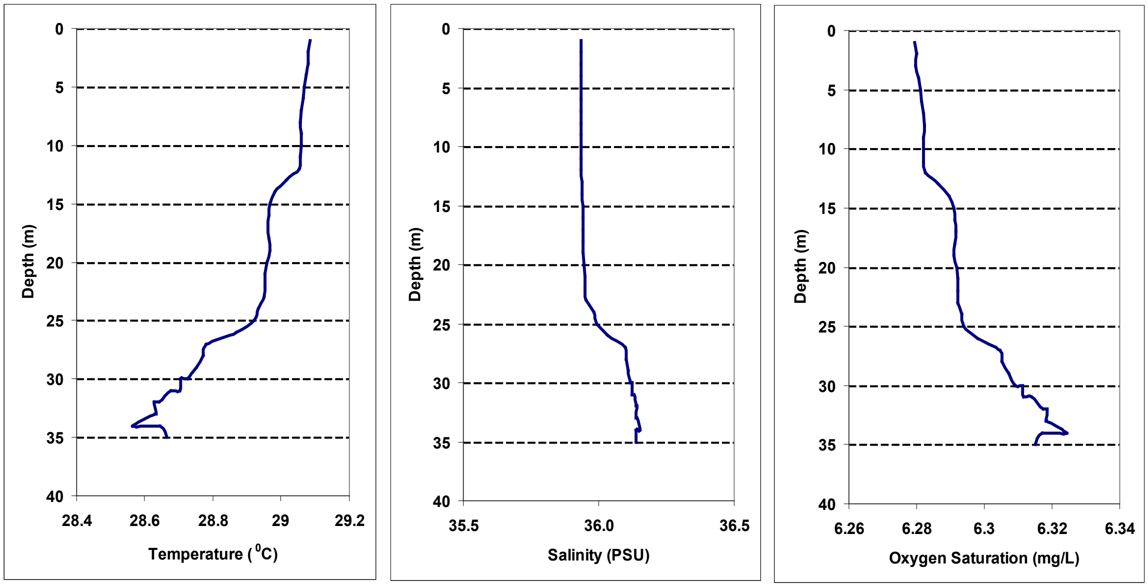

Figure 65. Temperature, salinity, and oxygen concentration profiles at station BR9.

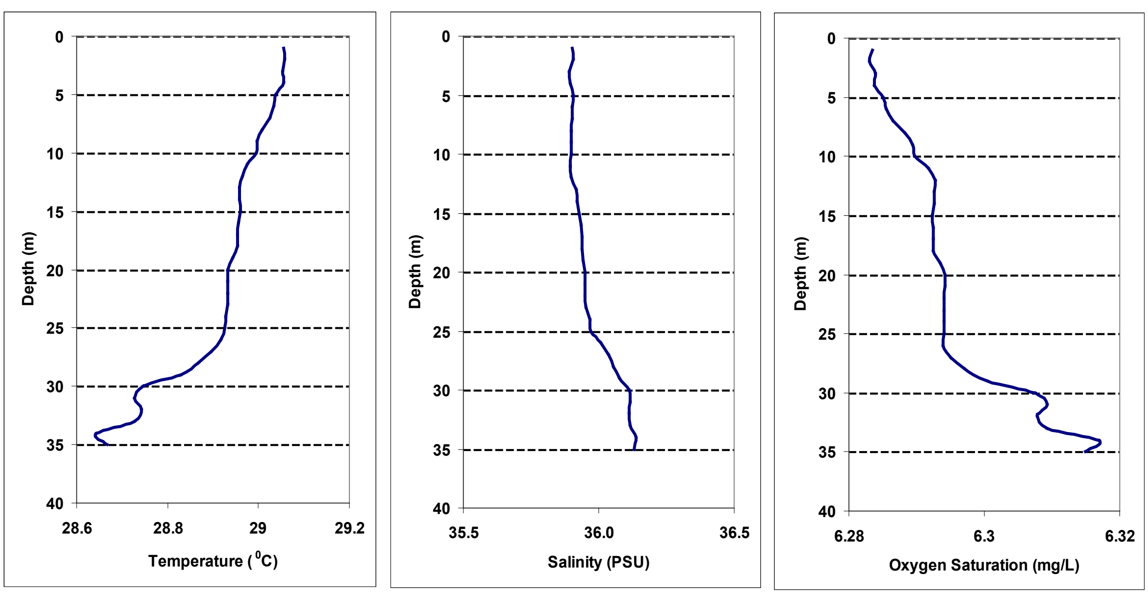

Figure 66. Temperature, salinity, and oxygen concentration profiles at station BR10.

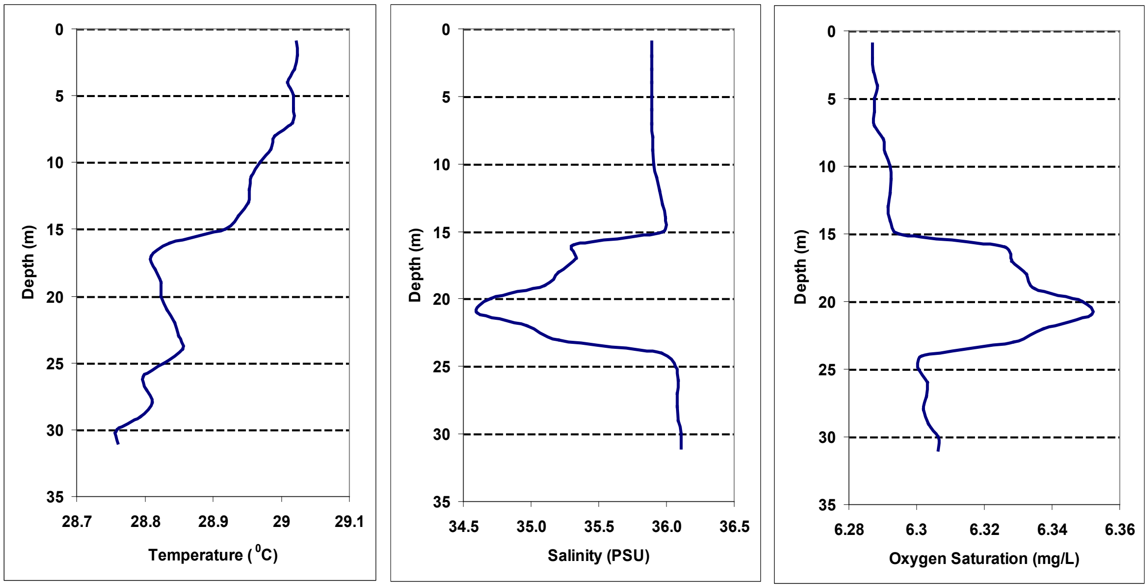

Figure 67. Temperature, salinity, and oxygen concentration profiles at station BR11.

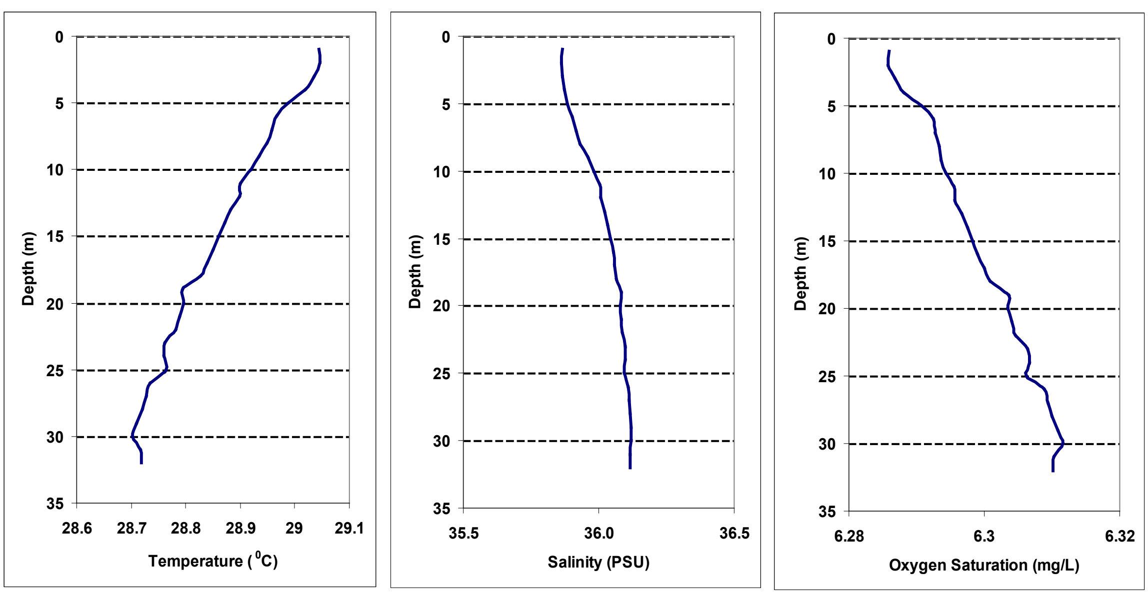

Figure 68. Temperature, salinity, and oxygen concentration profiles at station BR12.

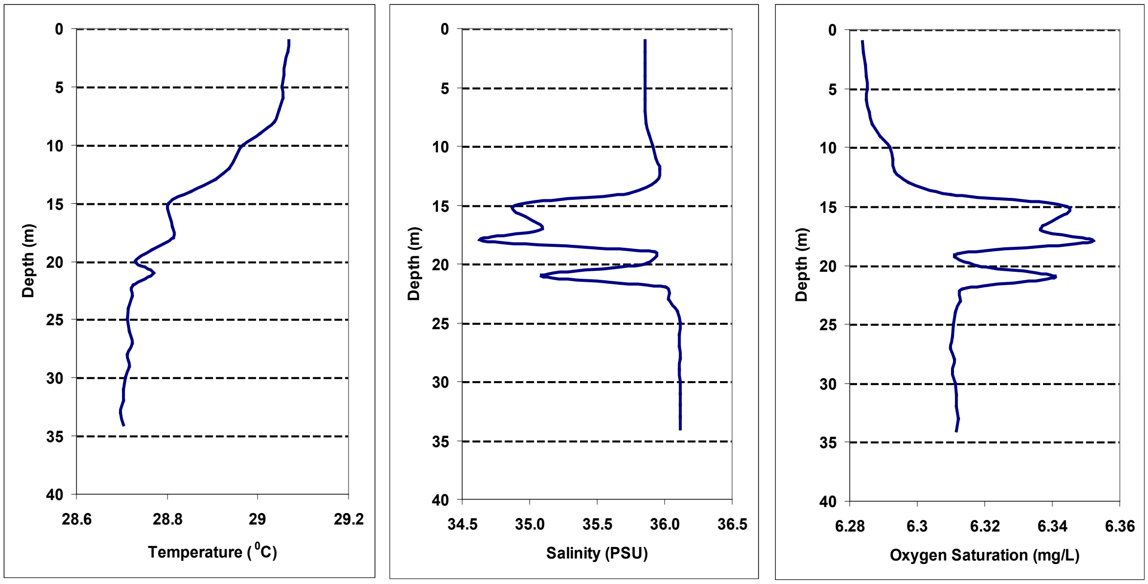

Figure 69. Temperature, salinity, and oxygen concentration profiles at station BR13.

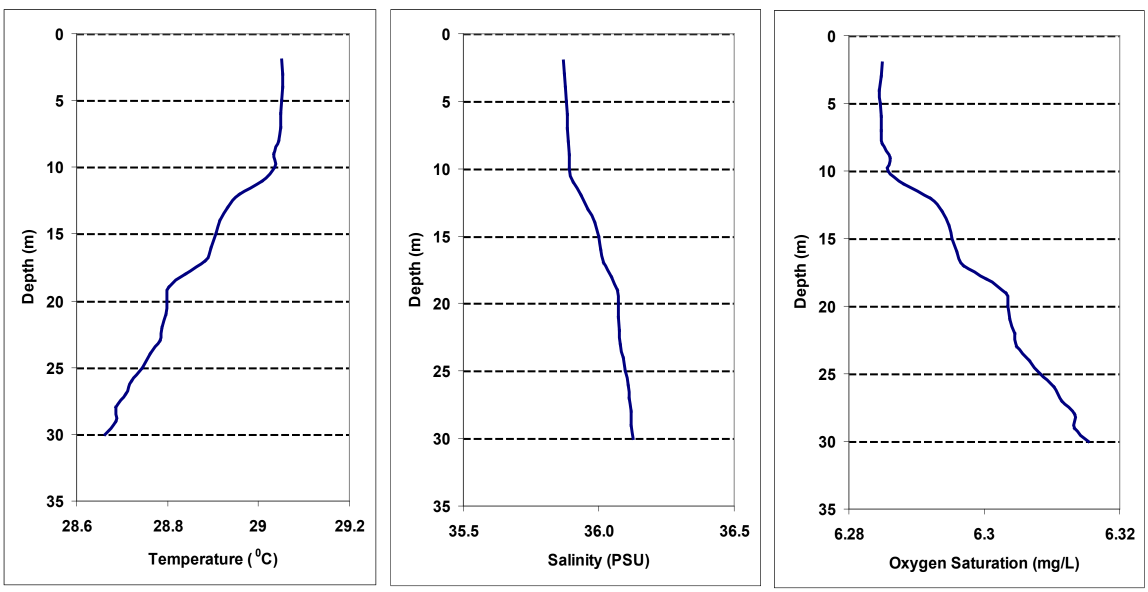

Figure 70. Temperature, salinity, and oxygen concentration profiles at station BR14.

10.5 Current Velocity and Direction

A RDI ADCP was dipped at the Broward outfall to obtain current direction and velocity. The current was northerly at the surface, decreasing in velocity and veering eastward with increasing depth. Table 32 lists the current data obtained from Broward outfall, while Figure 71 graphically depicts the data. The instrument was also dipped on October 10, 2006 (11:45 EDT) in conjunction with Shipek sampling; the current at that time was southward at about 16 cm/s (not shown).

Table 32. Current velocity and direction for the Broward outfall on October 14, 2006 at 07:40 EDT (see Table 10 for column descriptions).

Depth (m)	U (cm/s)	V (cm/s)	Magnitude (cm/s)	Direction (Degree)
3.5	16.76	79.00	80.76	11.98
5.5	21.00	80.14	82.85	14.68
7.5	12.76	68.46	69.64	10.56
9.5	12.12	66.84	67.93	10.28
11.5	12.64	63.20	64.45	11.31
13.5	16.48	59.56	61.80	15.47
15.5	21.74	54.02	58.23	21.92
17.5	26.24	47.66	54.41	28.84
19.5	28.12	43.30	51.63	33.00
21.5	23.82	39.10	45.78	31.35
23.5	16.00	33.78	37.38	25.34
25.5	7.36	22.28	23.46	18.28
27.5	9.74	13.08	16.31	36.67
29.5	14.96	11.12	18.64	53.38

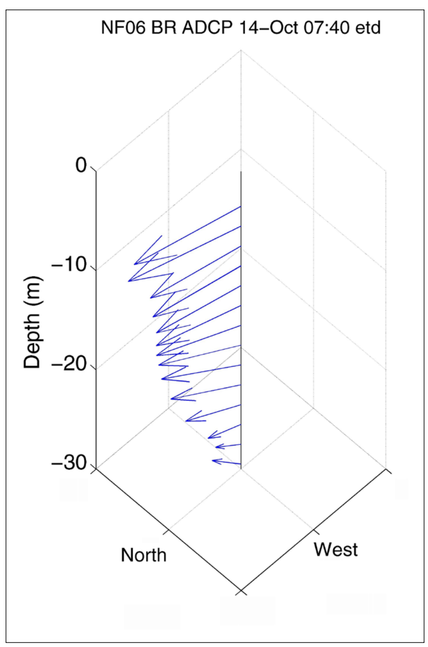

Figure 71. Plot of current vectors versus depth for the Broward outfall on October 14, 2006 at 07:40 EDT. Arrow lengths represent relative velocity (see Table 32 for values).

10.6 V-Fin

No V-Fin data were collected.

11. Boca Raton Outfall

11.1 Outfall Description

The Boca Raton ocean outfall is located approximately 1.6 km offshore of the southern section of Palm Beach County at a depth of 27.4 meters and has an average discharge flow rate of 11 MGD. Figure 72 shows the outfall pipe as recorded by the ship's multi-beam system. From these data, a location of 26°21.016'N, 80°3.243'W (26.350267°N, 80.05405°W) was determined. Table 33 lists the CTD sample stations and sample depths. Table 34 lists the sediment sample locations and depths. These values are shown graphically in Figure 73.

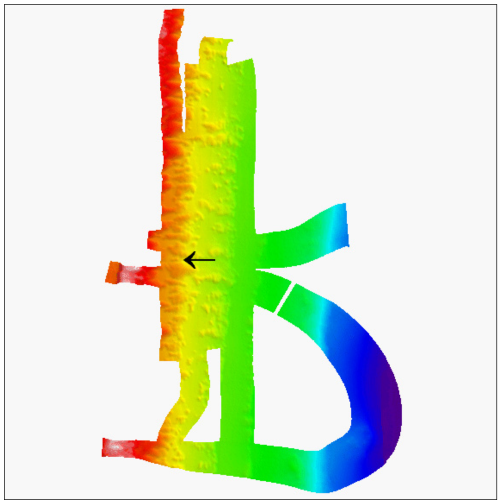

Figure 72. Multi-beam view of the seafloor in the vicinity of the Boca Raton outfall. The location of the outfall pipe end is marked by an arrow.

Table 33. CTD sample locations for the Boca Raton outfall.

Station	Date	Latitude	Longitude	Distance to Pipe End (m)	Depth (m)	Station	Date	Latitude	Longitude	Distance to Pipe End (m)	Depth (m)
BC1a	13-Oct	26.3506	-80.0540	37.40	0	BC6a	13-Oct	26.3515	-80.0538	139.38	0
BC1b	13-Oct	26.3506	-80.0540	37.40	13.71	BC6b	13-Oct	26.3515	-80.0538	139.38	13.93
BC1c	13-Oct	26.3506	-80.0540	37.40	27.43	BC6c	13-Oct	26.3515	-80.0538	139.38	27.86
BC2a	13-Oct	26.3511	-80.0546	107.66	0	BC7a	13-Oct	26.3515	-80.0535	147.68	0
BC2b	13-Oct	26.3511	-80.0546	107.66	12.7	BC7b	13-Oct	26.3515	-80.0535	147.68	14.63
BC2c	13-Oct	26.3511	-80.0546	107.66	25.4	BC7c	13-Oct	26.3515	-80.0535	147.68	29.26
BC3a	13-Oct	26.3512	-80.0541	103.90	0	BC8a	13-Oct	26.3520	-80.0543	194.34	0
BC3b	13-Oct	26.3512	-80.0541	103.90	13.6	BC8b	13-Oct	26.3520	-80.0543	194.34	13.03
BC3c	13-Oct	26.3512	-80.0541	103.90	27.2	BC8c	13-Oct	26.3520	-80.0543	194.34	26.03
BC4a	13-Oct	26.3511	-80.0536	102.94	0	BC9a	13-Oct	26.3520	-80.0538	194.34	0
BC4b	13-Oct	26.3511	-80.0536	102.94	14.66	BC9b	13-Oct	26.3520	-80.0538	194.34	13.73
BC4c	13-Oct	26.3511	-80.0536	102.94	29.32	BC9c	13-Oct	26.3520	-80.0538	194.34	27.46
BC5a	13-Oct	26.3515	-80.0543	139.38	0	BC10a	13-Oct	26.3520	-80.0534	203.33	0
BC5b	13-Oct	26.3515	-80.0543	139.38	12.65	BC10b	13-Oct	26.3520	-80.0534	203.33	14.63
BC5c	13-Oct	26.3515	-80.0543	139.38	25.3	BC10c	13-Oct	26.3520	-80.0534	203.33	29.26

Table 34. Sediment sample locations for the Boca Raton outfall.

Station	Date	Latitude	Longitude	Depth (m)
BC10	9-Oct	26.3498	-79.9534	237.0
BC11	9-Oct	26.3496	-80.0039	182.0
BC12	9-Oct	26.3507	-80.0341	118.0
BC13	9-Oct	26.3503	-80.0638	11.0
BC13b	9-Oct	26.3503	-80.0638	11.0
BC14	9-Oct	26.3411	-80.0539	29.5
BC14b	9-Oct	26.3412	-80.0542	29.5
BC15	9-Oct	26.3503	-80.0541	26.6
BC16	9-Oct	26.3512	-80.0541	26.9
BC17	9-Oct	26.3521	-80.0541	26.4
BC18	9-Oct	26.3530	-80.0541	26.1
BC18b	9-Oct	26.3532	-80.0539	26.1
BC19c	9-Oct	26.3532	-80.0539	25.7
BC20a	9-Oct	26.3591	-80.0542	23.2
BC20b	9-Oct	26.3591	-80.0539	24.5

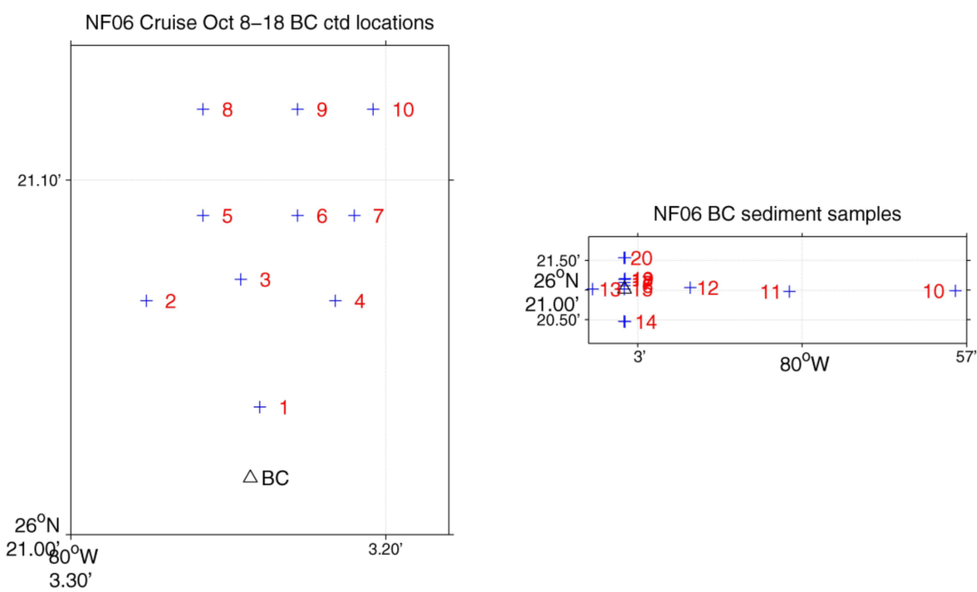

Figure 73. Location of the CTD (left panel) and Shipek sediment (right panel) sample sites for the Boca Raton outfall study. The location of the outfall pipe end is denoted by a triangle.

11.2 Nutrients

A total of 30 nutrient samples were collected during CTD operations around the Boca Raton outfall. These results are listed in Table 35 for concentrations in µM and in Table 36 for concentrations in mg/L. A graphic presentation of these results is also provided in Figure 74. Station BC1 was the site closest to the outfall, located 37 m north (Figure 73). The next closest stations were BC2, BC3, and BC4, located between 103-108 m north of the outfall in a transect running inshore to offshore. The next set of stations was 139-148 m north of the outfall (BC5, BC6, BC7), and the final set was located 194-203 m north of the outfall (BR8, BR9, BR10), with site 10 being the farthest north and offshore.

Table 35. Nutrient results in µM for the Boca Raton outfall (see Figure 73 for location map; BDL = below detection limit).

Station	Depth (m)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)	Station	Depth (m)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)
BC1a	1.2	1.13	1.30	3.45	0.46	1.90	BC6a	0.9	0.38	0.38	1.29	0.26	0.30
BC1b	13.6	0.35	0.03	0.96	0.08	BDL	BC6b	13.0	0.24	0.17	1.00	0.16	0.09
BC1c	24.2	0.21	0.05	0.60	0.16	BDL	BC6c	24.2	0.25	0.11	1.30	0.18	0.04
BC2a	4.5	0.26	0.04	0.70	0.21	BDL	BC7a	0.8	0.15	0.10	0.00	0.12	BDL
BC2b	11.9	0.14	0.08	0.56	0.16	BDL	BC7b	13.2	0.14	0.09	0.23	0.14	BDL
BC2c	22.5	0.24	0.07	0.11	0.13	0.01	BC7c	25.6	0.25	0.10	0.09	0.21	BDL
BC3a	2.4	0.99	1.11	3.18	0.51	1.88	BC8a	1.3	0.44	0.38	1.08	1.15	0.51
BC3b	12.4	0.18	0.09	0.61	0.15	0.01	BC8b	12.5	0.21	0.16	0.21	0.20	BDL
BC3c	24.0	0.23	0.08	0.33	0.14	BDL	BC8c	23.0	0.21	0.10	0.55	0.21	0.04
BC4a	0.9	1.93	2.12	7.22	0.97	3.30	BC9a	1.2	0.22	0.13	0.48	0.32	BDL
BC4b	13.5	0.24	0.09	1.35	0.22	0.01	BC9b	13.0	0.23	0.10	0.42	0.20	BDL
BC4c	26.0	0.26	0.11	0.61	0.19	0.04	BC9c	24.5	0.30	0.13	0.33	0.17	BDL
BC5a	1.1	0.49	0.46	1.85	0.31	0.75	BC10a	1.0	0.27	0.20	0.68	0.23	0.07
BC5b	11.4	0.14	0.10	0.24	0.13	0.04	BC10b	13.9	0.17	0.10	0.33	0.06	BDL
BC5c	22.3	0.25	0.10	0.26	0.13	0.04	BC10c	26.3	0.24	0.13	0.21	BDL	BDL

Table 36. Nutrient results in mg/L for the Boca Raton outfall (see Figure 73 for location map; BDL = below detection limit).

Station	Depth (m)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)	Station	Depth (m)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)
BC1a	1.2	0.005	BDL	0.013	0.002	BDL	BC6a	0.9	0.005	0.005	0.018	0.008	0.008
BC1b	13.6	0.016	0.018	0.048	0.014	0.053	BC6b	13.0	0.003	0.002	0.014	0.005	0.003
BC1c	24.2	0.003	0.001	0.008	0.005	BDL	BC6c	24.2	0.004	0.002	0.018	0.005	0.001
BC2a	4.5	0.004	0.001	0.010	0.007	BDL	BC7a	0.8	0.002	0.001	BDL	0.004	BDL
BC2b	11.9	0.002	0.001	0.008	0.005	BDL	BC7b	13.2	0.002	0.001	0.003	0.004	BDL
BC2c	22.5	0.003	0.001	0.002	0.004	BDL	BC7c	25.6	0.004	0.001	0.001	0.006	BDL
BC3a	2.4	0.014	0.016	0.045	0.016	0.053	BC8a	1.3	0.006	0.005	0.015	0.036	0.014
BC3b	12.4	0.003	0.001	0.009	0.005	BDL	BC8b	12.5	0.003	0.002	0.003	0.006	BDL
BC3c	24.0	0.003	0.001	0.005	0.004	BDL	BC8c	23.0	0.003	0.001	0.008	0.006	0.001
BC4a	0.9	0.027	0.030	0.101	0.030	0.092	BC9a	1.2	0.003	0.002	0.007	0.010	BDL
BC4b	13.5	0.003	0.001	0.019	0.007	BDL	BC9b	13.0	0.003	0.001	0.006	0.006	BDL
BC4c	26.0	0.004	0.002	0.009	0.006	0.001	BC9c	24.5	0.004	0.002	0.005	0.005	BDL
BC5a	1.1	0.007	0.006	0.026	0.010	0.021	BC10a	1.0	0.004	0.003	0.010	0.007	0.002
BC5b	11.4	0.002	0.001	0.003	0.004	0.001	BC10b	13.9	0.002	0.001	0.005	0.002	BDL
BC5c	22.3	0.004	0.001	0.004	0.004	0.001	BC10c	26.3	0.003	0.002	0.003	BDL	BDL

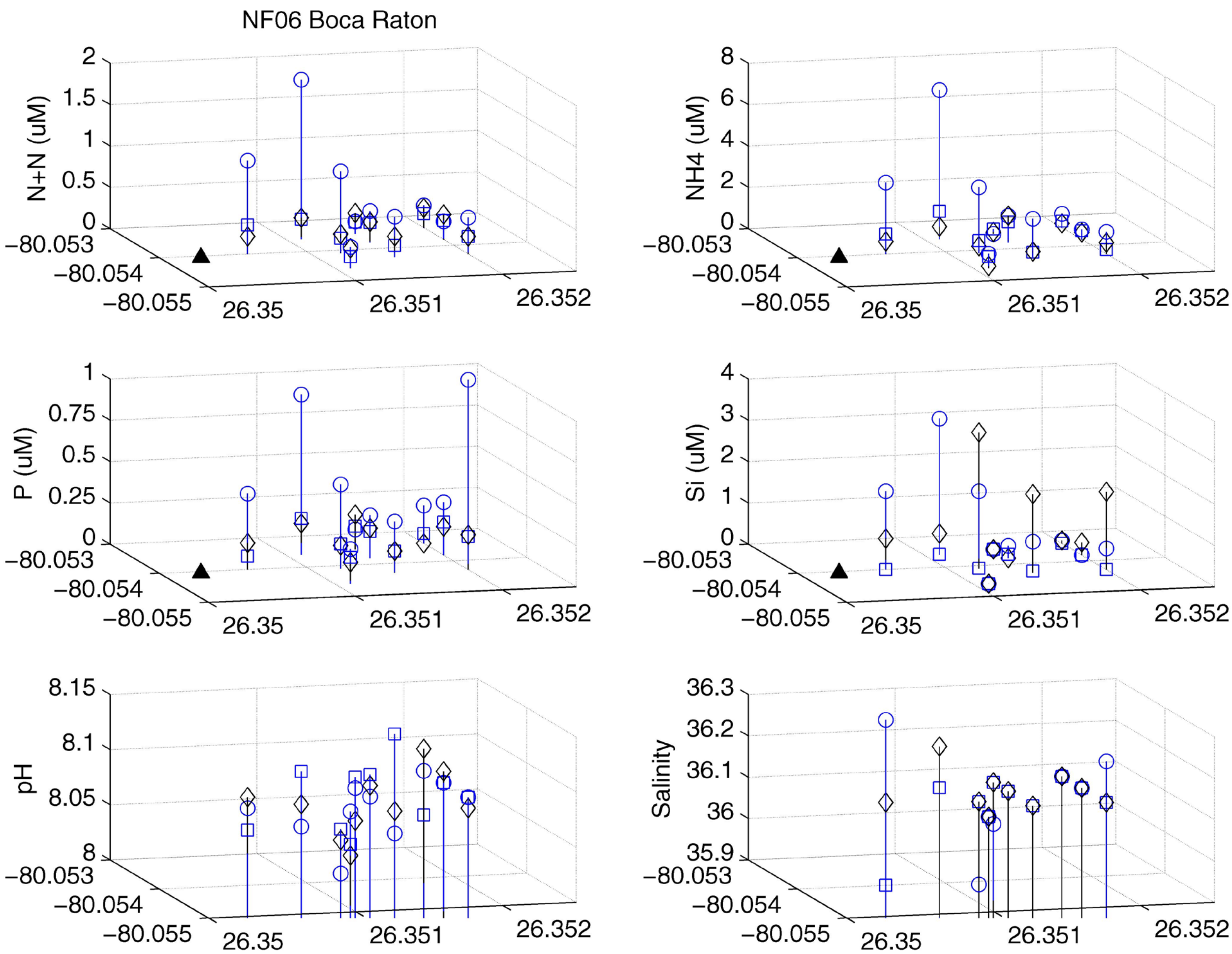

Figure 74. Three-dimensional presentation of nutrient results, pH, and salinity from CTD casts around the Boca Raton outfall. The format follows that of Figure 6. See Appendix 1 for tabulated data.

The highest analyte concentrations were not observed at the site closest to the outfall (e.g., NH_4, 3.45 µM), but rather at site BC4, the site located 148 m north of the outfall (e.g., NH_4, 7.22 µM). However, a low salinity signature was not observed in the CTD cast at that site (Figure 78). In comparison, concentrations were low at sites BC6-BC10 (NH_4 < 1 µM).

11.3 Chlorophyll and pH

A total of 30 chlorophyll and pH samples were collected during CTD operations around the Boca Raton outfall. Table 37 lists the results for the chlorophyll and pH samples collected along with the temperature and salinity data for each depth sampled. The chlorophyll concentrations were similar for most of the sites (0.6-0.7 µg/L).

Table 37. Temperature, salinity, pH, chlorophyll-*a,* and phaeopigment results for the Boca Raton outfall (N/A = not available).

Station	Depth (m)	Temperature (°C)	Salinity (PSU)	pH	Chlorophyll-*a* (µg/L)	Phaeopigments (µg/L)
BC1a	1.2	29.68	36.29	8.07	0.706	0.209
BC1b	13.6	28.99	35.94	8.05	0.714	0.191
BC1c	24.2	28.88	36.14	8.08	0.561	0.204
BC2a	4.5	29.16	36.09	8.08	0.734	0.246
BC2b	11.9	29.12	36.09	8.05	1.446	0.424
BC2c	22.5	28.90	36.14	8.04	N/A	N/A
BC3a	2.4	29.13	35.88	8.01	0.774	0.243
BC3b	12.4	28.98	36.12	8.05	0.745	0.208
BC3c	24.0	28.87	36.14	8.04	0.561	0.182
BC4a	0.9	29.12	35.69	8.04	0.699	0.197
BC4b	13.5	28.96	36.12	8.09	0.696	0.137
BC4c	26.0	28.86	36.15	8.06	0.603	0.190
BC5a	1.1	29.26	35.65	8.05	0.644	0.176
BC5b	11.4	29.14	36.11	8.14	0.608	0.214
BC5c	22.3	28.93	36.14	8.07	0.617	0.165
BC6a	0.9	29.01	34.93	8.07	0.475	0.174
BC6b	13.0	29.16	36.09	8.09	0.587	0.159
BC6c	24.2	29.09	36.11	8.08	0.681	0.151
BC7a	0.8	29.34	36.02	8.07	0.388	0.126
BC7b	13.2	29.17	36.10	8.08	0.666	0.245
BC7c	25.6	29.02	36.12	8.04	0.639	0.186
BC8a	1.3	29.16	36.15	8.08	0.618	0.187
BC8b	12.5	29.16	36.09	8.08	0.619	0.156
BC8c	23.0	29.09	36.11	8.07	0.653	0.201
BC9a	1.2	29.09	36.05	8.08	0.619	0.206
BC9b	13.0	29.08	36.11	8.08	0.575	0.215
BC9c	24.5	29.07	36.12	8.09	0.594	0.176
BC10a	1.0	29.05	36.11	8.08	0.752	0.233
BC10b	13.9	28.98	36.12	8.04	0.607	0.230
BC10c	26.3	28.94	36.13	8.10	0.630	0.226

11.4 CTD Casts

A total of 10 CTD casts were conducted at the Boca Raton outfall on October 13, 2006. At each station, water samples from near the bottom, at mid depth, and from near the surface were obtained. Water depths ranged from ~25 m inshore (BR2) to 29 m offshore (BR10). Figures 75-84 show the temperature, salinity, and oxygen saturation profiles for each station. A distinct thermocline was observed only in MC9, at ~19 m depth north of the outfall, and in BC7 at 21 m. Salinity measured near the open ocean had a value of 36 ppt for most casts, including all outer casts, indicating a more mixed water column than the other outfalls.

Cast BC1, located 37 m from the outfall and intended to be in the boil, showed evidence of the plume at ~6-13 m in both salinity and oxygen saturation; unfortunately, the plume signature was not captured at the surface and mid-depth (14 m) bottle openings. A small signature of low salinity water was observed at BC3 very near the surface (0-4 m), but a low salinity signature was not observed at the other sites, despite the highest NH_4 concentrations being observed at site BC4 (Table 35).

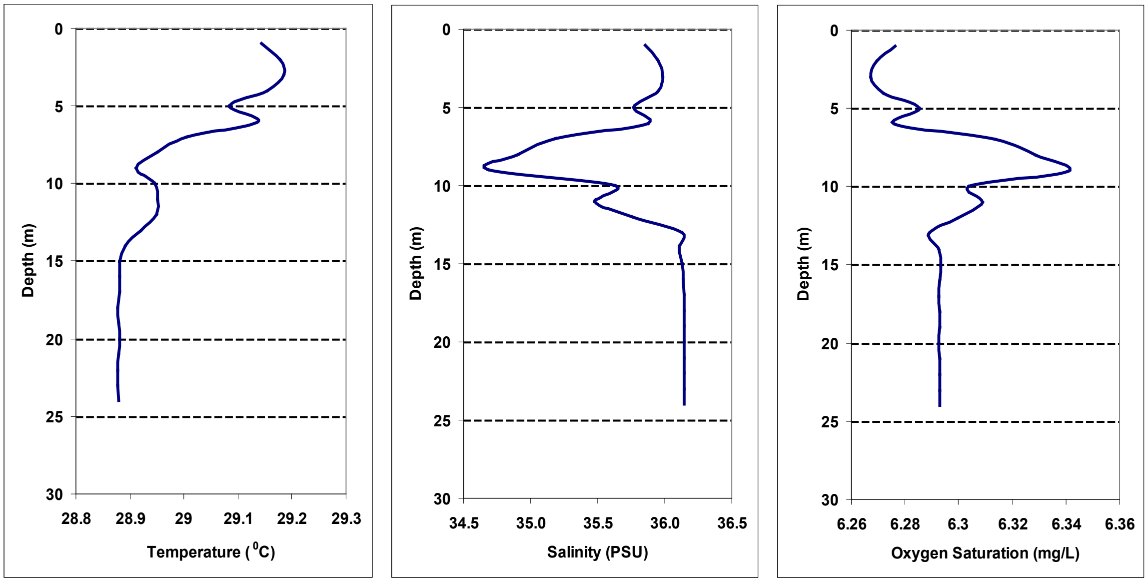

Figure 75. Temperature, salinity, and oxygen concentration profiles at station BC1.

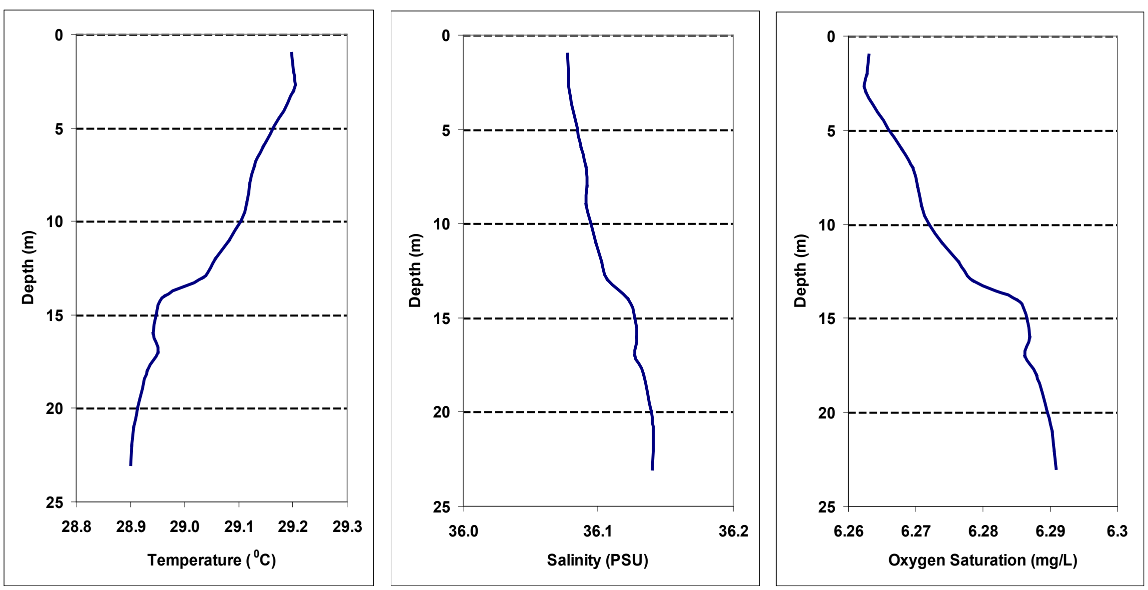

Figure 76. Temperature, salinity, and oxygen concentration profiles at station BC2.

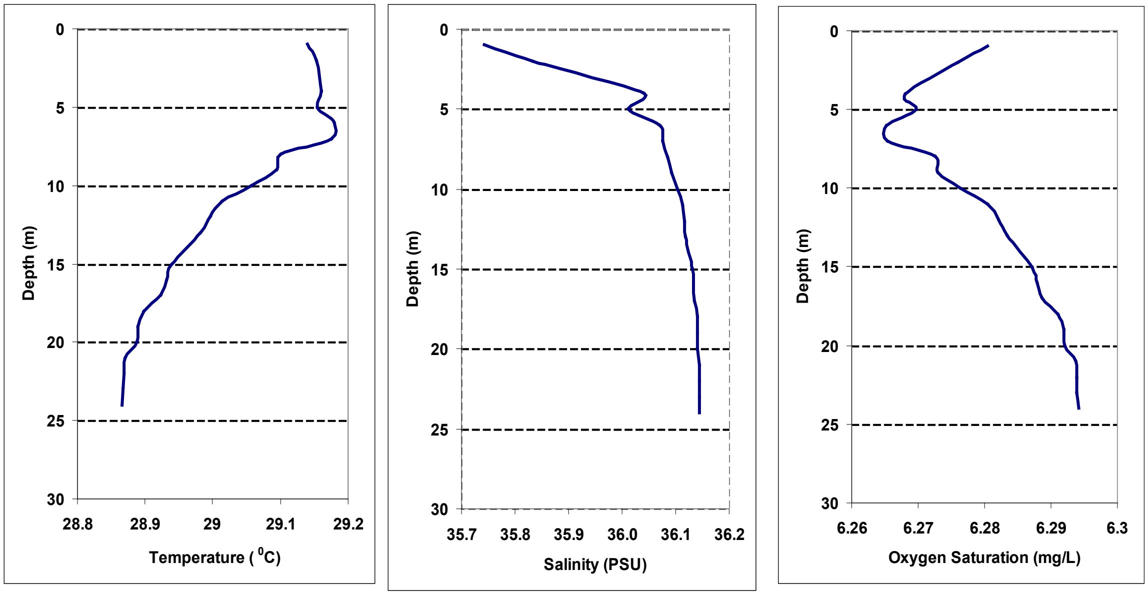

Figure 77. Temperature, salinity, and oxygen concentration profiles at station BC3.

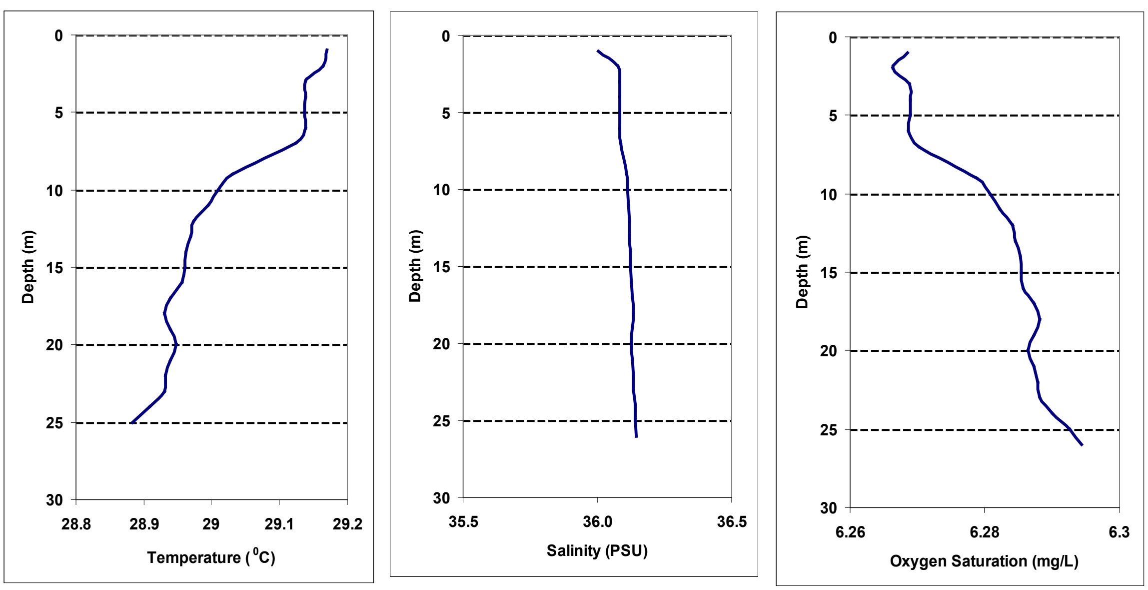

Figure 78. Temperature, salinity, and oxygen concentration profiles at station BC4.

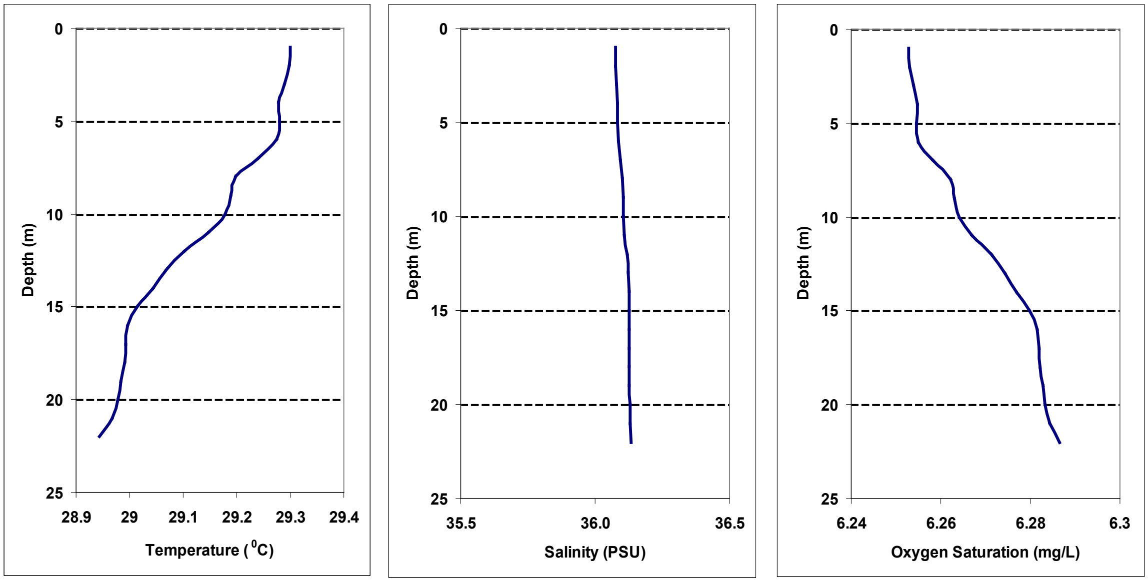

Figure 79. Temperature, salinity, and oxygen concentration profiles at station BC5.

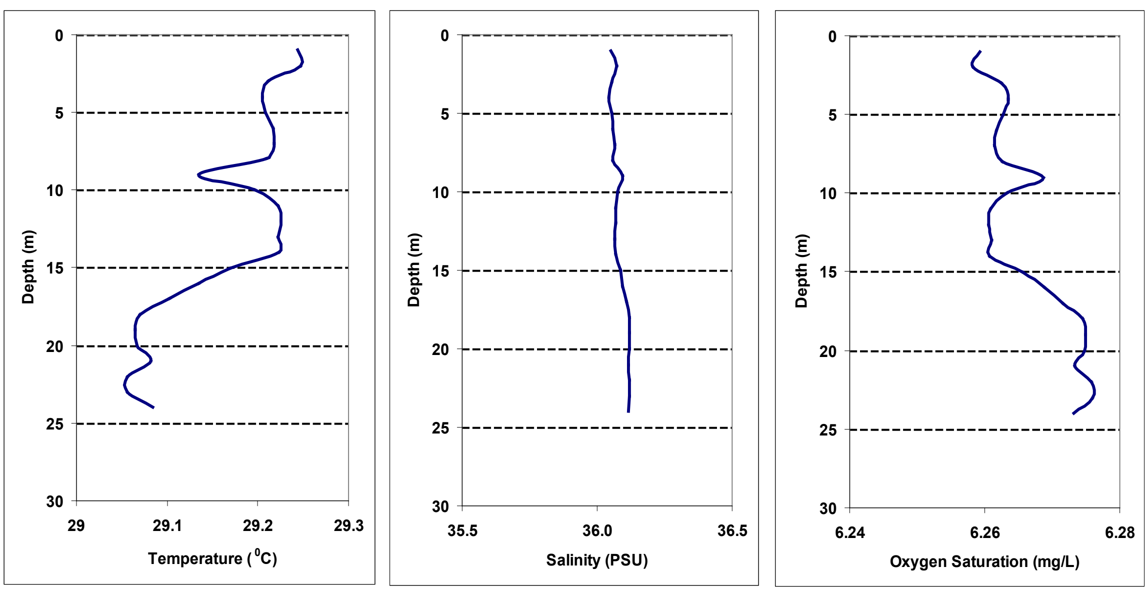

Figure 80. Temperature, salinity, and oxygen concentration profiles at station BC6.

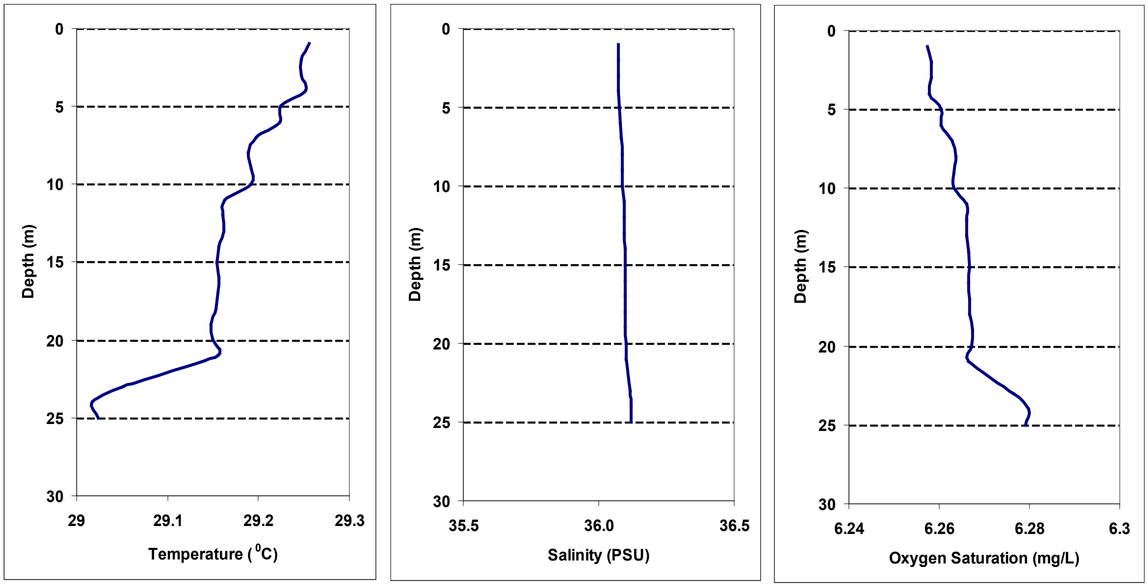

Figure 81. Temperature, salinity, and oxygen concentration profiles at station BC7.

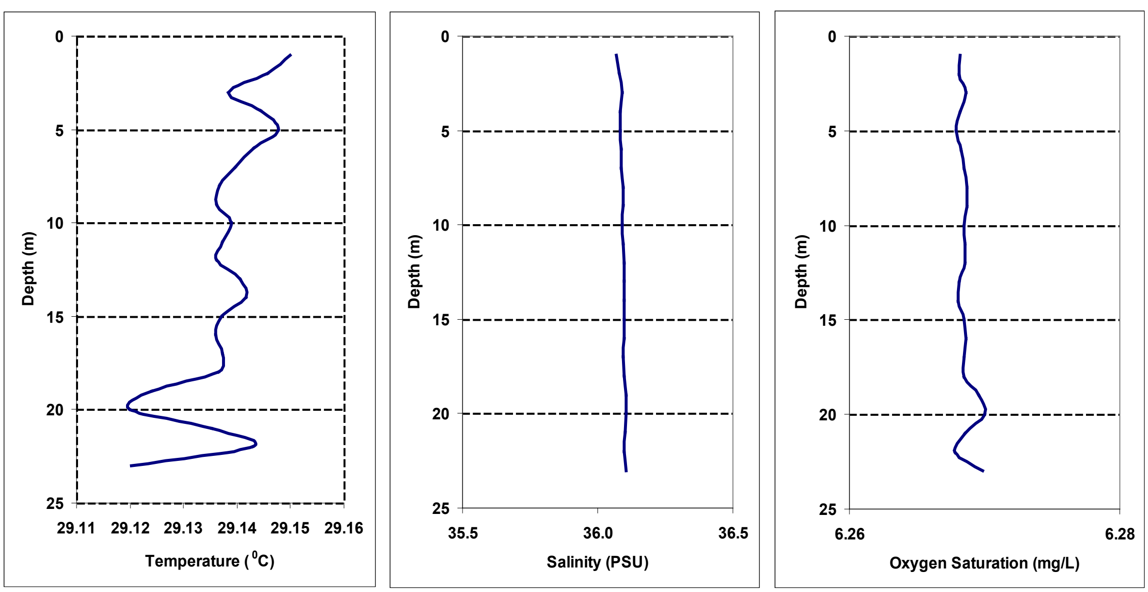

Figure 82. Temperature, salinity, and oxygen concentration profiles at station BC8.

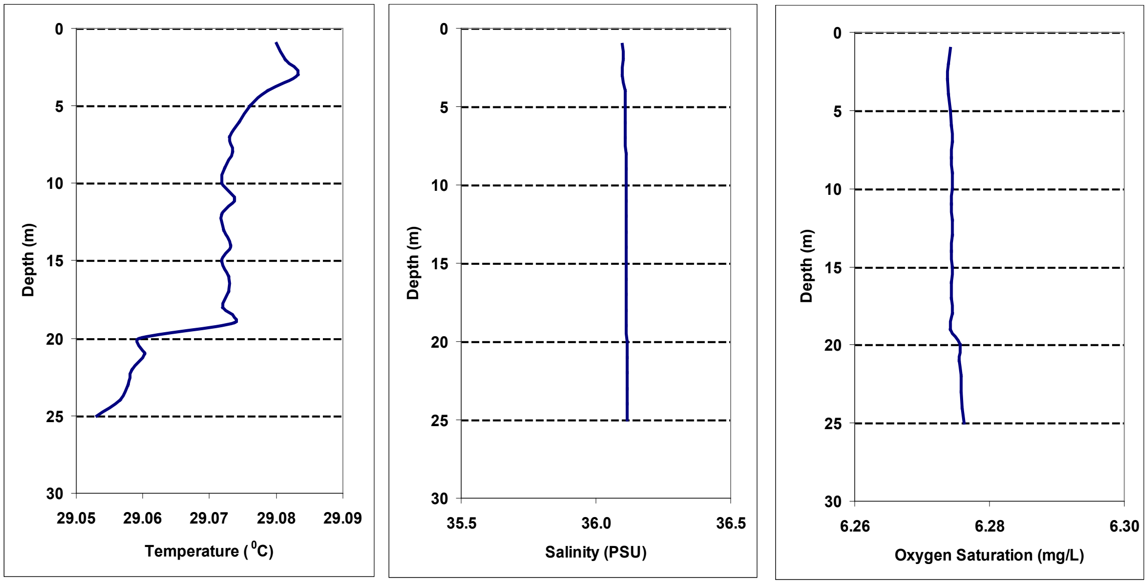

Figure 83. Temperature, salinity, and oxygen concentration profiles at station BC9.

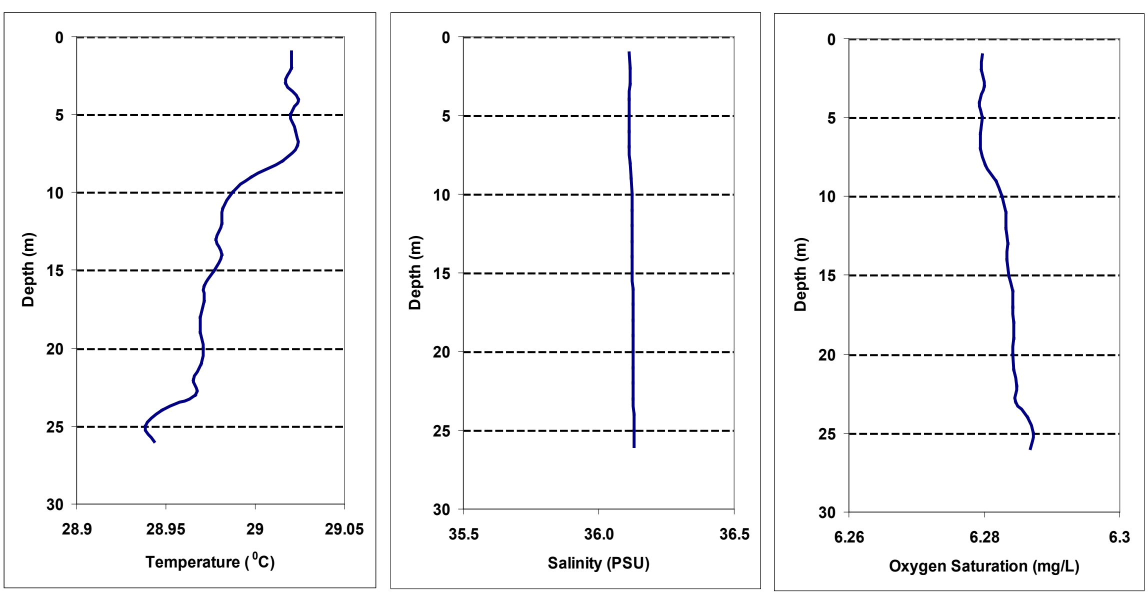

Figure 84. Temperature, salinity, and oxygen concentration profiles at station BC10.

11.5 Current Velocity and Direction

A RDI ADCP was dipped at the Boca Raton outfall to obtain current direction and velocity. Table 38 lists the current vector data obtained from the Boca Raton outfall, while Figure 85 graphically depicts the data. Overall, a northward current was observed with a magnitude of about 32 cm/s.

Table 38. Current velocity and direction for the Boca Raton outfall on October 13, 2006 at 07:45 EDT (see Table 10 for column descriptions).

Depth (m)	U (cm/s)	V (cm/s)	Magnitude (cm/s)	Direction (Degree)
3.75	15.57	31.46	35.10	26.34
5.75	13.93	33.34	36.14	22.67
7.75	8.71	33.43	34.55	14.61
9.75	2.67	36.09	36.18	4.23
11.75	-0.34	36.53	36.53	359.46
13.75	-0.84	35.01	35.02	358.62
15.75	0.76	33.53	33.54	1.29
17.75	1.89	31.94	32.00	3.38
19.75	1.46	30.76	30.79	2.71
21.75	-0.60	27.99	27.99	358.77

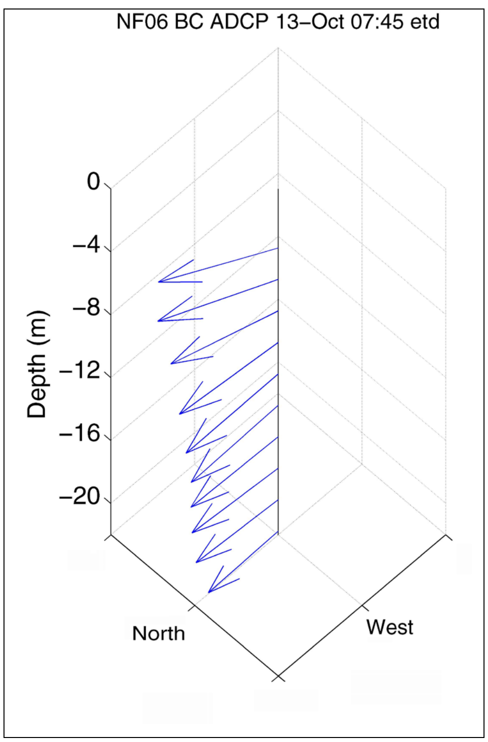

Figure 85. Plot of current vectors versus depth for the Boca Raton outfall on October 13, 2006 at 07:45 EDT. Arrow lengths represent relative velocity (see Table 38 for values).

11.6 V-Fin

A V-Fin was lowered via A-frame behind the ship to criss-cross the Boca Raton outfall to obtain additional salinity and temperature information for determining the location of the outfall plume. Figure 86 shows the track over the outfall plume, as well as the salinity and temperature deficits. The plume was clearly identified by salinity deficit but, as observed in other plumes, the temperature deficit was negligible. The plume development as seen in Figure 86 supports the northerly current direction observed in the ADCP profiles (Figure 85).

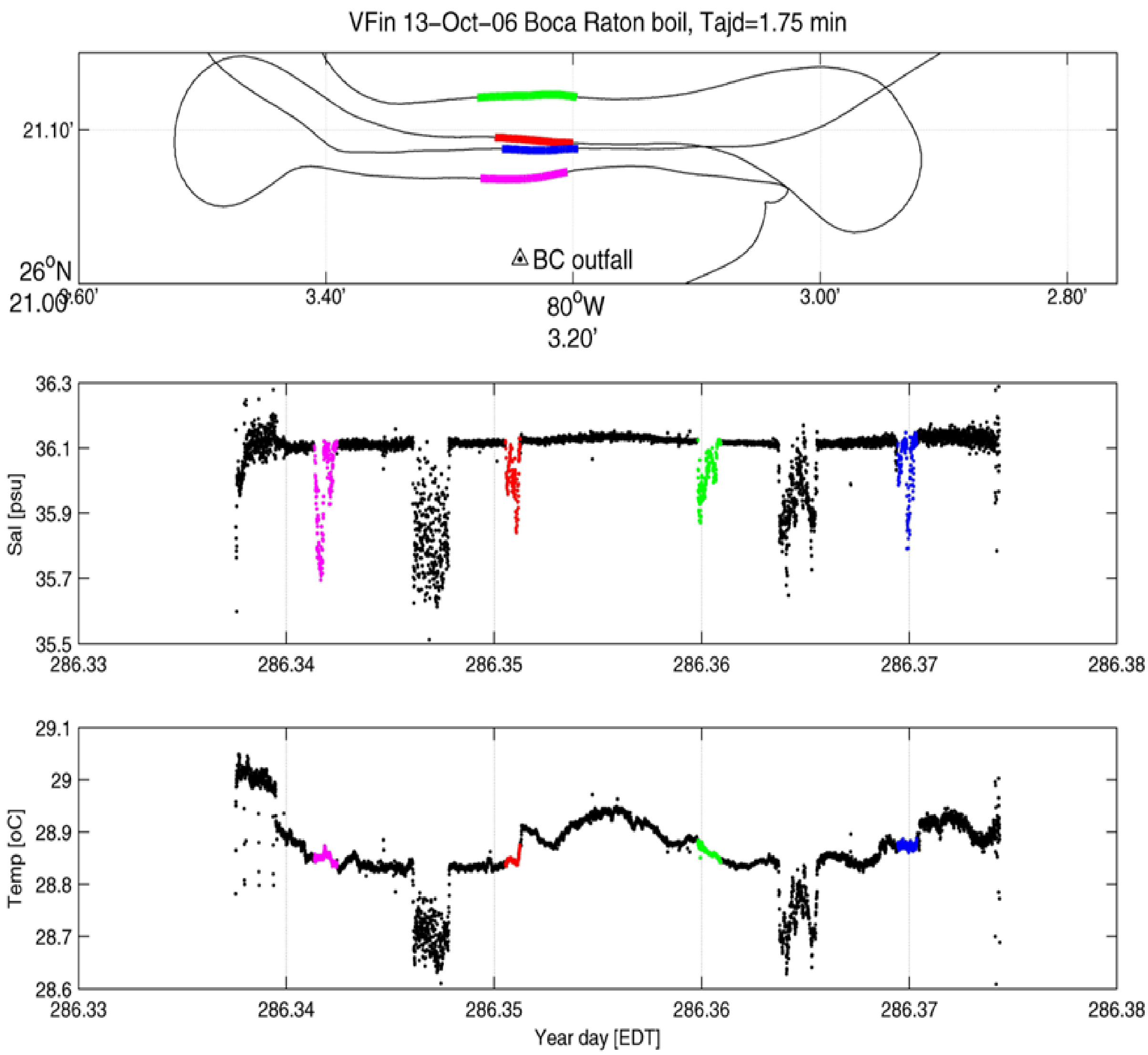

Figure 86. Top panel: Track of the V-Fin instrument on October 13, 2006 as it passed over the Boca Raton outfall plume. The middle and bottom panels show changes in salinity and temperature as the plume was traversed. Plume indications as determined by salinity deficit are highlighted in magenta, red, green, and blue.

12. South Central Outfall

12.1 Outfall Description

The South Central ocean outfall (http://www.scrwwtp.org) is located approximately 1.6 km offshore Delray Beach at a depth of 27.4 meters and has an average discharge flow rate of 12 MGD. Figure 87 shows the outfall pipe as recorded by the ship's multi-beam system. From these data, a location of 26°27.715'N, 80°2.525'W (26.461917°N, 80.042083°W) was determined. Table 39 lists the CTD sample stations and sample depths. Table 40 lists the sediment sample locations and depths. These values are shown graphically in Figure 88.

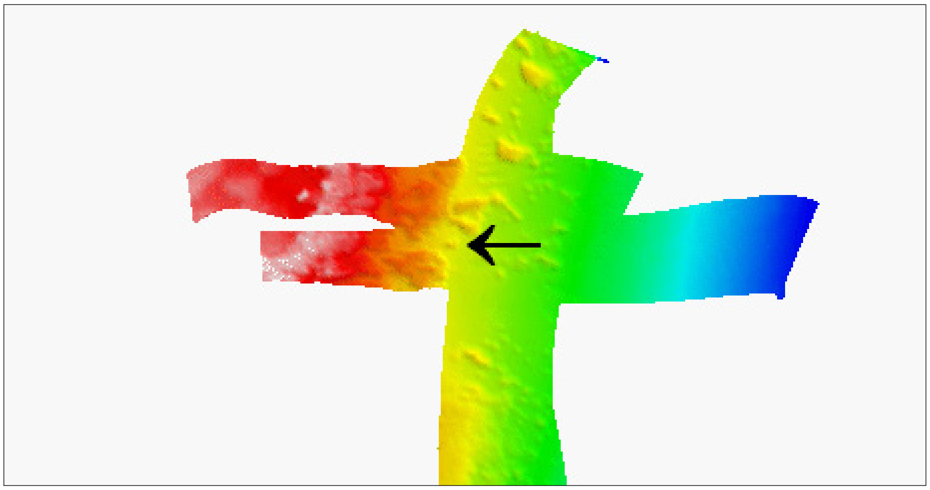

Figure 87. Multi-beam view of the seafloor in the vicinity of the South Central outfall. The location of the outfall pipe end is marked by an arrow.

Table 39. CTD sample locations for the South Central outfall.

Station	Date	Latitude	Longitude	Distance to Pipe End (m)	Depth (m)	Station	Date	Latitude	Longitude	Distance to Pipe End (m)	Depth (m)
SC1	12-Oct	26.4627	-80.0420	0.0	0	SC6c	12-Oct	26.4631	-80.0417	53.6	30
SC1b	12-Oct	26.4623	-80.0420	44.5	0	SC7a	12-Oct	26.4636	-80.0424	107.7	0
SC2a	12-Oct	26.4642	-80.0434	217.4	0	SC7b	12-Oct	26.4636	-80.0424	107.7	13.8
SC2b	12-Oct	26.4642	-80.0434	217.4	10.6	SC7c	12-Oct	26.4636	-80.0424	107.7	27.6
SC2c	12-Oct	26.4642	-80.0434	217.4	21.1	SC8a	12-Oct	26.4637	-80.0411	142.8	0
SC3a	12-Oct	26.4638	-80.0416	128.6	0	SC8b	12-Oct	26.4637	-80.0411	142.8	15.8
SC3b	12-Oct	26.4638	-80.0416	128.6	15.2	SC8c	12-Oct	26.4637	-80.0411	142.8	31.6
SC3c	12-Oct	26.4638	-80.0416	128.6	30.4	SC9a	12-Oct	26.4642	-80.0427	180.8	0
SC4a	12-Oct	26.4631	-80.0424	59.7	0	SC9b	12-Oct	26.4642	-80.0427	180.8	11.5
SC4b	12-Oct	26.4631	-80.0424	59.7	13.6	SC9c	12-Oct	26.4642	-80.0427	180.8	23.0
SC4c	12-Oct	26.4631	-80.0424	59.7	27.1	SC10a	12-Oct	26.4642	-80.0442	275.3	0
SC5a	12-Oct	26.4630	-80.0431	114.5	0	SC10b	12-Oct	26.4642	-80.0442	275.3	9.8
SC5b	12-Oct	26.4630	-80.0431	114.5	12.0	SC10c	12-Oct	26.4642	-80.0442	275.3	19.7
SC5c	12-Oct	26.4630	-80.0431	114.5	24.0	SC11a	12-Oct	26.4623	-80.0420	44.5	0
SC6a	12-Oct	26.4631	-80.0417	53.6	0	SC11b	12-Oct	26.4623	-80.0420	44.5	14.7
SC6b	12-Oct	26.4631	-80.0417	53.6	15	SC11c	12-Oct	26.4623	-80.0420	44.5	29.4

Table 40. Sediment sample locations for the South Central outfall.

Station	Date	Latitude	Longitude	Depth (m)
SC10	9-Oct	26.4622	-79.8554	345.0
SC10	9-Oct	26.4817	-79.8583	220.0
SC11	9-Oct	26.4612	-79.9669	203.0
SC12	9-Oct	26.4617	-80.0052	156.0
SC13	9-Oct	26.4781	-80.0421	22.7
SC14	9-Oct	26.4657	-80.0375	27.1
SC15	9-Oct	26.4646	-80.0421	28.0
SC16a	9-Oct	26.4637	-80.0422	N/A
SC16b	9-Oct	26.4632	-80.0421	N/A
SC16c	9-Oct	26.4633	-80.0421	N/A
SC17	9-Oct	26.4629	-80.0420	29.3
SC18	9-Oct	26.4620	-80.0537	8.5
SC19	9-Oct	26.4611	-80.0421	29.8
SC19	9-Oct	26.4611	-80.0421	29.8
SC20	9-Oct	26.4379	-80.0423	30.0
SC21	9-Oct	26.4440	-80.0419	41.8
SC21b	9-Oct	26.4601	-80.0426	41.8
SC22	9-Oct	26.4620	-80.0422	28.5

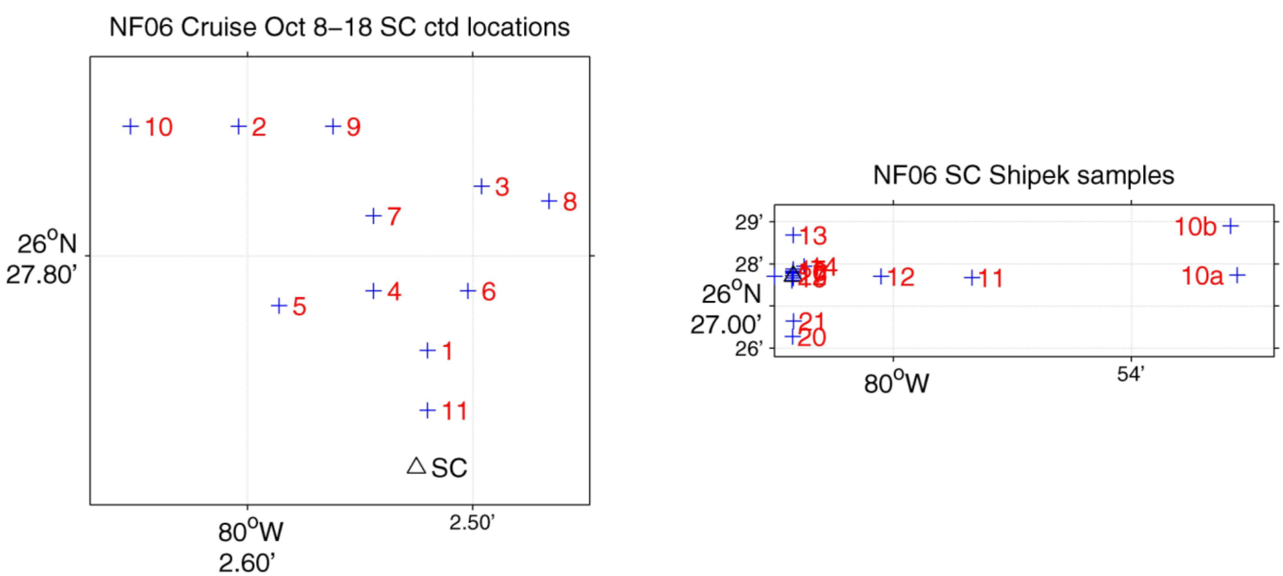

Figure 88. Location of the CTD (left panel) and Shipek sediment (right panel) sample sites for the South Central outfall study. The location of the outfall pipe end is denoted by a triangle.

12.2 Nutrients

Nutrient samples were collected, but the data were lost due to computer failure.

12.3 Chlorophyll and pH

A total of 33 chlorophyll and pH samples were collected during CTD operations around the South Central outfall. Table 41 lists the results for the chlorophyll and pH samples collected along with the temperature and salinity data for each depth sampled.

12.4 CTD Casts

A total of 11 CTD casts were conducted at the South Central outfall. At each station, the CTD obtained a sample near the bottom, at mid depth, and near the surface. No profiles were available due to an error with the CTD.

Table 41. Temperature, salinity, pH, chlorophyll-*a*, and phaeopigment results for the South Central outfall.

Station	Depth (m)	Temperature (°C)	Salinity (PSU)	pH	Chlorophyll-*a* (µg/L)	Phaeopigments (µg/L)
1a	0.5	28.85	35.86	N/A	N/A	N/A
1b	15.5	28.84	36.14	N/A	N/A	N/A
2a	1.1	28.98	36.10	8.28	0.343	0.111
2b	11.4	28.91	36.15	N/A	0.424	0.104
2c	20.3	28.80	36.16	8.23	0.316	0.144
3a	1.9	29.05	36.00	8.15	0.422	0.121
3b	19.5	28.85	36.06	8.15	0.518	0.204
3c	28.8	28.70	36.17	8.05	0.433	0.170
4a	1.8	28.69	35.81	8.36	0.402	0.126
4b	13.6	28.89	36.15	8.02	0.434	0.137
4c	25.3	28.84	36.16	N/A	0.419	0.148
5a	1.2	29.04	36.12	8.07	0.398	0.126
5b	11.7	28.81	36.15	N/A	0.406	0.132
5c	20.4	28.81	36.16	8.06	0.429	0.138
6a	1.2	29.03	36.05	N/A	0.403	0.115
6b	14.1	28.94	36.16	8.34	0.407	0.128
6c	28.0	28.78	36.16	8.26	0.416	0.133
7a	1.3	29.06	36.05	8.23	0.362	0.094
7b	13.5	28.94	36.14	8.23	0.437	0.122
7c	24.4	28.84	36.16	8.04	0.387	0.134
8a	1.2	29.13	35.98	N/A	0.439	0.119
8b	15.6	29.00	36.15	N/A	0.231	0.075
8c	28.6	28.90	36.14	N/A	0.481	0.196
9a	1.2	29.10	35.97	N/A	0.422	0.134
9b	11.8	29.02	36.14	8.03	0.418	0.129
9c	22.8	28.89	36.15	N/A	0.412	0.139
10a	1.0	29.15	35.89	N/A	0.455	0.129
10b	7.9	29.12	36.13	8.25	0.533	0.145
10c	16.5	28.87	36.15	8.29	0.486	0.135
11a	1.2	29.10	36.09	8.27	0.279	0.084
11b	15.1	28.96	36.15	8.06	0.214	0.074
11c	27.4	28.89	36.14	8.31	0.517	0.179

12.5 Current Velocity and Direction

A RDI ADCP was dipped at the South Central outfall to obtain current direction and velocity. Three dips were performed at this location. Tables 42-44 list the current data obtained from the South Central outfall, while Figures 89-91 graphically depict the data. During the first sampling event (October 9, 10:40 EDT), the current was to the south with low flow velocities (8-13 cm/s). When the site was sampled again on October 12 (09:00 EDT), the current had reversed to the north with velocities decreasing with depth from about 37 cm/s at 4 m to 28 cm/s at 22 m depth. The current remained to the north when the site was sampled later that day (17:00 EDT), with velocities decreasing with depth from 27 cm/s at 4 m to 17 cm/s at 22 m.

Table 42. Current velocity and direction for the South Central outfall on October 9, 2006 at 10:40 EDT (see Table 10 for column descriptions).

Depth (m)	U (cm/s)	V (cm/s)	Magnitude (cm/s)	Direction (Degree)
4	-2.3	-7.68	8.02	196.67
6	-3.86	-9.58	10.33	201.95
8	-3.56	-9.92	10.54	199.74
10	-1.42	-11.12	11.21	187.28
12	0.78	-11.64	11.67	176.17
14	3.76	-11.56	12.16	161.98
16	5.82	-11.52	12.91	153.2
18	5.88	-8.48	10.32	145.26

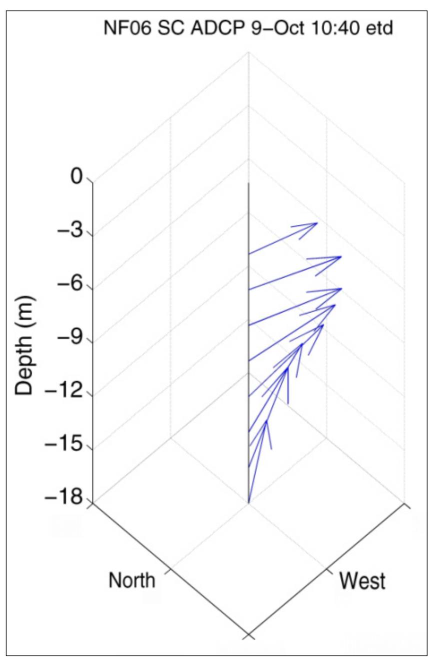

Figure 89. Plot of current vectors versus depth for the South Central outfall on October 9, 2006 at 10:40 EDT. Arrow lengths represent relative velocity (see Table 42 for values).

Table 43. Current velocity and direction for the South Central outfall on October 12, 2006 at 09:00 EDT (see Table 10 for column descriptions).

Depth (m)	U (cm/s)	V (cm/s)	Magnitude (cm/s)	Direction (Degree)
4	1.6	37.0	37.0	2.5
6	-3.1	36.6	36.8	355.2
8	-6.7	37.2	37.8	349.8
10	-8.1	36.8	37.7	347.6
12	-9.3	35.4	36.6	345.3
14	-9.4	33.5	34.8	344.3
16	-9.6	31.4	32.8	343.0
18	-9.3	29.5	31.0	342.5
20	-9.2	27.1	28.7	341.2
22	-9.7	25.9	27.7	339.5

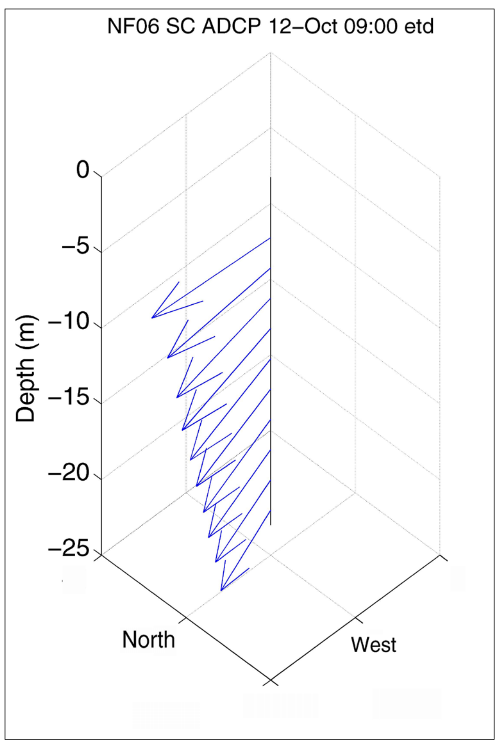

Figure 90. Plot of current vectors versus depth for the South Central outfall on October 12, 2006 at 09:00 EDT. Arrow lengths represent relative velocity (see Table 43 for values).

Table 44. Current velocity and direction for the South Central outfall on October 12, 2006 at 17:00 EDT (see Table 10 for column descriptions).

Depth (m)	U (cm/s)	V (cm/s)	Magnitude (cm/s)	Direction (Degree)
4.25	-12.22	23.92	26.86	332.94
6.25	-7.94	19.45	21.01	337.78
8.25	-6.52	19.62	20.67	341.61
10.25	-5.76	19.83	20.65	343.8
12.25	-4.12	20.36	20.77	348.57
14.25	-3.72	20.38	20.71	349.66
16.25	-3.58	19.37	19.7	349.52
18.25	-4.3	18.46	18.95	346.87
20.25	-4.83	18.06	18.7	345.02
22.25	-4.78	15.94	16.64	343.31

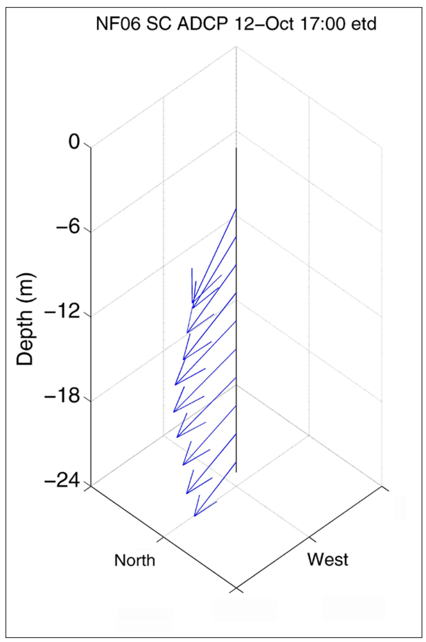

Figure 91. Plot of current vectors versus depth for the South Central outfall on October 12, 2006 at 17:00 EDT. Arrow lengths represent relative velocity (see Table 44 for values).

12.6 V-Fin

The V-Fin (tow body with CTD) was deployed to locate the surface expression of the South Central outfall plume on October 12, 2006. The resulting salinity and temperature data were then used to define the plume and allow sampling sites to be located for water sampling of the plume. Figure 92 shows the track over the outfall plume. Salinity and temperature deficits for the three plume encounters are denoted in magenta, red, and blue. In this experiment only, there was a noted temperature response to the plume, particularly for the third (blue colored) pass.

An “edge effect” was observed here (and in other V-Fin data presented earlier), in which the salinity was lower at the edges of the plume while the temperature was higher (Figure 93), as if the plume was more concentrated in those regions. This counter-intuitive observation (we instead expected mixing with the ambient waters to be maximal on the plume boundaries) was noted on most of the plume passes during the cruise.

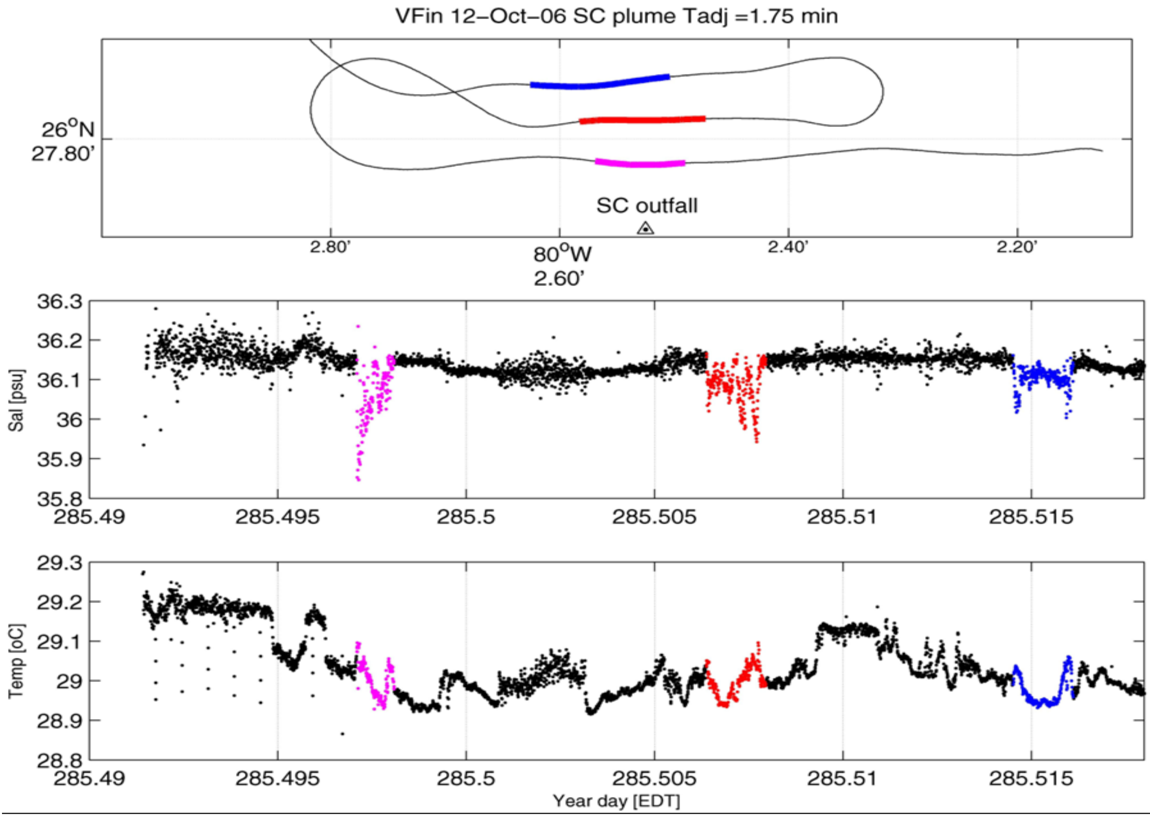

Figure 92. Top panel: Track of the V-Fin instrument on October 12, 2006 as it passed over the South Central outfall plume. The middle and bottom panels show changes in salinity and temperature as the plume was traversed. Plume indications as determined by salinity deficit are highlighted in magenta, red, and blue.

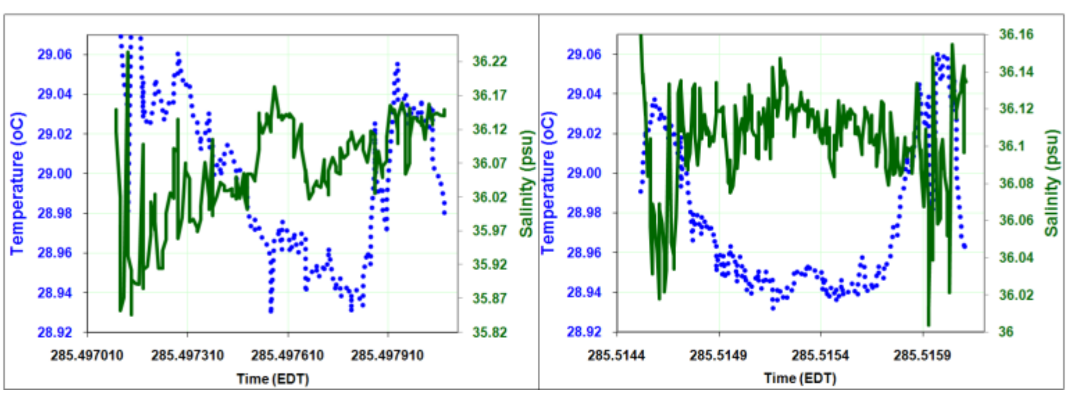

Figure 93. V-Fin data for October 12, 2006 showing temperature (dotted line) and salinity (solid line) during the first and third passes through the South Central plume. Note that the temperature and salinity are anti-correlated and that the maximum change occurs at the edge of the plume.

13. Boynton Inlet

13.1 Inlet Description

The Boynton Inlet is the southernmost outlet for the Lake Worth Lagoon. The inlet is approximately 61 m wide and 3.7 m deep. One CTD cast was conducted outside the inlet but within the inlet plume. Table 45 lists the station location and depths of the CTD cast.

Table 45. CTD cast for outside the Boynton Inlet.

Station	Date	Latitude	Longitude	Depth (m)
BI-1a	2-Oct	26.5445	-80.0375	3.9
BI-1b	12-Oct	26.5445	-80.0375	5.6

13.2 Nutrients

Nutrient samples were collected, but the data were lost due to a computer failure.

13.3 Chlorophyll and pH

A total of two chlorophyll and pH samples were collected during CTD operations around the Boynton Inlet. Table 46 lists the results for the chlorophyll and pH samples collected along with the temperature and salinity data for each depth sampled.

Table 46. Temperature, salinity, pH, chlorophyll-*a*, and phaeopigment results for outside of the Boynton Inlet.

Station	Depth (m)	Temperature (°C)	Salinity (PSU)	pH	Chlorophyll-*a* (µg/L)	Phaeopigments (µg/L)
1a	3.9	28.61	35.71	7.99	0.844	0.371
1b	5.6	28.61	35.73	8.09	0.855	0.377

13.4 CTD Cast

A total of one CTD cast was conducted outside the Boynton Inlet. At each station, the CTD obtained a sample near the bottom and near the surface. No profiles were available due to an error with the CTD.

13.5 Current Velocity and Direction

A RDI ADCP was dipped outside the Boynton Inlet to obtain current direction and velocity. Table 47 lists the current data obtained from outside the Boynton Inlet, while Figure 94 graphically depicts the data.

Table 47. Current velocity and direction for outside the Boynton Inlet on October 12, 2006 at 07:40 EDT (see Table 10 for column descriptions).

Depth (m)	U (cm/s)	V (cm/s)	Magnitude (cm/s)	Direction (Degree)
3.8	12.2	9.73	15.6	51.44
5.8	5.86	5.69	8.17	45.87

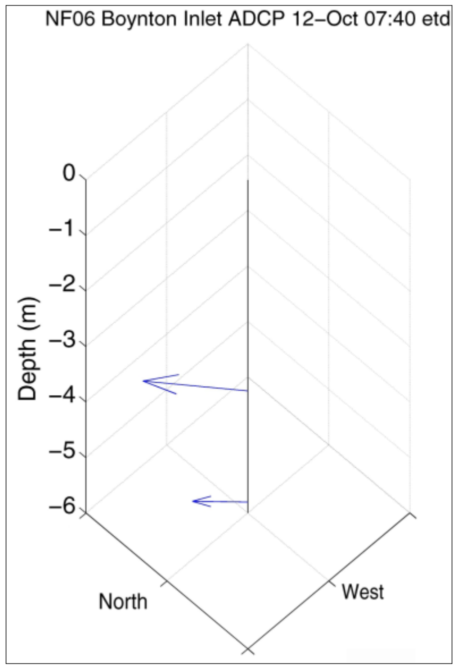

Figure 94. Plot of current vectors versus depth for the Boynton Inlet on October 12, 2006 at 07:40 EDT. Arrow lengths represent relative velocity (see Table 47 for values).

13.6 V-Fin

No V-Fin operations were conducted outside the Boynton Inlet.

14. C1-C2-C3 Transect

14.1 Station Locations

Three CTD casts were conducted off Broward County spanning the area from north of the Hollywood outfall to south of the Broward outfall (Figure 1). Table 48 lists the station locations and depths of the CTD casts. Table 49 lists the sediment sample locations and depths.

14.2 Nutrients

A total of nine nutrient samples were collected during CTD operations at the C1-C2-C3 transect. These results are listed in Table 50 for concentrations in µM, Table 51 for concentrations in mg/L, and are graphically shown in Figure 95.

Table 48. CTD sample locations for the C1-C2-C3 transect.

Station	Date	Latitude	Longitude	Depth (m)
C-1a	14-Oct	26.2002	-80.0715	1.4
C-1b	14-Oct	26.2002	-80.0715	3.8
C-1c	14-Oct	26.2002	-80.0715	11.4
C-2a	14-Oct	26.1300	-80.0820	1.5
C-2b	14-Oct	26.1300	-80.0820	9.4
C-2c	14-Oct	26.1300	-80.0820	17.6
C-3a	14-Oct	26.0639	-80.0906	1.1
C-3b	14-Oct	26.0639	-80.0906	11.1
C-3c	14-Oct	26.0639	-80.0906	18.3

Table 49. Sediment sample locations for the C1-C2-C3 transect.

Station	Date	Latitude	Longitude	Depth (m)
PE1	10-Oct	26.1400	-80.0687	58.8
PE2	10-Oct	26.1400	-80.0592	128.6
PE3	10-Oct	26.1401	-80.0299	200.0
PE4	10-Oct	26.1403	-79.9802	237.9

Table 50. Nutrient results in µM for the C1-C2-C3 transect. The last three lines are averaged values (BDL = below detection limit).

Station	Depth (m)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)
C1a	0.0	0.10	0.06	BDL	BDL	BDL
C1b	9.4	0.13	0.08	BDL	BDL	BDL
C1c	18.7	0.15	0.04	BDL	BDL	BDL
C2a	0.0	0.14	0.05	BDL	BDL	BDL
C2b	11.3	0.12	0.04	BDL	BDL	BDL
C2c	22.6	0.23	0.05	BDL	BDL	BDL
C3a	0.0	0.08	0.04	BDL	BDL	BDL
C3b	11.3	0.24	0.05	BDL	BDL	0.06
C3c	22.5	0.22	0.04	BDL	BDL	0.09
Surface	0.0	0.11	0.05	BDL	BDL	BDL
Mid	10.6	0.16	0.06	BDL	BDL	0.02
Bottom	21.3	0.20	0.04	BDL	BDL	0.03

Table 51. Nutrient results in mg/L for the C1-C2-C3 transect. The last three lines are averaged values (BDL = below detection limit).

Station	Depth (m)	N+N (μM)	NO_2 (μM)	NH_4 (μM)	P (μM)	Si (μM)
C1a	0.0	0.001	0.001	BDL	BDL	BDL
C1b	9.4	0.002	0.001	BDL	BDL	BDL
C1c	18.7	0.002	0.001	BDL	BDL	BDL
C2a	0.0	0.002	0.001	BDL	BDL	BDL
C2b	11.3	0.002	0.001	BDL	BDL	BDL
C2c	22.6	0.003	0.001	BDL	BDL	BDL
C3a	0.0	0.001	0.001	BDL	BDL	BDL
C3b	11.3	0.003	0.001	BDL	BDL	0.002
C3c	22.5	0.003	0.001	BDL	BDL	0.003
Surface	0.0	0.001	0.001	BDL	BDL	BDL
Mid	10.6	0.002	0.001	BDL	BDL	0.001
Bottom	21.3	0.003	0.001	BDL	BDL	0.001

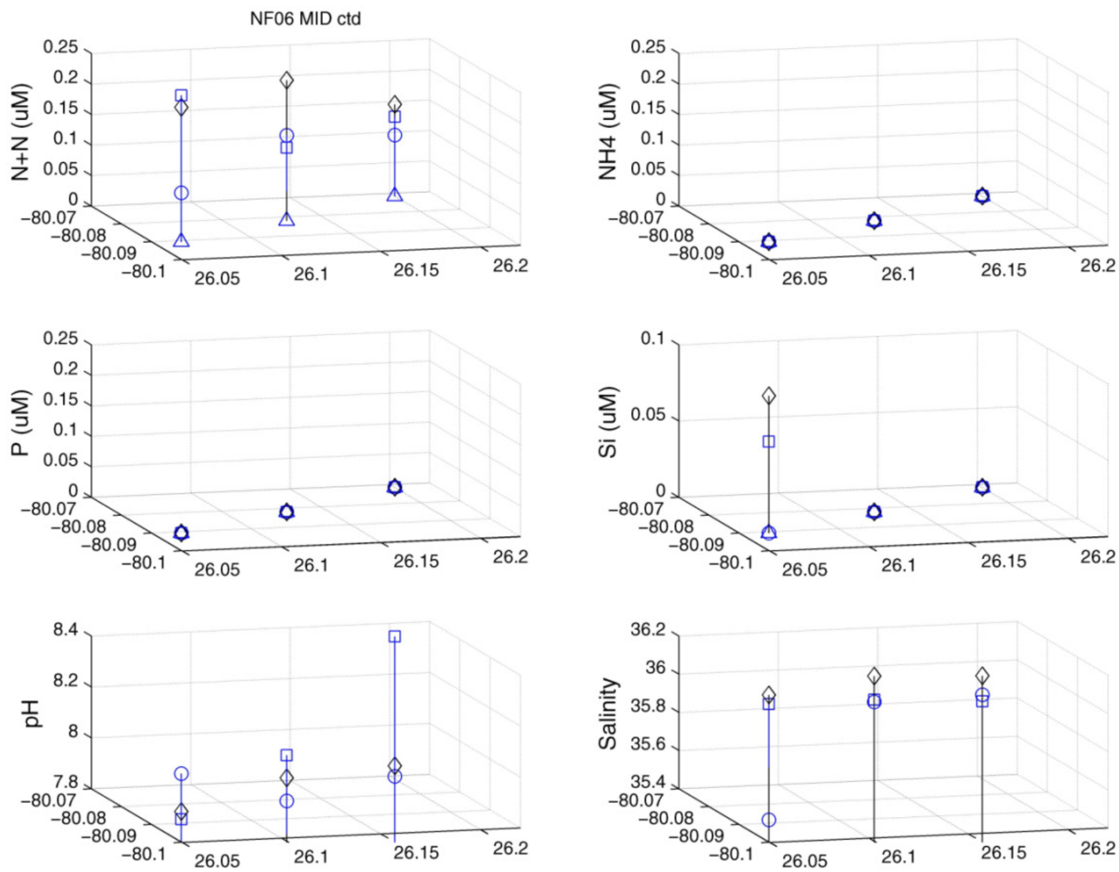

Figure 95. Three-dimensional presentation of nutrient results, pH, and salinity from CTD casts around the C1-C2-C3 transect. The format follows that of Figure 6. See Appendix 1 for tabulated data.

14.3 Chlorophyll and pH

A total of nine chlorophyll and pH samples were collected during CTD operations for the C1-C2-C3 transect. Table 52 lists the results for the chlorophyll and pH samples collected along with the temperature and salinity data for each depth sampled.

Table 52. Temperature, salinity, pH, chlorophyll-*a,* and phaeopigment results for the C1-C2-C3 transect. The last three lines are averaged values.

Station	Depth (m)	Temperature (°C)	Salinity (PSU)	pH	Chlorophyll-*a* (μg/L)	Phaeopigments (μg/L)
C1a	0	29.07	35.84	7.81	1.568	1.158
C1b	9.35	29.07	35.81	8.36	1.704	1.471
C1c	18.7	29.00	35.94	7.85	1.427	0.594
C2a	0	29.12	35.93	7.81	1.657	0.519
C2b	11.28	29.11	35.94	7.99	1.537	0.636
C2c	22.56	28.90	36.07	7.90	1.192	0.361
C3a	0	29.13	35.42	8.00	1.403	0.563
C3b	11.25	29.15	36.03	7.82	1.166	0.569
C3c	22.5	29.04	36.08	7.85	0.849	0.225
Surface	0.0	29.11	35.73	7.87	1.542	0.747
Mid	10.6	29.11	35.93	8.06	1.469	0.892
Bottom	21.3	28.98	36.03	7.87	1.156	0.393

14.4 CTD Casts

A total of three CTD casts were conducted at the C1-C2-C3 transect on October 14, 2006. Figures 96-98 show the temperature, salinity, and oxygen saturation for each station. Cast C1 results indicated a mixed water column; wind was from the north and strong (Figure 96). Cast C2 revealed a thermocline at 16 m but no change in salinity (Figure 97). Similarly, cast C3 found the thermocline at ~18 m (Figure 98). The depths and distances from shore were comparable to samples taken around the outfalls. C2 was north of the Port Everglades Inlet at a distance of 4.6 km; C3 was south of the inlet at a distance of 3.6 km.

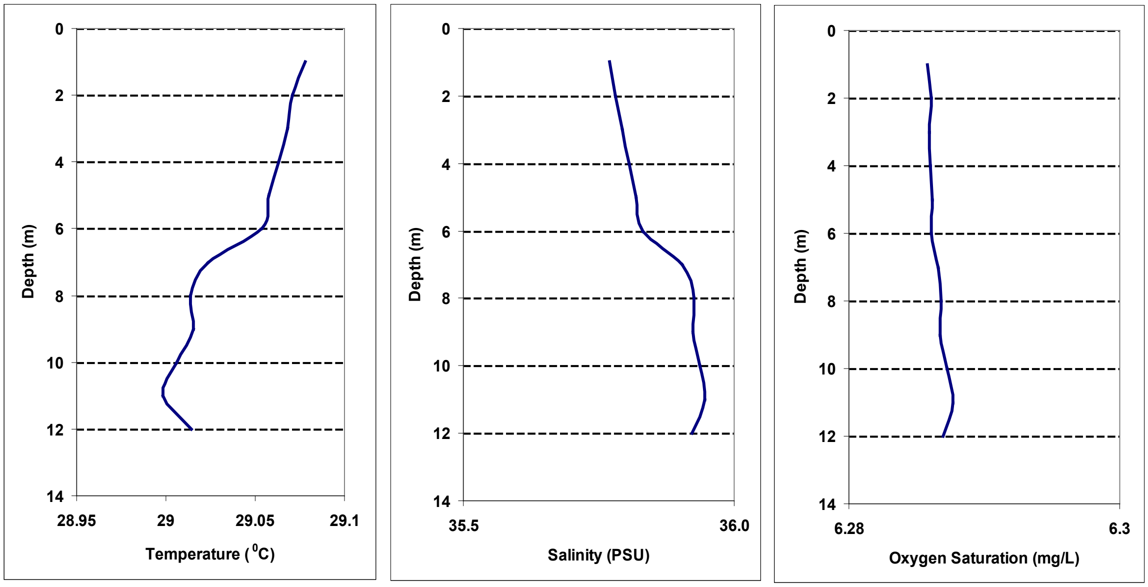

Figure 96. Temperature, salinity, and oxygen concentration profiles at station C-1.

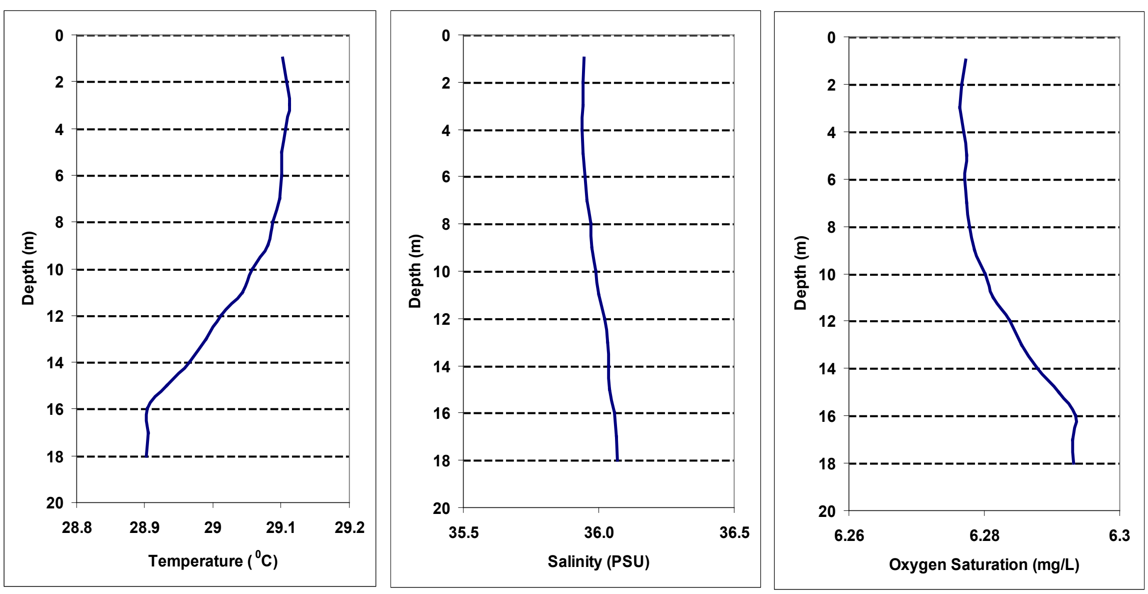

Figure 97. Temperature, salinity, and oxygen concentration profiles at station C-2.

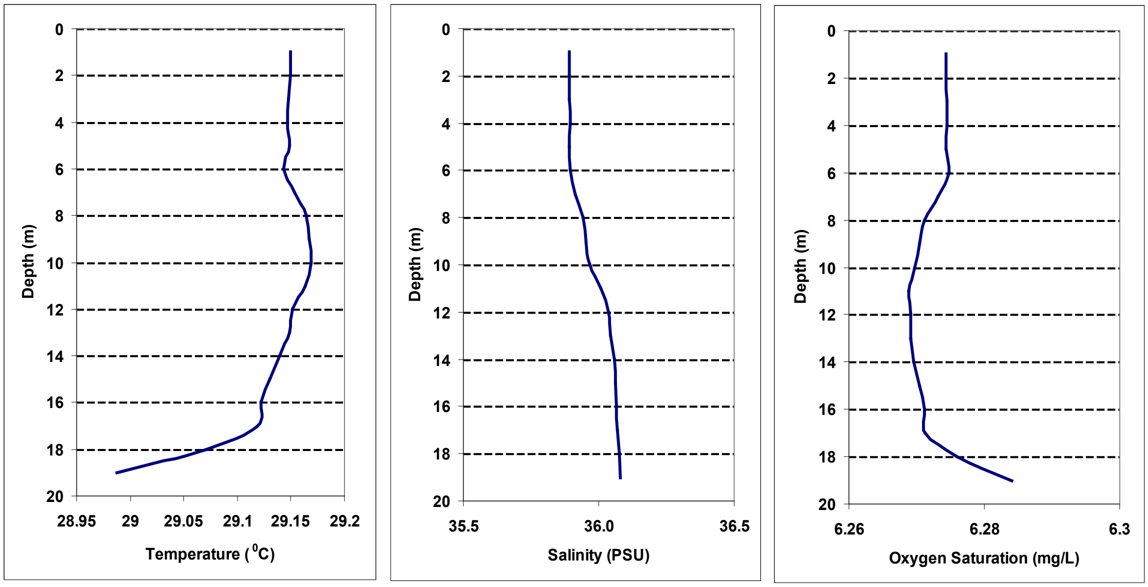

Figure 98. Temperature, salinity, and oxygen concentration profiles at station C-3.

14.5 Current Velocity and Direction

No ADCP operations were conducted for the C1-C2-C3 transect.

14.6 V-Fin

No V-Fin operations were conducted for the C1-C2-C3 transect.

15. Deep-Water Stations

15.1 Station Locations

CTD casts were conducted at three deep-water sites—Boca Raton Inlet (BRI), Port Everglades Inlet (PEI), and Miami Central Inlet (MCI)—shown in Figures 2 and 99. A total of six depths were sampled for each cast. These casts were conducted to collect information about the upwelled deep water that occurs at irregular times during the year. Table 53 lists the CTD sample locations and depths of the deep-water casts.

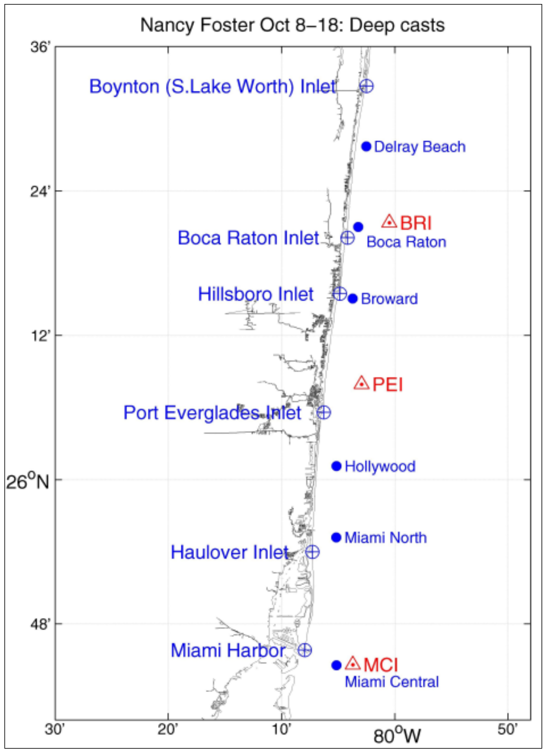

Figure 99. Location of the deep-water CTD cast sites.

Table 53. CTD sample locations for the deep-water sites.

Station	Date	Latitude	Longitude	Depth (m)
BRI-a	13-Oct	26.3561	-80.0081	1.1
BRI-b	13-Oct	26.3561	-80.0081	30.6
BRI-c	13-Oct	26.3561	-80.0081	61.0
BRI-d	13-Oct	26.3561	-80.0081	93.9
BRI-e	13-Oct	26.3561	-80.0081	127.6
BRI-f	13-Oct	26.3561	-80.0081	157.1
PEI-a	13-Oct	26.1323	-80.0488	2.0
PEI-b	13-Oct	26.1323	-80.0488	28.9
PEI-c	13-Oct	26.1323	-80.0488	55.7
PEI-d	13-Oct	26.1323	-80.0488	83.7
PEI-e	13-Oct	26.1323	-80.0488	125.4
PEI-f	13-Oct	26.1323	-80.0488	155.4
MCI-a	15-Oct	25.7432	-80.062	2.1
MCI-b	15-Oct	25.7432	-80.062	36.6
MCI-c	15-Oct	25.7432	-80.062	70.5
MCI-d	15-Oct	25.7432	-80.062	102.1
MCI-e	15-Oct	25.7432	-80.062	120.3
MCI-f	15-Oct	25.7432	-80.062	133.2

15.2 Nutrients

A total of 15 nutrient samples were collected during CTD operations of the deep-water sites. These results are listed in Table 54 for concentrations in µM, Table 55 for concentrations in mg/L, and graphically in Figure 100. Locations of the sites are shown in Figure 2.

Table 54. Nutrient results in µM for the deep-water sites (BDL = below detection limit).

Station	Depth (m)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)
BRI-a	1.1	0.10	BDL	BDL	BDL	0.22
BRI-b	30.6	BDL	BDL	BDL	BDL	0.19
BRI-c	61.0	0.10	0.10	BDL	BDL	0.61
BRI-d	93.9	1.38	0.22	BDL	BDL	1.37
BRI-e	127.6	7.97	0.07	BDL	0.39	5.20
BRI-f	157.1	13.92	0.02	BDL	1.03	8.02
PEI-a	2.0	0.20	0.01	BDL	BDL	0.64
PEI-b	28.9	0.01	BDL	BDL	BDL	0.50
PEI-c	55.7	0.03	0.01	BDL	BDL	0.77
PEI-d	83.7	2.43	0.27	BDL	0.03	2.20
PEI-e	125.4	6.56	0.06	BDL	0.38	4.26
PEI-f	155.4	14.56	0.02	BDL	1.27	9.38
MCI-a	2.1	0.09	0.04	BDL	0.05	0.46
MCI-b	36.6	0.05	0.03	BDL	0.03	0.30
MCI-c	70.5	0.28	0.26	BDL	0.04	0.54
MCI-d	102.1	2.91	0.25	BDL	0.25	2.20
MCI-e	120.3	8.25	0.09	BDL	0.64	4.65
MCI-f	133.2	10.88	0.04	0.64	1.44	6.52

Table 55. Nutrient results in mg/L for the deep-water sites (BDL = below detection limit).

Station	Depth (m)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)
BRI-a	1.1	0.001	BDL	BDL	BDL	0.006
BRI-b	30.6	0.000	BDL	BDL	BDL	0.005
BRI-c	61.0	0.001	0.001	BDL	BDL	0.017
BRI-d	93.9	0.019	0.003	BDL	BDL	0.038
BRI-e	127.6	0.112	0.001	BDL	0.012	0.146
BRI-f	157.1	0.195	BDL	BDL	0.032	0.225
PEI-a	2.0	0.003	BDL	BDL	BDL	0.018
PEI-b	28.9	0.000	BDL	BDL	BDL	0.014
PEI-c	55.7	0.000	BDL	BDL	BDL	0.022
PEI-d	83.7	0.034	0.004	BDL	0.001	0.062
PEI-e	125.4	0.092	0.001	BDL	0.012	0.119
PEI-f	155.4	0.204	BDL	BDL	0.039	0.263
MCI-a	2.1	0.001	0.001	BDL	0.002	0.013
MCI-b	36.6	0.001	BDL	BDL	0.001	0.008
MCI-c	70.5	0.004	0.004	BDL	0.001	0.015
MCI-d	102.1	0.041	0.004	BDL	0.008	0.062
MCI-e	120.3	0.116	0.001	BDL	0.020	0.130
MCI-f	133.2	0.152	0.001	0.009	0.045	0.183

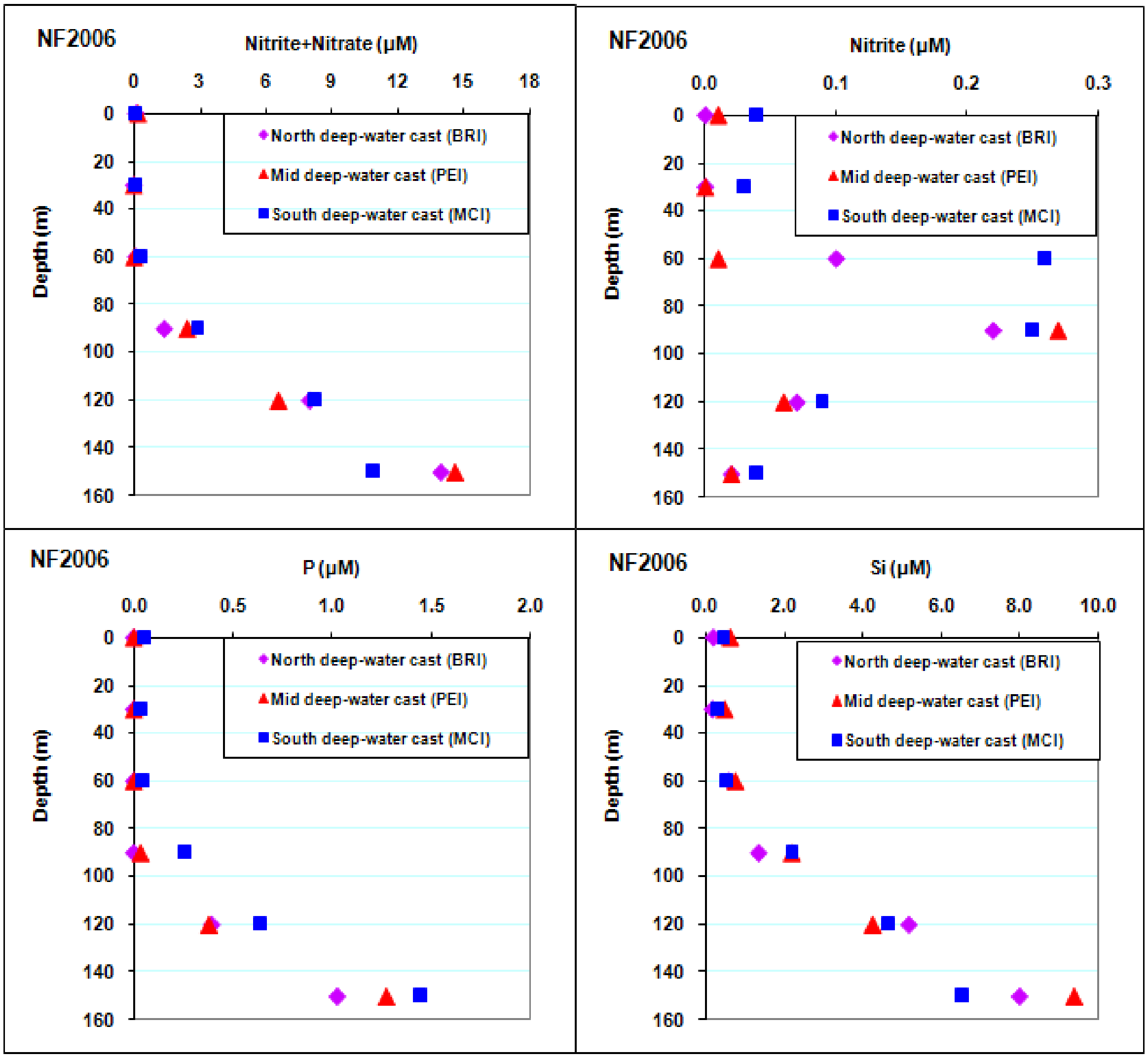

Figure 100. Nutrient results (N+N, nitrate, orthophosphate, and silica) in µM for the three deep-water sites versus depth.

15.3 Chlorophyll and pH

A total of nine chlorophyll and 15 pH samples were collected during CTD operations for the deep-water sites. Table 56 lists the results for the chlorophyll and pH samples collected, along with the temperature and salinity data for each depth sampled. Figure 101 graphically displays these data.

Table 56. Temperature, salinity, pH, chlorophyll-*a*, and phaeopigment results for the deep-water sites.

Station	Depth (m)	Temperature (°C)	Salinity (PSU)	pH	Chlorophyll-*a* (µg/L)	Phaeopigments (µg/L)
BRI-a	1.1	29.30	36.06	8.09	0.164	0.055
BRI-b	30.6	28.98	36.15	8.11	0.242	0.084
BRI-c	61.0	27.91	36.22	8.07	N/A	N/A
BRI-d	93.9	23.49	36.45	7.99	N/A	N/A
BRI-e	127.6	18.35	36.21	7.89	N/A	N/A
BRI-f	157.1	14.95	35.94	7.79	0.014	0.039
PEI-a	2.0	29.16	36.05	8.09	0.242	0.058
PEI-b	28.9	28.98	36.16	8.09	0.177	0.058
PEI-c	55.7	28.24	36.20	8.02	N/A	N/A
PEI-d	83.7	24.89	36.36	7.98	N/A	N/A
PEI-e	125.4	19.46	36.32	7.89	N/A	N/A
PEI-f	155.4	14.49	35.86	7.77	0.025	0.046
MCI-a	2.1	28.87	36.18	8.08	0.166	0.042
MCI-b	36.6	28.88	36.18	8.05	0.173	0.052
MCI-c	70.5	28.05	36.20	8.03	N/A	N/A
MCI-d	102.1	22.70	36.39	7.96	N/A	N/A
MCI-e	120.3	18.12	36.25	7.85	N/A	N/A
MCI-f	133.2	16.55	36.12	7.81	0.026	0.049

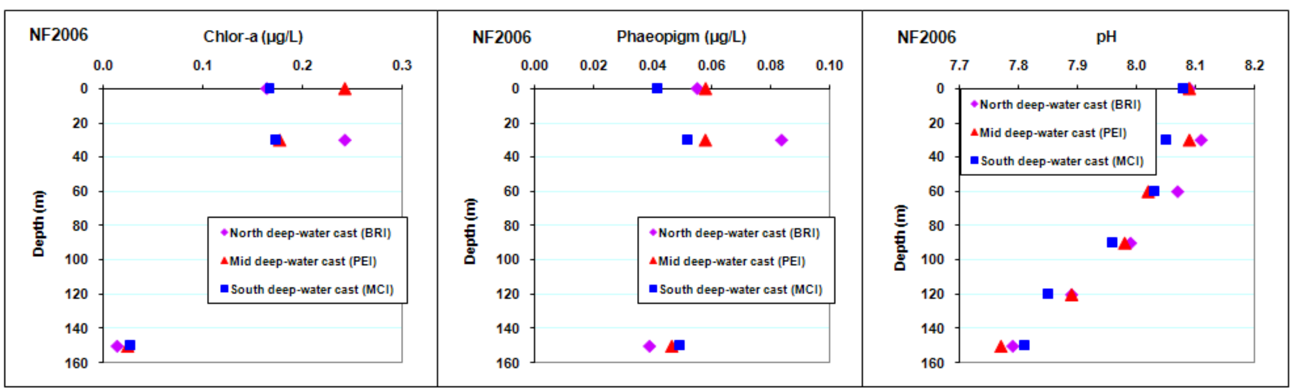

Figure 101. Chlorophyll-*a*, phaeopigments (in µg/L), and pH for the three deep-water sites versus depth.

15.4 CTD Casts

A total of three CTD casts were conducted at deep-water sites. At each station, the CTD obtained a sample near the bottom, at mid depth, and near the surface. Figures 102-104 show the temperature, salinity, and oxygen saturation for each station. A thermocline at ~100 m was seen in MCI but is less distinct in BRI and PEI. A salinity maximum at that depth was observed in all three casts.

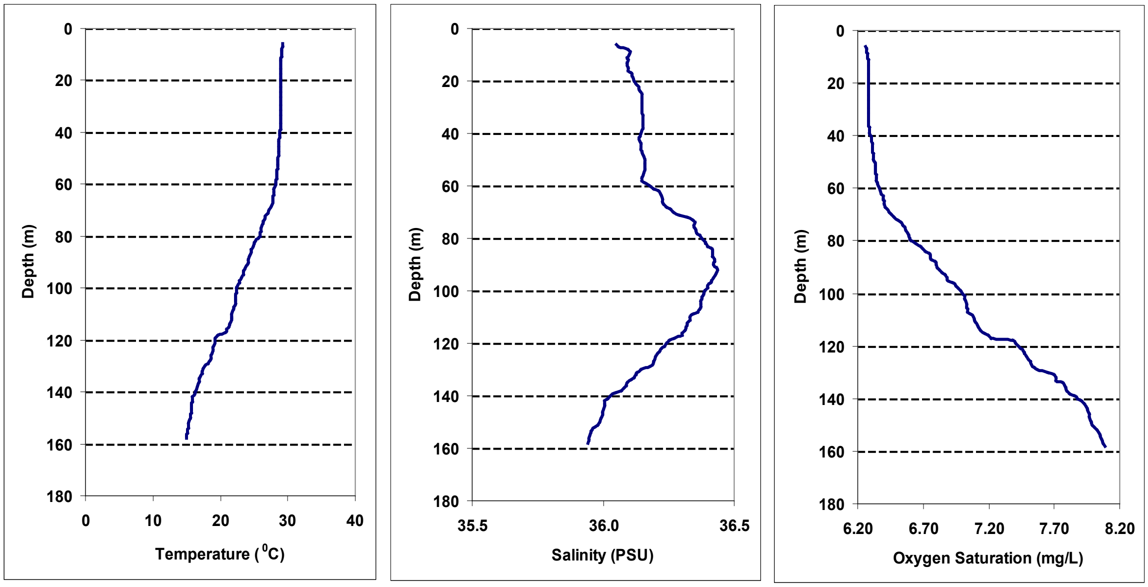

Figure 102. Temperature, salinity, and oxygen concentration profiles at station BRI on October 13, 2006.

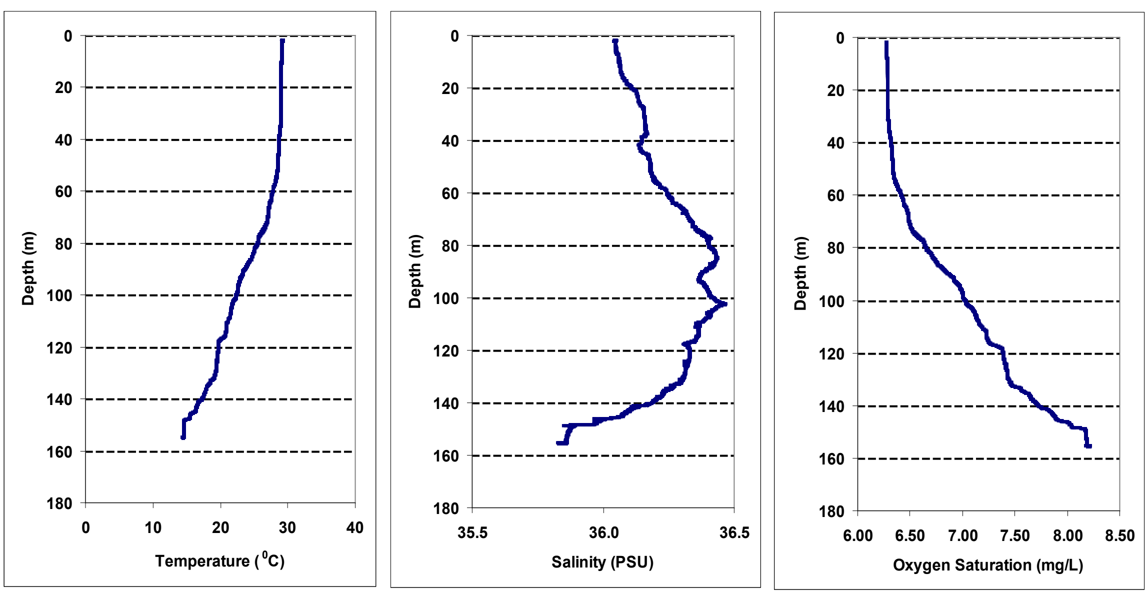

Figure 103. Temperature, salinity, and oxygen concentration profiles at station PEI on October 14, 2006.

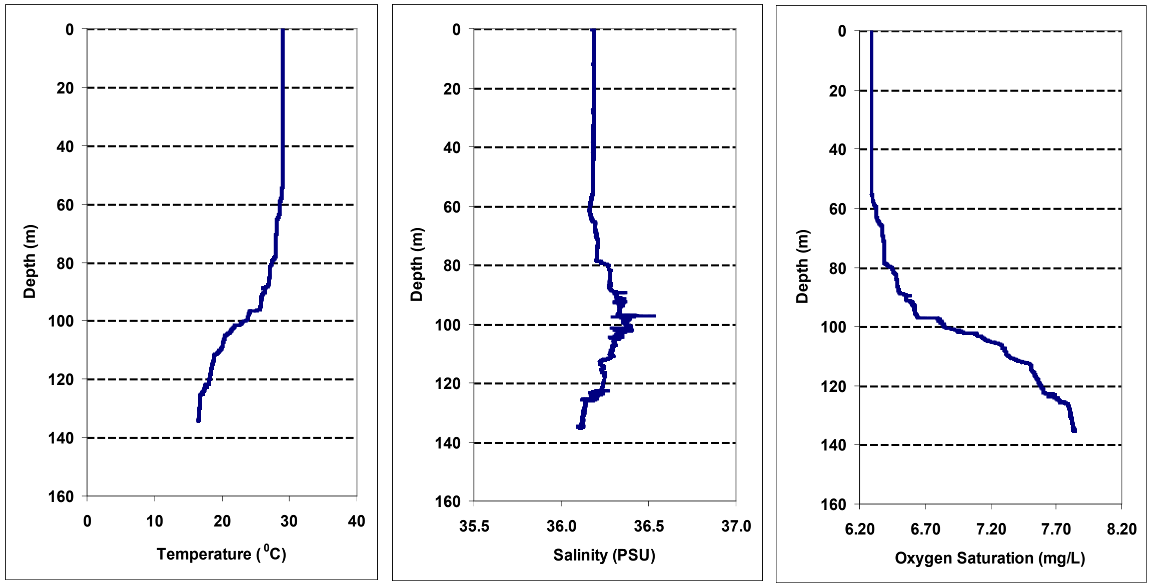

Figure 104. Temperature, salinity, and oxygen concentration profiles at station MCI on October 15, 2006.

15.5 Current Velocity and Direction

No ADCP operations were conducted for the deep-water sites.

15.6 V-Fin

No V-Fin operations were conducted for the deep-water sites.

16. Microbiological Results

A total of 177 microbiological analyses were performed on samples collected from the 2006 RV *Nancy Foster* cruise. For surface water samples, 24 were analyzed by IDEXX for enterococci, and 11 samples were analyzed by membrane filtration for each of the following: enterococci, *E. coli*, *Bacteroides* spp., and *S. aureus*. Six samples were analyzed for *Cryptosporidium* and *Giardia*, and eight samples were analyzed for the following viruses: enterovirus, norovirus, and coliphage.

For CTD samples (bottom depth), 11 samples were analyzed by IDEXX for enterococci, five samples were analyzed by membrane filtration for enterococci, *E. coli*, *Bacteroides* spp., and *S. aureus*, and five samples were analyzed for enterovirus, norovirus, and coliphage. A total of 69 samples were analyzed by PCR for a variety of targets (see section 6.5). Tables 57-62 provide a summary of the data. Overall, the frequency of target detection appeared to be higher for the southern boils compared to the northern boils. This finding is consistent with the higher discharge rates expected for the southern boils (Table 1; EPA, 2003b; Koopman *et al*., 2006).

The viable enterococci counts in boil samples were low, ranging from <1-5 colony-forming units (CFU) per 100 ml (Table 57), and no samples were over EPA guidelines for recreational water quality (EPA, 2003a). Enterococci concentrations in the sediment samples were generally low, although relatively high concentrations were observed at the Broward outfall site (Table 58). Currently, there are no EPA guidelines in place for enterococci in sediment. The concentrations of *Bacteroides* spp. were also low for all of the samples tested.

Table 57. Microbiological analysis of water collected from the six outfall boil surfaces (srf)[1] and near the bottom of the water column (btm) by CTD Niskin bottle (see Table 1 for outfall abbreviations; NP = not performed).

Microbiological analysis	SC srf	SC btm	BC srf	BC btm	BR srf	HW srf[2]	HW srf	HW btm	MN srf	MN btm	MC srf	MC btm
Enterococci IDEXX (MPN/100 ml)	<1	<1	<1	3	1	<1	<1	21	5	10	<1	<1
Enterococci (CFU/100 ml)	<1	<1	<1	<1	<1	5	1	4	<1	<1	<1	1
E. coli (CFU/100 ml)	>67	>67	>67	>67	>40	>50	25	>50	>50	>50	48	>50
S. aureus (CFU/100 ml)	22	>100	<1	1	1	>50	5	>25	>50	>50	5	<1
Bacteroides (CFU/100 ml)	<1	<1	<1	<1	<1	3	<1	<1	<1	<1	<1	<1
Cryptosporidium (oocysts/100 L)	NP	NP	<1.1	NP	8	55	17	NP	8	NP	235	NP
Giardia (cysts/100 L)	NP	NP	<1.1	NP	2	68	19	NP	120	NP	146	NP

[1]Surface samples were collected by bucket except for *Cryptosporidium* and *Giardia* analyses which utilized the ship's flow through system to filter water through a Filta-Max column.
[2]The Hollywood boil was sampled twice during this cruise (October 15 and 17, 2006); the bottom was sampled on October 17, 2006.

Table 58. Microbiological analysis of sediment samples collected near the six outfall pipes by Shipek.

Station ID	SC-19	BC-15	BR-15e	HW-19a	MN-1BC	MC-16
Enterococci IDEXX (MPN/100 ml)	<1	<1	665	1	1	10

Compared to enterococci, more bacteria were obtained on mTEC plates designed to enumerate *E. coli*. Most of the plates had confluent growth, so exact concentrations were only obtained for two of the sites (HW and MC, Table 57). The other values given in Table 57 were calculated assuming that confluent growth consisted of at least 600 CFU. Confluent growth was also observed on mTEC plates for two of the inlet sites (BRI and MCI, Table 59).

Table 59. Microbiological analysis of surface water from inlets (NP = not performed).

	Inlets			
Microbiological analysis	Boynton	Broward	Port Everglades	Miami Central
Enterococci IDEXX (MPN/100 ml)	5	<1	<1	<1
Enterococci (CFU/100 ml)	1	0	<1	<1
E. coli (CFU/100 ml)	<1	>17	5	>50
S. aureus (CFU/100 ml)	<1	1	1	1
Bacteroides (CFU/100 ml)	<1	<1	<1	<1
Cryptosporidium (cysts/100 L)	NP	NP	NP	NP
Giardia (cysts/100 L)	NP	NP	NP	NP

Confluent growth was also obtained on SCA plates designed to enumerate *S. aureus* for some of the outfalls (SC, HW, and MN) (Table 57). All of the filters used for *S. aureus* enumeration were also processed for total DNA extraction; however, positive detection of *S. aureus* by PCR was only obtained for the Miami-Dade North and Miami-Dade Central outfalls (Table 57). This finding opens the possibility that at least some of the mauve growth seen on the SCA plates were not true *S. aureus* colonies. Nonetheless, the growth on SCA plates was markedly higher from outfall samples compared to inlet samples (Table 59). There was a pattern of more *S. aureus* detection in the southern boils compared to the northern boils.

Cryptosporidium and *Giardia* were detected in the boil water of four of the five tested outfalls (BR, HW, MN, and MC). The Hollywood outfall was tested twice, and concentrations of *Cryptosporidium* ranged from 17-55 oocysts/100 L and concentrations of *Giardia* ranged from 19-68 cysts/100 L. Relatively high concentrations of *Giardia* were seen in the Miami-Dade North boil (120 cysts/100 L) and of both *Giardia* and *Cryptosporidium* in the Miami-Dade Central boil (146 and 235 per 100 L, respectively).

Although *Cryptosporidium* and *Giardia* are specifically mentioned as organisms of concern by the EPA (2003b) and this reference is cited by Koopman *et al.* (2006), little information was located regarding the concentration of these parasites in marine outfall areas. Information is more readily available for source water, effluents, and rivers. For example, treated wastewater effluent can contain 1×10^4 *Cryptosporidium* cysts/100 L; whereas, "pristine" waters may contain 0.1 cysts/100 L (National Research Council, 2004). Johnson *et al.* (1995) did report results from the bottom of an outfall in Hawaii. A range of 7-22/100 L of *Giardia* and *Cryptosporidium* was reported in that study.

Higher concentrations of *Cryptosporidium* and *Giardia* were observed in south Florida in comparison to an outfall in Hawaii (Johnson *et al.,* 1995). However, the results are not directly comparable because the boil rather than the bottom was sampled in this study (Table 60). One might assume that boil concentrations would be lower than bottom samples because the buoyant plume dilutes rapidly as it rises (Koopman *et al.,* 2006). However, the buoyant plume is relatively narrow at the point of discharge compared to the boil (EPA, 2003b); thus, samples collected via Niskin bottle from the bottom of the water column were unlikely to represent pure end-of-pipe effluent. This appears to be the case here because bottom samples were more saline than boil samples. The method of concentration also differed between the two studies. The Filta-Max method used in this study yielded higher recoveries than a variety of other protocols (Lee *et al.,* 2004), including one of those used for the outfall in Hawaii. Concentration efficiency for the Filta-Max method was estimated to be >70% according to the manufacturer's website (www.idexx.com/water/filtamax/). Lee *et al.* (2004) found Filta-Max recovery of *Cryptosporidium parvum* oocysts to range from 40-97% depending on the sample type, turbidity, and dose of spike.

It should be noted that EPA Method 1623 (EPA, 2001) does not provide information about viability/infectivity of the cysts or oocysts. Survival of *Cryptosporidium* and *Giardia* in marine waters was reported by Johnson *et al.* (1997). Survival was dependent on light, salinity, and turbidity. The estimated time for 90% inactivation of *Cryptosporidium* in marine water was 2 days in the light and 4 days in the dark. The estimated time for 90% inactivation of *Giardia* in marine water was <2 hours in the light and >2 days in the dark.

Table 60. PCR analysis of surface water collected from the outfall boil sites (srf) by bucket and from water collected near the bottom of the water column (btm) by CTD Niskin bottle.

PCR analysis	SC srf	SC btm	BC srf	BC btm	BR srf	HW srf[1]	HW srf	HW btm	MN srf	MN btm	MC srf	MC btm
Enterococci	-	-	-	-	-	+	+	-	+	-	+	-
Human-specific enterococci	-	-	-	-	-	-	-	-	-	+	+	+
Human-specific *Bacteroides*	-	-	-	-	-	+	-	-	-	-	+	-
Salmonella spp.	-	-	-	-	-	-	-	-	-	-	-	+
E. coli 0157:H7	-	-	-	-	-	-	-	-	-	-	-	-
C. jejuni	-	-	-	-	-	-	-	-	-	-	-	-
S. aureus	-	-	-	-	-	-	-	-	+	+	+	+

[1]The Hollywood boil was sampled twice during this cruise (October 15 and 17, 2006); the bottom was sampled on October 17, 2006.

Differences in the frequency of detection of enterovirus were observed for the Taqman qPCR method conducted by the NOAA laboratory in Charleston, South Carolina and for the commercial Cepheid qPCR assay conducted at AOML in Miami, Florida (Table 61). The commercial Cepheid assay detected enterovirus in eight samples comprising the four southern outfalls, whereas the other method did not detect enterovirus in these particular samples. Information on the primer and probe sequences and detection sensitivity of the commercial Cepheid assay is proprietary and not available from Cepheid at this time; therefore, it is not possible to fully evaluate the possible reasons for the performance differences observed between the two assays. The RNA extraction methods for the two assays were also different, and differences in extraction performance can effect detection (Tables 61-62). Nonetheless, the geographic pattern of detection by the Cepheid assay was consistent with the pattern of other microbial contaminants in that detection tended to be more frequent at the southern boils.

Table 61. PCR analysis[1] of viruses in surface water collected from the outfall boil sites (srf) by bucket and from water collected near the bottom of the water column (btm) by CTD Niskin bottle (BI = Boynton Inlet; NP = not performed).

Molecular analysis	SC srf	SC btm	BC srf	BC btm	BR srf	HW srf[2]	HW srf	HW btm	MN srf	MN btm	MC srf	MC btm	BI
Noroviruses GI	-	NP	-	-	-	-	-	-	-	-	-	-	-
Noroviruses GII	-	NP	-	-	-	-	+	-	-	+	+	-	-
Noroviruses (Cepheid)	-	-	-	-	-	-	-	-	+	+	+	+	NP
Enteroviruses	-	NP	-	-	-	-	-	-	-	-	-	-	-
Enteroviruses (Cepheid)	-	-	-	-	+	+	+	+	+	+	+	+	NP
Coliphage MS2	-	NP	-	-	-	+	-	-	+	+	+	-	-

[1]Analyses performed by the NOAA laboratory in Charleston, South Carolina except for Cepheid analyses, which were performed by NOAA/AOML in Miami, Florida.
[2]The Hollywood boil was sampled twice during this cruise (October 15 and 17, 2006); the bottom was sampled on October 17, 2006.

Table 62. Expansion of Table 61 showing the viral analyses[1] in which results differed depending on the method of RNA extraction.

Molecular analysis	SC srf	SC btm	BC srf	BC btm	BR srf	HW srf	HW srf	HW btm	MN srf	MN btm	MC srf	MC btm	BI
						CEFAS extraction							
Norovirus GII	-	NP	-	-	-	-	-	-	-	+	+	-	-
Coliphage MS2	-	NP	-	-	-	+	-	-	+	+	-	-	-
						Qiagen extraction							
Norovirus GII	-	NP	-	-	-	-	-	+	-	+	+	-	-
Coliphage MS2	-	NP	-	-	-	-	-	-	-	+	+	-	-

[1]Analyses performed by the NOAA laboratory in Charleston, South Carolina (by J. Stewart and J. Gregory).

17. Auxiliary Data

17.1 ADCP Data from GSR-N and GSR-S

An ADCP was installed at a site at the north end of the Gulf Stream Reef (GSR-N) on July 25, 2006 at a depth of 52 feet below mean sea level, at the location 26°31.247'N, 80°1.939'W. A second ADCP unit, GSR-S, was installed on September 29, 2006 at 26°29.272'N, 80°2.350'W (see Figure 105). A subset of these data, which include the time period of the RV *Nancy Foster* cruise, is shown in Figures 106 (GSR-N) and 107 (GSR-S).

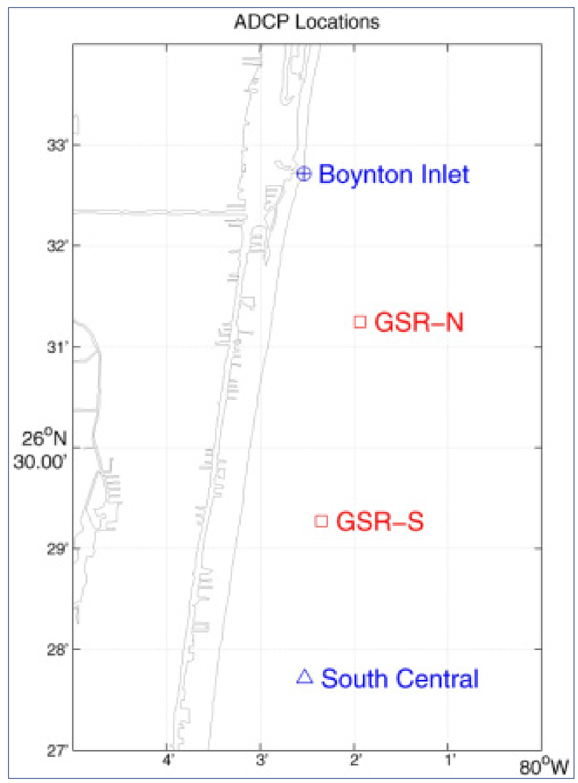

Figure 105. Map that depicts the location of the two ADCP instruments (GSR-N and GSR-S) installed in the area of the 2006 RV *Nancy Foster* cruise.

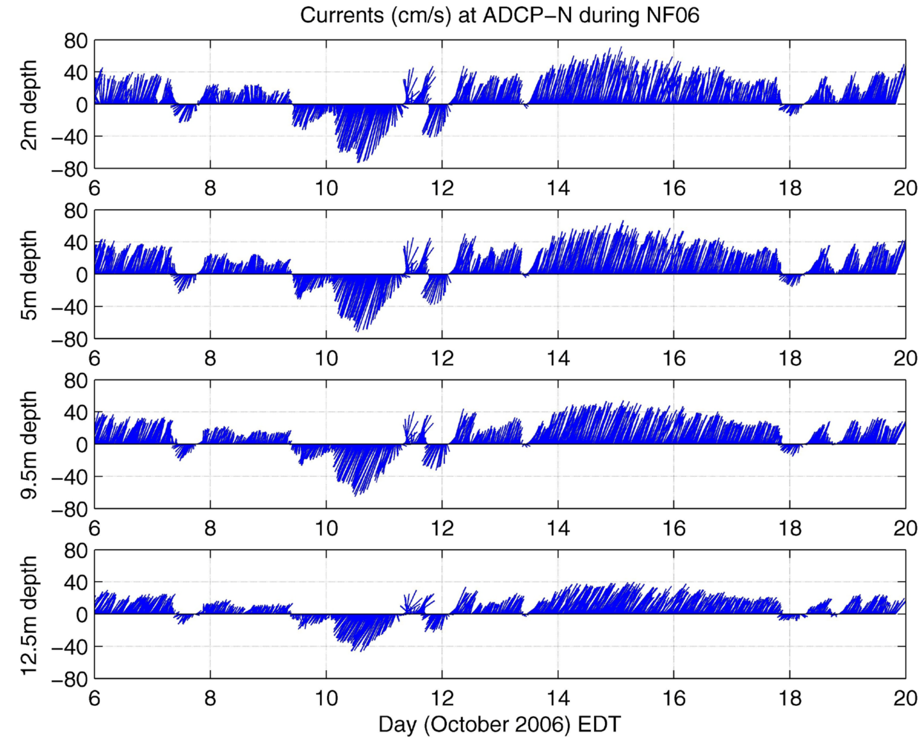

Figure 106. Stick plots of current data from the GSR-N ADCP instrument at depths near the surface (upper panel) to lower depths (lower panels). During most of Leg 3 (beginning on October 12, 2006), where the water sampling occurred, the ocean current at GSR-N was northerly.

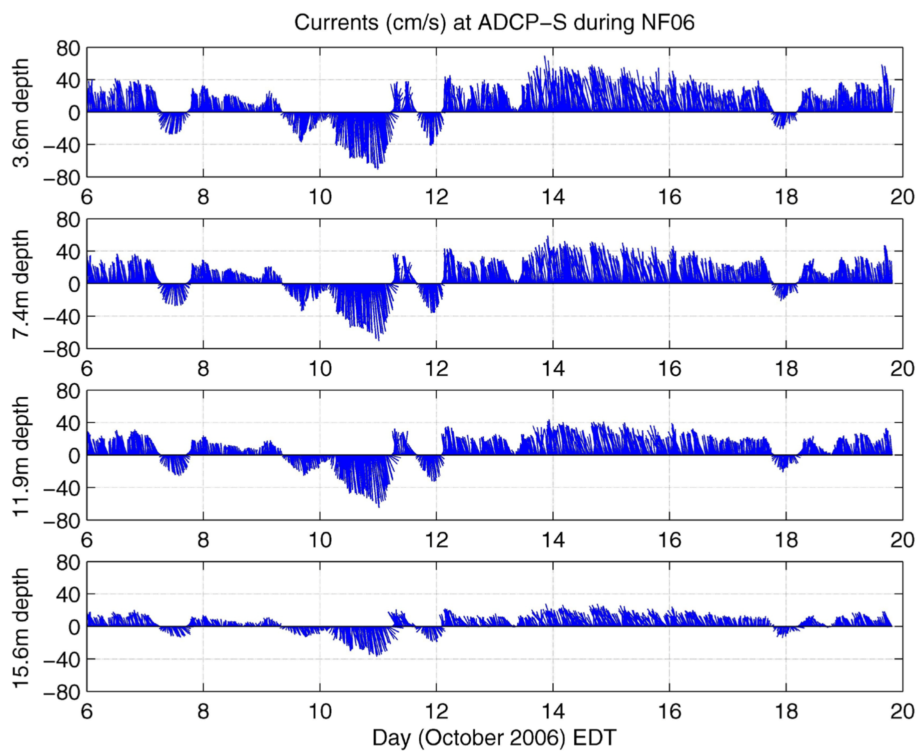

Figure 107. Stick plots of current data from the GSR-S ADCP instrument at depths near the surface (upper panel) to lower depths (lower panels). As with GSR-N, the current at GSR-S was northerly.

17.2 LKWF1 Meteorological Data

Meteorological data are continuously recorded from the Coastal-Marine Automated Network (C-MAN) station LKWF1 located in Lake Worth, Florida at 26°36'42"N 80°2'0"W. These data are stored at NOAA's National Data Buoy Center (http://www.ndbc.noaa.gov/ station_page.php?station=LKWF1). Figure 108 displays wind speed data from the LKWF1 station that correspond with the dates of the 2006 RV *Nancy Foster* FACE cruise.

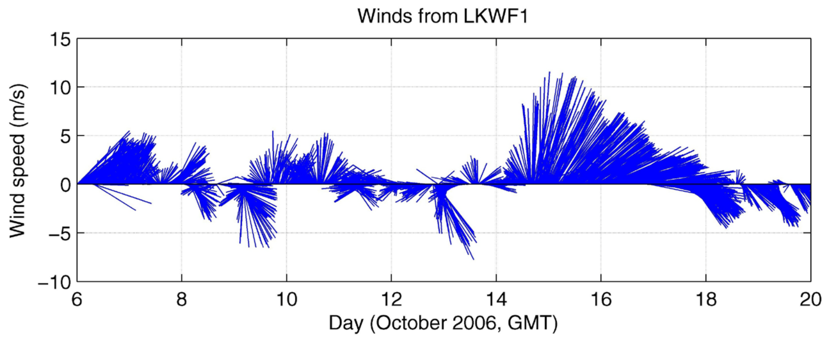

Figure 108. Wind barbs indicating direction toward which wind was blowing. Wind velocity is proportional to the length of the barb, according to the axis on the left. Data was obtained from the LKWF1 C-MAN station in Lake Worth, Florida (north of the Boynton Inlet).

17.3 Ship's Meteorological Data

The RV *Nancy Foster* records a suite of meteorological data. A subset of this data, the ship's true wind speed, is shown in Figure 109 for the time period of Leg 3.

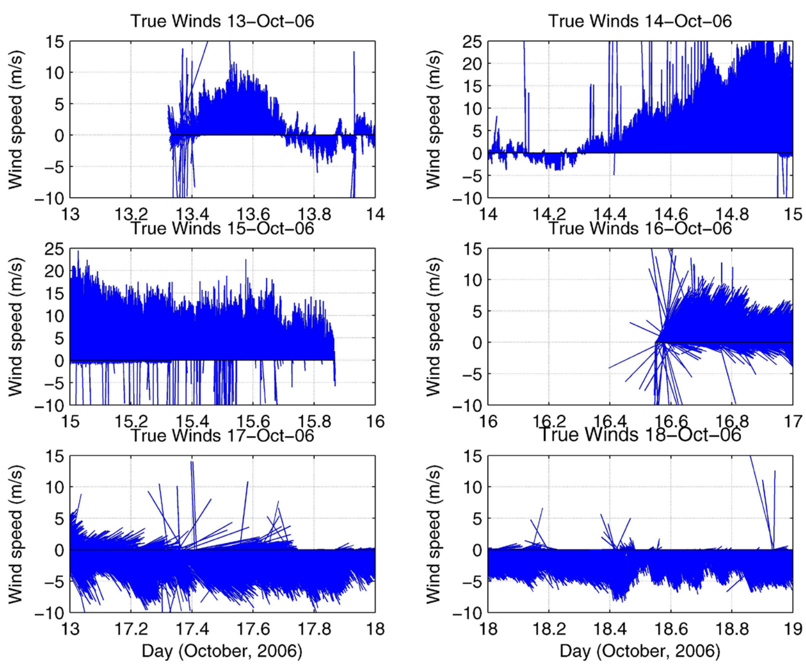

Figure 109. True wind speed data depicted as wind barbs gathered during Leg 3 of the 2006 FACE cruise aboard the RV *Nancy Foster*. These data were obtained by correcting mast wind speed and direction for the ship's orientation and motion.

17.4 Sea Grass Sampling Project

A companion project to the cruise was a project to obtain samples of sea grass and sediments from various locations near the six ocean outfalls. This project was accomplished with the assistance of various diving organizations in the area. Figure 110 provides a graphic presentation of the locations of the sample sites. Location data are provided in Table 63. Results are presented in Swart and Drayer (2007) and briefly summarized in Section 17.5.

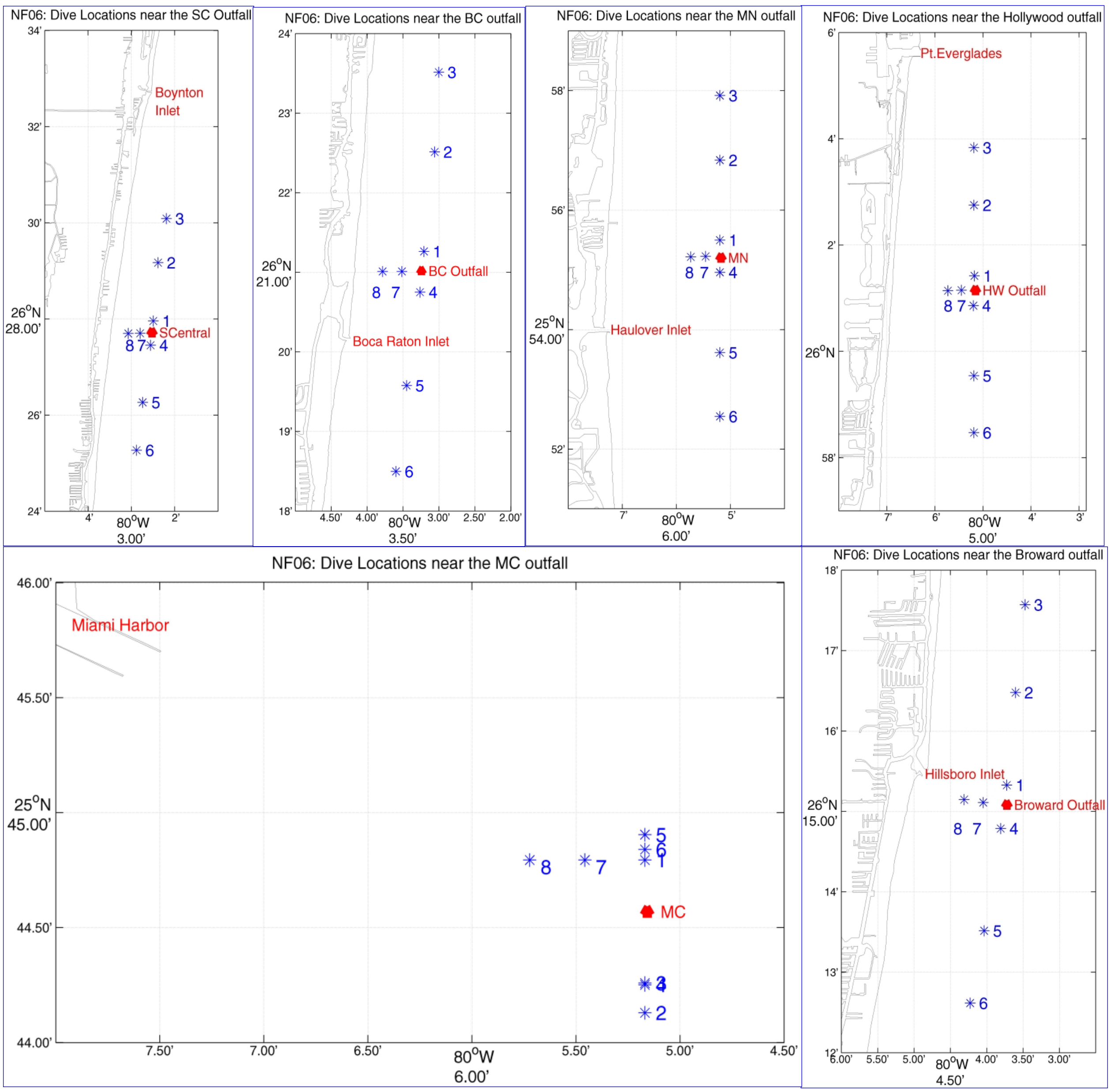

Figure 110. Location of the dive sites visited to obtain sea grass and sediment samples.

Table 63. Sea grass sampling locations.

Station	Depth (m)	Latitude	Longitude	Station	Depth (m)	Latitude	Longitude
SC-1	95	26°27.9583	80°2.4945	BC-1	89	26°21.2625	80°3.2079
SC-2	75	26°29.1716	80°2.3854	BC-2	89	26°22.5127	80°3.0590
SC-3	79	26°30.0875	80°2.1898	BC-3	95	26°23.5147	80°3.0032
SC-4	95	26°27.4531	80°2.5582	BC-4	89	26°20.7506	80°3.2638
SC-5	92	26°26.2655	80°2.7414	BC-5	98	26°19.5780	80°3.4499
SC-6	92	26°25.2684	80°2.8814	BC-6	79	26°18.4983	80°3.5988
SC-7	66	26°27.7021	80°2.7991	BC-7	59	26°21.0112	80°3.5151
SC-8	36	26°27.6980	80°3.0708	BC-8	36	26°21.0112	80°3.7849
BR-1	118	26°15.3269	80°3.7249	HW-1	112	26°1.4216	80°5.1787
BR-2	105	26°16.4779	80°3.6050	HW-2	98	26°2.7522	80°5.1887
BR-3	105	26°17.5690	80°3.4731	HW-3	85	26°3.8327	80°5.1887
BR-4	112	26°14.7874	80°3.8088	HW-4	112	26°0.8614	80°5.1987
BR-5	98	26°13.5166	80°4.0366	HW-5	112	25°59.5408	80°5.1887
BR-6	95	26°12.6173	80°4.2284	HW-6	105	25°58.4703	80°5.1887
BR-7	82	26°15.1111	80°4.0486	HW-7	85	26°1.1515	80°5.4488
BR-8	52	26°15.1471	80°4.3123	HW-8	69	26°1.1415	80°5.7289
MN-1	115	25°55.4987	80°5.1970	MC-1	115	25°44.7940	80°5.1688
MN-2	138	25°56.8378	80°5.1970	MC-2	112	25°44.1298	80°5.1688
MN-3	102	25°57.9197	80°5.1970	MC-3	98	25°44.2588	80°5.1688
MN-4	105	25°54.9600	80°5.1970	MC-4	112	25°44.2511	80°5.1688
MN-5	115	25°53.6157	80°5.1970	MC-5	118	25°44.9045	80°5.1688
MN-6	118	25°52.5478	80°5.1970	MC-6	125	25°44.8395	80°5.1688
MN-7	75	25°55.2270	80°5.4600	MC-7	95	25°44.7940	80°5.4570
MN-8	66	25°55.2173	80°5.7337	MC-8	79	25°44.7940	80°5.7221

17.5 Stable Isotopes Project

A total of 110 samples for sedimentary organic material were obtained from sites stretching from Miami to West Palm Beach (Figure 3). The sites were arranged in a grid pattern designed to capture any chemical signature associated with the sewage outfalls. Of these samples, 67 were analyzed for stable N and C isotopic composition, as described in Swart and Drayer (2007), yielding a mean value for N of +2.86‰ and for C of -17.64‰. In addition, 206 algal samples were collected from 48 sampling sites. These yielded a nitrogen isotopic composition of +4.86‰ and a carbon isotopic composition of -19.46‰ (Figure 111). No significant differences were apparent among the sites. Therefore, these algal and sediment samples showed no conclusive proof of anthropogenic-associated nitrogen influencing the algal samples. A more complete report is available in Swart and Drayer (2007).

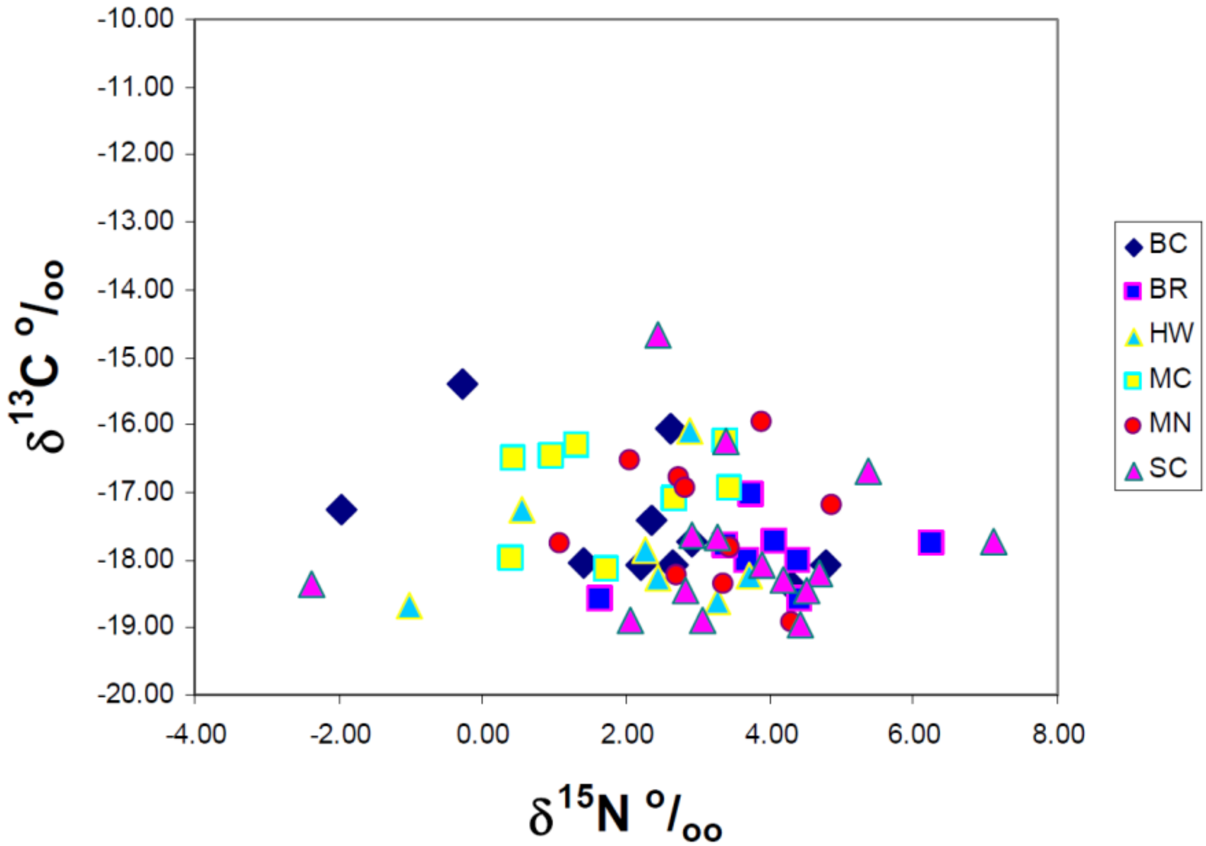

Figure 111: Carbon and nitrogen isotopic composition of organic material from sediment samples.

18. Overview and Summary

18.1 Boil Measurements

Current data obtained from the dipped ADCP for all the boil sites are summarized in Table 64. Overall, a flow to the south was seen during the first part of the cruise, and then the currents reversed to the north, starting around October 11-12, 2006. The flow characteristics of the area have been described previously (EPA, 2003b) as northerly flow associated with the Florida Current (Current Regime *i*), southerly flow associated with Gulf Stream eddies (Current Regime *ii*), and rotary-like flow (Current Regime *iii*) characterized by rapid, sometimes repetitive counterclockwise rotation of the current resulting in interspersed flows to the north and to the south. In this study, an instance of Current Regime *iii* at the Miami-Dade North outfall was indicated on October 12, 2006 (Figures 106 and 107). Northerly flow dominates in the area, with previous estimates at ~60% (SEFLOE II report results cited in EPA, 2003b and Koopman *et al.,* 2006). More recent data from an ADCP established at the Gulf Stream Reef (NOAA/AOML, 2009) indicates that the current is northerly approximately 86% of the time.

Table 64. Summary of ocean current measurements from the dipped ADCP.

Station ID	Date	Time	Description
MC-10	8-Oct	10:00	Southwest current; magnitude decreased from 21.6 cm/s at 4 m to 17 cm/s at 10 m.
SC-13	9-Oct	10:40	South current; low flow velocities.
BR-20	10-Oct	11:40	South current; maximum velocity at 17.25 m.
HW-21	10-Oct	21:00	South current; magnitude decreases from 37 cm/s near surface to 23 cm/s near bottom.
MN-21	11-Oct	14:00	Shear in water column; south current from near the surface, ~6 cm/s to 20 m then shift to north-northwest from 20 m to near bottom. Magnitude minimum at shear inflection point.
MN-21b	11-Oct	20:20	South flow.
Boynton Inlet	12-Oct	07:40	North-northeast current.
SC-Boil 1	12-Oct	09:00	North current.
SC-Boil 2	12-Oct	17:00	North current; flow speed decreasing with depth 37-28 cm/s.
BC-Boil	13-Oct	07:45	North current; flow speed decreasing with depth.
BR Boil	14-Oct	07:40	North current; maximum flow near surface, decreasing to minimum flow near bottom.
HW-Boil	17-Oct	08:30	North current, more north-northwest at surface; minimum flow at 8.6m, maximum flow near bottom.
MN-Boil 1	17-Oct	19:00	East current with maximum flow at 14.25 m.
MN-Boil 2	18-Oct	07:40	North current, maximum velocity at 14.3 m.

The nutrient concentrations from the treated wastewater boil sites are summarized in Figure 112 and Appendix 2 (note that no data were available for the South Central boil). A surface boil was visually evident for all of the outfalls, consistent with that reported by the EPA (2003b) and Koopman *et al.* (2006) and with that expected from a buoyant plume in a weak pycnocline (see the temperature and salinity profiles presented above). The relative concentration of nutrients was roughly in agreement with the wastewater-treated plant nutrient fluxes and discharges reported by Koopman *et al.* (2006) (Tables 2 and 65). It is important to appreciate the ephemeral nature of the boil. As a general observation, higher concentrations occasionally were found on a cast other than that chosen to represent the boil proper.

Table 65. Summary of ocean outfall monitoring as reported in Koopman *et al.* (2006).[1] NR = not reported.

	SC		BC		BR		HW		MN		MC	
Analysis	**Avg**	**Max**	**Avg**	**Max**	**Avg**	**Max**	**Avg**	**Max**	**Avg**	**Max**	**Avg**	**Max**
Total N (mg-N/L)	18.7	22.2	16.9	19.9	14.8	19.9	16.6	21.2	17.5	20.5	16.8	22.5
NH_4 (mg-N/L)	11.7	15.4	10.5	14.2	NR	NR	11.9	15	NR	NR	NR	NR
N+N (mg-N/L)	4.1	7.1	3.3	3.8	NR	NR	1.2	4.8	NR	NR	NR	NR
Total P (mg-P/L)	1.7	4.0	0.7	1.3	1.3	2.0	1.1	1.4	1.7	2.1	1.6	3.4
Fecal coliform[2] (CFU/100 ml)	1.0	16.5	3.1	74.8	7.0	53.0	2.7	2120	1.2	67.3	1.3	19.6

[1]Data are from the 2003 and 2004 Florida Department of Environmental Protection Discharge Monitoring Reports.
[2]For fecal coliform, the values in the average column represent the geometric mean of the data.

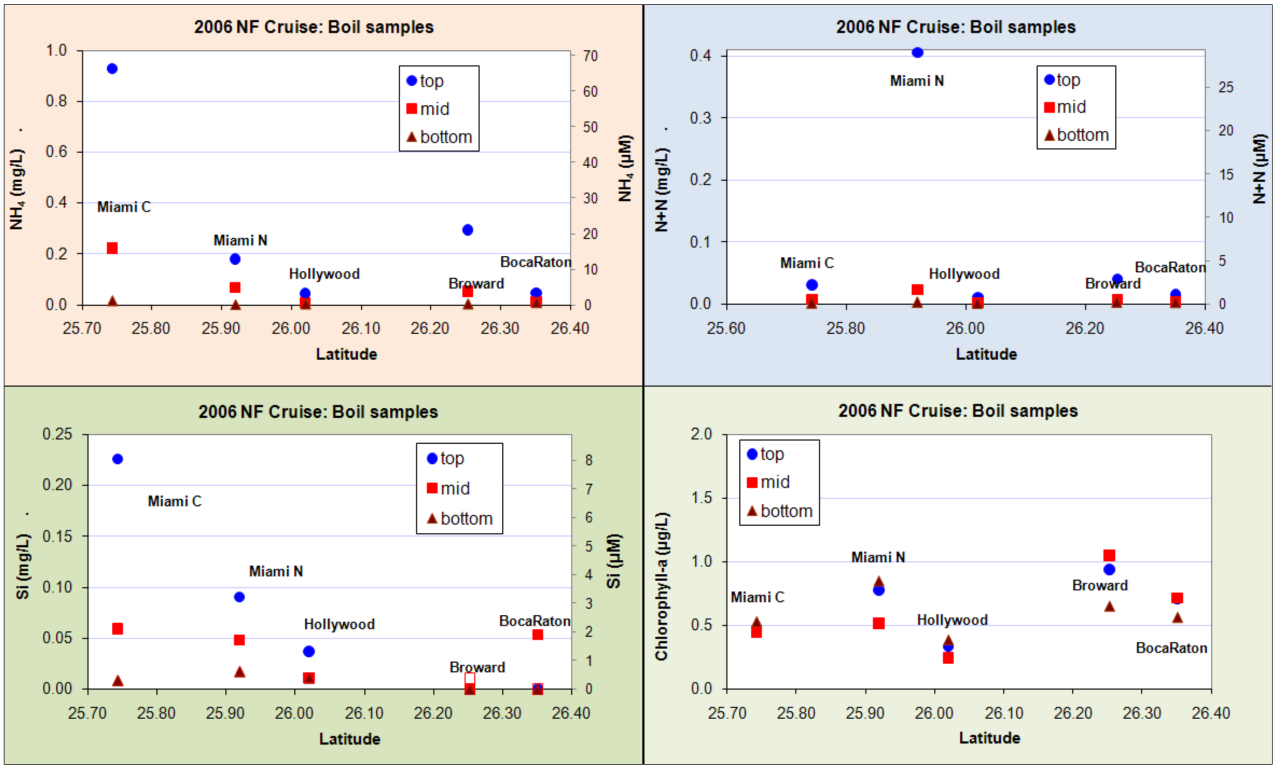

Figure 112. Nutrient results for boil samples from the five outfalls (results were not available for South Central) for NH_4 (top left), N+N (top right), and Si (bottom left) plotted versus the latitude of the outfall. Units are given as mg/L (left vertical axis) and in µM (right vertical axis). Bottom right panel shows the chlorophyll-*a* results (in µg/L).

18.2 Plume Characteristics Versus Depth and Distance from the Outfall

At each treated wastewater effluent plume, a variety of measurements were obtained during the ship's transects, as described above and given in Appendix 1. What do these data indicate about the dilution of the plume with distance down-current of the boil? To answer this question, we decided to distinguish which of the samples taken during the three crossings of the plume represented the plume maxima for the surface, mid, and deep levels. For each crossing of the plume, the sample with the maximum in all (or most) of the analytes was found. This maxima was not always at the same location when comparing surface, mid, and bottom samples.

For each depth, the nutrient concentrations from the determined maxima of N+N, NH_4, and NO_3 (Figure 113) and P, Si, and chlorophyll-*a* (Figure 114) are plotted versus distance from the outfall. Bottom samples were fairly constant with distance. Mid-depth samples were constant with distance for one of the outfalls (BC), whereas the other outfalls showed relative elevation either at the outfall (MN, MC) or at the next sampling site from the outfall (BR, HW). The surface data versus distance regression was strongly negative for most analytes and most outfall plumes.

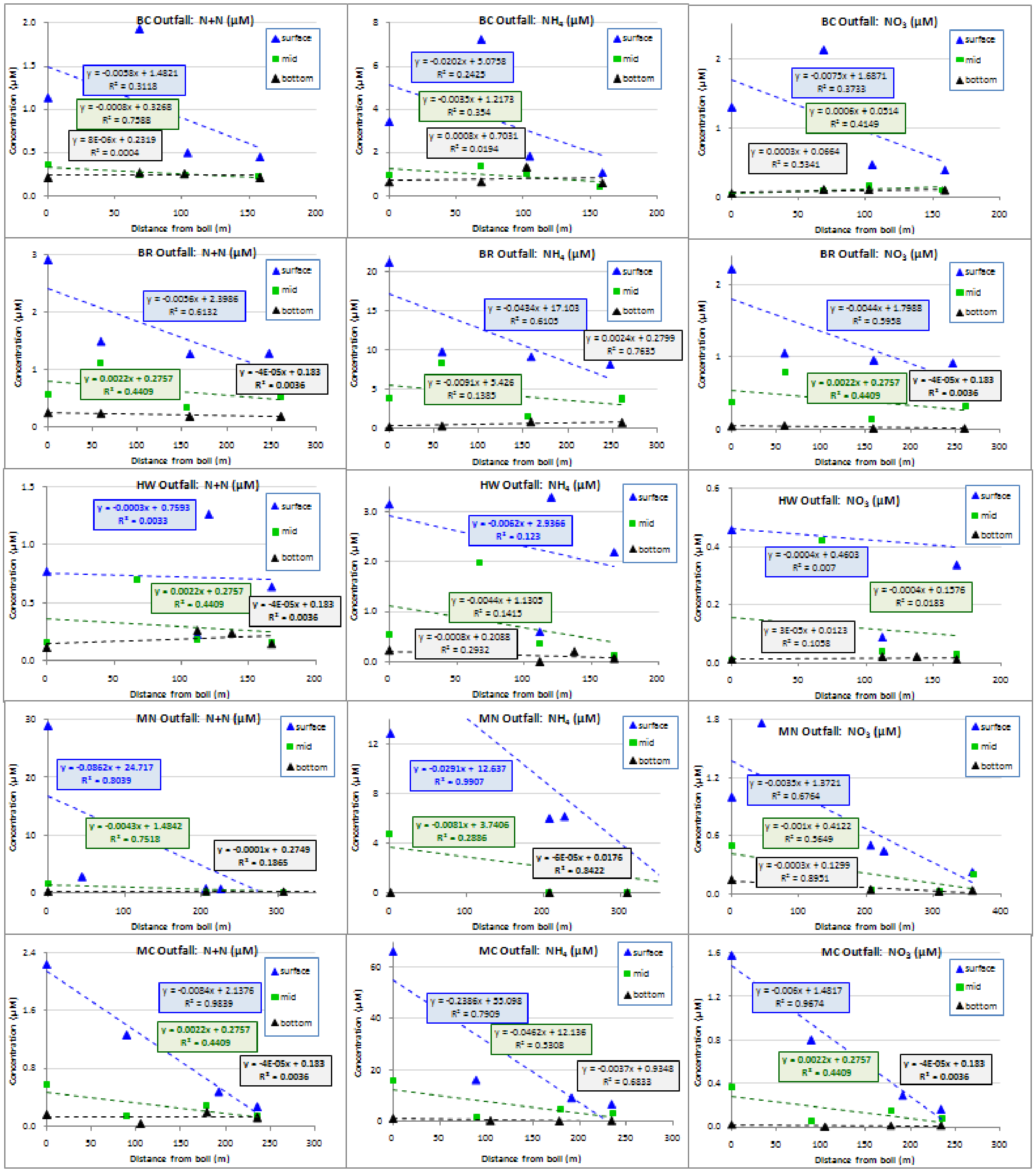

Figure 113. Concentration of nutrients at the plume centers with distance from the boil. Results are for N+N, NH_4, and NO_3.

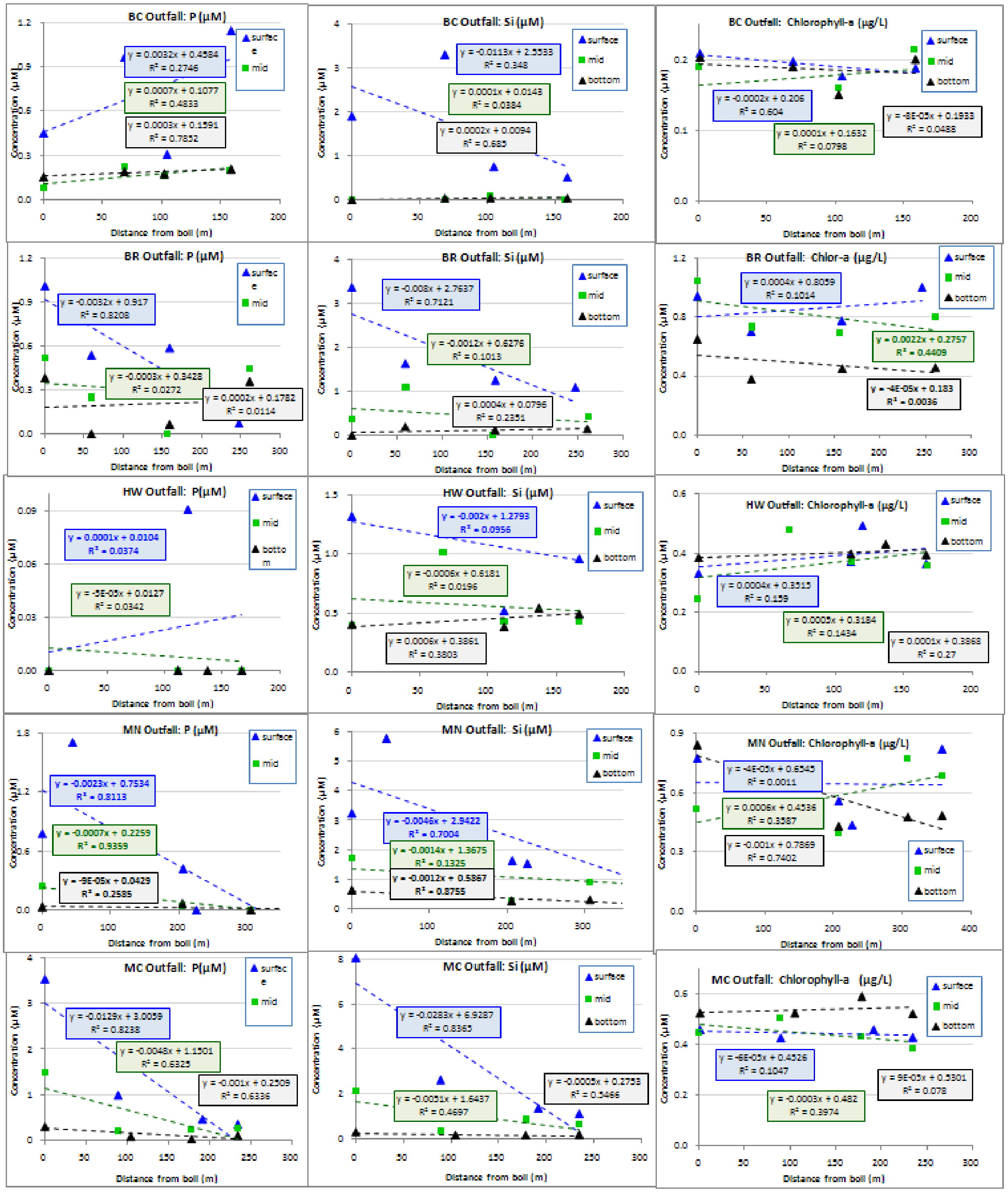

Figure 114. Concentration of nutrients at the plume centers with distance from the boil. Results are for P, Si, and chlorophyll-*a*.

Dilutions (boil concentration/downcurent concentration) can be estimated from the data in Figures 113-114; however, determination of the initial (boil) concentration was shown to be problematic due to the difficulty of sampling the very transient boil, so that in some cases the highest concentration observed was not actually at the boil. Nevertheless, Figure 115 shows the average dilution of key nutrients versus distance for the outfalls investigated during this study. On average, dilutions of surface sample concentrations on the order of 5-10 over the distance of the casts (~200 to 350 m) were observed.

Figure 115. Average dilution of nutrients in surface samples. The vertical axis represents the dilution, and the horizontal axis represents the distance from the outfall pipe (m). Each point represents the averaged distance and averaged concentration of the surface samples versus averaged downcurrent cast distance from the outfall pipe.

To examine the effect of distance on concentration further, regression statistics of the individual concentration values versus distance for each of the five outfalls were computed. In Table 66, the slope and x-intercept of each regression is shown for the nutrients Si, N+N, NH_4, P, and NO_2. The correlation coefficients were not high. This likely was because it was difficult to obtain an adequate sampling of the highly-transitory plume. The data showed qualitatively that the Miami Central and Broward plumes had the highest initial concentration slopes, as expected for the outfalls with the greatest flow rates. The x-intercept of the regression line provided an estimate of when the concentration theoretically became zero (i.e., x-intercept of the regression). In all cases but one, this result was obtained within a few hundred meters. The exception was orthophosphate (P) found at the Boca Raton outfall, which had an outlier concentration of 1.15 µM which highly affected the statistics. However, the data from Table 66 comports with that seen in Figures 113 and 114, where the concentration maxima from each analyte, plotted versus distance, indicated a rapid diminution of concentration with distance.

Each plume measurement depth level was considered separately in the above analysis; therefore, a question arose as to the whether the plume maxima (as determined by the sample with maxima of concentrations of "most" analytes) were the same for the surface, mid, or deep samples. In Figure 116, the plume maxima were plotted for the five analyzed outfalls. The plots were not plotted to geographic scale. These data again demonstrated the highly inhomogeneous nature of the plume as it became dispersed into the receiving waters.

Table 66. Regression results (slope and x-intercepts) for outfall surface nutrients versus distance.

Outfall Name	Analyte	Slope	x-intercept (m)	Outfall Name	Analyte	Slope	x-intercept (m)
BC	Si	-0.014	163	MN	Si	-0.006	461
	N+N	-0.007	194		N+N	-0.083	291
	NH_4	-0.025	183		NH_4	-0.036	354
	P	0.000	21074		P	-0.002	401
	NO_2	-0.008	176		NO_2	-0.003	364
BR	Si	-0.006	306	MC	Si	-0.016	305
	N+N	-0.004	378		N+N	-0.005	338
	NH_4	-0.034	341		NH_4	-0.130	278
	P	-0.002	313		P	-0.007	288
	NO_2	-0.004	342		NO_2	-0.003	320
HW	Si	-0.008	225				
	N+N	-0.007	194				
	NH_4	-0.025	183				
	P	-0.001	501				
	NO_2	-0.008	176				

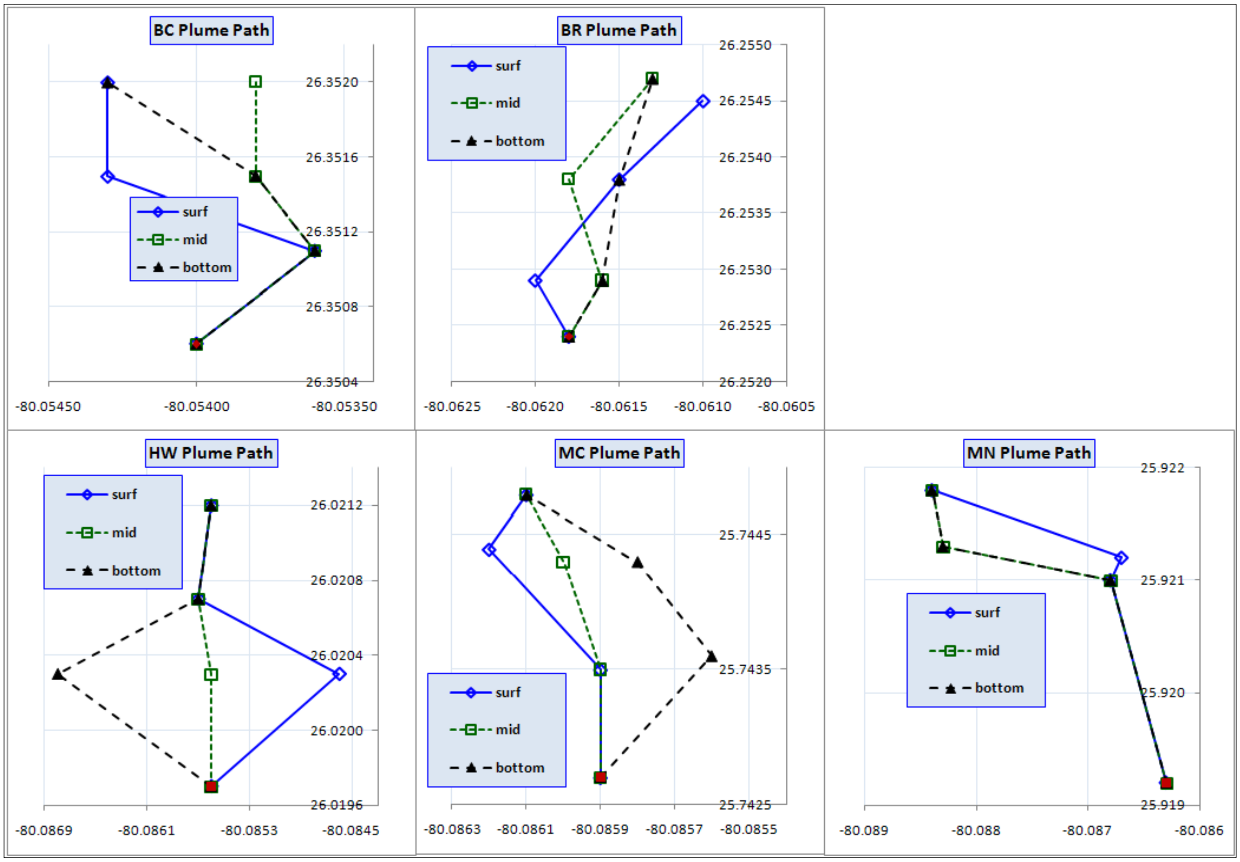

Figure 116. Location of plume maxima for surface (blue), mid (green), and bottom (black) sample depths from the five sampled outfalls. The boil is denoted in red.

18.3 Comparison of Nutrient Concentrations

The six wastewater treatment plant outfalls investigated in this study differed considerably in daily flow and nutrient output (Tables 1 and 2), and these differences were reflected in the receiving waters. To facilitate outfall comparisons, the average concentration was calculated for each nutrient species at each depth and across a single crossing of the plume (there were always three crossings of the plume with three stops for CTD-rosette sampling at each outfall). A cast that attempted to sample right at the boil was also performed (distance from boil = zero). These data are shown in Figures 117-121 for the five outfalls (recall that no data were obtained at South Central). In general, the highest nutrient concentrations and salinity deficits associated with the outfalls were observed in surface samples collected near the outfall, with significant decreases observed with depth (even at the outfall) and with distance from the outfall. The chlorophyll-*a* concentration pattern showed no obvious relationship with the nutrient concentration pattern.

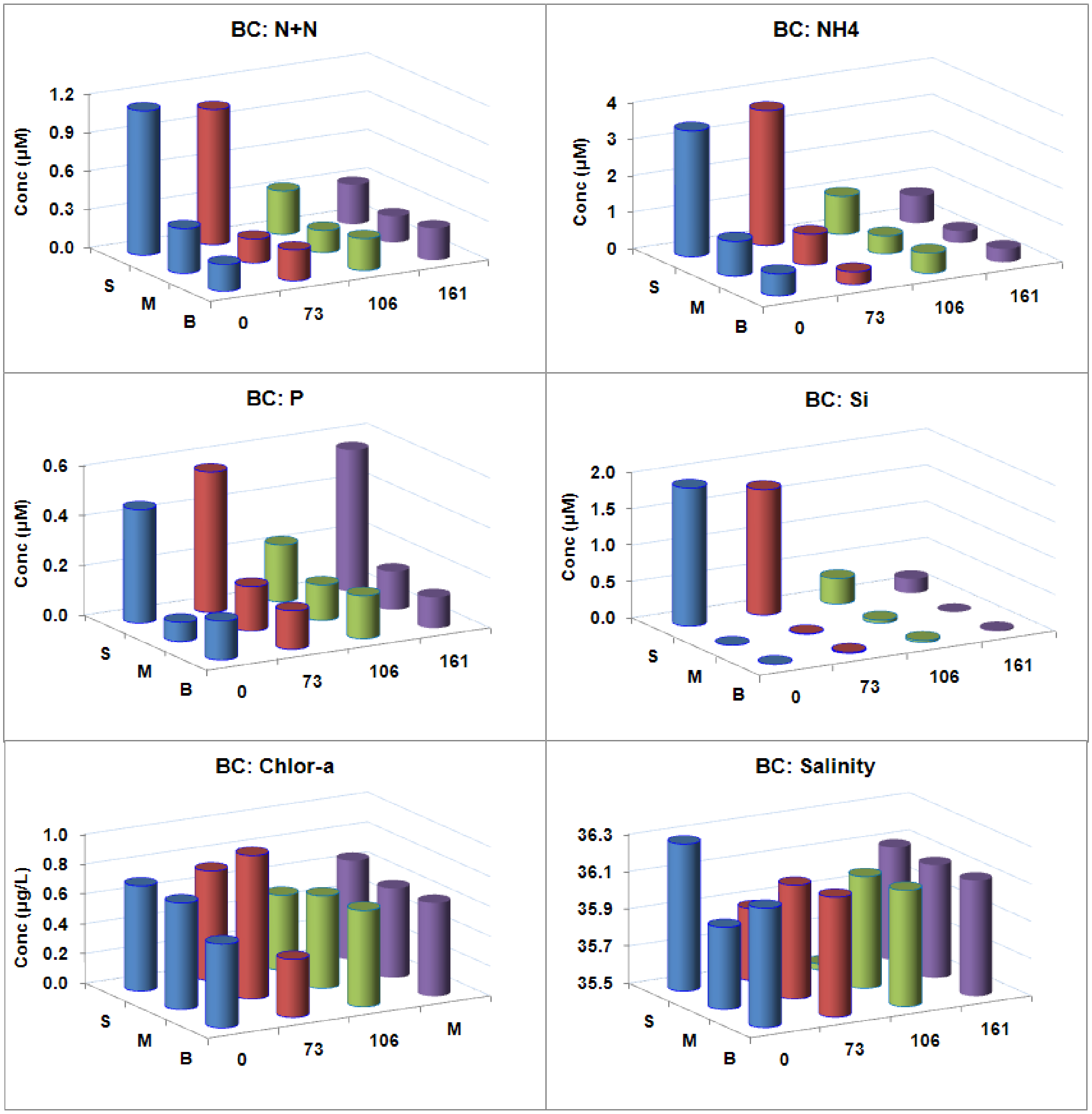

Figure 117. Averaged nutrient, chlorophyll-*a*, and salinity data from the Boca Raton outfall study plotted versus average distance and depth (S = surface, M = middle, B = bottom samples). Horizontal axis is distance from the boil in meters. Compared with the other outfalls, it is likely that the heart of this boil was missed in the cast denoted as zero distance (see Figure 75, CTD results for cast BC1). Note a decline in the concentration of nutrients with distance without a substantial increase in the concentration from samples at deeper depths.

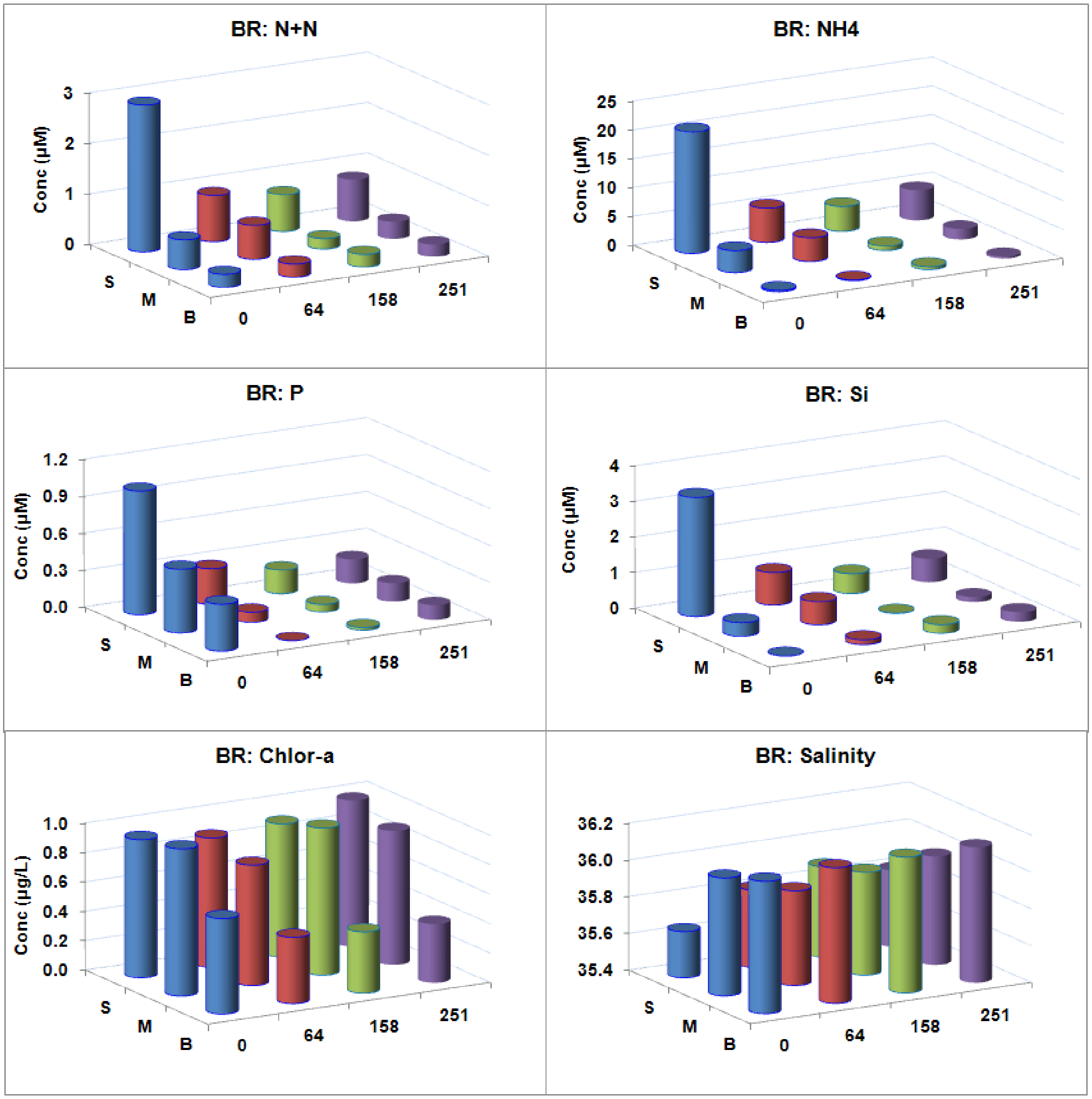

Figure 118. Averaged nutrient, chlorophyll-*a*, and salinity data from the Broward outfall study. Format is the same as in Figure 117.

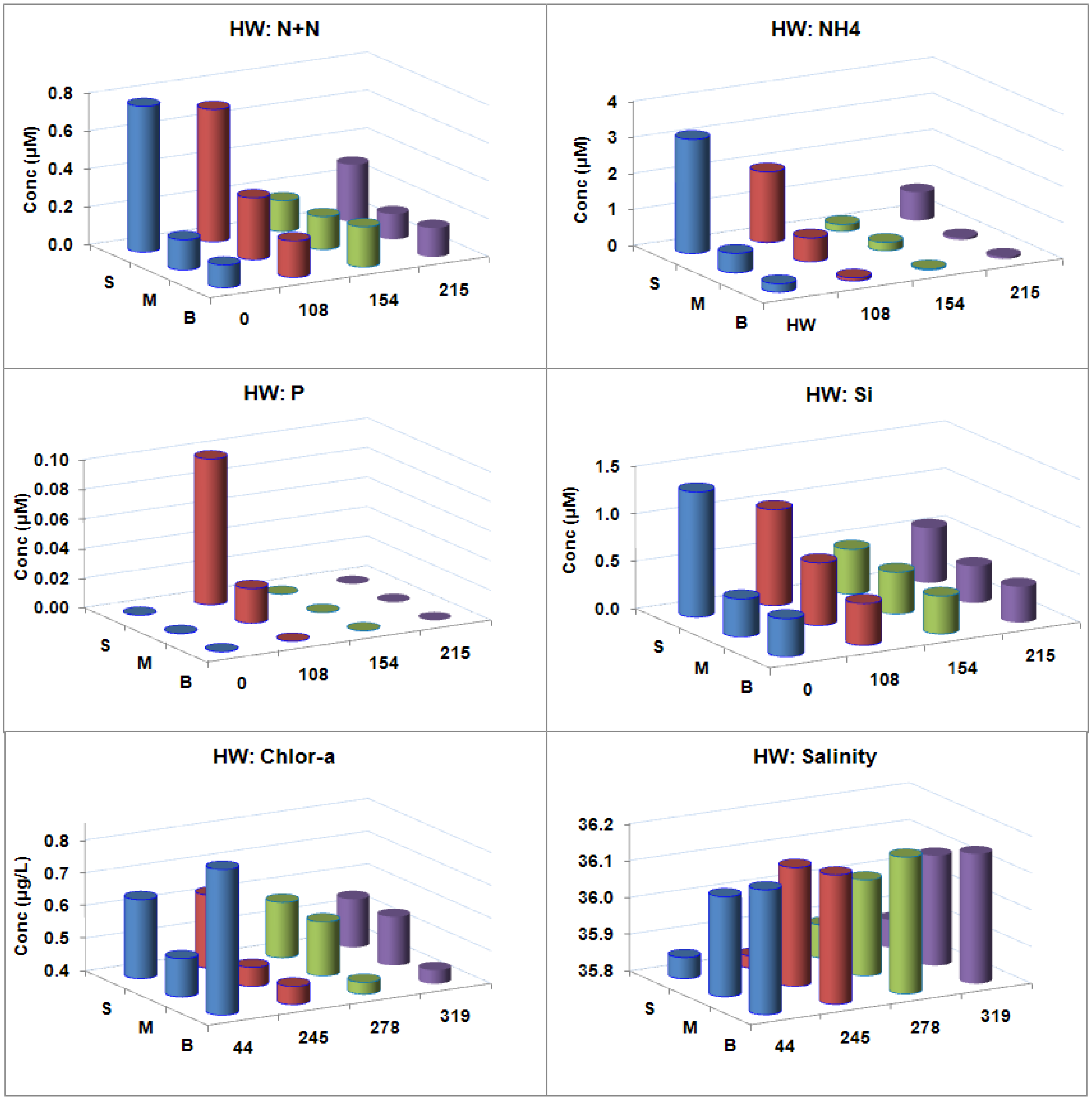

Figure 119. Averaged nutrient, chlorophyll-*a*, and salinity data from the Hollywood outfall study. Format is the same as in Figure 117.

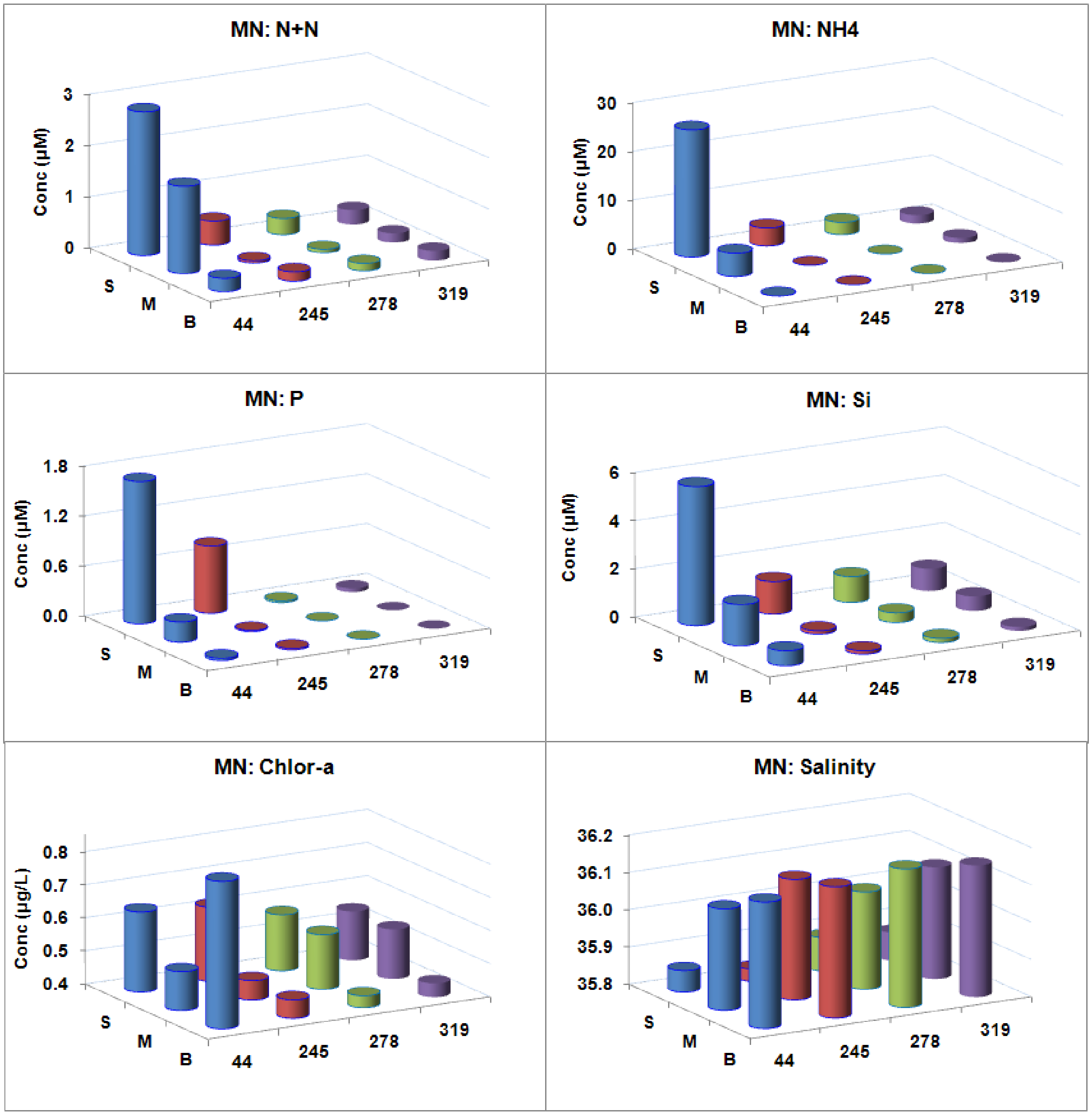

Figure 120. Averaged nutrient, chlorophyll-*a*, and salinity data from the Miami-Dade North outfall study. Format is the same as in Figure 117. Distances are from sample MN2 (surface only, not plotted).

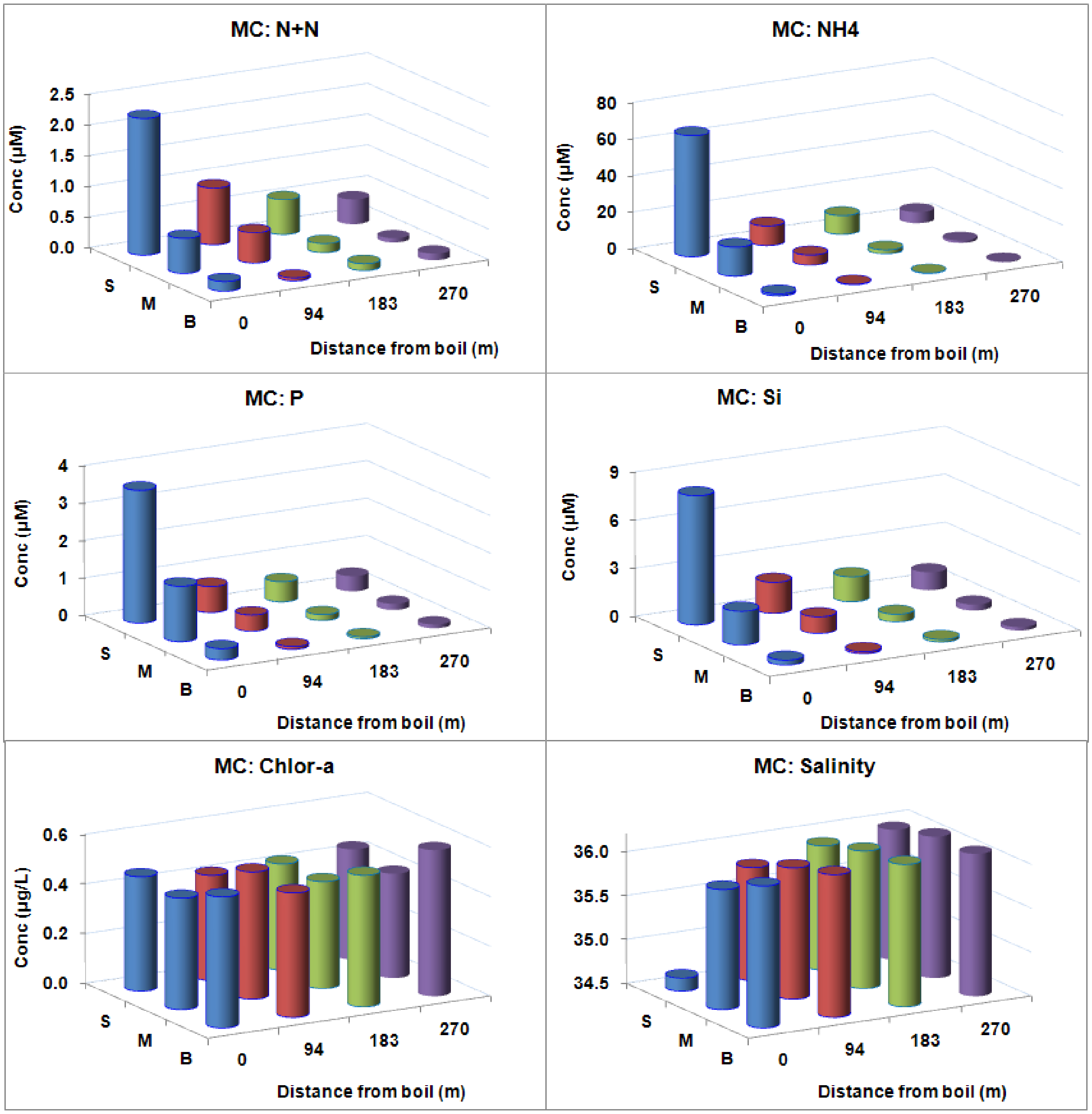

Figure 121. Averaged nutrient, chlorophyll-*a*, and salinity data from the Miami-Dade Central outfall study. Format is the same as in Figure 117.

18.4 CTD Overview

Casts were generally made near the boil at three inshore locations (inner casts), three locations in line with the outfall (middle casts), and three seaward of the outfall (outer casts). A thermocline at 10-30 m was found in most middle and outer casts and a better defined (and deeper) thermocline was observed in the outer casts. The inner casts tended to be less regular. Generally, the plume was clearly denoted in salinity, temperature, and oxygen saturation only in the near-boil casts. The plume was generally indicated as a salinity deficit at the upper 5-10 m in the middle casts and less regularly in the inner or outer casts; the plume was not as definitive in temperature and oxygen saturation data. Other sources of salinity, temperature, and oxygen saturation deviations (e.g., inlet plumes) were observed.

18.5 Summary

The above data suggest the following general conclusions:

- The ephemeral nature of the rising plume and boil was the predominant feature observed; similarly, the downcurrent plume was capricious and irregular. The dynamic nature of the plume was reflected in essentially all the data sets. Unequivocal observation of the boil was problematic except in calm seas.

- Nutrient concentrations were highest at the outfall boils and the deep-water sites (BRI, MCI, and PEI). For N+N, the highest concentrations measured on the cruise were from the Miami-Dade boil (29 µM), followed by the deep-water samples PEI (14.6 µM), BRI (13.9 µM), MCI (10.9 µM), all at 150-m depth, 8.3 µM (BRI, 120-m depth), 6.6 µM (PEI, 120-m depth), and 6.0 µM (Hollywood boil, 25-m depth). For NH_4, the highest concentrations found were at 66.3 µM (Miami-Central), 30.2 µM (Hollywood at a depth of 25 m), 26.1 µM (Miami-Dade North), 21.1 µM (Broward), and 15.9 µM (Miami-Dade Central), at the boils unless otherwise noted. The highest P concentrations found were at 3.6 µM (Miami-Dade Central), 2.0 and 1.7 µM (Miami-Dade North), 1.5 µM (Miami-Dade Central, 16-m depth), 1.3 µM (PEI deep site, 150 m depth), and ~1 µM for the Boca Raton, Broward, Miami-Central, and Hollywood outfalls. For Si, the highest concentrations measured were 9.4 µM at the PEI deep site (150 m depth), 8.3 µM at the Hollywood outfall (25 m depth), 8.1 µM at the Miami-Dade Central boil, 8.1 µM at the BRI deep-water site (150 m depth), 6.5 µM at the MCI deep-water site (150 m depth), and 5.8 µM at the Miami-Dade North boil. Because of the transitory nature of the boil, we cannot assume that the most undiluted portion of the plume was always sampled.

- The outfall plume was unequivocally observed below the surface only in casts very near the boil (e.g., BR13, BR11, BC1, MN2), as would be expected for a buoyant plume. In all other casts, the plume, as tracked by salinity deficit, remained at the surface, generally in the upper 10 m of the water column.

- In most cases, a rapid (<300 m) diminution of nutrient concentration with distance was observed, implying that the concentrations became indistinguishable from "background" concentrations within a kilometer. This situation was not obtained with chlorophyll-*a* and phaeopigments, where there was no clear impact of the plume at any depth.

- There was no substantial increases noted in bottom concentrations, implying that plume spread was primarily horizontal, with limited vertical mixing occurring in these studies.

- Salinity was found to be in deficit at the boil, as expected. The salinity deficit decreased with distance as dilution occurred. This was paralleled by the nutrient concentrations. Within a few hundred meters of the boil, the salinity deficit was substantially reduced, as was the case for nutrient concentrations.

- In general, data from the more outer, offshore (thus deeper) CTD casts indicated more distinct thermoclines at 20-30 m. Middle casts showed more irregular thermoclines at 10-20 m; the inner casts were more irregular, usually without a clear thermocline.

19. Acknowledgments

We thank the captain and crew of the RV *Nancy Foster* for their help with operations and data collection.

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Appendix 1. All nutrient results (BDL = below detection limit).

Station		Date	D m	Chlor µg/L	Phae µg/L	N+N µM	NO_2 µM	NH_4 µM	P µM	Si µM	N+N mg/L[N]	NO_2 mg/L[N]	NH_4 mg/L[N]	P mg/L[P]	Si mg/L[Si]
SC	1	12-Oct	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	2a	12-Oct	0	0.343	0.111	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	3a	12-Oct	0	0.422	0.121	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	4a	12-Oct	0	0.402	0.126	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	5a	12-Oct	0	0.398	0.126	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	6a	12-Oct	0	0.403	0.115	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	7a	12-Oct	0	0.362	0.094	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	8a	12-Oct	0	0.439	0.119	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	9a	12-Oct	0	0.422	0.134	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	10a	12-Oct	0	0.455	0.129	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	11a	12-Oct	0	0.279	0.084	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	1b	12-Oct	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	2b	12-Oct	10.6	0.424	0.104	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	3b	12-Oct	15.2	0.518	0.204	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	4b	12-Oct	13.6	0.434	0.137	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	5b	12-Oct	12	0.406	0.132	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	6b	12-Oct	15	0.407	0.128	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	7b	12-Oct	13.8	0.437	0.122	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	8b	12-Oct	15.8	0.231	0.075	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	9b	12-Oct	11.5	0.418	0.129	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	10b	12-Oct	9.84	0.533	0.145	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	11b	12-Oct	14.7	0.214	0.074	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	2c	12-Oct	21.1	0.316	0.144	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	3c	12-Oct	30.4	0.433	0.170	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	4c	12-Oct	27.1	0.419	0.148	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	5c	12-Oct	24	0.429	0.138	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	6c	12-Oct	30	0.416	0.133	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	7c	12-Oct	27.6	0.387	0.134	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	8c	12-Oct	31.6	0.481	0.196	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	9c	12-Oct	23	0.412	0.139	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	10c	12-Oct	19.7	0.486	0.135	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SC	11c	12-Oct	29.4	0.517	0.179	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BI	1a	12-Oct	0	0.844	0.371	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BI	1b	12-Oct	8	0.855	0.377	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BC	1a	13-Oct	0	0.706	0.209	1.13	1.30	3.45	0.46	1.90	0.016	0.018	0.048	0.014	0.053
BC	2a	13-Oct	0	0.734	0.246	0.26	0.04	0.70	0.21	BDL	0.004	0.001	0.001	0.007	BDL
BC	3a	13-Oct	0	0.774	0.243	0.99	1.11	3.18	0.51	1.88	0.014	0.016	0.044	0.016	0.053
BC	4a	13-Oct	0	0.699	0.197	1.93	2.12	7.22	0.97	3.30	0.027	0.030	0.101	0.030	0.092
BC	5a	13-Oct	0	0.644	0.176	0.49	0.46	1.85	0.31	0.75	0.007	0.006	0.026	0.010	0.021
BC	6a	13-Oct	0	0.475	0.174	0.38	0.38	1.29	0.26	0.30	0.005	0.005	0.018	0.008	0.008
BC	7a	13-Oct	0	0.388	0.126	0.15	0.10	BDL	0.12	BDL	0.002	0.001	BDL	0.004	BDL
BC	8a	13-Oct	0	0.618	0.187	0.44	0.38	1.08	1.15	0.51	0.006	0.005	0.015	0.036	0.014
BC	9a	13-Oct	0	0.619	0.206	0.22	0.13	0.48	0.32	BDL	0.003	0.002	0.007	0.010	BDL
BC	10a	13-Oct	0	0.752	0.233	0.27	0.20	0.68	0.23	0.07	0.004	0.003	0.010	0.007	0.002
BC	1b	13-Oct	13.7	0.714	0.191	0.35	0.03	0.96	0.08	BDL	0.005	BDL	0.013	0.002	BDL
BC	2b	13-Oct	12.7	1.446	0.424	0.14	0.08	0.56	0.16	BDL	0.002	0.001	0.008	0.005	BDL
BC	3b	13-Oct	13.6	0.745	0.208	0.18	0.09	0.61	0.15	0.01	0.003	0.001	0.009	0.005	BDL

Appendix 1. All nutrient results (BDL = below detection limit).

Station		Date	D m	Chlor µg/L	Phae µg/L	N+N µM	NO_2 µM	NH_4 µM	P µM	Si µM	N+N mg/L[N]	NO_2 mg/L[N]	NH_4 mg/L[N]	P mg/L[P]	Si mg/L[Si]
BC	4b	13-Oct	14.7	0.696	0.137	0.24	0.09	1.35	0.22	0.01	0.003	0.001	0.019	0.007	BDL
BC	5b	13-Oct	12.7	0.608	0.214	0.14	0.10	0.24	0.13	0.04	0.002	0.001	0.003	0.004	0.001
BC	6b	13-Oct	13.9	0.587	0.159	0.24	0.17	1.00	0.16	0.09	0.003	0.002	0.014	0.005	0.003
BC	7b	13-Oct	14.6	0.666	0.245	0.14	0.09	0.23	0.14	BDL	0.002	0.001	0.003	0.004	BDL
BC	8b	13-Oct	13	0.619	0.156	0.21	0.16	0.21	0.20	BDL	0.003	0.002	0.003	0.006	BDL
BC	9b	13-Oct	13.7	0.575	0.215	0.23	0.10	0.42	0.20	BDL	0.003	0.001	0.006	0.006	BDL
BC	10b	13-Oct	14.6	0.607	0.230	0.17	0.10	0.33	0.06	BDL	0.002	0.001	0.005	0.002	BDL
BC	1c	13-Oct	27.4	0.561	0.204	0.21	0.05	0.60	0.16	BDL	0.003	0.001	0.008	0.005	BDL
BC	2c	13-Oct	25.4	0.000	0.000	0.24	0.07	0.11	0.13	0.01	0.003	0.001	0.002	0.004	BDL
BC	3c	13-Oct	27.2	0.561	0.182	0.23	0.08	0.33	0.14	BDL	0.003	0.001	0.005	0.004	BDL
BC	4c	13-Oct	29.3	0.603	0.190	0.26	0.11	0.61	0.19	0.04	0.004	0.002	0.009	0.006	0.001
BC	5c	13-Oct	25.3	0.617	0.165	0.25	0.10	0.26	0.13	0.04	0.004	0.001	0.004	0.004	0.001
BC	6c	13-Oct	27.9	0.681	0.151	0.25	0.11	1.30	0.18	0.04	0.004	0.002	0.018	0.006	0.001
BC	7c	13-Oct	29.3	0.639	0.186	0.25	0.10	0.09	0.21	BDL	0.004	0.001	0.001	0.006	BDL
BC	8c	13-Oct	26	0.653	0.201	0.21	0.10	0.55	0.21	0.04	0.003	0.001	0.008	0.006	0.001
BC	9c	13-Oct	27.5	0.594	0.176	0.30	0.13	0.33	0.17	BDL	0.004	0.002	0.005	0.005	BDL
BC	10c	13-Oct	29.3	0.630	0.226	0.24	0.13	0.21	BDL	BDL	0.003	0.002	0.003	BDL	BDL
BRI	a	13-Oct	0	0.164	0.055	0.10	BDL	BDL	BDL	0.22	0.001	BDL	BDL	BDL	0.006
BRI	b	13-Oct	30	0.242	0.084	BDL	BDL	BDL	BDL	0.19	BDL	BDL	BDL	BDL	0.005
BRI	c	13-Oct	60	NA	NA	0.10	0.10	BDL	BDL	0.61	0.001	0.001	BDL	BDL	0.017
BRI	d	13-Oct	90	NA	NA	1.38	0.22	BDL	BDL	1.37	0.019	0.003	BDL	BDL	0.038
BRI	e	13-Oct	120	NA	NA	7.97	0.07	BDL	0.39	5.20	0.112	0.001	BDL	0.012	0.146
BRI	f	13-Oct	150	0.014	0.039	13.92	0.02	BDL	1.03	8.02	0.195	BDL	BDL	0.032	0.225
PEI	a	13-Oct	0	0.242	0.058	0.20	0.01	BDL	BDL	0.64	0.003	BDL	BDL	BDL	0.018
PEI	b	13-Oct	30	0.177	0.058	0.01	BDL	BDL	BDL	0.50	BDL	BDL	BDL	BDL	0.014
PEI	c	13-Oct	60	NA	NA	0.03	0.01	BDL	BDL	0.77	BDL	BDL	BDL	BDL	0.022
PEI	d	13-Oct	90	NA	NA	2.43	0.27	BDL	0.03	2.20	0.034	0.004	BDL	0.001	0.062
PEI	e	13-Oct	120	NA	NA	6.56	0.06	BDL	0.38	4.26	0.092	0.001	BDL	0.012	0.119
PEI	f	13-Oct	150	0.025	0.046	14.56	0.02	BDL	1.27	9.38	0.204	BDL	BDL	0.039	0.263
C1-3	1a	14-Oct	0	1.568	1.158	0.10	0.06	BDL	BDL	BDL	0.001	0.001	BDL	BDL	BDL
C1-3	1b	14-Oct	9.35	1.704	1.471	0.13	0.08	BDL	BDL	BDL	0.002	0.001	BDL	BDL	BDL
C1-3	1c	14-Oct	18.7	1.427	0.594	0.15	0.04	BDL	BDL	BDL	0.002	0.001	BDL	BDL	BDL
C1-3	2a	14-Oct	0	1.657	0.519	0.14	0.05	BDL	BDL	BDL	0.002	0.001	BDL	BDL	BDL
C1-3	2b	14-Oct	11.3	1.537	0.636	0.12	0.04	BDL	BDL	BDL	0.002	0.001	BDL	BDL	BDL
C1-3	2c	14-Oct	22.6	1.192	0.361	0.23	0.05	BDL	BDL	BDL	0.003	0.001	BDL	BDL	BDL
C1-3	3a	14-Oct	0	1.403	0.563	0.08	0.04	BDL	BDL	BDL	0.001	0.001	BDL	BDL	BDL
C1-3	3b	14-Oct	11.3	1.166	0.569	0.24	0.05	BDL	BDL	0.06	0.003	0.001	BDL	BDL	0.002
C1-3	3c	14-Oct	22.5	0.849	0.225	0.22	0.04	BDL	BDL	0.09	0.003	0.001	BDL	BDL	0.003
BR	1a	14-Oct	0	0.940	0.166	2.91	2.22	21.09	1.01	3.35	0.041	0.031	0.295	0.031	0.094
BR	2a	14-Oct	0	0.772	0.193	0.93	0.66	6.49	0.52	0.92	0.013	0.009	0.091	0.016	0.026
BR	3a	14-Oct	0	0.774	0.243	1.28	0.95	9.17	0.58	1.25	0.018	0.013	0.128	0.018	0.035
BR	4a	14-Oct	0	0.850	0.185	1.13	0.82	7.97	0.34	1.11	0.016	0.011	0.112	0.010	0.031
BR	5a	14-Oct	0	1.209	0.355	0.26	0.06	0.98	BDL	BDL	0.004	0.001	0.014	BDL	BDL
BR	6a	14-Oct	0	0.869	0.185	0.55	0.29	2.42	BDL	0.43	0.008	0.004	0.034	BDL	0.012
BR	7a	14-Oct	0	0.699	0.226	1.50	1.05	9.79	0.53	1.63	0.021	0.015	0.137	0.017	0.046
BR	8a	14-Oct	0	1.001	0.403	1.29	0.91	8.20	0.07	1.09	0.018	0.013	0.115	0.002	0.031
BR	9a	14-Oct	0	1.072	0.438	0.36	0.21	1.33	BDL	BDL	0.005	0.003	0.019	BDL	BDL
BR	10a	14-Oct	0	1.093	0.556	0.12	0.03	BDL	BDL	BDL	0.002	BDL	BDL	BDL	BDL
BR	11a	14-Oct	0	1.811	1.039	0.24	0.07	BDL	BDL	BDL	0.003	0.001	BDL	BDL	BDL

Appendix 1. All nutrient results (BDL = below detection limit).

Station		Date	D m	Chlor µg/L	Phae µg/L	N+N µM	NO_2 µM	NH_4 µM	P µM	Si µM	N+N mg/L[N]	NO_2 mg/L[N]	NH_4 mg/L[N]	P mg/L[P]	Si mg/L[Si]
BR	1b	14-Oct	16.8	1.050	0.137	0.59	0.38	3.82	0.52	0.38	0.008	0.005	0.053	0.016	0.011
BR	2b	14-Oct	17.5	0.804	0.112	0.54	0.33	3.75	0.45	0.43	0.008	0.005	0.053	0.014	0.012
BR	3b	14-Oct	17.6	1.408	0.490	0.12	0.01	0.82	0.18	BDL	0.002	BDL	0.011	0.006	BDL
BR	4b	14-Oct	17.3	0.732	0.146	1.12	0.80	8.24	0.25	1.09	0.016	0.011	0.115	0.008	0.031
BR	5b	14-Oct	16.3	0.779	0.140	0.29	0.14	1.73	BDL	BDL	0.004	0.002	0.024	BDL	BDL
BR	6b	14-Oct	16.5	0.692	0.149	0.36	0.15	1.55	BDL	0.02	0.005	0.002	0.022	BDL	0.001
BR	7b	14-Oct	16.2	0.511	0.130	0.78	0.50	4.10	BDL	0.87	0.011	0.007	0.057	BDL	0.024
BR	8b	14-Oct	19.4	1.148	0.385	0.20	0.04	BDL	BDL	BDL	0.003	0.001	BDL	BDL	BDL
BR	9b	14-Oct	19.2	1.107	0.364	0.14	0.03	BDL	BDL	BDL	0.002	BDL	BDL	BDL	BDL
BR	10b	14-Oct	18.9	1.210	0.725	0.13	0.05	BDL	BDL	BDL	0.002	0.001	BDL	BDL	BDL
BR	11b	14-Oct	17.1	1.137	0.448	0.39	0.22	1.28	BDL	BDL	0.005	0.003	0.018	BDL	BDL
BR	1c	14-Oct	33.5	0.649	0.157	0.26	0.05	0.24	0.38	BDL	0.004	0.001	0.003	0.012	BDL
BR	2c	14-Oct	35	0.459	0.125	0.20	0.02	0.78	0.36	0.16	0.003	BDL	0.011	0.011	0.004
BR	3c	14-Oct	35.2	0.452	0.035	0.20	0.02	0.88	0.07	0.13	0.003	BDL	0.012	0.002	0.004
BR	4c	14-Oct	34.5	0.380	0.060	0.25	0.06	0.36	BDL	0.21	0.004	0.001	0.005	BDL	0.006
BR	5c	14-Oct	32.6	0.397	0.112	0.27	0.07	0.36	BDL	0.19	0.004	0.001	0.005	BDL	0.005
BR	6c	14-Oct	32.9	0.317	0.105	0.29	0.09	0.66	BDL	0.35	0.004	0.001	0.009	BDL	0.010
BR	7c	14-Oct	32.4	0.391	0.113	0.29	0.06	BDL	BDL	0.21	0.004	0.001	BDL	BDL	0.006
BR	8c	14-Oct	38.8	0.345	0.077	0.26	0.07	BDL	BDL	0.46	0.004	0.001	BDL	BDL	0.013
BR	9c	14-Oct	38.4	0.482	0.121	0.26	0.07	0.03	BDL	0.24	0.004	0.001	BDL	BDL	0.007
BR	10c	14-Oct	37.8	0.579	0.107	0.24	0.03	BDL	BDL	BDL	0.003	BDL	BDL	BDL	BDL
BR	11c	14-Oct	34.2	0.628	0.148	0.25	0.08	BDL	BDL	BDL	0.004	0.001	BDL	BDL	BDL
MCI	a	15-Oct	0	0.166	0.042	0.09	0.04	BDL	0.05	0.46	0.001	0.001	BDL	0.002	0.013
MCI	b	15-Oct	30	0.173	0.052	0.05	0.03	BDL	0.03	0.30	0.001	BDL	BDL	0.001	0.008
MCI	c	15-Oct	60	NA	NA	0.28	0.26	BDL	0.04	0.54	0.004	0.004	BDL	0.001	0.015
MCI	d	15-Oct	90	NA	NA	2.91	0.25	BDL	0.25	2.20	0.041	0.004	BDL	0.008	0.062
MCI	e	15-Oct	120	NA	NA	8.25	0.09	BDL	0.64	4.65	0.116	0.001	BDL	0.020	0.130
MCI	f	15-Oct	150	0.026	0.049	10.88	0.04	0.64	1.44	6.52	0.152	0.001	0.009	0.045	0.183
MCI	10a	16-Oct	0	0.461	0.128	2.23	1.58	66.32	3.55	8.07	0.031	0.022	0.928	0.110	0.226
MCI	2a	16-Oct	0	0.416	0.096	0.53	0.31	5.37	0.40	1.20	0.007	0.004	0.075	0.012	0.034
MCI	3a	16-Oct	0	0.428	0.097	1.00	0.61	10.97	0.70	2.00	0.014	0.009	0.154	0.022	0.056
MCI	4a	16-Oct	0	0.429	0.099	1.26	0.80	15.94	0.99	2.62	0.018	0.011	0.223	0.031	0.073
MCI	5a	16-Oct	0	0.422	0.105	0.66	0.41	11.42	0.57	1.73	0.009	0.006	0.160	0.018	0.048
MCI	6a	16-Oct	0	0.399	0.096	0.57	0.36	10.68	0.58	1.60	0.008	0.005	0.150	0.018	0.045
MCI	7a	16-Oct	0	0.461	0.116	0.48	0.29	8.92	0.47	1.36	0.007	0.004	0.125	0.014	0.038
MCI	8a	16-Oct	0	0.411	0.089	0.38	0.22	7.77	0.40	1.25	0.005	0.003	0.109	0.012	0.035
MCI	9a	16-Oct	0	0.431	0.110	0.27	0.16	6.41	0.36	1.11	0.004	0.002	0.090	0.011	0.031
MCI	1a	16-Oct	0	0.488	0.105	0.57	0.32	4.01	0.47	1.01	0.008	0.004	0.056	0.015	0.028
MCI	10b	16-Oct	15.7	0.448	0.122	0.57	0.37	15.94	1.48	2.11	0.008	0.005	0.223	0.046	0.059
MCI	2b	16-Oct	16.6	0.429	0.093	0.55	0.33	5.61	0.44	1.11	0.008	0.005	0.079	0.014	0.031
MCI	3b	16-Oct	16.1	0.596	0.121	0.79	0.49	9.08	0.62	1.63	0.011	0.007	0.127	0.019	0.046
MCI	4b	16-Oct	15.8	0.507	0.123	0.14	0.05	1.61	0.21	0.39	0.002	0.001	0.023	0.007	0.011
MCI	5b	16-Oct	16.2	0.403	0.093	0.03	BDL	0.13	0.09	0.14	BDL	BDL	0.002	0.003	0.004
MCI	6b	16-Oct	15.4	0.434	0.094	0.28	0.15	4.64	0.24	0.87	0.004	0.002	0.065	0.007	0.024
MCI	7b	16-Oct	14.5	0.451	0.095	0.13	0.05	1.79	0.13	0.41	0.002	0.001	0.025	0.004	0.011
MCI	8b	16-Oct	16.3	0.397	0.091	0.01	BDL	0.11	0.11	0.17	BDL	BDL	0.002	0.003	0.005
MCI	9b	16-Oct	14.7	0.386	0.107	0.14	0.07	3.19	0.26	0.66	0.002	0.001	0.045	0.008	0.018
MCI	1b	16-Oct	17.2	0.475	0.110	0.05	BDL	0.35	0.11	0.25	0.001	BDL	0.005	0.003	0.007
MCI	10c	16-Oct	31.3	0.527	0.173	0.16	0.02	1.12	0.30	0.31	0.002	BDL	0.016	0.009	0.009

Appendix 1. All nutrient results (BDL = below detection limit).

Station		Date	D m	Chlor µg/L	Phae µg/L	N+N µM	NO_2 µM	NH_4 µM	P µM	Si µM	N+N mg/L[N]	NO_2 mg/L[N]	NH_4 mg/L[N]	P mg/L[P]	Si mg/L[Si]
MCI	2c	16-Oct	33.2	0.526	0.123	0.04	BDL	0.29	0.08	0.17	0.001	BDL	0.004	0.002	0.005
MCI	3c	16-Oct	32.1	0.429	0.099	0.05	BDL	0.23	0.14	0.12	0.001	BDL	0.003	0.004	0.003
MCI	4c	16-Oct	31.5	0.545	0.126	0.05	BDL	0.11	BDL	0.06	0.001	BDL	0.002	BDL	0.002
MCI	5c	16-Oct	32.3	0.590	0.151	0.19	0.01	0.11	0.02	0.17	0.003	BDL	0.002	0.001	0.005
MCI	6c	16-Oct	30.8	0.550	0.133	0.08	0.01	0.16	0.12	0.14	0.001	BDL	0.002	0.004	0.004
MCI	7c	16-Oct	29	0.447	0.104	0.07	BDL	0.24	0.01	0.17	0.001	BDL	0.003	BDL	0.005
MCI	8c	16-Oct	32.5	0.662	0.206	0.13	0.02	0.16	0.08	0.25	0.002	BDL	0.002	0.002	0.007
MCI	9c	16-Oct	29.4	0.523	0.138	0.12	0.01	0.32	0.10	0.20	0.002	BDL	0.004	0.003	0.006
MCI	1c	16-Oct	34.3	0.578	0.128	0.07	BDL	0.58	0.12	0.17	0.001	BDL	0.008	0.004	0.005
HW	10a	17-Oct	0	0.333	0.046	0.77	0.46	3.17	BDL	1.32	0.011	0.006	0.044	BDL	0.037
HW	1ab	17-Oct	0	0.406	0.114	0.25	0.03	0.55	0.13	0.63	0.004	BDL	0.008	0.004	0.018
HW	2a	17-Oct	0	0.475	0.129	0.59	0.32	2.03	0.08	0.87	0.008	0.004	0.028	0.002	0.024
HW	3a	17-Oct	0	0.494	0.115	1.26	0.81	3.31	0.09	1.54	0.018	0.011	0.046	0.003	0.043
HW	4a	17-Oct	0	0.335	0.076	0.08	BDL	BDL	BDL	0.52	0.001	BDL	BDL	BDL	0.015
HW	5a	17-Oct	0	0.373	0.081	0.23	0.09	0.59	BDL	0.52	0.003	0.001	0.008	BDL	0.015
HW	6a	17-Oct	0	0.439	0.103	0.18	0.01	BDL	BDL	0.38	0.003	BDL	BDL	BDL	0.011
HW	7a	17-Oct	0	0.507	0.117	0.23	0.03	BDL	BDL	0.43	0.003	BDL	BDL	BDL	0.012
HW	8a	17-Oct	0	0.365	0.086	0.64	0.34	2.20	BDL	0.96	0.009	0.005	0.031	BDL	0.027
HW	9a	17-Oct	0	0.177	0.058	0.03	BDL	0.15	BDL	0.35	BDL	BDL	0.002	BDL	0.010
HW	10b	17-Oct	14.3	0.244	0.064	0.16	0.01	0.54	BDL	0.40	0.002	BDL	0.008	BDL	0.011
HW	1bb	17-Oct	10.1	0.409	0.111	0.20	0.02	0.01	0.04	0.57	0.003	BDL	BDL	0.001	0.016
HW	2b	17-Oct	13.8	0.480	0.125	0.70	0.42	1.97	0.04	1.01	0.010	0.006	0.028	0.001	0.028
HW	3b	17-Oct	17.1	0.509	0.122	0.08	BDL	BDL	BDL	0.40	0.001	BDL	BDL	BDL	0.011
HW	4b	17-Oct	17.3	0.473	0.068	0.13	BDL	0.33	BDL	0.49	0.002	BDL	0.005	BDL	0.014
HW	5b	17-Oct	13.4	0.371	0.091	0.18	0.04	0.36	BDL	0.43	0.003	0.001	0.005	BDL	0.012
HW	6b	17-Oct	8	0.462	0.101	0.21	0.01	BDL	BDL	0.40	0.003	BDL	BDL	BDL	0.011
HW	7b	17-Oct	7.71	0.480	0.107	0.21	0.02	0.06	BDL	0.38	0.003	BDL	0.001	BDL	0.011
HW	8b	17-Oct	13.8	0.357	0.082	0.16	0.03	0.12	BDL	0.43	0.002	BDL	0.002	BDL	0.012
HW	9b	17-Oct	18.6	0.238	0.059	0.03	BDL	BDL	BDL	0.35	BDL	BDL	BDL	BDL	0.010
HW	11	17-Oct	25.2	0.214	0.065	5.95	4.56	30.22	0.83	8.26	0.083	0.064	0.423	0.026	0.231
HW	10c	17-Oct	28.5	0.384	0.096	0.12	0.01	0.23	BDL	0.40	0.002	BDL	0.003	BDL	0.011
HW	1cb	17-Oct	20.2	0.430	0.118	0.24	0.02	0.20	BDL	0.54	0.003	BDL	0.003	BDL	0.015
HW	2c	17-Oct	27.5	0.460	0.120	0.25	BDL	0.06	BDL	0.43	0.004	BDL	0.001	BDL	0.012
HW	3c	17-Oct	34.2	0.493	0.124	0.09	BDL	BDL	BDL	0.35	0.001	BDL	BDL	BDL	0.010
HW	4c	17-Oct	34.6	0.483	0.108	0.19	0.02	0.10	BDL	0.43	0.003	BDL	0.001	BDL	0.012
HW	5c	17-Oct	26.8	0.397	0.095	0.26	0.02	BDL	BDL	0.38	0.004	BDL	BDL	BDL	0.011
HW	6c	17-Oct	16	0.453	0.098	0.19	0.01	BDL	BDL	0.38	0.003	BDL	BDL	BDL	0.011
HW	7c	17-Oct	15.4	0.550	0.094	0.18	0.02	BDL	BDL	0.32	0.003	BDL	BDL	BDL	0.009
HW	8c	17-Oct	27.5	0.394	0.096	0.15	0.01	0.07	BDL	0.49	0.002	BDL	0.001	BDL	0.014
HW	9c	17-Oct	37.1	0.470	0.098	0.13	0.01	0.11	BDL	0.32	0.002	BDL	0.002	BDL	0.009
MN	1a	17-Oct	0	0.778	0.200	29.00	1.00	12.85	0.78	3.24	0.406	0.014	0.180	0.024	0.091
MN	2a	17-Oct	0	0.642	0.189	2.81	1.77	26.1	1.71	5.78	0.039	0.025	0.365	0.053	0.162
MN	3a	18-Oct	0	0.402	0.124	0.37	0.23	2.66	0.13	0.90	0.005	0.003	0.037	0.004	0.025
MN	4a	18-Oct	0	0.398	0.124	0.21	0.12	1.36	0.06	0.44	0.003	0.002	0.019	0.002	0.012
MN	5a	18-Oct	0	0.412	0.120	0.58	0.39	5.08	2.00	1.14	0.008	0.005	0.071	0.062	0.032
MN	6a	18-Oct	0	0.560	0.112	0.76	0.50	6.02	0.42	1.63	0.011	0.007	0.084	0.013	0.046
MN	7a	18-Oct	0	0.437	0.122	0.68	0.44	6.20	BLD	1.53	0.010	0.006	0.087	BDL	0.043
MN	8a	18-Oct	0	0.417	0.128	0.13	0.01	BDL	BLD	0.10	0.002	BDL	BDL	BDL	0.003
MN	9a	18-Oct	0	0.825	0.218	0.35	0.22	2.52	BDL	1.77	0.005	0.003	0.035	BDL	0.050

Appendix 1. All nutrient results (BDL = below detection limit).

Station		Date	D m	Chlor µg/L	Phae µg/L	N+N µM	NO_2 µM	NH_4 µM	P µM	Si µM	N+N mg/L[N]	NO_2 mg/L[N]	NH_4 mg/L[N]	P mg/L[P]	Si mg/L[Si]
MN	10a	18-Oct	0	0.874	0.265	0.08	0.04	BDL	BDL	1.24	0.001	0.001	BDL	BDL	0.035
MN	11a	18-Oct	0	0.900	0.256	0.07	0.01	BDL	BDL	1.29	0.001	BDL	BDL	BDL	0.036
MN	1b	17-Oct	15.3	0.517	0.188	1.71	0.49	4.79	0.24	1.71	0.024	0.007	0.067	0.008	0.048
MN	3b	18-Oct	18.6	0.468	0.141	0.08	0.02	BDL	BDL	0.36	0.001	BDL	BDL	BDL	0.010
MN	4b	18-Oct	19	0.390	0.112	0.06	0.01	BDL	BDL	0.17	0.001	BDL	BDL	BDL	0.005
MN	5b	18-Oct	19	0.384	0.115	0.04	0.02	BDL	BDL	0.11	0.001	BDL	BDL	BDL	0.003
MN	6b	18-Oct	14	0.396	0.117	0.11	0.04	BDL	0.04	0.27	0.002	0.001	BDL	0.001	0.008
MN	7b	18-Oct	14.8	0.530	0.136	0.10	0.03	BDL	BDL	0.13	0.001	BDL	BDL	BDL	0.004
MN	8b	18-Oct	14.4	0.492	0.129	0.11	0.01	BDL	BDL	0.10	0.002	BDL	BDL	BDL	0.003
MN	9b	18-Oct	10.2	0.687	0.177	0.34	0.20	3.12	BDL	1.34	0.005	0.003	0.044	BDL	0.038
MN	10b	18-Oct	10.4	0.776	0.219	0.05	0.03	BDL	BDL	0.91	0.001	BDL	BDL	BDL	0.025
MN	11b	18-Oct	13.6	0.594	0.169	BDL	BDL	BDL	BDL	0.02	BDL	BDL	BDL	BDL	0.001
MN	1c	17-Oct	30.7	0.845	0.279	0.26	0.14	0.02	0.03	0.62	0.004	0.002	BDL	0.001	0.017
MN	3c	18-Oct	37.2	0.405	0.126	0.14	0.02	BDL	BDL	0.11	0.002	BDL	BDL	BDL	0.003
MN	4c	18-Oct	38	0.408	0.164	0.10	0.01	BDL	BDL	0.11	0.001	BDL	BDL	BDL	0.003
MN	5c	18-Oct	38	0.414	0.122	0.11	0.03	BDL	BDL	0.11	0.002	BDL	BDL	BDL	0.003
MN	6c	18-Oct	28.2	0.430	0.119	0.30	0.04	BDL	0.061	0.25	0.004	0.001	BDL	0.002	0.007
MN	7c	18-Oct	29.6	0.422	0.123	0.12	0.01	BDL	BDL	0.10	0.002	BDL	BDL	BDL	0.003
MN	8c	18-Oct	28.8	0.433	0.139	0.19	0.02	0.12	BDL	0.21	0.003	BDL	0.002	BDL	0.006
MN	9c	18-Oct	20.4	0.486	0.113	0.24	0.03	BDL	BDL	0.18	0.003	BDL	BDL	BDL	0.005
MN	10c	18-Oct	20.8	0.479	0.156	0.21	0.02	BDL	BDL	0.29	0.003	BDL	BDL	BDL	0.008
MN	11c	18-Oct	27.2	0.523	0.149	0.14	0.02	BDL	BDL	0.05	0.002	BDL	BDL	BDL	0.001

Appendix 2. Nutrient results from boil samples.

Location	Date	Station	Lat	Lon	D (m)	T (°C)	Sal (Units)	pH (Units)	Ch-*a* (µg/L)	Pha (µg/L)	N+N (µM)	NO_2 (µM)	NH_4 (µM)	P (µM)	Si (µM)
SC	12-Oct	1b	26.46	-80.04	0										
BC	13-Oct	1a	26.35	-80.05	0	29.7	36.3	8.1	0.706	0.209	1.13	1.3	3.45	0.455	1.9
BC	13-Oct	1b	26.35	-80.05	13.7	29.0	35.9	8.1	0.714	0.191	0.35	0.03	0.96	0.077	0
BC	13-Oct	1c	26.35	-80.05	27.4	28.9	36.1	8.1	0.561	0.204	0.21	0.05	0.60	0.156	0
BR	14-Oct	1a	26.25	-80.06	0	28.9	35.7	9.2	0.940	0.166	2.91	2.22	21.09	1.005	3.35
BR	14-Oct	1b	26.25	-80.06	16.8	28.9	36.0	8.2	1.050	0.137	0.59	0.38	3.82	0.517	0.38
BR	14-Oct	1c	26.25	-80.06	33.5	28.8	36.1	8.4	0.649	0.157	0.26	0.05	0.24	0.38	0
HW	17-Oct	10a	26.02	-80.09	0	28.7	36.0	8.0	0.333	0.046	0.77	0.46	3.17	0	1.32
HW	17-Oct	10b	26.02	-80.09	14.3	28.7	36.2	8.1	0.244	0.064	0.16	0.01	0.54	0	0.4
HW	17-Oct	10c	26.02	-80.09	28.5	28.7	36.2	8.0	0.384	0.096	0.12	0.01	0.23	0	0.4
MN	17-Oct	1a	25.92	-80.09	0	28.5	35.9	7.9	0.778	0.200	29	1.00	12.85	0.78	3.24
MN	17-Oct	1b	25.92	-80.09	15.3	28.5	36.1	7.9	0.517	0.188	1.708	0.49	4.79	0.243	1.71
MN	17-Oct	1c	25.92	-80.09	30.7	28.5	36.1	8.0	0.845	0.279	0.26	0.14	0.02	0.029	0.62
MC	16-Oct	10a	25.74	-80.09	0	28.6	34.7	8.0	0.461	0.128	2.23	1.58	66.32	3.552	8.07
MC	16-Oct	10b	25.74	-80.09	15.7	28.6	35.9	8.0	0.448	0.122	0.57	0.37	15.94	1.48	2.11
MC	16-Oct	10c	25.74	-80.09	31.3	28.5	36.1	8.1	0.527	0.173	0.16	0.02	1.12	0.304	0.31