



Fixed-Station Water-Quality Monitoring at Cape Lookout National Seashore, Middle Marshes Site

2008-2009 Data Summary

Natural Resource Data Series NPS/SECN/NRDS—2014/609



ON THE COVER

Middle Marshes area of the Rachel Carson Reserve. Photograph by John Fear, NCNERR staff.

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January 2014

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science Center
Fort Collins, Colorado

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Please cite this publication as:

Rinehart, A. 2014. Fixed-station water-quality monitoring at Cape Lookout National Seashore, Middle Marshes site: 2008-2009 data summary. Natural Resource Data Series NPS/SECN/NRDS—2014/609. National Park Service, Fort Collins, Colorado.

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Summary and Key Findings

In 2007, the National Park Service (NPS) Southeast Coast Network (SECN) Inventory and Monitoring Program began a partnership with the North Carolina National Estuarine Research Reserve (NCNERR) to collect water-quality data in the estuarine waters near Cape Lookout National Seashore (CALO). The Middle Marshes site was originally established by the NCNERR in 1997, and continuously monitored until 2003. A joint NPS-NCNERR continuous monitoring station has been operational since April 2008 in the Middle Marshes area. Methods used are adapted from the water-quality monitoring program established by the National Estuarine Research Reserve Program (Wenner and Geist 2001). The Cape Lookout National Seashore fixed-station water-quality monitoring site is part of the SECN estuarine water-quality monitoring program, which routinely collects data in the vicinity of seven coastal parks along the southeastern U.S. coast (DeVivo et al. 2008, Gregory et al. 2013). Highlights from the 2008-2009 data record are summarized below.

- Salinity, DO, pH, turbidity, water temperature, specific conductance (to compute salinity), and water-level data were collected continuously at the Middle Marshes site at CALO. Monthly on-site measurements of water clarity conditions, and laboratory analyses of total dissolved phosphorus, dissolved inorganic phosphorus, total dissolved nitrogen, dissolved inorganic nitrogen, and chlorophyll *a* levels were also made at the Middle Marshes site.
- Dissolved inorganic nitrogen and phosphorus were rated *good* for all readings during 2008-09. All chlorophyll *a* results were *good* for the two-year span. Secchi disk depths, used to calculate water clarity, hit bottom 16 of the 19 months. Seven of the 16 months when the Secchi disk hit the bottom, the reading would still be in the *good* category. Only two *fair* water clarity results were reported during the time span.
- Individual and monthly mean low readings of salinity at Middle Marshes (CALOshak2) in 2008 occurred in April at 27.8 and 31.9 ppt, respectively. In 2009, individual and monthly mean low salinity reading of 18.9 and 21.7 ppt occurred in December during a period of heavy rainfall. Conversely, individual and monthly mean high readings at Middle Marshes in 2008 were 39.1 and 36.7 ppt respectively in September. Whereas individual and monthly mean high readings in 2009 were 38.6 and 36.6 ppt respectively in July.
- Mean monthly DO levels were ranging from 5.9 to 8.6 mg/L in 2008. Mean daily DO levels were never below 5.0 mg/L at Middle Marshes in 2008 or in 2009. Individual readings below 5.0 mg/L were common in 2008 occurring between June and September. In 2009 monthly mean DO ranged from 6.0 to 9.5 mg/L. The lowest recorded individual DO reading of 1.06 mg/L occurred in April 2009.
- Monthly mean pH values ranged from 7.9 to 8.3 in 2008. pH in 2009 had a monthly mean range of 7.6 to 8.6.
- Average monthly turbidity at Middle Marshes never exceeded 15 NTUs in 2008 and did not exceed 22.2 NTUs in 2009. For a two-day period in mid-September the daily average for turbidity was 199 and 107 NTUs, and occurred during a period of heavy local rainfall. Excluding those two days, the mean daily turbidity for 2009 did not exceed 44 NTUs.

- Monthly mean water temperatures that were recorded in 2008 peaked in July at 27.8°C (82.04°F), and bottomed out in November at 11.7°C (53.06°F). Individual readings at CALOshak2 ranged from 32.92°C (91.26°F) in August to 7.02°C (44.64°F) in November. Monthly mean and individual water temperatures in 2009 ranged from highs in August of 28.1°C (82.58°F) and 33.28°C (91.90°F) respectively, to lows of 8.0°C (46.4°F) and 0.8°C (33.44°F) respectively in January.
- During 2008, 40% of all potential data collected at CALOshak2 and 74% in 2009 were used in analysis. During 2008-09 missing and anomalous data were caused by several factors, including but not limited to equipment malfunction from October to mid-November 2008, calibration errors in July- August of 2008 and May- June 2009 that affected dissolved oxygen and pH, and bio-fouling that affected turbidity in early July 2008.

Introduction

Water resources are important to park management from ecological, regulatory, and visitor-experience perspectives. Water resources include freshwater, marine water, and estuaries; the zone where fresh and salt water mix. Estuarine water-quality in and around NPS units were selected as one of several Vital Signs to be monitored by the SECN Inventory and Monitoring Program (DeVivo et al. 2008). Data collected as a part of this effort are intended to foster a better understanding of water resources in and around park units and contribute to a better understanding of ecological processes and physical systems (Gregory et al. 2013).

To effectively monitor the diverse and dynamic set of estuarine water resources at its Network's coastal park areas, the SECN has implemented a two-pronged monitoring approach. The first aspect consists of collecting data from continuously recording fixed stations located in each park unit and collecting discrete nutrient samples during month site visits. The second aspect consists of conducting periodic (every five years) synoptic assessments of water quality at a larger spatial scale in the waters surrounded coastal park areas. When combined, these two approaches give a more complete picture of physical processes, diurnal and seasonal variations, and spatial patterns during critical portions of the year than either could if implemented singularly.

The SECN has identified four specific monitoring objectives for which data are collected and analyzed as part of this overall effort. Objectives 1 and 2 below are addressed in this report (Gregory et al. 2013):

1. Determine daily and seasonal water-quality patterns for six core parameters (DO, salinity, temperature, pH, depth, and turbidity) at fixed monitoring stations using continuous data loggers.
2. Determine monthly and seasonal patterns in nutrients (nitrogen, phosphorus, and chlorophyll *a*) at fixed monitoring stations by collecting discrete water samples.
3. Determine status and spatial variability of water and nutrient chemistry conditions in estuarine waters every five years.
4. Determine status and spatial variability of benthic sediment quality (organic contaminants, carbon, and metal levels) every ten years in estuarine waters.

In 2007, the SECN began a cooperative effort with the NCNERR to manage sites and collect continuous water-quality and monthly nutrient data in the waters around CALO. This data is used to assess water-quality conditions and examine trends in temporal variability. This report provides a summary of data collected at the Middle Marshes (CALOshak2) site during 2008-2009, and presents a snapshot of conditions to seashore managers as well as information on short-term variability and seasonal trends of conditions in waters in the vicinity of CALO.

Cape Lookout National Seashore

CALO comprises the southern terminus of the outer banks in eastern North Carolina. The 56 mile long barrier island chain is composed of three main islands, North and South Core Banks, and Shackleford Banks. North and South Core Banks have a general Northeast to Southwest

orientation, while Shackleford Banks has a Southeast to northwest orientation (Figure 1). The Core Bank islands are currently separated by a series of inlets consisting of New Drum, New-Old Drum, and Ophelia Inlet that have changed numerous times throughout history as a result of hurricanes and other powerful storms (Mallinson 2008).

There are a variety of potential water-quality concerns in and around CALO. Impervious surfaces associated with the towns of Beaufort and Morehead City can cause flashier runoff that may contain hydrocarbons and other byproducts of urbanization. A large military base and a complex of smaller bases are located less than 25 miles away. Beaufort Inlet is dredged to maintain the shipping channels for public, private and military purposes (personal commun. John Fear, research coordinator, NCNERR). Dredging activities have the potential to re-suspend toxins or contaminants that have been deposited and “locked up” in the sediment, back into the water column (Bella and McCauley 1972).

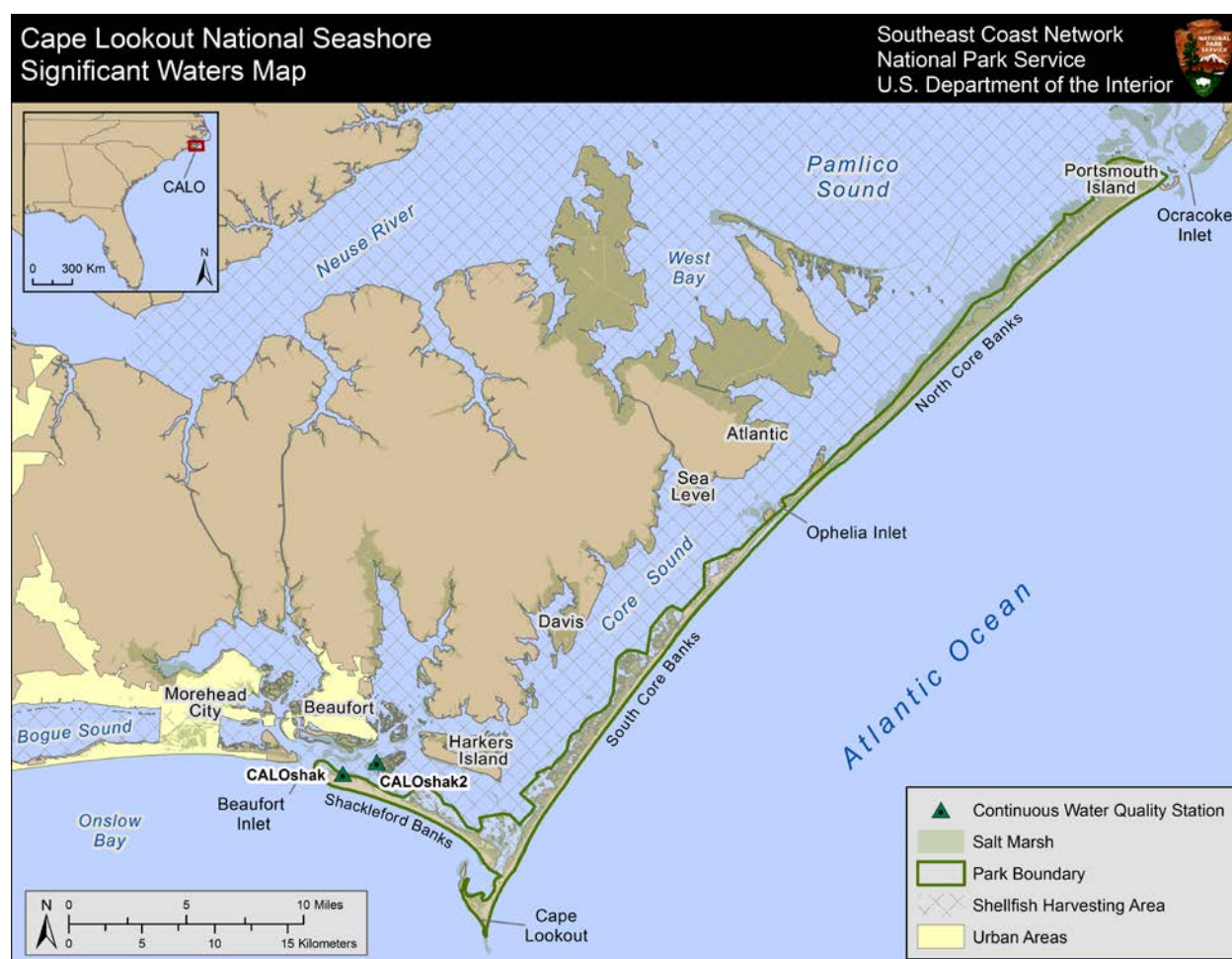


Figure 1. Location of continuous water-quality monitoring stations at Cape Lookout National Seashore in 2008-2009. Map shows estuarine and marine water resources in the vicinity of Cape Lookout National Seashore in North Carolina. Depicted are areas of salt marsh (U.S. Fish and Wildlife Service 2013), urbanization (United States Census Bureau 2013), and areas designated as having special uses or restrictions (North Carolina Department of Environment and Natural Resources 2013).

Methods

Data collection as part of this monitoring effort consists of two fixed stations located in the southern water at CALO on Shackleford Banks (CALOshak) and in the Middle Marshs area between Harkers Island and the Beaufort Inlet (CALOshak2). This report only summarizes the data collected at the Middle Marshes site (CALOshak2; Table 1). Data collection at the Middle Marshes fixed-station site is modeled after an ongoing coastal water-quality monitoring program using methods established by the National Estuarine Research Reserve Program (Wenner and Geist 2001). Detailed field and lab standard operating procedures and methods have been reported for the continuously collected data in Gregory et al. (2013). Methods for both are briefly summarized in the following sections.

Sampling Location at Middle Marshes (CALOshak2)

This site is located near the center of Back Sound and within the boundary of the Rachel Carson Reserve, a protected area managed by the NCNERR. The Rachel Carson Reserve is a 2,315 acre natural area that lies between the town of Beaufort, and Cape Lookout N.S. The Middle Marshes area is the eastern edge of the reserve, and consists of a one mile by two mile tidally influence wetland that provide important habitat for numerous species. The station is not mounted to any permanent structure such as a dock or piling, but is housed horizontally in a modified crab pot, to keep it submerged and protected from damage. A buoy is attached to the housing to aid in locating the sonde for retrievals. The location for this site was selected by NCNERR because of the previously continuous monitoring that was conducted there from 1997 to 2003. It is also in the vicinity of other monitoring efforts conducted by state, federal and university research programs.

Table 1. Location of the Middle Marshes sampling site at Cape Lookout National Seashore during 2008 and 2009.

Name	Location Description	Location (lat /long)	Period of Record
CALOshak2	Middle Marshes	34.694517/-76.6185	04/2008 – Present

Continuous Data

Continuously collected data includes DO, pH, specific conductance (to compute salinity), water temperature, depth and turbidity. Readings for these parameters are collected at 15-minute intervals using YSI data sondes (Model 6600) which are deployed in 3–5 week intervals depending on routine instrument maintenance schedules. The data collection platform at CALOshak2 consists of a modified crab pot design to house the sonde horizontally, approximately 0.3 m from the bottom. The different mount design is a result of shallow water at the site and the lack of a permanent structure to attach the sonde mount. Figure 2 shows a photo of the station and additional details on site selection and installation procedures are reported by Gregory et al. (2013).

Prior to deployment, the data sonde is calibrated according to YSI recommendations for pH (two-point calibration), DO, specific conductance (for salinity measurements), depth and turbidity (two-point calibration) (YSI Incorporated 2011), with additional instructions provided in Gregory et al. (2013). After instrument retrieval, the data sonde is returned to the laboratory where post deployment readings are made using calibration standards to evaluate the accuracy

and validity of the data collected for that deployment period. All pre-deployment and post-retrieval calibration information is recorded on calibration data sheets that are archived at SECN office locations. After post-retrieval processing is complete, the sonde is cleaned, reconditioned, and readied for redeployment with methods outlined by YSI (2011). Performance specifications of the YSI 6600 are shown in Table 2.

Data generated during the deployment period are reviewed and certified by SECN staff prior to being made available to park staff. During the data review process data may be flagged (marked as suspect) for a variety of reasons including: the presence of heavy fouling on equipment, lack of post calibration data, readings outside of equipment specifications, calibration errors, and extended deployment times. All flagged data remain in the data set, but are excluded from analyses and reports. Water-quality data are not corrected; however missing periods of data may result from problems such as probe failures that cause complete loss of data.



Figure 2. Photo of continuous data collection sonde mount used at Middle Marshes (CALOshak2) at Cape Lookout National Seashore. Photo by John Fear, NCNERR staff.

Table 2. Performance specifications of YSI 6600 EDS data loggers deployed at continuous monitoring site (YSI Incorporated 2011).

Parameter	Range	Resolution	Accuracy
Dissolved Oxygen (% saturation)	0–500%	0.1%	0 to 200%: +/- 2% of reading or 2% air saturation, whichever is greater.
Dissolved Oxygen (mg/L)	0–50 mg/L	0.01 mg/L	0 to 20 mg/L: +/- 2% of reading or 0.2 mg/L whichever is greater.
Conductivity	0–100 mS/cm	0.001 to 0.1 mS/cm; range dependent	+/- 0.5% of reading + 0.001 mS/cm
Temperature	-5–50 °C	0.01 °C	+/- 0.15°C
pH	0 to 14 units	0.01 units	+/- 0.2
Depth	0–9 m (0–30 ft)	0.001m (0.001ft)	+/- 0.018m (+/- 0.06 ft)
Salinity	0–70 ppt	0.01 ppt	+/- 1% of reading or 0.1 ppt, whichever is greater.
Turbidity	0–1000 NTU	0.1 NTU	+/- 2% of reading or 0.3 NTU, whichever is greater.

Discrete Data

Water sample collection for this project is conducted by NCNERRS staff, usually at the time of routine station maintenance. Secchi depth is measured using a standard 8-inch diameter black and white Secchi disk. Water samples are collected as grabs in clean, field rinsed sample containers. Samples are filtered using a 0.45 micron filter prior to preservation. Water samples and chlorophyll *a* filters are shipped to water-quality analysis labs on wet ice. QA/QC field sampling includes both field blanks and duplicates. Original chain of custody paperwork accompanies all samples to the laboratory. Data collection standard operating procedures are further documented in Gregory et al. (2013). Samples were analyzed by Chesapeake Biological Laboratory in Solomons, Maryland.

Water clarity scores and water clarity conditions were derived from estimated light attenuation coefficients (k) using the equation: $k = a / Z_{\text{Secchi}}$, where Z is Secchi depth, in meters and a is assigned to one of three values depending on the water body's naturally occurring clarity conditions ($a = 1.0$ for naturally turbid conditions, $a = 1.4$ for moderately turbid conditions, or $a = 1.7$ for clear water estuaries). Constants used for CALO are 1.4 (Lisa Smith 2009, USEPA personal communication) and were estimated for each water clarity class based on values reported by Smith et al. (2006). This method of estimating water clarity condition is generally used when information on water column light transmission are missing; the SECN is reporting derived values for data consistency among other Network parks and recently collected datasets where water column light transmission information was not collected.

Assessment Criteria

Water quality was assessed for each of the parameters following the East/Gulf Coast site criteria in United State Environmental Protection Agency's (USEPA) National Coastal Assessment IV Report (Table 3) using data from the monthly samples. The categorical assessments (i.e., *good*, *fair*, and *poor*) use measurements of chlorophyll *a*, nutrients, dissolved oxygen and water clarity and are intended to highlight a range of conditions including acutely degraded water-quality

conditions. Light attenuation coefficients (k) were used to assess water clarity conditions using criteria categories in Smith et al. (2006) which are equivalent to the USEPA criteria for the assessed water bodies (United States Environmental Protection Agency 2012).

Table 3. USEPA (2012) coastal water-quality monitoring condition criteria for water-quality parameters collected by the Southeast Coast Network.

Rating	Water Clarity ¹ (k)	Chlorophyll a ($\mu\text{g/L}$)	Dissolved Inorganic Nitrogen (DIN) (mg/L)	Dissolved Inorganic Phosphorus (DIP) (mg/L)	Dissolved Oxygen (mg/L)
Good	<1.61	<5	<0.1	<0.01	>5
Fair	1.61–2.30	5–20	0.1–0.5	0.01–0.05	2–5
Poor	>2.30	>20	>0.5	>0.05	<2

¹ Light attenuation coefficients (k) were used to assess water clarity conditions using criteria categories in Smith et al. (2006) which are comparable to the USEPA (2012) criteria for the assessed water bodies.

Results

Continuous Data

Individual and monthly mean low readings of salinity at Middle Marshes (CALOshak2) in 2008 occurred in April at 27.8 and 31.9 ppt, respectively. In 2009 individual and monthly mean low salinity reading of 18.9 and 21.7 ppt occurred in December during a period of heavy rainfall. Conversely, individual and monthly mean high readings at Middle Marshes in 2008 were 39.1 and 36.7 ppt respectively in September. Whereas individual and monthly mean high readings in 2009 were 38.6 and 36.6 ppt respectively in July.

Mean monthly dissolved oxygen levels were ranging from 5.9 to 8.6 mg/L in 2008. Mean daily DO levels were never below 5.0 mg/L at Middle Marshes in 2008 or in 2009. Individual readings below 5.0 mg/L were common in 2008 occurring between June and September. In 2009 monthly mean dissolved oxygen ranged from 6.0 to 9.5 mg/L. The lowest recorded individual DO reading of 1.1 mg/L occurred in April 2009.

Monthly mean pH values ranged from 7.9 to 8.3 in 2008. pH in 2009 had a monthly mean range of 7.6 to 8.6.

Average monthly turbidity at Middle Marshes never exceeded 15 NTUs in 2008 and did not exceed 22.2 NTUs in 2009. For a two-day period in mid-September the daily average for turbidity was 199 and 107 NTUs and occurred during a period of heavy local rainfall. Excluding those two days, the mean daily turbidity for 2009 did not exceed 44 NTUs.

Monthly mean water temperatures that were recorded in 2008 peaked in July at 27.8°C (82.0°F), and bottomed out in November at 11.7°C (53.1°F). Individual readings at CALOshak2 ranged from 32.9°C (91.3°F) in August to 7.0°C (44.6°F) in November. Monthly mean and individual water temperatures in 2009 ranged from highs in August of 28.1°C (82.58°F) and 33.28°C (91.90°F) respectively, to lows of 8.0°C (46.4°F) and 0.8°C (33.44°F) respectively in January.

Mean daily values for each parameter are displayed in Figures 3 through 8. Minimum and maximum values with the mean and standard deviation for each month are shown in Table 4. Percentage of expected count indicates the level of completeness of the monthly data sets used for calculating mean, maximum and minimum statistics, and equals the number of data points collected (i.e., not missing or flagged) divided by the total number of expected points for a complete month of data. For those months where all of the data were either missing and/or flagged, the percentage of values is 0% and no statistics (mean, maximum or minimum) are presented. When the percentage of values is low, the statistics (mean, maximum and minimum) may be less informative than for those months where all or nearly all of the data were used in the calculation of summary statistics.

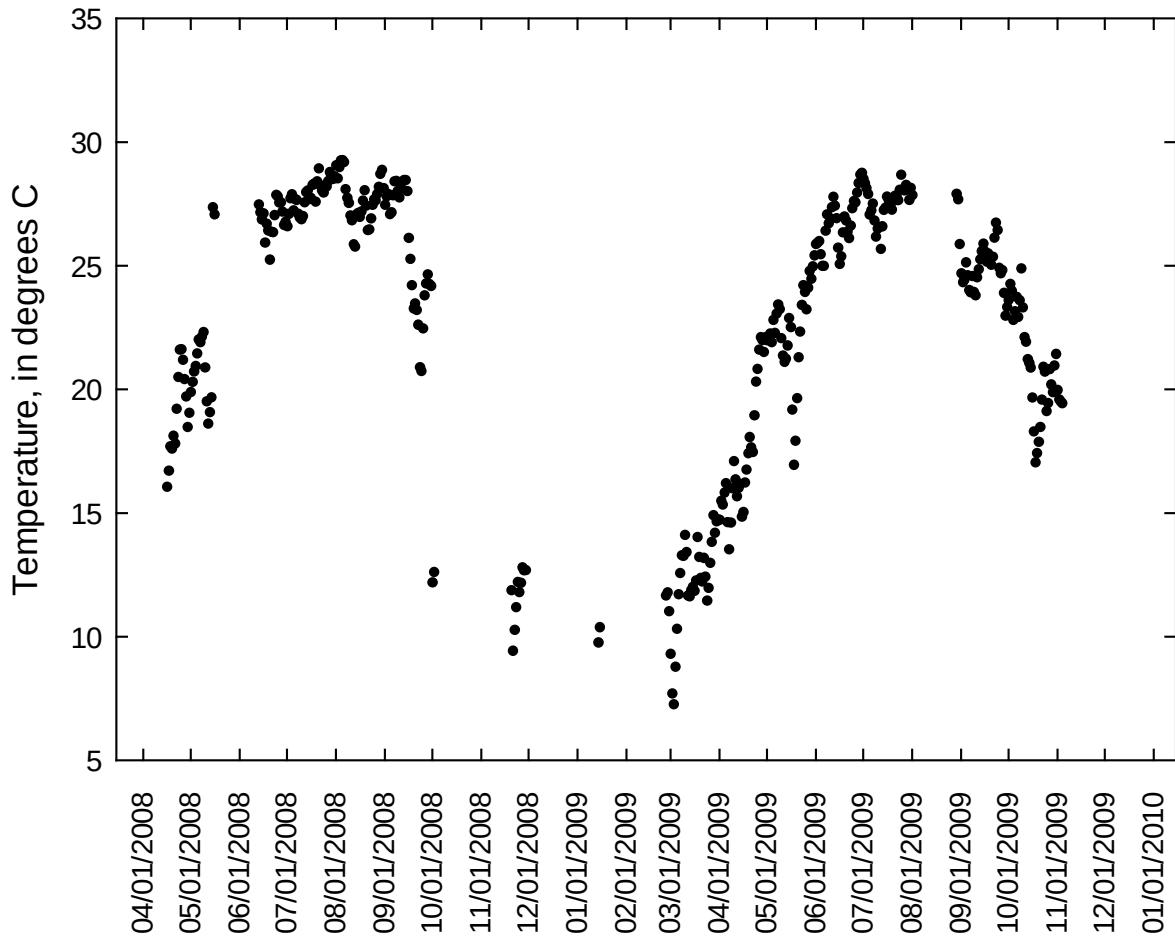


Figure 3. Mean daily values for water temperature at Middle Marshes (CALOshak2) at Cape Lookout National Seashore during 2008-2009. Breaks in data record indicate missing and/or flagged data.

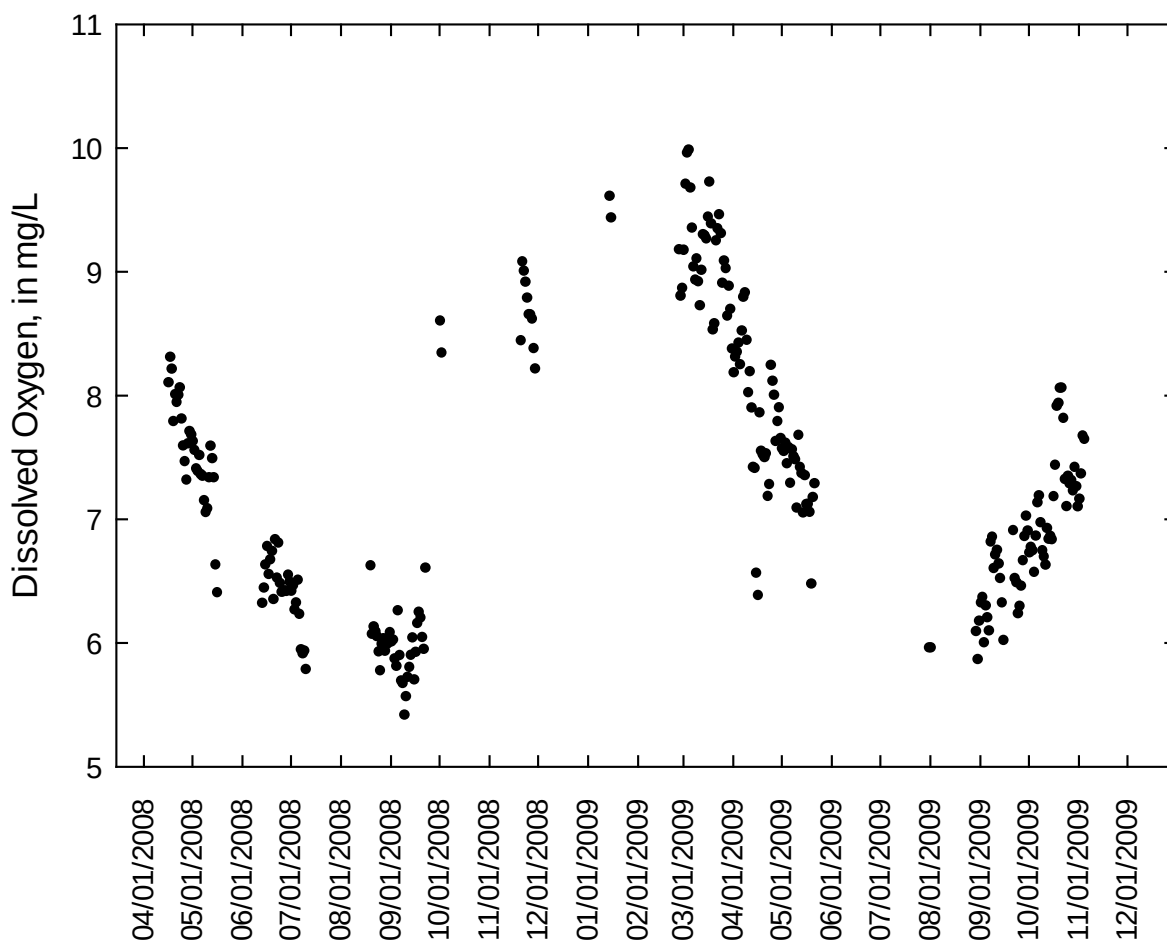


Figure 4. Mean daily values for dissolved oxygen at Middle Marshes (CALOshak2) at Cape Lookout National Seashore during 2008-2009. Breaks in data record indicate missing and/or flagged data.

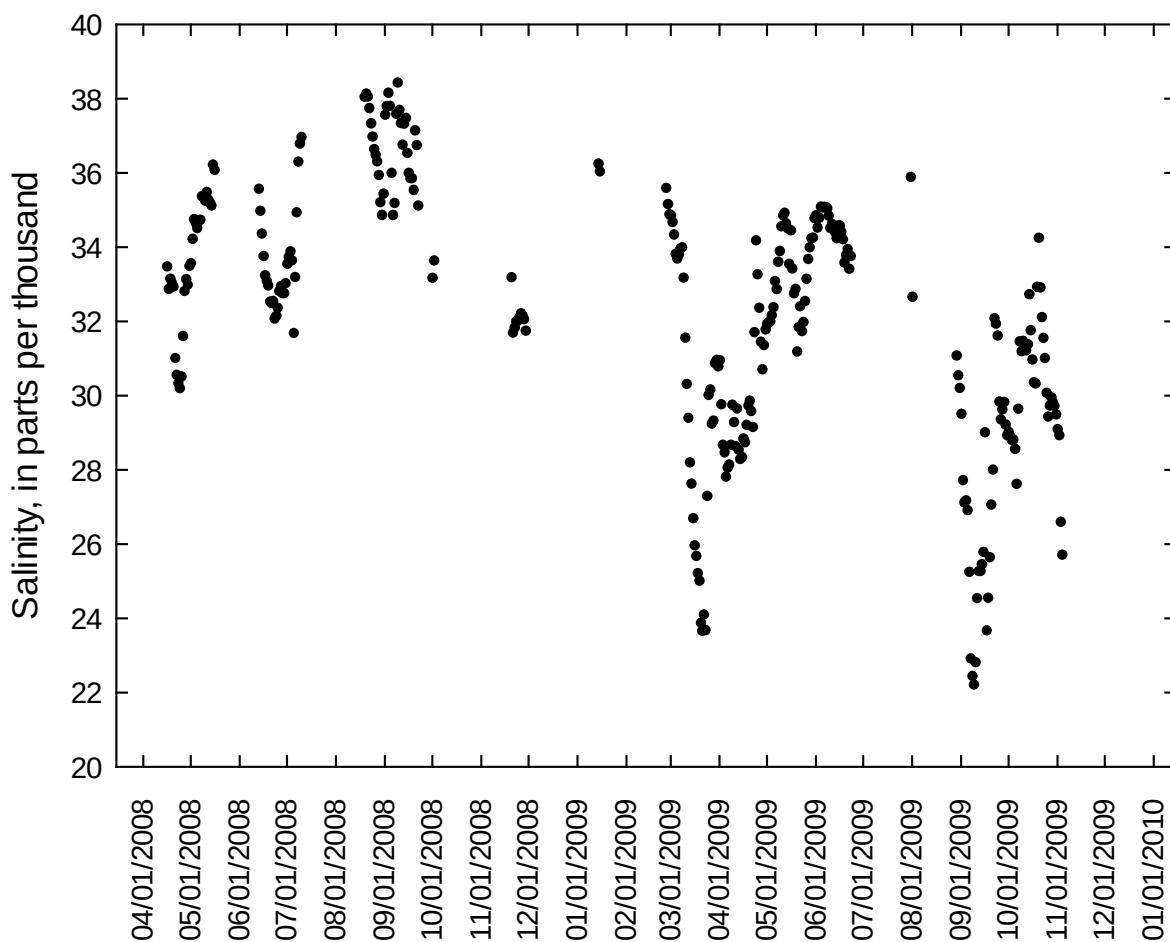


Figure 5. Mean daily values for salinity at Middle Marshes (CALOshak2) at Cape Lookout National Seashore during 2008-2009. Breaks in data record indicate missing and/or flagged data.

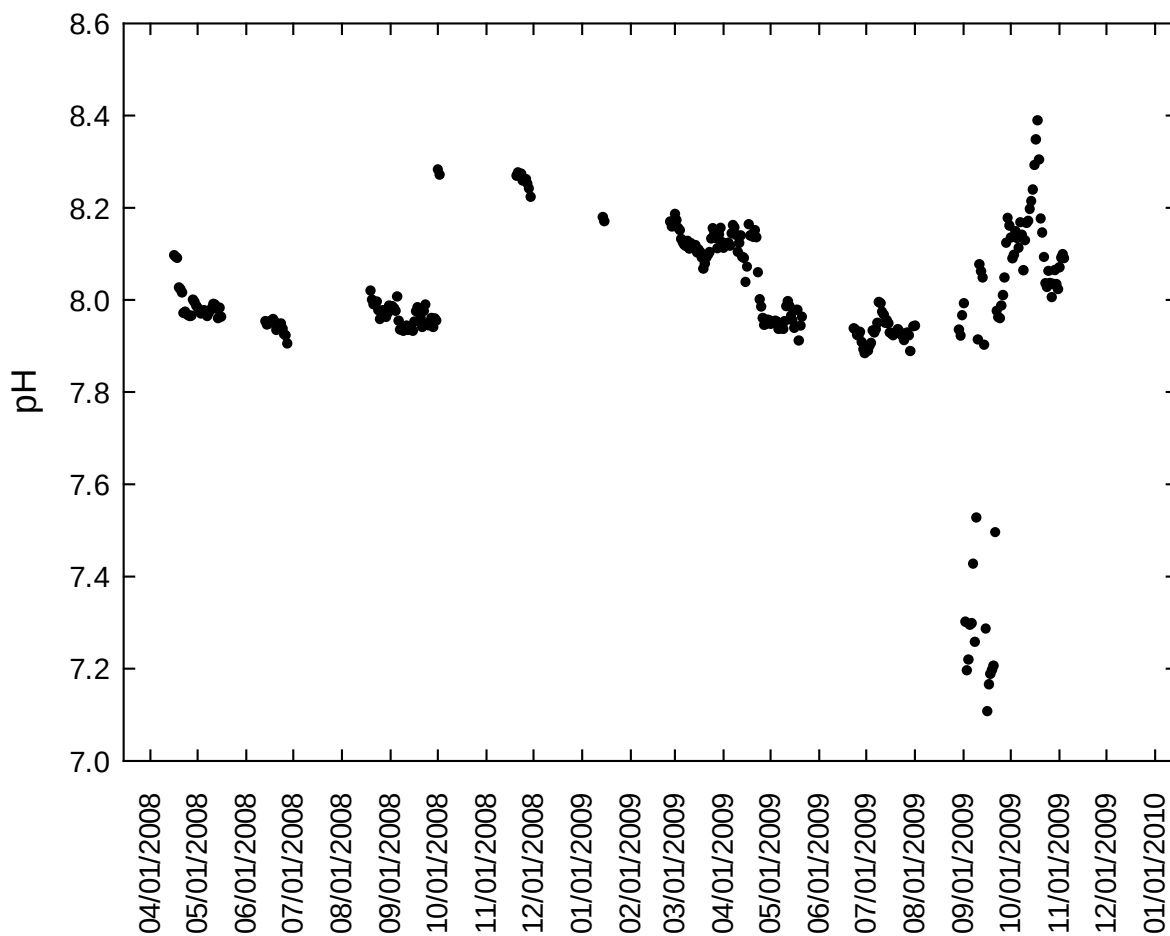


Figure 6. Mean daily values for pH at Middle Marshes (CALOshak2) at Cape Lookout National Seashore during 2008-2009. Breaks in data record indicate missing and/or flagged data.

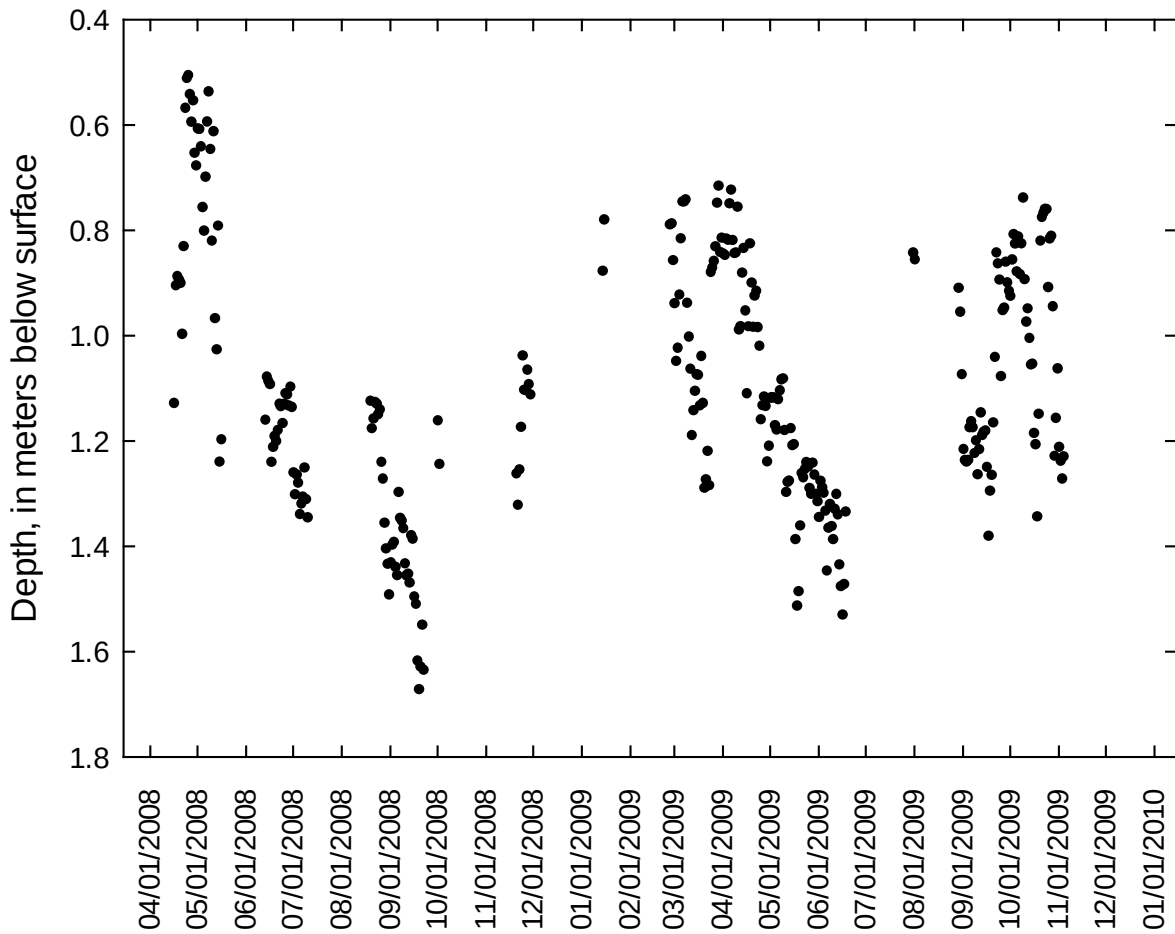


Figure 7. Mean daily values for data sonde deployment depth at Middle Marshes (CALOshak2) at Cape Lookout National Seashore during 2008-2009. Breaks in data record indicate missing and/or flagged data.

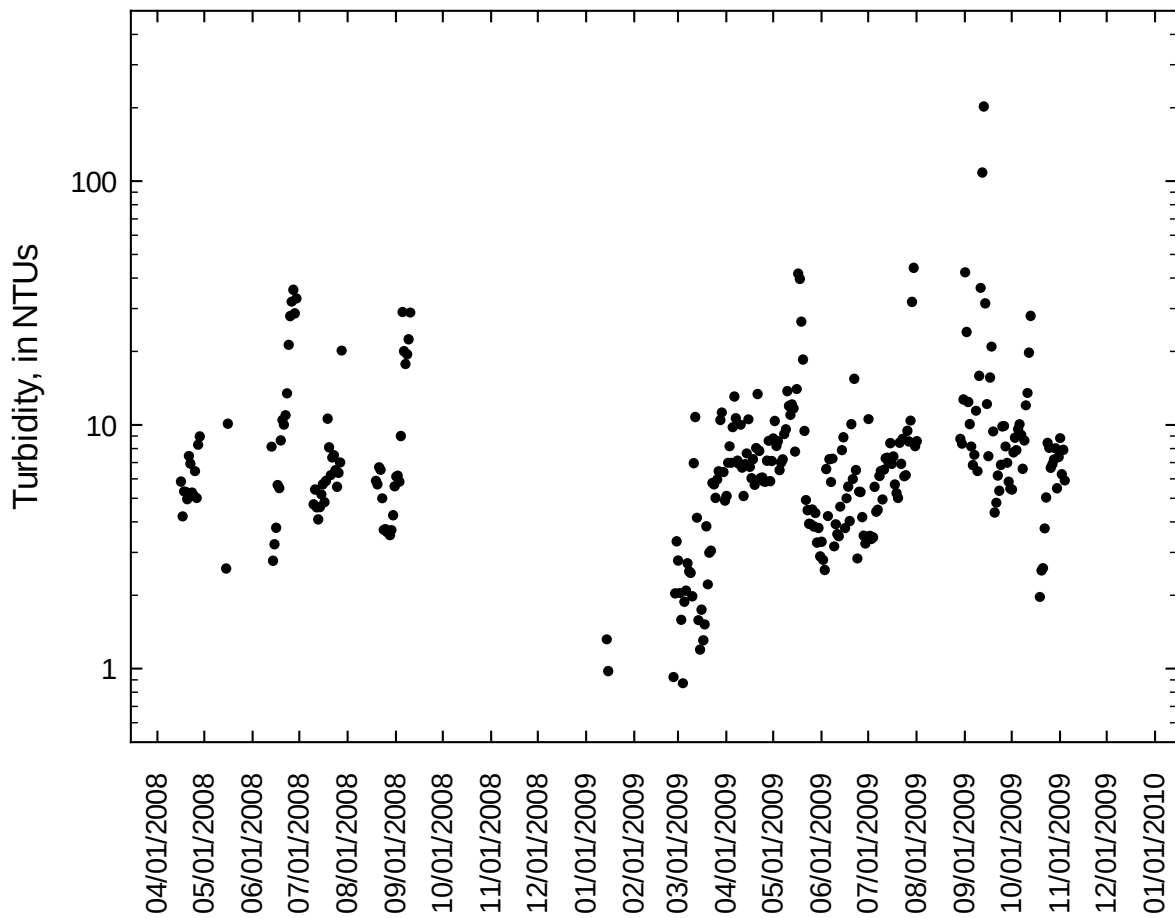


Figure 8. Mean daily values for turbidity at Middle Marshes (CALOshak2) at Cape Lookout National Seashore during 2008-2009. Breaks in data record indicate missing and/or flagged data.

Table 4. Monthly minimum, maximum, and mean values for water-quality parameters collected at Middle Marshes (CALOshak2) at Cape Lookout National Seashore during 2008-2009. Standard deviation (stdev) of the mean values are provided in parentheses. Percentage of values for each month indicates the number of data points collected during one calendar month of data collection divided by the total number of expected points for a complete month of data.

	Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/L)	Depth (m)	pH	Turbidity (NTU)
April 2008 Expected count 1,289						
Actual Count	1,289	1,277	1,277	1,277	1,289	1,156
Minimum	14.82	27.75	5.58	0.19	7.81	1.2
Mean (stdev)	19.1 (2.3)	31.9 (1.6)	7.8 (0.8)	0.7 (0.3)	8.0 (0.1)	5.9 (6.0)
Maximum	25.56	34.69	10.44	1.53	8.15	122.7
Percentage	100%	99%	99%	99%	100%	90%
May 2008 Expected count 2,976						
Actual Count	1,390	1,390	1,390	1,390	1,390	0
Minimum	16.45	30.30	5.41	0.02	7.82	--
Mean (stdev)	20.5 (1.8)	34.7 (0.9)	7.4 (0.6)	0.7 (0.3)	8.0 (0.0)	--
Maximum	26.23	36.23	9.37	1.45	8.06	--
Percentage	47%	47%	47%	47%	47%	0%
June 2008 Expected count 2,880						
Actual Count	1,781	1,781	1,781	1,781	1,589	1,749
Minimum	23.59	31.57	4.16	0.47	7.76	0.2
Mean (stdev)	26.9 (1.3)	33.3 (1.3)	6.5 (0.9)	1.2 (0.3)	7.9 (0.1)	14.2 (12.2)
Maximum	31.57	36.5	8.61	1.79	8.03	111.3
Percentage	62%	62%	62%	62%	55%	61%
July 2008 Expected count 2,976						
Actual Count	2,976	999	999	999	0	1,785
Minimum	24.06	28.96	4.08	0.55	--	0.8
Mean (stdev)	27.8 (1.4)	34.1 (1.6)	6.2 (0.8)	1.3 (0.3)	--	6.8 (5.3)
Maximum	32.53	37.2	7.86	1.94	--	55
Percentage	100%	34%	34%	34%	0%	60%
August 2008 Expected count 2,976						
Actual Count	2,975	1,087	1,087	1,087	1,087	1,060
Minimum	23.56	34.05	4.19	0.66	7.83	0
Mean (stdev)	27.7 (1.4)	36.7 (1.1)	6.0 (0.7)	1.2 (0.3)	8.0 (0.1)	4.6 (3.1)
Maximum	32.92	38.31	7.08	1.94	8.06	18.7
Percentage	100%	37%	37%	37%	37%	36%
September 2008 Expected count 2,880						
Actual Count	2,880	2,186	2,186	2,186	2,880	1,024
Minimum	19.21	29.52	3.98	0.9	7.75	0.4
Mean (stdev)	25.8 (2.6)	36.7 (1.8)	5.9 (0.7)	1.5 (0.3)	8.0 (0.1)	14.9 (10.3)
Maximum	31.37	39.09	7.27	2.23	8.05	77.2
Percentage	100%	76%	76%	76%	100%	36%
October 2008 Expected count 2,976						
Actual Count	62	0	0	0	62	0
Minimum	23.27	--	--	--	7.81	--
Mean (stdev)	24.1 (0.7)	--	--	--	8.0 (0.1)	--
Maximum	26.16	--	--	--	8.03	--
Percentage	2%	0%	0%	0%	2%	0%

Table 4. Continued.

	Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/L)	Depth (m)	pH	Turbidity (NTU)
November 2008 Expected count 2,880						
Actual Count	1,078	1,078	1,078	1,078	1,078	0
Minimum	7.02	29.26	7.37	0.65	8.16	--
Mean (stdev)	11.7 (1.7)	32.3 (1.0)	8.6 (0.5)	1.2 (0.3)	8.3 (0.0)	--
Maximum	14.79	34.61	10.04	1.71	8.3	--
Percentage	37%	37%	37%	37%	37%	0%
December 2008 Expected count 2,976						
Actual Count	0	0	0	0	0	0
Minimum	--	--	--	--	--	--
Mean (stdev)	--	--	--	--	--	--
Maximum	--	--	--	--	--	--
Percentage	0%	0%	0%	0%	0%	0%
January 2009 Expected count 2,976						
Actual Count	1,672	1,672	1,672	1,672	1,672	1,672
Minimum	0.80	33.90	7.88	0.14	8.01	0.9
Mean (stdev)	8.0 (2.1)	36.0 (0.5)	9.5 (0.5)	0.7 (0.3)	8.2 (0.0)	3.3 (1.9)
Maximum	14.18	37.22	10.83	1.73	8.28	19.1
Percentage	56%	56%	56%	56%	56%	56%
February 2009 Expected count 2,688						
Actual Count	2,659	2,659	2,659	2,659	2,659	2,658
Minimum	3.61	33.25	7.69	0.02	6.83	0.2
Mean (stdev)	10.1 (2.1)	36.6 (0.9)	9.1 (0.5)	0.7 (0.3)	8.2 (0.0)	10.3 (29.0)
Maximum	16.48	38.59	10.78	1.36	8.25	345.7
Percentage	99%	99%	99%	99%	99%	99%
March 2009 Expected count 2,976						
Actual Count	2,975	2,975	2,975	2,975	2,975	2,963
Minimum	4.18	21.82	4.51	0.08	7.70	0.0
Mean (stdev)	12.1 (2.3)	29.6 (3.9)	9.2 (0.8)	1.0 (0.3)	8.1 (0.0)	3.9 (4.3)
Maximum	19.51	35.56	11.74	1.71	8.27	60.3
Percentage	100%	100%	100%	100%	100%	100%
April 2009 Expected count 2,880						
Actual Count	2,880	2,880	2,880	2,880	2,880	2,880
Minimum	10.57	25.85	1.06	0.37	7.62	1.7
Mean (stdev)	17.0 (2.9)	29.8 (1.7)	7.9 (1.1)	0.9 (0.3)	8.1 (0.1)	7.5 (5.4)
Maximum	27.06	35.43	9.92	1.78	8.24	172.1
Percentage	100%	100%	100%	100%	100%	100%
May 2009 Expected count 2,976						
Actual Count	2,975	2,975	2,059	2,975	2,059	2,902
Minimum	15.37	28.63	3.17	0.62	7.66	0.0
Mean (stdev)	22.2 (2.3)	33.1 (1.3)	7.3 (1.0)	1.2 (0.3)	8.0 (0.1)	10.9 (14.9)
Maximum	30.13	35.75	9.59	1.91	8.08	329.0
Percentage	100%	100%	69%	100%	69%	98%

Table 4. Continued.

	Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/L)	Depth (m)	pH	Turbidity (NTU)
June 2009 Expected count 2,880						
Actual Count	2,880	2,267	0	1,795	613	2,395
Minimum	23.21	31.65	--	0.80	7.80	0.0
Mean (stdev)	26.5 (1.5)	34.5 (0.6)	--	1.4 (0.3)	7.9 (0.1)	5.3 (12.5)
Maximum	31.73	35.78	--	1.96	8.00	179.8
Percentage	100%	79%	0%	62%	21%	83%
July 2009 Expected count 2,976						
Actual Count	2,975	0	0	0	2,899	2,928
Minimum	23.79	--	--	--	7.72	0.0
Mean (stdev)	27.5 (1.2)	--	--	--	7.9 (0.1)	7.7 (14.9)
Maximum	31.70	--	--	--	8.06	638.8
Percentage	100%	0%	0%	0%	97%	98%
August 2009 Expected count 2,976						
Actual Count	2,976	348	348	348	2,976	2,083
Minimum	25.49	29.99	4.55	0.20	6.65	0.0
Mean (stdev)	28.1 (1.3)	32.2 (2.0)	6.0 (0.6)	0.9 (0.2)	7.7 (0.3)	9.5 (12.0)
Maximum	33.28	36.60	6.98	1.32	8.01	186.0
Percentage	100%	12%	12%	12%	100%	70%
September 2009 Expected count 2,880						
Actual Count	2,879	2,879	2,331	2,879	2,879	2,869
Minimum	21.23	19.26	2.48	0.45	6.99	0.0
Mean (stdev)	24.9 (1.1)	27.0 (3.1)	6.5 (0.7)	1.1 (0.3)	7.6 (0.4)	22.1 (53.3)
Maximum	28.49	34.55	8.18	1.80	8.24	818.4
Percentage	100%	100%	81%	100%	100%	100%
October 2009 Expected count 2,976						
Actual Count	2,976	2,976	2,976	2,976	2,976	2,392
Minimum	14.50	26.69	4.95	0.37	7.84	0.0
Mean (stdev)	21.1 (2.4)	30.5 (1.7)	7.2 (0.6)	0.9 (0.3)	8.1 (0.1)	8.6 (6.7)
Maximum	26.95	36.08	8.88	1.77	8.45	102.5
Percentage	100%	100%	100%	100%	100%	80%
November 2009 Expected count 2,880						
Actual Count	1,051	1,051	1,051	1,051	1,051	443
Minimum	12.10	21.72	6.12	0.32	7.89	0.0
Mean (stdev)	17.4 (2.5)	27.3 (2.2)	7.8 (0.7)	1.0 (0.3)	8.3 (0.2)	7.3 (5.5)
Maximum	22.23	32.25	9.71	1.86	8.64	55.0
Percentage	36%	36%	36%	36%	36%	15%
December 2009 Expected count 2,976						
Actual Count	2,086	2,086	2,086	2,086	2,086	0
Minimum	6.76	18.93	7.73	0.12	8.34	--
Mean (stdev)	13.2 (2.4)	21.7 (1.0)	8.9 (0.6)	0.9 (0.3)	8.6 (0.1)	--
Maximum	17.85	24.00	10.61	1.60	8.74	--
Percentage	70%	70%	70%	70%	70%	0%

Discrete Data

Monthly water-quality data collected at CALO during 2008-2009 are shown in Table 5. Condition categories of assessed parameters from USEPA (2012) except for water clarity which was assessed using light attenuation values (*k*) derived from Secchi depth readings using a constant for estuarine water with naturally turbid conditions (Smith et al. 2006)). In cases when the Secchi disk hit bottom, an accurate (*k*) value cannot be computed. These values are presented as estimated values. Condition categories generally correspond to those used by USEPA in the National Coastal Condition Report IV (United States Environmental Protection Agency 2012). Nutrient results were not available for September and December of 2009. Dissolved inorganic nitrogen and phosphorus levels were generally low and were rated *good* for all readings during 2008-09. All chlorophyll *a* levels were low >5 ug/l and were rated as *good* for the two-year span. Secchi disk depths, used to calculate water clarity, hit bottom 16 of the 19 months. Seven of the 16 months when the Secchi disk hit the bottom, the reading would still be in the *good* category. Only two fair water clarity results were reported during the time span.

Table 5. Monthly nutrient data collected at Middle Marshes (CALOshak2) at Cape Lookout National Seashore during 2008-2009. Water clarity was assessed using light attenuation values (*k*) using a constant for estuarine water with naturally turbid conditions (Smith et al. 2006) and assessment categories that correspond to USEPA (2012). Condition of other assessed parameters from USEPA (2012). [Green (●), *good*; yellow (●), *fair*; and red (●), *poor*; *k*, light attenuation coefficient; µg/L, micrograms per liter; mg/L, milligrams per liter; --, missing data or no calculation conducted; B, Secchi disk hit bottom, value estimated or not calculated; Chl *a*, chlorophyll *a*; DO, dissolved oxygen; DIN, dissolved inorganic nitrogen; DIP, dissolved inorganic phosphorus; TDN, total dissolved nitrogen; TDP, total dissolved phosphorus].

Date	Time	Water Clarity (<i>k</i>)	Chl <i>a</i> (µg/L)	DO (mg/L)	DIN (mg/L)	DIP (mg/L)	TDN (mg/L)	TDP (mg/L)
04/17/2008	12:55	1.40B	2.98	--	--	--	0.19	0.0155
5/15/2008	13:35	1.17B	2.84	7.79	--	--	0.19	0.0118
06/12/2008	10:35	B	3.00	6.42	--	--	0.24	0.0194
07/11/2008	9:35	B	2.60	5.12	--	--	0.18	0.0129
8/20/2008	15:24	B	4.63	6.6	0.0113	0.0024	0.31	0.0199
10/01/2008	15:20	B	3.22	--	--	--	0.28	0.0198
11/19/2008	9:44	1.12B	4.98	9.09	0.0298	0.0054	0.3	0.0165
01/14/2009	13:58	B	2.44	9.53	--	--	0.24	0.0137
02/25/2009	14:22	B	0.73	10.09	0.0165	0.0029	0.23	0.013
03/25/2009	10:10	1.12B	1.76	9.38	--	--	0.3	0.0145
04/24/2009	14:30	B	1.86	9.07	--	--	--	--
05/22/2009	10:45	1.87	4.63	8.8	--	--	0.23	0.0152
06/24/2009	14:30	1.40	1.24	--	--	--	0.23	0.0138
07/31/2009	9:27	B	1.50	--	0.0348	0.006	0.28	0.025
08/28/2009	8:50	B	2.01	5.24	--	--	0.24	0.0227
09/22/2009	15:25	1.87	3.75	7.15	--	--	0.26	0.0167
10/20/2009	14:45	1.40B	1.40	8.3	--	--	0.31	0.022
11/24/2009	15:30	0.97B	2.17	7.78	--	--	0.31	0.0161
12/22/2009	16:15	1.40B	0.85	10.38	--	--	0.29	0.0142

Anomalies and Missing Data

The period of data collection presented in this report is April 17, 2008 at 13:45 through December 31, 2009 at 23:45. Missing or anomalous data during the reporting year may be due to several factors, including equipment malfunction, calibration errors, excessive bio-fouling, or periods of time when equipment is not deployed (such as during extreme storm events or routine equipment swaps). During 2008, 40% of all potential continuous data at CALOshak2 were used in figures and tables. During 2009, 74% of all potential data were used. Table 6 provides a listing of parameters affected by data anomalies and descriptions for possible error sources for a given date range. During 2008-09, missing and anomalous data were caused by several factors, including but not limited to equipment malfunction from October to mid-November 2008, calibration errors in July- August of 2008 and May- June 2009 that affected dissolved oxygen and pH, and bio-fouling that affected turbidity in early July 2008. No corrections were applied to data.

Table 6. Description of anomalous and deleted data and associated periods of record for the data collection at Middle Marshes (CALOshak2) at Cape Lookout National Seashore during 2008-2009.

Parameter	Description	Start Date & Time	End Date & Time
All	Missing Data	5/15/2008 1:45 PM	5/15/2008 1:45 PM
		8/20/2008 4:00 PM	8/20/2008 4:00 PM
		10/1/2008 3:30 PM	11/19/2008 10:45 AM
		2/25/2009 2:15 PM	2/25/2009 3:00 PM
		3/25/2009 10:15 AM	3/25/2009 10:15 AM
		5/22/2009 10:45 AM	5/22/2009 10:45 AM
		7/31/2009 9:15 AM	7/31/2009 9:15 AM
		9/22/2009 3:30 PM	9/22/2009 3:30 PM
		11/24/2009 4:15 PM	11/24/2009 4:30 PM
Dissolved Oxygen	Data is marked suspect due to a calibration error.	7/11/2008 9:45 AM	8/20/2008 3:45 PM
		5/22/2009 11:00 AM	6/24/2009 2:30 PM
	Data is marked suspect due to heavy fouling.	9/23/2008 6:30 PM	10/1/2008 3:15 PM
	Data is marked suspect due to mount / equipment issues.	11/30/2008 4:30 PM	1/14/2009 1:45 PM
	Data is suspect due to an unknown sonde malfunction.	4/17/2008 1:45 PM	4/17/2008 4:30 PM
		5/3/2008 12:00 PM	5/3/2008 1:15 PM
		5/4/2008 1:15 PM	5/4/2008 1:45 PM
		6/24/2009 2:45 PM	7/31/2009 9:00 AM
		7/31/2009 9:30 AM	8/28/2009 8:45 AM
		11/5/2009 6:00 PM	11/24/2009 4:00 PM
		12/22/2009 5:30 PM	12/31/2009 12:00 AM
	Data marked suspect because no post calibration was performed and data quality cannot be verified.	5/15/2008 2:00 PM	6/12/2008 10:30 AM
	Data marked suspect due to optical wiper malfunction.	9/16/2009 10:30 PM	9/22/2009 3:15 PM

Table 6. Continued.

Parameter	Description	Start Date & Time	End Date & Time
Dissolved Oxygen (continued)	Data was deleted due to YSI 6600 data sonde being out of water. The salinity and dissolved oxygen readings indicated that the sonde was out of water.	2/6/2009 11:00 PM	2/6/2009 11:15 PM
		2/7/2009 11:15 PM	2/8/2009 1:00 AM
		2/8/2009 1:00 PM	2/8/2009 1:15 PM
		2/9/2009 12:15 AM	2/9/2009 2:00 AM
		2/10/2009 2:00 AM	2/10/2009 2:30 AM
		2/23/2009 1:15 AM	2/23/2009 1:15 AM
		2/26/2009 3:45 PM	2/26/2009 3:45 PM
		11/5/2009 3:30 PM	11/5/2009 5:45 PM
pH	Data is marked suspect due to a calibration error.	7/11/2008 9:45 AM	8/20/2008 3:45 PM
		5/22/2009 11:00 AM	6/24/2009 2:30 PM
	Data is marked suspect due to heavy fouling.	6/29/2008 12:00 AM	7/11/2008 9:30 AM
		7/30/2009 2:15 PM	7/31/2009 9:00 AM
	Data is marked suspect due to mount / equipment issues.	11/30/2008 4:30 PM	1/14/2009 1:45 PM
	Data is suspect due to an unknown sonde malfunction.	5/3/2008 12:00 PM	5/3/2008 1:15 PM
		5/4/2008 1:15 PM	5/4/2008 1:45 PM
		11/5/2009 6:00 PM	11/24/2009 4:00 PM
		12/22/2009 5:30 PM	12/31/2009 12:00 AM
	Data marked suspect because no post calibration was performed and data quality cannot be verified.	5/15/2008 2:00 PM	6/12/2008 10:30 AM
	Data was deleted due to YSI 6600 data sonde being out of water. The salinity and dissolved oxygen readings indicated that the sonde was out of water.	2/6/2009 11:00 PM	2/6/2009 11:15 PM
		2/7/2009 11:15 PM	2/8/2009 1:00 AM
		2/8/2009 1:00 PM	2/8/2009 1:15 PM
		2/9/2009 12:15 AM	2/9/2009 2:00 AM
		2/10/2009 2:00 AM	2/10/2009 2:30 AM
		2/23/2009 1:15 AM	2/23/2009 1:15 AM
		2/26/2009 3:45 PM	2/26/2009 3:45 PM
		11/5/2009 3:30 PM	11/5/2009 5:45 PM
Salinity	Data is marked suspect due to a calibration error.	7/11/2008 9:45 AM	8/20/2008 3:45 PM
	Data is marked suspect due to heavy fouling.	9/23/2008 6:30 PM	10/1/2008 3:15 PM
	Data is marked suspect due to mount / equipment issues.	11/30/2008 4:30 PM	1/14/2009 1:45 PM
	Data is suspect due to an unknown sonde malfunction.	4/17/2008 1:45 PM	4/17/2008 4:30 PM
		5/3/2008 12:00 PM	5/3/2008 1:15 PM
		5/4/2008 1:15 PM	5/4/2008 1:45 PM
		6/24/2009 2:45 PM	7/31/2009 9:00 AM
		7/31/2009 9:30 AM	8/28/2009 8:45 AM
		11/5/2009 6:00 PM	11/24/2009 4:00 PM
		12/22/2009 5:30 PM	12/31/2009 12:00 AM

Table 6. Continued.

Parameter	Description	Start Date & Time	End Date & Time
Salinity (continued)	Data marked suspect because no post calibration was performed and data quality cannot be verified.	5/15/2008 2:00 PM	6/12/2008 10:30 AM
	Data was deleted due to YSI 6600 data sonde being out of water. The salinity and dissolved oxygen readings indicated that the sonde was out of water.	2/6/2009 11:00 PM	2/6/2009 11:15 PM
		2/7/2009 11:15 PM	2/8/2009 1:00 AM
		2/8/2009 1:00 PM	2/8/2009 1:15 PM
		2/9/2009 12:15 AM	2/9/2009 2:00 AM
		2/10/2009 2:00 AM	2/10/2009 2:30 AM
		2/23/2009 1:15 AM	2/23/2009 1:15 AM
		2/26/2009 3:45 PM	2/26/2009 3:45 PM
		11/5/2009 3:30 PM	11/5/2009 5:45 PM
Temperature	Data is marked suspect due to mount / equipment issues.	11/30/2008 4:30 PM	1/14/2009 1:45 PM
	Data is suspect due to an unknown sonde malfunction.	5/3/2008 12:00 PM	5/3/2008 1:15 PM
		5/4/2008 1:15 PM	5/4/2008 1:45 PM
		11/5/2009 6:00 PM	11/24/2009 4:00 PM
		12/22/2009 5:30 PM	12/31/2009 12:00 AM
	Data marked suspect because no post calibration was performed and data quality cannot be verified.	5/15/2008 2:00 PM	6/12/2008 10:30 AM
	Data was deleted due to YSI 6600 data sonde being out of water. The salinity and dissolved oxygen readings indicated that the sonde was out of water.	2/6/2009 11:00 PM	2/6/2009 11:15 PM
		2/7/2009 11:15 PM	2/8/2009 1:00 AM
		2/8/2009 1:00 PM	2/8/2009 1:15 PM
		2/9/2009 12:15 AM	2/9/2009 2:00 AM
		2/10/2009 2:00 AM	2/10/2009 2:30 AM
		2/23/2009 1:15 AM	2/23/2009 1:15 AM
		2/26/2009 3:45 PM	2/26/2009 3:45 PM
		11/5/2009 3:30 PM	11/5/2009 5:45 PM
Turbidity	Data is marked suspect due to a calibration error.	11/19/2008 11:00 AM	11/30/2008 4:15 PM
	Data is marked suspect due to heavy fouling.	6/30/2008 4:00 PM	7/11/2008 9:30 AM
		7/30/2008 12:00 AM	8/20/2008 3:45 PM
		10/15/2009 12:00 AM	10/20/2009 2:45 PM
	Data is marked suspect due to mount / equipment issues.	11/30/2008 4:30 PM	1/14/2009 1:45 PM
	Data is suspect due to an unknown sonde malfunction.	5/3/2008 12:00 PM	5/3/2008 1:15 PM
		5/4/2008 1:15 PM	5/4/2008 1:45 PM
		11/5/2009 6:00 PM	11/24/2009 4:00 PM
		12/22/2009 5:30 PM	12/31/2009 12:00 AM
	Data marked suspect because no post calibration was performed and data quality cannot be verified.	5/15/2008 2:00 PM	6/12/2008 10:30 AM
	Data marked suspect due to optical wiper malfunction.	4/29/2008 2:45 PM	5/3/2008 11:45 AM
		5/3/2008 1:30 PM	5/4/2008 1:00 PM
		5/4/2008 2:00 PM	5/15/2008 1:30 PM

Table 6. Continued.

Parameter	Description	Start Date & Time	End Date & Time
Turbidity (continued)	Data marked suspect due to optical wiper malfunction (continued).	9/11/2008 4:00 PM	10/1/2008 3:15 PM
	Data was deleted due to YSI 6600 data sonde being out of water. The salinity and dissolved oxygen readings indicated that the sonde was out of water.	2/6/2009 11:00 PM	2/6/2009 11:15 PM
		2/7/2009 11:15 PM	2/8/2009 1:00 AM
		2/8/2009 1:00 PM	2/8/2009 1:15 PM
		2/9/2009 12:15 AM	2/9/2009 2:00 AM
		2/10/2009 2:00 AM	2/10/2009 2:30 AM
		2/23/2009 1:15 AM	2/23/2009 1:15 AM
		2/26/2009 3:45 PM	2/26/2009 3:45 PM
		11/5/2009 3:30 PM	11/5/2009 5:45 PM
	Turbidity data is marked suspect due to calibration error. Small negative turbidity values indicate a calibration error.	8/20/2008 11:45 PM	8/20/2008 11:45 PM
		8/27/2008 4:30 AM	8/27/2008 4:30 AM
		8/27/2008 5:30 AM	8/27/2008 6:00 AM
		8/27/2008 6:00 PM	8/27/2008 7:15 PM
		8/27/2008 9:00 PM	8/27/2008 9:00 PM
		8/28/2008 6:00 AM	8/28/2008 6:00 AM
		8/28/2008 6:30 AM	8/28/2008 7:15 AM
		8/28/2008 9:30 PM	8/28/2008 9:30 PM
		8/30/2008 11:00 PM	8/30/2008 11:00 PM
		8/31/2008 9:00 PM	8/31/2008 9:00 PM
		8/31/2008 9:30 PM	8/31/2008 10:15 PM
		8/31/2008 11:00 PM	8/31/2008 11:30 PM
		3/16/2009 1:45 AM	3/16/2009 2:00 AM
		3/18/2009 3:30 AM	3/18/2009 3:30 AM
		3/23/2009 8:00 AM	3/23/2009 8:45 AM
		3/23/2009 8:00 PM	3/23/2009 9:00 PM
		5/24/2009 9:15 AM	5/24/2009 9:15 AM
		5/24/2009 11:00 PM	5/24/2009 11:00 PM
		5/25/2009 8:45 AM	5/25/2009 8:45 AM
		5/25/2009 9:15 AM	5/25/2009 9:30 AM
		5/25/2009 10:15 AM	5/25/2009 10:30 AM
		5/25/2009 11:00 PM	5/25/2009 11:00 PM
		5/26/2009 12:00 AM	5/26/2009 12:00 AM
		5/26/2009 9:45 AM	5/26/2009 9:45 AM
		5/26/2009 10:15 AM	5/26/2009 11:45 AM
		5/27/2009 12:45 AM	5/27/2009 1:00 AM
		5/27/2009 10:30 AM	5/27/2009 12:45 PM
		5/28/2009 12:45 AM	5/28/2009 12:45 AM
		5/28/2009 2:15 AM	5/28/2009 2:15 AM

Table 6. Continued.

Parameter	Description	Start Date & Time	End Date & Time
Turbidity (continued)	Turbidity data is marked suspect due to calibration error. Small negative turbidity values indicate a calibration error (continued).	5/28/2009 11:45 AM	5/28/2009 11:45 AM
		5/28/2009 12:15 PM	5/28/2009 12:15 PM
		5/28/2009 12:45 PM	5/28/2009 12:45 PM
		5/28/2009 1:15 PM	5/28/2009 1:15 PM
		5/29/2009 1:15 AM	5/29/2009 2:00 AM
		5/29/2009 2:30 AM	5/29/2009 2:30 AM
		5/29/2009 2:15 PM	5/29/2009 2:15 PM
		5/30/2009 1:45 AM	5/30/2009 3:00 AM
		5/30/2009 3:30 AM	5/30/2009 3:30 AM
		5/30/2009 12:30 PM	5/30/2009 12:30 PM
		5/30/2009 1:00 PM	5/30/2009 1:15 PM
		5/30/2009 4:00 PM	5/30/2009 4:00 PM
		5/31/2009 1:15 AM	5/31/2009 4:45 AM
		5/31/2009 1:45 PM	5/31/2009 1:45 PM
		5/31/2009 4:30 PM	5/31/2009 4:30 PM
		6/1/2009 4:00 AM	6/1/2009 5:00 AM
		6/1/2009 2:30 PM	6/1/2009 3:00 PM
		6/1/2009 3:30 PM	6/1/2009 6:30 PM
		6/2/2009 3:00 AM	6/2/2009 6:00 AM
		6/2/2009 6:30 AM	6/2/2009 6:30 AM
		6/2/2009 5:00 PM	6/2/2009 6:45 PM
		6/3/2009 4:15 AM	6/3/2009 4:15 AM
		6/3/2009 4:45 AM	6/3/2009 5:15 AM
		6/3/2009 5:45 AM	6/3/2009 6:45 AM
		6/3/2009 4:45 PM	6/3/2009 4:45 PM
		6/3/2009 5:30 PM	6/3/2009 6:45 PM
		6/3/2009 7:15 PM	6/3/2009 8:00 PM
		6/4/2009 5:00 AM	6/4/2009 7:45 AM
		6/4/2009 5:45 PM	6/4/2009 8:45 PM
		6/5/2009 5:45 AM	6/5/2009 5:45 AM
		6/5/2009 6:30 AM	6/5/2009 7:30 AM
		6/5/2009 8:00 AM	6/5/2009 8:00 AM
		6/5/2009 8:30 AM	6/5/2009 8:45 AM
		6/6/2009 10:15 PM	6/6/2009 10:45 PM
		6/7/2009 10:00 AM	6/7/2009 10:00 AM
		6/7/2009 3:30 PM	6/7/2009 3:30 PM
		6/7/2009 9:45 PM	6/7/2009 9:45 PM
		6/7/2009 11:00 PM	6/7/2009 11:15 PM
		6/8/2009 12:30 AM	6/8/2009 12:30 AM

Table 6. Continued.

Parameter	Description	Start Date & Time	End Date & Time
Turbidity (continued)	Turbidity data is marked suspect due to calibration error. Small negative turbidity values indicate a calibration error (continued).	6/8/2009 8:30 AM	6/8/2009 9:45 AM
		6/8/2009 10:15 AM	6/8/2009 10:30 AM
		6/8/2009 9:45 PM	6/8/2009 11:15 PM
		6/8/2009 11:45 PM	6/8/2009 11:45 PM
		6/9/2009 12:45 AM	6/9/2009 12:45 AM
		6/9/2009 9:30 AM	6/9/2009 10:45 AM
		6/9/2009 11:30 AM	6/9/2009 11:30 AM
		6/9/2009 12:00 PM	6/9/2009 12:00 PM
		6/9/2009 10:00 PM	6/10/2009 12:00 AM
		6/10/2009 12:30 AM	6/10/2009 12:30 AM
		6/10/2009 1:00 AM	6/10/2009 1:00 AM
		6/10/2009 9:45 AM	6/10/2009 12:45 PM
		6/10/2009 10:45 PM	6/11/2009 1:45 AM
		6/11/2009 2:15 AM	6/11/2009 2:15 AM
		6/11/2009 10:15 AM	6/11/2009 12:45 PM
		6/11/2009 1:15 PM	6/11/2009 1:15 PM
		6/11/2009 9:45 PM	6/11/2009 9:45 PM
		6/11/2009 10:45 PM	6/11/2009 10:45 PM
		6/11/2009 11:30 PM	6/11/2009 11:30 PM
		6/12/2009 12:00 AM	6/12/2009 12:00 AM
		6/12/2009 12:30 AM	6/12/2009 1:15 AM
		6/12/2009 1:45 AM	6/12/2009 1:45 AM
		6/12/2009 10:45 AM	6/12/2009 11:45 AM
		6/12/2009 12:30 PM	6/12/2009 12:45 PM
		6/12/2009 1:15 PM	6/12/2009 1:15 PM
		6/12/2009 7:45 PM	6/12/2009 7:45 PM
		6/12/2009 10:45 PM	6/12/2009 10:45 PM
		6/12/2009 11:45 PM	6/12/2009 11:45 PM
		6/13/2009 12:15 AM	6/13/2009 1:45 AM
		6/13/2009 2:15 AM	6/13/2009 2:45 AM
		6/13/2009 11:30 AM	6/13/2009 11:30 AM
		6/13/2009 12:00 PM	6/13/2009 2:15 PM
		6/13/2009 11:45 PM	6/13/2009 11:45 PM
		6/14/2009 1:30 AM	6/14/2009 1:45 AM
		6/14/2009 2:15 AM	6/14/2009 2:15 AM
		6/14/2009 2:45 AM	6/14/2009 3:00 AM
		6/14/2009 12:30 PM	6/14/2009 1:15 PM
		6/14/2009 1:45 PM	6/14/2009 2:45 PM
		6/14/2009 3:30 PM	6/14/2009 3:30 PM

Table 6. Continued.

Parameter	Description	Start Date & Time	End Date & Time
Turbidity (continued)	Turbidity data is marked suspect due to calibration error. Small negative turbidity values indicate a calibration error (continued).	6/15/2009 12:45 AM	6/15/2009 2:00 AM
		6/15/2009 2:30 AM	6/15/2009 3:45 AM
		6/15/2009 1:00 PM	6/15/2009 1:15 PM
		6/15/2009 1:45 PM	6/15/2009 4:45 PM
		6/16/2009 1:30 AM	6/16/2009 3:30 AM
		6/16/2009 4:00 AM	6/16/2009 4:30 AM
		6/16/2009 2:00 PM	6/16/2009 2:30 PM
		6/16/2009 3:00 PM	6/16/2009 3:30 PM
		6/16/2009 4:15 PM	6/16/2009 4:15 PM
		6/16/2009 4:45 PM	6/16/2009 5:00 PM
		6/17/2009 3:00 AM	6/17/2009 3:45 AM
		6/17/2009 4:15 AM	6/17/2009 4:15 AM
		6/17/2009 5:00 AM	6/17/2009 5:00 AM
		6/17/2009 3:00 PM	6/17/2009 3:00 PM
		6/17/2009 3:45 PM	6/17/2009 4:30 PM
		6/17/2009 5:00 PM	6/17/2009 5:00 PM
		6/17/2009 5:30 PM	6/17/2009 5:30 PM
		6/17/2009 6:15 PM	6/17/2009 6:30 PM
		6/18/2009 3:30 AM	6/18/2009 3:45 AM
		6/18/2009 4:30 AM	6/18/2009 4:30 AM
		6/18/2009 5:00 AM	6/18/2009 5:30 AM
		6/18/2009 6:00 AM	6/18/2009 6:00 AM
		6/18/2009 4:00 PM	6/18/2009 6:30 PM
		6/18/2009 7:00 PM	6/18/2009 7:45 PM
		6/18/2009 8:15 PM	6/18/2009 8:15 PM
		6/19/2009 4:00 AM	6/19/2009 4:00 AM
		6/19/2009 4:30 AM	6/19/2009 4:45 AM
		6/19/2009 5:15 AM	6/19/2009 5:45 AM
		6/19/2009 6:30 AM	6/19/2009 6:30 AM
		6/19/2009 3:45 PM	6/19/2009 5:00 PM
		6/19/2009 5:30 PM	6/19/2009 8:00 PM
		6/20/2009 4:45 AM	6/20/2009 7:45 AM
		6/20/2009 7:00 PM	6/20/2009 7:00 PM
		6/20/2009 7:30 PM	6/20/2009 8:45 PM
		6/21/2009 6:15 AM	6/21/2009 8:15 AM
		6/21/2009 8:45 AM	6/21/2009 8:45 AM
		6/21/2009 9:00 PM	6/21/2009 9:15 PM
		6/21/2009 10:15 PM	6/21/2009 10:15 PM
		6/22/2009 3:45 AM	6/22/2009 3:45 AM

Table 6. Continued.

Parameter	Description	Start Date & Time	End Date & Time
Turbidity (continued)	Turbidity data is marked suspect due to calibration error. Small negative turbidity values indicate a calibration error (continued).	6/22/2009 7:15 AM	6/22/2009 8:30 AM
		6/22/2009 9:00 AM	6/22/2009 9:15 AM
		6/22/2009 9:45 AM	6/22/2009 10:00 AM
		6/22/2009 8:30 PM	6/22/2009 8:30 PM
		6/22/2009 9:00 PM	6/22/2009 10:00 PM
		6/23/2009 10:30 AM	6/23/2009 10:30 AM
		6/23/2009 8:45 PM	6/23/2009 8:45 PM
		6/23/2009 10:00 PM	6/23/2009 10:00 PM
		6/24/2009 5:30 AM	6/24/2009 5:30 AM
		6/24/2009 8:45 AM	6/24/2009 8:45 AM
		6/24/2009 9:30 AM	6/24/2009 9:45 AM
		6/24/2009 10:15 AM	6/24/2009 10:15 AM
		6/24/2009 10:45 AM	6/24/2009 11:15 AM
		6/24/2009 11:45 AM	6/24/2009 11:45 AM
		6/24/2009 10:15 PM	6/25/2009 12:15 AM
		6/25/2009 9:15 AM	6/25/2009 11:45 AM
		6/25/2009 10:15 PM	6/25/2009 10:15 PM
		6/25/2009 10:45 PM	6/26/2009 12:45 AM
		6/26/2009 10:45 AM	6/26/2009 10:45 AM
		6/26/2009 11:15 AM	6/26/2009 1:00 PM
		6/27/2009 12:45 AM	6/27/2009 1:30 AM
		6/28/2009 12:30 AM	6/28/2009 12:30 AM
		6/28/2009 1:00 AM	6/28/2009 1:00 AM
		6/28/2009 1:30 AM	6/28/2009 2:00 AM
		6/28/2009 1:30 PM	6/28/2009 1:45 PM
		6/28/2009 2:15 PM	6/28/2009 3:00 PM
		6/29/2009 3:00 AM	6/29/2009 3:15 AM
		6/29/2009 3:30 PM	6/29/2009 3:30 PM
		6/29/2009 4:00 PM	6/29/2009 4:00 PM
		6/30/2009 2:15 AM	6/30/2009 2:30 AM
		6/30/2009 3:00 AM	6/30/2009 4:15 AM
		6/30/2009 2:45 PM	6/30/2009 3:00 PM
		6/30/2009 4:00 PM	6/30/2009 4:00 PM
		6/30/2009 4:45 PM	6/30/2009 5:00 PM
		7/1/2009 2:45 AM	7/1/2009 3:00 AM
		7/1/2009 3:30 AM	7/1/2009 4:45 AM
		7/1/2009 4:45 PM	7/1/2009 4:45 PM
		7/1/2009 6:00 PM	7/1/2009 6:00 PM
		7/1/2009 6:30 PM	7/1/2009 6:30 PM

Table 6. Continued.

Parameter	Description	Start Date & Time	End Date & Time
Turbidity (continued)	Turbidity data is marked suspect due to calibration error. Small negative turbidity values indicate a calibration error (continued).	7/2/2009 7:00 PM	7/2/2009 7:00 PM
		7/3/2009 5:15 AM	7/3/2009 5:15 AM
		7/4/2009 7:00 AM	7/4/2009 7:15 AM
		7/4/2009 7:30 PM	7/4/2009 7:30 PM
		7/4/2009 8:00 PM	7/4/2009 8:00 PM
		7/4/2009 8:30 PM	7/4/2009 8:30 PM
		7/5/2009 6:45 AM	7/5/2009 8:15 AM
		7/6/2009 9:30 AM	7/6/2009 9:30 AM
		7/7/2009 10:30 PM	7/7/2009 10:30 PM
		7/8/2009 9:15 AM	7/8/2009 9:30 AM
		7/8/2009 10:15 AM	7/8/2009 10:30 AM
		7/8/2009 11:00 PM	7/8/2009 11:15 PM
		7/9/2009 11:00 PM	7/9/2009 11:00 PM
		7/10/2009 11:30 PM	7/10/2009 11:45 PM
		7/15/2009 3:00 PM	7/15/2009 3:00 PM
		7/16/2009 3:15 AM	7/16/2009 3:15 AM
		7/20/2009 8:45 PM	7/20/2009 8:45 PM
		7/21/2009 9:30 PM	7/21/2009 9:30 PM
		7/23/2009 10:45 AM	7/23/2009 10:45 AM
		8/2/2009 5:45 AM	8/2/2009 5:45 AM
		8/7/2009 10:30 PM	8/7/2009 11:00 PM
		8/16/2009 7:30 AM	8/16/2009 1:45 PM
		8/16/2009 2:15 PM	8/25/2009 6:30 AM
		8/27/2009 7:15 AM	8/27/2009 11:30 AM
		9/8/2009 5:45 AM	9/8/2009 5:45 AM
		9/8/2009 6:45 AM	9/8/2009 6:45 AM
		9/23/2009 12:30 AM	9/23/2009 12:30 AM
		9/23/2009 1:30 PM	9/23/2009 1:30 PM
		9/24/2009 2:30 PM	9/24/2009 2:30 PM
		10/1/2009 8:00 PM	10/1/2009 8:15 PM
		10/20/2009 10:00 PM	10/20/2009 10:00 PM
		10/20/2009 10:30 PM	10/20/2009 11:15 PM
		10/21/2009 10:00 AM	10/21/2009 10:00 AM
		10/21/2009 10:45 AM	10/21/2009 12:00 PM
		10/21/2009 10:45 PM	10/21/2009 11:00 PM
		10/21/2009 11:30 PM	10/21/2009 11:45 PM
		10/22/2009 10:45 AM	10/22/2009 11:15 AM
		10/22/2009 11:45 AM	10/22/2009 12:00 PM
		10/22/2009 12:45 PM	10/22/2009 12:45 PM

Table 6. Continued.

Parameter	Description	Start Date & Time	End Date & Time
Turbidity (continued)	Turbidity data is marked suspect due to calibration error. Small negative turbidity values indicate a calibration error (continued).	10/22/2009 11:30 PM	10/23/2009 12:45 AM
		10/23/2009 11:15 AM	10/23/2009 1:45 PM
		10/24/2009 1:30 AM	10/24/2009 1:45 AM
		10/31/2009 8:00 AM	10/31/2009 8:00 AM
		11/1/2009 9:15 AM	11/1/2009 9:15 AM
		11/3/2009 9:45 PM	11/3/2009 9:45 PM
		11/4/2009 10:30 PM	11/4/2009 10:30 PM
		11/24/2009 4:45 PM	12/22/2009 5:15 PM
	Turbidity data marked suspect due to lone spike, less than 1,000 but more than 200 from previous and following readings.	5/9/2009 6:15 AM	5/9/2009 6:15 AM
		5/12/2009 9:30 PM	5/12/2009 9:30 PM
		5/20/2009 5:15 PM	5/20/2009 5:15 PM
		5/27/2009 2:00 PM	5/27/2009 2:00 PM
		6/9/2009 11:00 AM	6/9/2009 11:00 AM
		6/18/2009 11:15 PM	6/18/2009 11:15 PM
		6/19/2009 10:30 PM	6/19/2009 10:30 PM
		6/23/2009 2:30 PM	6/23/2009 2:30 PM
		7/8/2009 6:30 PM	7/8/2009 6:30 PM
		7/25/2009 9:15 AM	7/25/2009 9:15 AM
		7/30/2009 6:15 AM	7/30/2009 6:15 AM
		7/30/2009 7:00 AM	7/30/2009 7:00 AM
		7/31/2009 12:30 AM	7/31/2009 12:30 AM
		7/31/2009 5:15 AM	7/31/2009 5:15 AM
		8/10/2009 2:15 PM	8/10/2009 2:15 PM
		8/25/2009 7:15 AM	8/25/2009 7:15 AM
		8/27/2009 3:45 AM	8/27/2009 5:00 AM
		9/2/2009 9:00 PM	9/2/2009 9:00 PM
		9/4/2009 10:45 PM	9/4/2009 10:45 PM
		9/8/2009 11:45 AM	9/8/2009 11:45 AM
	Turbidity data marked suspect due to spikes of 1000 NTU or higher. Spiking turbidity data could be a result of direct interference from a foreign body and/or the EDS wiper parking over the optics.	2/23/2009 6:45 PM	2/23/2009 6:45 PM
		8/6/2009 6:15 AM	8/6/2009 6:15 AM
		8/9/2009 2:45 PM	8/9/2009 2:45 PM
		8/10/2009 3:00 PM	8/10/2009 3:00 PM
		9/8/2009 12:30 PM	9/8/2009 12:30 PM
		9/8/2009 1:15 PM	9/8/2009 1:15 PM

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