



# Fixed-Station Water-Quality Monitoring at Cumberland Island National Seashore

## *2015–2016 Data Summary*

Natural Resource Data Series NPS/SECN/NRDS—2018/1193



#### ON THE COVER

A brown pelican (*Pelecanus occidentalis*) and a ring-billed gull (*Larus delawarensis*) perch on a dock behind the Cumberland Island National Seashore visitor's center. Photo by Wendy Wright.

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Natural Resource Data Series NPS/SECN/NRDS—2018/1193

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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## Summary and Key Findings

In 2005 the National Park Service (NPS) Southeast Coast Network (SECN) Inventory and Monitoring Program began collecting water-quality data in the estuarine waters near Cumberland Island National Seashore (CUIIS) as part of the NPS Vital Signs monitoring program. The current continuous-monitoring station is located on the Sea Camp dock.

This station collects pH, dissolved oxygen, temperature, salinity, conductivity, turbidity, and water level data every 15 minutes. Southeast Coast Network staff make additional water-quality measurements, which include monthly measurements of water-clarity conditions, nutrient concentrations, and chlorophyll *a* levels. Network staff follow methods adapted from the water-quality monitoring program established by the National Estuarine Research Reserve Program (Wenner and Geist 2001). Data and results are compared to EPA criteria (EPA 2012) which rate conditions as good, fair, or poor.

The Cumberland Island National Seashore fixed-station water-quality monitoring site is part of the SECN estuarine water- and sediment-quality monitoring effort, which routinely collects data in the vicinity of seven coastal park units located along the southeastern U.S. coast (DeVivo et al. 2008; Gregory et al. 2013). Information collected by this monitoring program will be used to help managers make better-informed decisions by understanding trends and variability related to water-quality conditions in park waters. Summary data are presented in annual data reports published by the Southeast Coast Network.

- Chlorophyll *a* concentrations were fair (11 visits) to good (7 visits) for the period of record, ranging from 2.6 µg/L to 18.47 µg/L.
- Water clarity was mostly good (14 visits) to fair (3 visits), with one poor reading.
- Over the period of record, six samples were pulled for dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP). All of the DIN concentrations were rated as good. Five of the DIP concentrations were fair, and one was good.
- Water temperatures in 2015–2016 ranged from a minimum monthly mean of 12.4 °C (54.3 °F) in February 2015 to a maximum monthly mean of 30.5 °C (86.9 °F) in July 2016. Individual temperatures ranged from a minimum of 8.0 °C (46.4 °F) in February 2015 to a maximum of 32.6 °C (90.7 °F) in July 2016.
- Mean monthly dissolved oxygen levels were fair to good throughout the period, ranging from 4.4 mg/L to 8.4 mg/L. Individual values ranged from 1.9 mg/L in August 2016 to 9.7 mg/L in February 2016.
- Mean monthly pH values ranged from 7.6 to 8.2. Individual readings ranged from 7.2 in August 2016 to 8.6 in January 2015.
- Monthly mean turbidity values were highest during August 2015 at 42.2 NTUs. The maximum individual turbidity reading for any given month was 207.8 NTUs and was recorded in September 2015. There are no EPA criteria to grade turbidity as good, fair, or poor.
- The tidal range across the two-year collection period (the difference in sonde depth from the lowest low tide to highest high tide) at the Sea Camp dock at Cumberland Island National Seashore is 3.7 meters (12.1 feet). This number is affected by Hurricane Matthew, which hit the area in early October 2016 (see Figure 9). Average daily tidal range calculations are beyond the scope of this report.



**Figure 1.** Location of continuous water-quality monitoring station at Cumberland Island National Seashore Sea Camp dock (CUIS03). Map shows estuarine and marine water resources in the vicinity of Cumberland Island National Seashore in Georgia. Map indicates areas of salt marsh (USFWS 2015), urbanization (USCB 2015), 303(d) listed water bodies (EPA 2015), and areas designated as having special uses or restrictions.

# Introduction

Due to the importance of water resources to park management from ecological, regulatory, and visitor experience perspectives, estuarine water quality in and around parks was selected as one of several Vital Signs to be monitored by the National Park Service (NPS) Inventory and Monitoring (I&M) 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 near park units, and contribute to a better understanding of ecological processes and physical systems in the region (Gregory et al. 2013).

To effectively monitor diverse and dynamic estuarine water resources, the Southeast Coast Network (SECN) implemented a two-pronged monitoring approach. This approach consists of both data collection from continuously recording fixed stations located in each park, and collection of periodic discrete water samples for analysis (Gregory et al. 2013). When combined, these approaches provide a more complete picture of physical processes, diurnal and seasonal variation, and spatial patterns during critical portions of the year than either approach could provide if implemented singularly.

The Southeast Coast Network has identified four specific monitoring objectives (detailed below) for which data are collected and analyzed as part of this effort (Gregory et al. 2013). The contents of this report address objectives 1 and 2:

1. Determine daily and seasonal water-quality patterns for five core parameters (dissolved oxygen, salinity, temperature, pH, 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 through collection of 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) in estuarine waters every ten years.

This report provides an annual summary of data collected during 2015–2016 at Cumberland Island National Seashore and places these values in context of current water-quality criteria suggested by the U.S. Environmental Protection Agency (EPA 2012), as well as concurrent regional climatic conditions that may influence local water-quality conditions. This report is intended to provide park resource managers and partners with information on the short-term variability and seasonal trends in water quality across Cumberland Island National Seashore.

## Cumberland Island National Seashore

Cumberland Island National Seashore is located between the mouths of the Satilla and St. Marys Rivers along the coast of Georgia. As Georgia's southernmost barrier island, Cumberland Island is bound on the east by the Atlantic Ocean and the west by the extensive salt marshes and estuaries of the Cumberland River and Cumberland Sound (Figure 1). The Cumberland Island National Seashore is comprised of the majority of Cumberland Island proper and the surrounding marshes and islands (with the exception of Little Cumberland Island, all of which is privately owned, and several private inholdings on the island itself). The east coast of the island is an almost continuous strip of beaches that face the ocean, whereas the western side is a network of tidal creeks that flow through salt marshes and eventually open out into coastal water. Aquatic habitats associated with the island include marine areas (offshore water and associated bottom areas), tidal creeks, saltwater ponds, intertidal areas (beaches, salt marshes, tide pools), and inland ponds (both brackish and fresh water). Although Cumberland Island is considered relatively pristine in comparison to more highly developed barrier islands, both point and nonpoint sources of pollutants can be found nearby that have the potential to affect the island. In addition to the numerous industrial and municipal waste facilities in the area, the submarine base at Kings Bay is of potential concern due to the effects of channel dredging as well as other activity on the base. There are also a significant number of U.S. Environmental Protection Agency (USEPA) listed Superfund sites nearby, most of which are located in the vicinity of Brunswick, Georgia, a port city located approximately 16 miles (25.7 kilometers) north of Cumberland in Glynn County (Alber et al. 2005).

## Weather and Hydrologic Setting

Daily rainfall totals were collected at the Brunswick weather and climate station located approximately 27 miles (43.4 kilometers) northwest of the southern end of Cumberland Island (NOAA NCDC 2015) and are included here (Figure 2) as an aid for interpreting water-quality results. The Brunswick weather and climate station is used because it has an extensive period of record. These data are presented for 2015–2016.

Additional climate data and analyses, such as departure from 30-year averages and extended drought and precipitation information, are available for individual interpretation on the [Southeast Coast Network Climate Analyzer Website](http://www.climateanalyzer.org/secn) (<http://www.climateanalyzer.org/secn>). This additional data may add context to the data presented in this report.

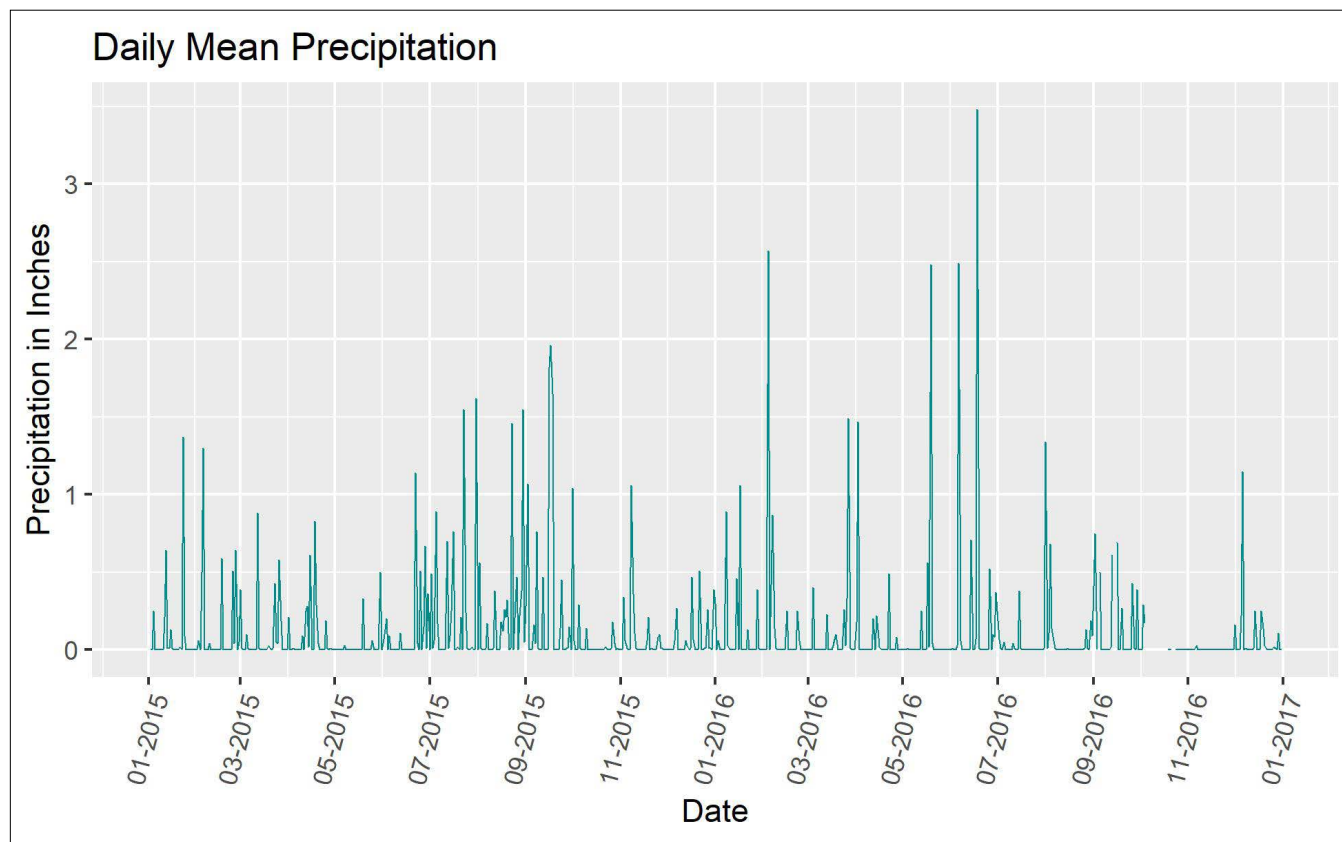


**Figure 2.** Daily precipitation at Cumberland Island National Seashore January 1, 2015–December 31, 2016. Data source: NOAA-NCDC (2015).



**Figure 3.** Continuous data collection platform on Sea Camp dock at Cumberland Island National Seashore. NPS Photo.

**Table 1.** Location of continuous water-quality monitoring stations at Cumberland Island National Seashore.

| <b>Name</b> | <b>Location Description</b> | <b>Location (lat /long)</b> | <b>Period of Record</b> |
|-------------|-----------------------------|-----------------------------|-------------------------|
| CUIS01      | Plum Orchard dock           | 30.854866 / -81.467229      | 1/6/07 to 9/1/10        |
| CUIS02      | Old House Creek dock        | 30.798004 / -81.47027       | 8/3/05 to 9/1/10        |
| CUIS03      | Sea Camp dock               | 30.764303 / -81.4712        | 10/1/2010 to present    |

# Methods

Data collection at the Cumberland Island NS fixed station site is modeled after an ongoing water-quality monitoring program established by the National Estuarine Research Reserve System (NERRS) program (Wenner and Geist 2001). Detailed field and laboratory standard operating procedures and methods have been outlined for the continuously collected data in Gregory et al. (2013). Methods for both are briefly summarized in the following sections.

## Sampling Location

The Cumberland Island National Seashore fixed-station site is located on the northwest corner, non-floating portion of a large dock owned by the National Park Service (Figure 1, Figure 3). This dock is located near the Cumberland Island National Seashore's public camping area known as Sea Camp. It is one of the two docks used for the visitor ferry, and is also used to a lesser extent by private boaters accessing the island and park boats carrying park personnel.

The station is located on a tidal river, which is part of the Intracoastal Waterway. The station is on the backside of a barrier island consisting of complex dune ecosystems, forests and salt marsh. The river has shifting sand bars and heavy siltation issues. The nearby shoreline is highly eroded with accreted sand and silt along the river. There is a relatively recently constructed wooden bulkhead along the shoreline to protect that section of shoreline from erosion.

## Continuous Data

Continuously collected data include dissolved oxygen, pH, specific conductance, water temperature, depth, and turbidity. Data are collected at 15-minute intervals using YSI data sondes (Model 6600). Sondes are deployed in three- to five-week intervals depending on routine instrument maintenance schedules. The data sondes were deployed and retrieved by SECN staff.

The data collection platform consists of a 4-inch (10.2 centimeter [cm]) diameter PVC tube attached vertically to a piling on the Sea Camp dock with the sonde suspended within and approximately 0.5 meters (1.3 ft) from the bottom (Figure 3). Water is allowed to freely circulate via openings cut into the PVC housing. A locking cap on the top of the

PVC tube prevents unwanted tampering, and a carriage bolt inserted through the housing at the submerged end prevents instrument loss should the attachment hardware fail. Anti-fouling paint is used on the PVC tube to extend deployment intervals, which are sometimes shortened due to excessive biofouling. The sonde guard is covered with 0.25-inch brass or plastic mesh screen to prevent fish, crabs, and detritus from entering the protective housing, which could skew measurements or damage the instrument probes. Additional details on initial site selection and installation procedures can be found in Gregory et al. (2013).

Prior to deployment, the data sonde is calibrated according to YSI recommendations for pH (two-point calibration), dissolved oxygen, specific conductance, depth, and turbidity (two-point calibration; YSI Incorporated 2011; Gregory et al. 2013). After instrument retrieval, data sondes are 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 archived at the Southeast Coast Network office in Athens, Georgia. After post-retrieval processing is complete, the sonde is cleaned, reconditioned, and readied for redeployment following methods outlined by YSI (2011). Performance specifications of the YSI 6600 are shown in Table 2.

Data generated during the deployment periods are reviewed and certified by SECN staff prior to being made available to park staff or the public. During 2013, the Southeast Coast Network transitioned continuous data management tasks to Aquarius.

Beginning in January 2015, turbidity, dissolved oxygen, specific conductance, temperature, depth, and pH values were assigned grades of excellent, good, fair, or poor—and corrections to these values were made when appropriate—based on differences between pre-calibration and post-calibration measurement. USGS guidance served as the basis for data grades and corrections (Wagner et al. 2006). As with previous years, invalid or unusable data were deleted from data sets prior to publication. Data sets are available at the [NPS Aquarius Web Data Portal](#) (Aquatic Informatics Inc. 2015).

## Discrete Data

Water sample collection for this project was conducted by SECN staff. Secchi depth was measured with standard equipment—an 8-inch (20.3-cm) black and white Secchi disk. Water samples were collected as grabs in lab-cleaned and field-rinsed containers. Filtration was conducted using a 0.45-micron filter, and samples were transported and shipped on wet ice. QA/QC field sampling included both field blanks and duplicates collected on random dates throughout the year. Filtered samples and chlorophyll filters were placed on ice prior to shipment for laboratory analyses. Original chain-of-custody paperwork accompanied all samples to the laboratory. Data collection standard operating procedures are further documented in Gregory et al. (2013).

Water-clarity conditions were derived from estimated light attenuation coefficients ( $k$ ) using the equation:  $K_d = c / \text{Secchi depth (in meters)}$  and  $c = 1.0$ . “ $c$ ” is assigned to one of three values depending on the water body’s naturally occurring clarity conditions—i.e.,  $a = 1.0$  for naturally turbid conditions,  $a = 1.4$  for normal turbidity conditions, or  $a = 1.7$  for waters supporting submerged aquatic vegetation (SAV) restoration (EPA 2016). Cumberland Island National

Seashore uses a coefficient of 1.0 for naturally turbid conditions. These constants were estimated for each water-clarity class based on values reported in the literature (Smith et al. 2006). This method of estimating water-clarity condition is generally used when information on light transmission in the water column is missing. The Southeast Coast Network is reporting derived values to maintain data consistency across other network parks.

## Assessment Criteria

Water quality was assessed for each of the parameters using data from the monthly samples, and following the East/Gulf Coast site criteria in the EPA National Coastal Assessment IV Report (EPA 2012; Table 3). 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 EPA criteria for the assessed water bodies.

**Table 2.** Performance specifications of YSI 6600 EDS data loggers deployed at the continuous monitoring site (YSI 2011) [mg/L—milligrams per liter; mS/cm—milli-Siemens per centimeter ; m—meter; ft—foot; ppt—parts per thousand; NTU—nephelometric turbidity unit].

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

**Table 3.** Coastal water-quality monitoring condition criteria for water-quality parameters collected by the Southeast Coast Network. Based on thresholds set by EPA (2012) [ $\mu\text{g/L}$ —micrograms per liter; mg/L—milligrams per liter].

| Rating | Water Clarity ( $k$ ) <sup>1</sup> | Chlorophyll $a$ ( $\mu\text{g/L}$ ) | Dissolved Inorganic Nitrogen (DIN) (mg/L) | Dissolved Inorganic Phosphorus (DIP) (mg/L) | Dissolved Oxygen (mg/L) |
|--------|------------------------------------|-------------------------------------|-------------------------------------------|---------------------------------------------|-------------------------|
| Good   | < 2.3                              | < 5                                 | < 0.1                                     | < 0.01                                      | >5                      |
| Fair   | 2.30–2.99                          | 5–20                                | 0.1–0.5                                   | 0.01–0.05                                   | 2–5                     |
| Poor   | > 2.99                             | > 20                                | > 0.5                                     | > 0.05                                      | <2                      |

<sup>1</sup> Light attenuation coefficients ( $k$ ) were used to assess water-clarity conditions using criteria categories in Smith et al. (2006) which are comparable to the EPA (2012) criteria for the assessed water bodies.

# Results

## Continuous Data

Figures 4 through 8 depict the daily mean for each parameter for the entire data collection period. Relative water depth collected by SECN staff at the site (Figure 9) is included in this section as an aid to data interpretation because it includes information that shows daily tidal fluctuations.

Summary statistics (minimum, maximum, mean, and standard deviation) are provided in Table 4. The percentage-of-values field indicates the level of completeness of the monthly data sets used for calculating mean, maximum, and minimum statistics, and equals the number of valid 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 in which 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. For months in which the percentage of values is low, the statistics (mean, maximum, and minimum) may be less accurate than for months in which all data were used in the calculation of summary statistics.

## Discrete Data

Monthly water-quality data collected during 2015–2016 at the SECN site near Cumberland National Seashore are shown in Table 5. Condition categories correspond to those used by the EPA in the National Coastal Condition Report IV (2012).

## Results Summary

Chlorophyll *a* concentrations were fair (11 visits) to good (7 visits) for the period of record, ranging from 2.6 µg/L to 18.47 µg/L (Table 5).

Water clarity was mostly good (14 visits) to fair (3 visits), with one poor reading (Table 5).

Over the period of record, six samples were pulled for dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP). All of the DIN concentrations were rated as good. Five of the DIP concentrations were fair, and one was good (Table 5).

Water temperatures in 2015–2016 ranged from a minimum monthly mean of 12.4 °C (54.3 °F) in February 2015 to a maximum monthly mean of 30.5 °C (86.9 °F) in July 2016. Individual temperatures ranged from a minimum of 8.0 °C (46.4 °F) in February 2015 to a maximum of 32.6°C (90.7 °F) in July 2016 (Table 4, Figure 4).

Mean monthly dissolved oxygen levels were fair to good throughout the period, ranging from 4.4 mg/L to 8.4 mg/L. Individual values ranged from 1.9 mg/L in August 2016 to 9.7 mg/L in February 2016 (Table 4, Figure 6).

Mean monthly pH values ranged from 7.6 to 8.2. Individual readings ranged from 7.2 in August 2016 to 8.6 in January 2015 (Table 4, Figure 7).

Monthly mean turbidity values were highest during August 2015 at 42.2 NTUs. The maximum reading of 207.8 NTUs was recorded in September 2015 (Table 4, Figure 8). There are no EPA criteria to grade turbidity as good, fair, or poor.

The tidal range across the two-year collection period (the difference in sonde depth from the lowest low tide to highest high tide) at the Sea Camp dock at Cumberland Island National Seashore is 3.7 meters (12.1 feet). Average daily tidal range calculations are beyond the scope of this report (Figure 9).

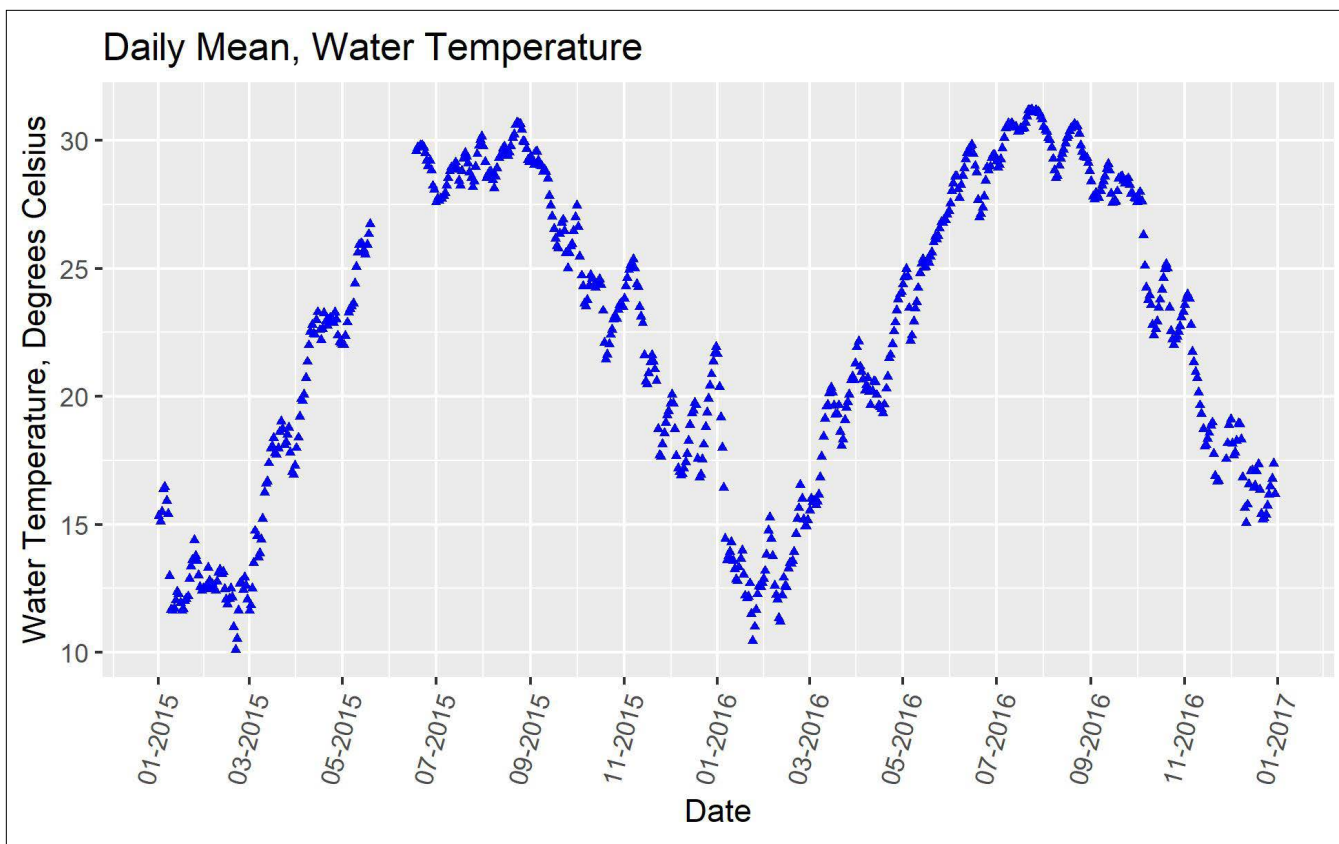


**Figure 4.** Mean daily water temperature at the Sea Camp dock site at Cumberland Island National Seashore during 2015–2016. Breaks in data record indicate missing and/or flagged data.

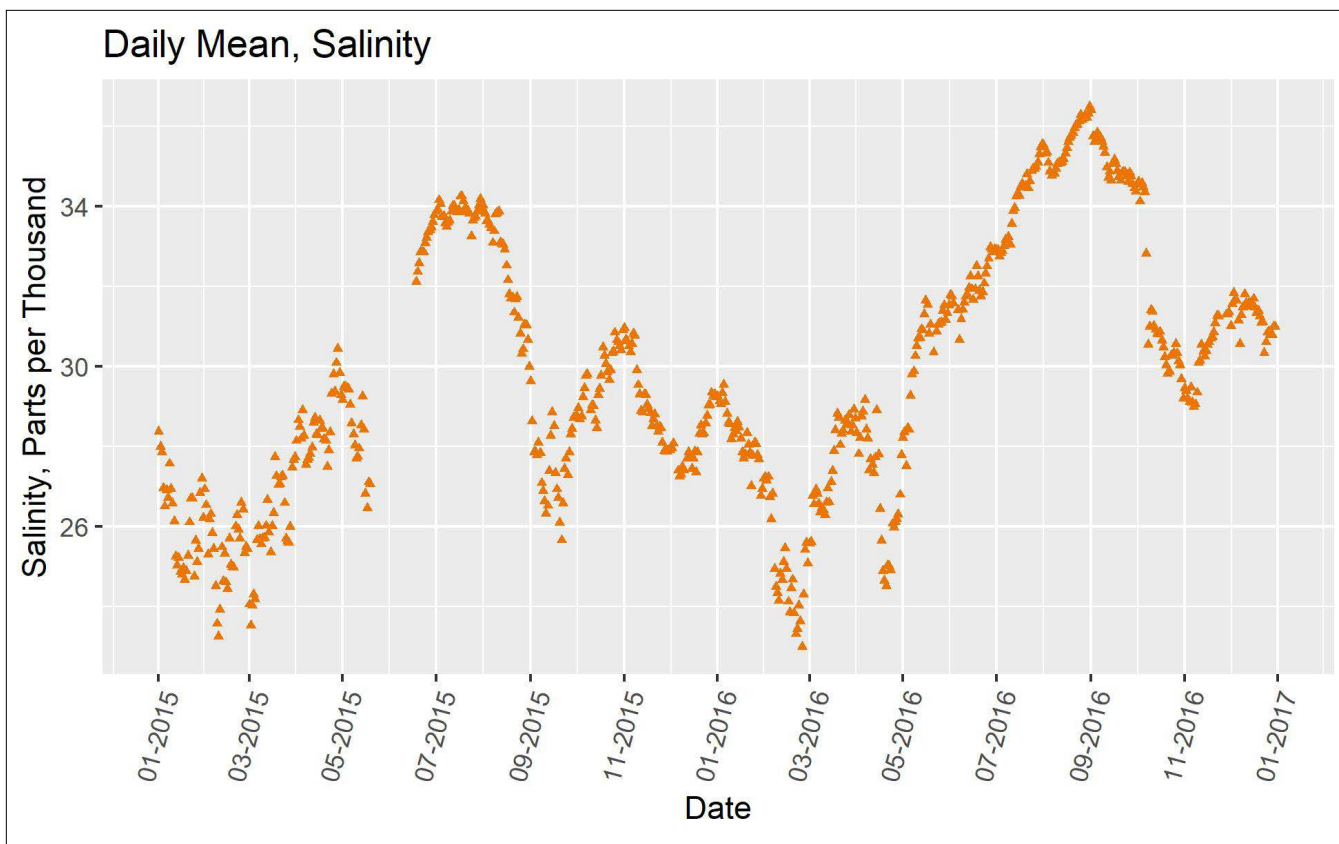


**Figure 5.** Mean daily values for salinity at the Sea Camp dock site at Cumberland Island National Seashore during 2015–2016. Breaks in data record indicate missing and/or flagged data.

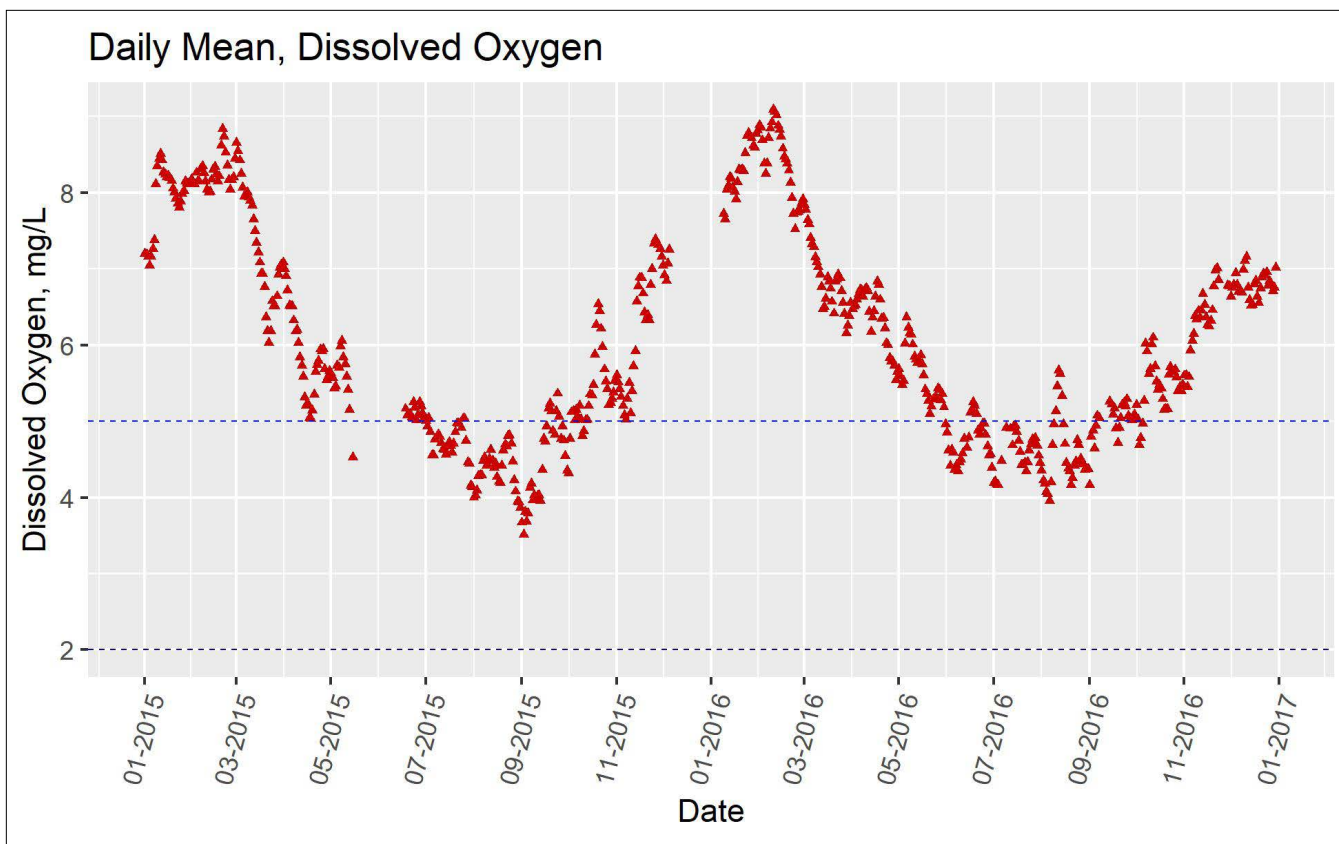


**Figure 6.** Mean daily values for dissolved oxygen at the Sea Camp dock site at Cumberland Island National Seashore during 2015–2016. Breaks in data record indicate missing and/or flagged data. Dashed lines indicate thresholds for good (above 5 mg/L), fair (2–5 mg/L), and poor (less than 2 mg/L) criteria.

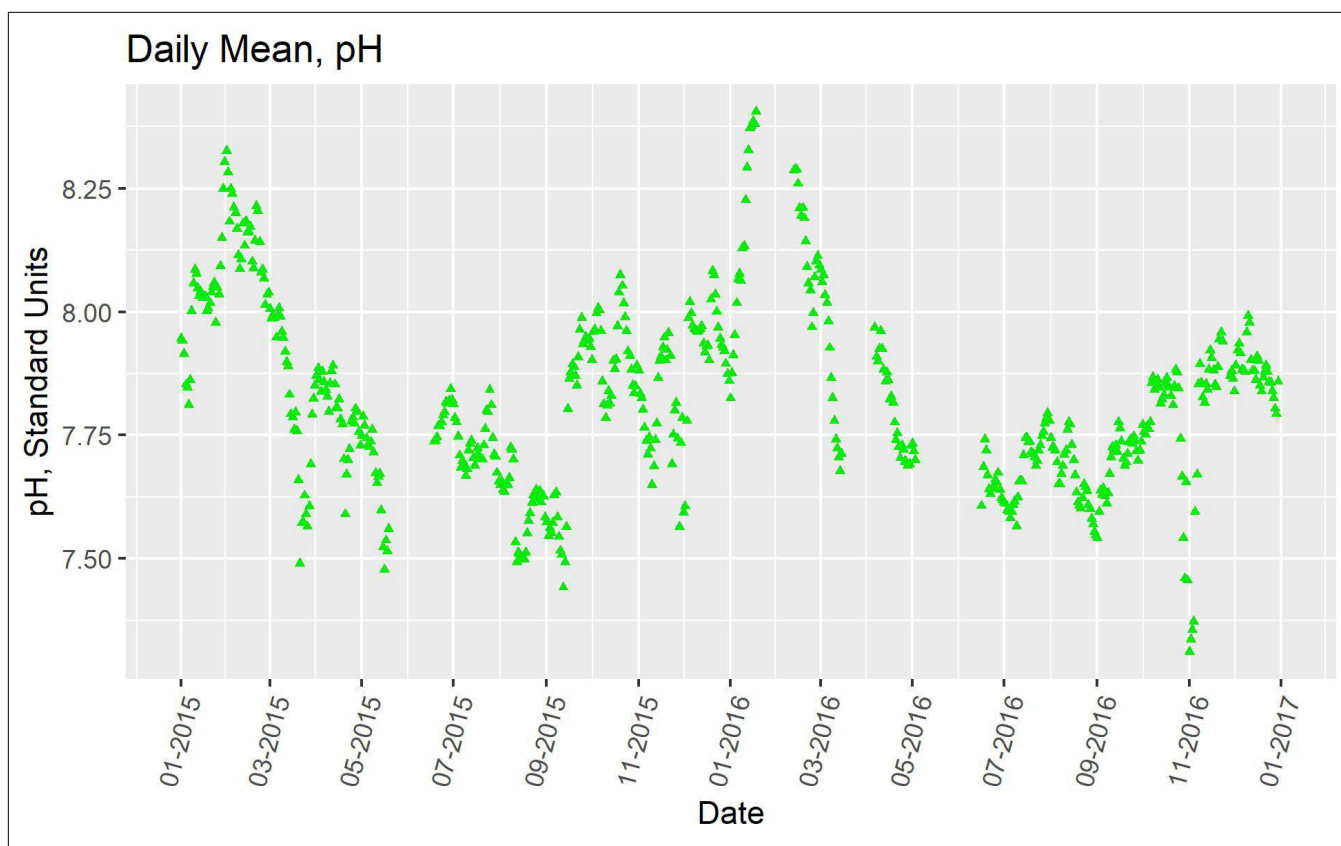


**Figure 7.** Mean daily values for pH at at the Sea Camp dock site at Cumberland Island National Seashore during 2015–2016. Breaks in data record indicate missing and/or flagged data.

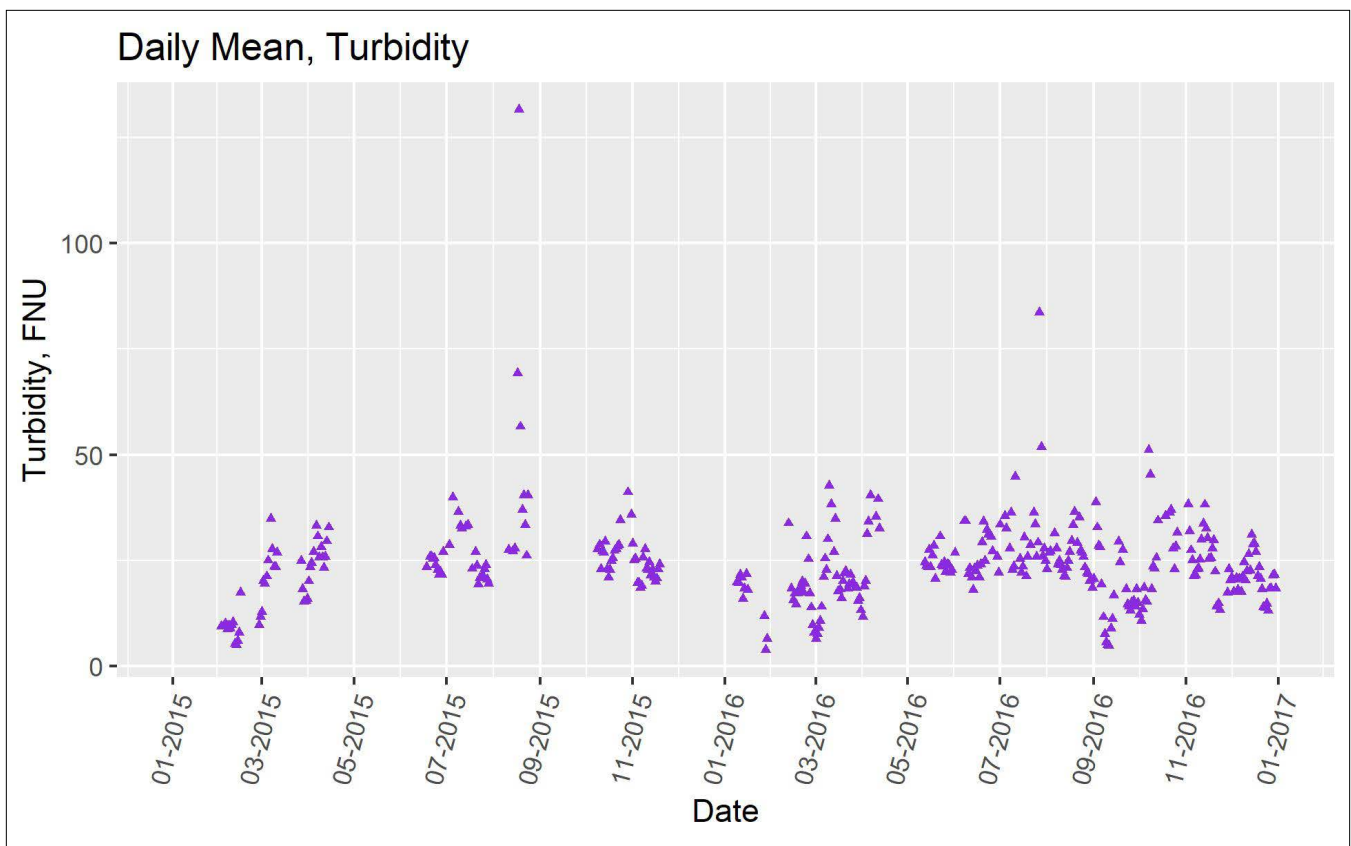


**Figure 8.** Mean daily values for turbidity (NTUs) at the Sea Camp dock site at Cumberland Island National Seashore during 2015–2016. Note that the Sea Camp dock was replaced in late August–early September 2015. Breaks in data record indicate missing and/or flagged data.

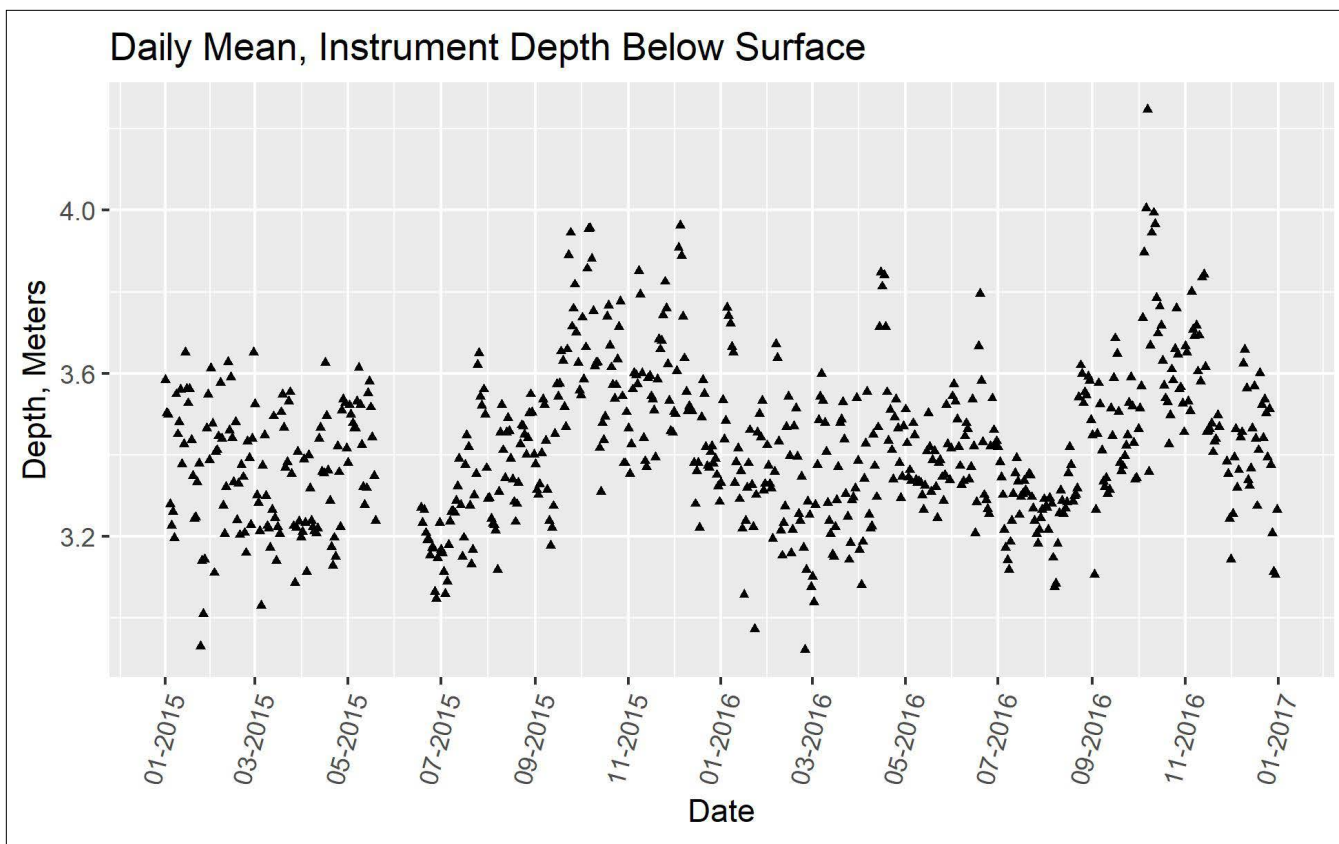


**Figure 9.** Mean daily values for depth at the Sea Camp dock site at Cumberland Island National Seashore during 2015–2016. Breaks in data record indicate missing and/or flagged data.

**Table 4.** Monthly minimum, maximum, and mean values for parameters collected by the YSI 6-series data sonde at Cumberland Island National Seashore during 2015–2016. Percent 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 [PPT—parts per thousand; mg/L—milligrams per liter; m—meter; NTU—nephelometric turbidity unit; SD—standard deviation].

| Month                                  | Metric       | Temperature (°C) | Salinity (PPT) | Dissolved Oxygen, (mg/L) | Depth (m) | pH   | Turbidity (NTU) |
|----------------------------------------|--------------|------------------|----------------|--------------------------|-----------|------|-----------------|
| January 2015<br>(Expected count 2976)  | Actual Count | 2972             | 2977           | 2913                     | 2977      | 2977 | 370             |
|                                        | Minimum      | 9.8              | 22.9           | 6.2                      | 1.61      | 7.7  | 0               |
|                                        | Maximum      | 17.4             | 33             | 9                        | 4.67      | 8.6  | 99.1            |
|                                        | Mean         | 13.3             | 26.2           | 7.9                      | 3.38      | 8    | 30              |
|                                        | SD           | 1.6              | 2.0            | 0.5                      | 0.7       | 0.15 | 28.1            |
|                                        | Percent      | 100%             | 100%           | 98%                      | 100%      | 100% | 12%             |
| February 2015<br>(Expected count 2688) | Actual Count | 2680             | 2687           | 2536                     | 2687      | 2687 | 1488            |
|                                        | Minimum      | 8                | 20.4           | 7.1                      | 1.58      | 7.9  | 0               |
|                                        | Maximum      | 14.5             | 31.6           | 9.4                      | 4.7       | 8.5  | 64.8            |
|                                        | Mean         | 12.4             | 25.3           | 8.3                      | 3.38      | 8.1  | 10              |
|                                        | SD           | 0.9              | 1.9            | 0.3                      | 0.7       | 0.11 | 8.9             |
|                                        | Percent      | 100%             | 100%           | 94%                      | 100%      | 100% | 55%             |
| March 2015<br>(Expected count 2976)    | Actual Count | 2942             | 2976           | 2783                     | 2976      | 2972 | 1468            |
|                                        | Minimum      | 11.3             | 21.9           | 4.6                      | 1.89      | 7.3  | 4.8             |
|                                        | Maximum      | 21.3             | 32.9           | 8.9                      | 4.85      | 8.2  | 97.3            |
|                                        | Mean         | 16.4             | 26             | 7.3                      | 3.31      | 7.8  | 22.2            |
|                                        | SD           | 2.3              | 2              | 0.8                      | 0.7       | 0.18 | 13.7            |
|                                        | Percent      | 99%              | 100%           | 94%                      | 100%      | 100% | 49%             |
| April 2015<br>(Expected count 2880)    | Actual Count | 2858             | 2838           | 2540                     | 2879      | 2879 | 1247            |
|                                        | Minimum      | 17.1             | 25.1           | 3.9                      | 1.72      | 7.5  | 7.2             |
|                                        | Maximum      | 25.4             | 34             | 7.5                      | 4.77      | 8.1  | 102             |
|                                        | Mean         | 21.9             | 28.6           | 5.8                      | 3.33      | 7.8  | 28.9            |
|                                        | SD           | 1.6              | 1.5            | 0.7                      | 0.7       | 0.13 | 17.3            |
|                                        | Percent      | 99%              | 99%            | 88%                      | 100%      | 100% | 43%             |
| May 2015<br>(Expected count 2976)      | Actual Count | 1872             | 1864           | 1453                     | 1880      | 1878 | 0               |
|                                        | Minimum      | 21.5             | 25.5           | 3.1                      | 1.95      | 7.3  | NA              |
|                                        | Maximum      | 28.7             | 33.7           | 6.9                      | 4.79      | 8.1  | NA              |
|                                        | Mean         | 24.6             | 28.3           | 5.4                      | 3.44      | 7.7  | NA              |
|                                        | SD           | 1.7              | 1.4            | 0.7                      | 0.7       | 0.14 | NA              |
|                                        | Percent      | 63%              | 63%            | 49%                      | 63%       | 63%  | 0%              |
| June 2015<br>(Expected count 2880)     | Actual Count | 1289             | 1294           | 1118                     | 1293      | 1293 | 1083            |
|                                        | Minimum      | 26.1             | 31.1           | 3.8                      | 2.04      | 7.5  | 3.2             |
|                                        | Maximum      | 31.6             | 36.4           | 6.4                      | 4.5       | 8.1  | 146.9           |
|                                        | Mean         | 29.3             | 33             | 5.1                      | 3.19      | 7.8  | 24.7            |
|                                        | SD           | 0.9              | 0.8            | 0.5                      | 0.6       | 0.1  | 13.8            |
|                                        | Percent      | 45%              | 45%            | 39%                      | 45%       | 45%  | 38%             |

**Table 4. (continued)** Monthly minimum, maximum, and mean values for parameters collected by the YSI 6-series data sonde at Cumberland Island National Seashore during 2015–2016. Percent 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 [PPT—parts per thousand; mg/L—milligrams per liter; m—meter; NTU—nephelometric turbidity unit; SD—standard deviation].

| Month                                   | Metric       | Temperature (°C) | Salinity (PPT) | Dissolved Oxygen, (mg/L) | Depth (m) | pH   | Turbidity (NTU) |
|-----------------------------------------|--------------|------------------|----------------|--------------------------|-----------|------|-----------------|
| July 2015<br>(Expected count 2976)      | Actual Count | 2959             | 2976           | 2627                     | 2976      | 2976 | 2261            |
|                                         | Minimum      | 25.3             | 31.8           | 2.7                      | 1.79      | 7.4  | 4.1             |
|                                         | Maximum      | 31.1             | 36.7           | 6.3                      | 4.71      | 8.2  | 186             |
|                                         | Mean         | 28.7             | 33.9           | 4.7                      | 3.31      | 7.7  | 27.7            |
|                                         | SD           | 1.1              | 0.8            | 0.6                      | 0.7       | 0.14 | 19.9            |
|                                         | Percent      | 99%              | 100%           | 88%                      | 100%      | 100% | 76%             |
| August 2015<br>(Expected count 2976)    | Actual Count | 2969             | 2976           | 2667                     | 2975      | 2975 | 1994            |
|                                         | Minimum      | 27.3             | 27.5           | 2.5                      | 1.93      | 7.3  | 2.9             |
|                                         | Maximum      | 31.6             | 36             | 5.8                      | 4.8       | 8.1  | 225             |
|                                         | Mean         | 29.5             | 32.3           | 4.4                      | 3.37      | 7.6  | 42.2            |
|                                         | SD           | 0.8              | 1.6            | 0.5                      | 0.7       | 0.16 | 31.5            |
|                                         | Percent      | 100%             | 100%           | 90%                      | 100%      | 100% | 67%             |
| September 2015<br>(Expected count 2880) | Actual Count | 2878             | 2759           | 2669                     | 2878      | 2869 | 465             |
|                                         | Minimum      | 24.3             | 23.8           | 2                        | 1.99      | 7.3  | 9.2             |
|                                         | Maximum      | 30.7             | 34.3           | 6                        | 4.97      | 8.4  | 207.8           |
|                                         | Mean         | 27.4             | 27.6           | 4.5                      | 3.52      | 7.7  | 37.2            |
|                                         | SD           | 1.5              | 2              | 0.7                      | 0.7       | 0.25 | 30.5            |
|                                         | Percent      | 100%             | 96%            | 93%                      | 100%      | 100% | 16%             |
| October 2015<br>(Expected count 2976)   | Actual Count | 2974             | 2763           | 2824                     | 2975      | 2975 | 1894            |
|                                         | Minimum      | 20.2             | 26.7           | 2.9                      | 2.01      | 7.6  | 7.2             |
|                                         | Maximum      | 28.5             | 34.1           | 7                        | 5.07      | 8.3  | 116.2           |
|                                         | Mean         | 23.8             | 29.7           | 5.4                      | 3.62      | 7.9  | 29.3            |
|                                         | SD           | 1.4              | 1.4            | 0.7                      | 0.7       | 0.16 | 17.3            |
|                                         | Percent      | 100%             | 93%            | 95%                      | 100%      | 100% | 64%             |
| November 2015<br>(Expected count 2880)  | Actual Count | 2880             | 2843           | 2786                     | 2880      | 2874 | 1579            |
|                                         | Minimum      | 16.5             | 27.1           | 3.9                      | 2.28      | 7.5  | 4.8             |
|                                         | Maximum      | 25.7             | 33.1           | 7.8                      | 5.07      | 8.2  | 111.9           |
|                                         | Mean         | 21.8             | 29.2           | 6.2                      | 3.57      | 7.8  | 22.8            |
|                                         | SD           | 2.5              | 1.3            | 0.9                      | 0.7       | 0.14 | 13.5            |
|                                         | Percent      | 100%             | 99%            | 97%                      | 100%      | 100% | 55%             |
| December 2015<br>(Expected count 2976)  | Actual Count | 2976             | 2638           | 540                      | 2976      | 2974 | 0               |
|                                         | Minimum      | 15.5             | 26.2           | 5.9                      | 1.99      | 7.4  | NA              |
|                                         | Maximum      | 22.6             | 32.6           | 7.6                      | 4.68      | 8.3  | NA              |
|                                         | Mean         | 18.8             | 28.1           | 7                        | 3.49      | 7.9  | NA              |
|                                         | SD           | 1.6              | 1.2            | 0.3                      | 0.7       | 0.15 | NA              |
|                                         | Percent      | 100%             | 89%            | 18%                      | 100%      | 100% | 0%              |

**Table 4. (continued)** Monthly minimum, maximum, and mean values for parameters collected by the YSI 6-series data sonde at Cumberland Island National Seashore during 2015–2016. Percent 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 [PPT—parts per thousand; mg/L—milligrams per liter; m—meter; NTU—nephelometric turbidity unit; SD—standard deviation].

| Month                                  | Metric       | Temperature (°C) | Salinity (PPT) | Dissolved Oxygen, (mg/L) | Depth (m) | pH   | Turbidity (NTU) |
|----------------------------------------|--------------|------------------|----------------|--------------------------|-----------|------|-----------------|
| January 2016<br>(Expected count 2976)  | Actual Count | 2975             | 2914           | 2131                     | 2975      | 1757 | 1074            |
|                                        | Minimum      | 8.5              | 25.8           | 6.7                      | 1.69      | 7.7  | 0               |
|                                        | Maximum      | 22.2             | 31.2           | 9.4                      | 4.77      | 8.5  | 69.8            |
|                                        | Mean         | 13.8             | 28.2           | 8.3                      | 3.41      | 8.2  | 16.6            |
|                                        | SD           | 2.7              | 1.2            | 0.4                      | 0.7       | 0.2  | 12.9            |
|                                        | Percent      | 100%             | 98%            | 72%                      | 100%      | 59%  | 36%             |
| February 2016<br>(Expected count 2784) | Actual Count | 2778             | 2645           | 2660                     | 2784      | 1792 | 1518            |
|                                        | Minimum      | 9.5              | 21.1           | 6.6                      | 1.74      | 7.8  | 4.2             |
|                                        | Maximum      | 18.4             | 31.2           | 9.7                      | 4.66      | 8.5  | 152.8           |
|                                        | Mean         | 13.8             | 25             | 8.4                      | 3.31      | 8.2  | 18.4            |
|                                        | SD           | 1.5              | 2              | 0.5                      | 0.7       | 0.12 | 15.9            |
|                                        | Percent      | 100%             | 95%            | 96%                      | 100%      | 64%  | 55%             |
| March 2016<br>(Expected count 2976)    | Actual Count | 2959             | 2893           | 2821                     | 2976      | 1489 | 2694            |
|                                        | Minimum      | 14.9             | 24             | 5.3                      | 1.87      | 7.4  | 1.3             |
|                                        | Maximum      | 22.4             | 31.8           | 8.6                      | 4.74      | 8.2  | 119.4           |
|                                        | Mean         | 18.6             | 27.5           | 6.9                      | 3.34      | 7.9  | 20              |
|                                        | SD           | 1.9              | 1.6            | 0.5                      | 0.7       | 0.18 | 16.1            |
|                                        | Percent      | 99%              | 97%            | 95%                      | 100%      | 50%  | 91%             |
| April 2016<br>(Expected count 2880)    | Actual Count | 2873             | 2826           | 2532                     | 2879      | 2456 | 941             |
|                                        | Minimum      | 18.7             | 23.2           | 4.3                      | 1.69      | 7.4  | 2.8             |
|                                        | Maximum      | 25.6             | 32.9           | 7.5                      | 4.77      | 8.2  | 149.6           |
|                                        | Mean         | 21.1             | 27             | 6.4                      | 3.44      | 7.8  | 31.8            |
|                                        | SD           | 1.5              | 2              | 0.5                      | 0.7       | 0.14 | 24.8            |
|                                        | Percent      | 100%             | 98%            | 88%                      | 100%      | 85%  | 33%             |
| May 2016<br>(Expected count 2976)      | Actual Count | 2969             | 2781           | 2577                     | 2976      | 327  | 2068            |
|                                        | Minimum      | 21               | 25.4           | 3.7                      | 1.71      | 7.4  | 4.3             |
|                                        | Maximum      | 28.3             | 34.7           | 7.3                      | 4.89      | 8    | 165.7           |
|                                        | Mean         | 25.2             | 30.5           | 5.6                      | 3.37      | 7.7  | 27.7            |
|                                        | SD           | 1.5              | 1.7            | 0.6                      | 0.7       | 0.14 | 23.7            |
|                                        | Percent      | 100%             | 93%            | 87%                      | 100%      | 11%  | 69%             |
| June 2016<br>(Expected count 2880)     | Actual Count | 2879             | 2726           | 2368                     | 2879      | 1497 | 2247            |
|                                        | Minimum      | 26.2             | 29.2           | 2.6                      | 1.99      | 7.3  | 2.9             |
|                                        | Maximum      | 30.6             | 34.8           | 6.5                      | 4.87      | 8    | 137.4           |
|                                        | Mean         | 28.6             | 32             | 4.7                      | 3.43      | 7.7  | 27              |
|                                        | SD           | 1                | 1              | 0.6                      | 0.7       | 0.12 | 19.8            |
|                                        | Percent      | 100%             | 95%            | 82%                      | 100%      | 52%  | 78%             |

**Table 4 (continued).** Monthly minimum, maximum, and mean values for parameters collected by the YSI 6-series data sonde at Cumberland Island National Seashore during 2015–2016. Percent 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 [PPT—parts per thousand; mg/L—milligrams per liter; m—meter; NTU—nephelometric turbidity unit; SD—standard deviation].

| Month                                   | Metric       | Temperature (°C) | Salinity (PPT) | Dissolved Oxygen, (mg/L) | Depth (m) | pH   | Turbidity (NTU) |
|-----------------------------------------|--------------|------------------|----------------|--------------------------|-----------|------|-----------------|
| July 2016<br>(Expected count 2976)      | Actual Count | 2975             | 2816           | 2414                     | 2976      | 2975 | 2344            |
|                                         | Minimum      | 28.6             | 31.5           | 2.2                      | 1.96      | 7.3  | 2.9             |
|                                         | Maximum      | 32.6             | 36.7           | 6                        | 4.7       | 8.1  | 205.3           |
|                                         | Mean         | 30.5             | 34.1           | 4.6                      | 3.28      | 7.7  | 33.6            |
|                                         | SD           | 0.8              | 1.1            | 0.5                      | 0.7       | 0.15 | 26.3            |
|                                         | Percent      | 100%             | 95%            | 81%                      | 100%      | 100% | 79%             |
| August 2016<br>(Expected count 2976)    | Actual Count | 2975             | 2785           | 2461                     | 2975      | 2968 | 2491            |
|                                         | Minimum      | 27.8             | 33.5           | 1.9                      | 1.94      | 7.2  | 2.1             |
|                                         | Maximum      | 32.4             | 37.1           | 6.4                      | 4.68      | 8.1  | 130.3           |
|                                         | Mean         | 29.8             | 35.6           | 4.6                      | 3.35      | 7.7  | 25.9            |
|                                         | SD           | 0.8              | 0.6            | 0.7                      | 0.7       | 0.13 | 18.3            |
|                                         | Percent      | 100%             | 94%            | 83%                      | 100%      | 100% | 84%             |
| September 2016<br>(Expected count 2880) | Actual Count | 2880             | 2856           | 2322                     | 2880      | 2873 | 2448            |
|                                         | Minimum      | 26.9             | 33.3           | 2.3                      | 1.8       | 7.3  | 0               |
|                                         | Maximum      | 29.8             | 36.8           | 7.5                      | 4.81      | 8    | 119.3           |
|                                         | Mean         | 28.2             | 35.1           | 5.1                      | 3.43      | 7.7  | 17.7            |
|                                         | SD           | 0.5              | 0.6            | 0.7                      | 0.7       | 0.12 | 17.6            |
|                                         | Percent      | 100%             | 99%            | 81%                      | 100%      | 100% | 85%             |
| October 2016<br>(Expected count 2976)   | Actual Count | 2976             | 2917           | 2697                     | 2976      | 2975 | 2054            |
|                                         | Minimum      | 21.1             | 28.6           | 3.3                      | 2.21      | 7.3  | 1.3             |
|                                         | Maximum      | 28.7             | 35.5           | 6.8                      | 5.23      | 8.1  | 160.7           |
|                                         | Mean         | 24.1             | 31.3           | 5.5                      | 3.67      | 7.8  | 28.4            |
|                                         | SD           | 1.8              | 1.8            | 0.5                      | 0.7       | 0.15 | 24.8            |
|                                         | Percent      | 100%             | 98%            | 91%                      | 100%      | 100% | 69%             |
| November 2016<br>(Expected count 2880)  | Actual Count | 2732             | 2719           | 2451                     | 2732      | 2714 | 2395            |
|                                         | Minimum      | 15.1             | 28.5           | 4.5                      | 1.97      | 7.3  | 3.4             |
|                                         | Maximum      | 24.9             | 32.8           | 7.5                      | 5.12      | 8.2  | 127.8           |
|                                         | Mean         | 19.6             | 30.3           | 6.4                      | 3.56      | 7.8  | 24.6            |
|                                         | SD           | 2.3              | 1              | 0.5                      | 0.7       | 0.22 | 17.2            |
|                                         | Percent      | 95%              | 94%            | 85%                      | 95%       | 94%  | 83%             |
| December 2016<br>(Expected count 2976)  | Actual Count | 2976             | 2879           | 2602                     | 2976      | 2970 | 2664            |
|                                         | Minimum      | 14               | 29.7           | 4.8                      | 1.76      | 7.6  | 2               |
|                                         | Maximum      | 19.9             | 33.3           | 7.7                      | 4.94      | 8.2  | 84.1            |
|                                         | Mean         | 16.8             | 31.3           | 6.8                      | 3.4       | 7.9  | 20.7            |
|                                         | SD           | 1.3              | 0.7            | 0.4                      | 0.7       | 0.1  | 14.5            |
|                                         | Percent      | 100%             | 97%            | 87%                      | 100%      | 100% | 90%             |

**Table 5.** Monthly water-quality data collected at the SECN water-quality site near Cumberland Island National Seashore during 2015–2016. Water clarity was assessed with light attenuation values (k) using a constant for estuarine water with moderately turbid conditions (Smith et al. 2006) and assessment categories that correspond to EPA (2012) criteria. Condition of other assessed parameters based on EPA (2012) [green<sup>a</sup>—good; yellow<sup>b</sup>—fair; red<sup>c</sup>—poor; *k*—light attenuation coefficient; µg/L—micrograms per liter; mg/L—milligrams per liter; – is data not collected or missing].

| Collection Date | Water Clarity (k) <sup>1</sup> | Chlorophyll a (µg/L) | Dissolved Inorganic Nitrogen (mg/L) | Dissolved Inorganic Phosphorus (mg/L) | Dissolved Oxygen (mg/L) | Total Dissolved Nitrogen <sup>2</sup> (mg/L) | Total Dissolved Phosphorus <sup>2</sup> (mg/L) |
|-----------------|--------------------------------|----------------------|-------------------------------------|---------------------------------------|-------------------------|----------------------------------------------|------------------------------------------------|
| 01/29/2015      | 1.33 <sup>a</sup>              | 2.7 <sup>a</sup>     | –                                   | –                                     | 8.08 <sup>a</sup>       | 0.36                                         | 0.0334                                         |
| 03/26/2015      | 1.67 <sup>a</sup>              | 3.3 <sup>a</sup>     | –                                   | –                                     | 6.31 <sup>a</sup>       | 0.40                                         | 0.0324                                         |
| 05/20/2015      | 2.50 <sup>b</sup>              | 10.6 <sup>b</sup>    | 0.0228 <sup>a</sup>                 | 0.0126 <sup>b</sup>                   | 5.66 <sup>a</sup>       | 0.39                                         | 0.0299                                         |
| 06/17/2015      | 2.50 <sup>b</sup>              | 18.5 <sup>b</sup>    | –                                   | –                                     | 5.63 <sup>a</sup>       | 0.31                                         | 0.0302                                         |
| 07/07/2015      | 1.67 <sup>a</sup>              | 7.1 <sup>b</sup>     | –                                   | –                                     | 4.03 <sup>b</sup>       | 0.35                                         | 0.0412                                         |
| 08/11/2015      | 2.50 <sup>b</sup>              | 8.3 <sup>b</sup>     | 0.0809 <sup>a</sup>                 | 0.0202 <sup>b</sup>                   | 4.54 <sup>b</sup>       | 0.32                                         | 0.0394                                         |
| 09/09/2015      | 1.33 <sup>a</sup>              | 2.6 <sup>a</sup>     | –                                   | –                                     | 4.07 <sup>b</sup>       | 0.62                                         | 0.0389                                         |
| 10/08/2015      | 1.67 <sup>a</sup>              | 4.2 <sup>a</sup>     | –                                   | –                                     | 4.78 <sup>b</sup>       | 0.40                                         | 0.0342                                         |
| 11/11/2015      | 1.33 <sup>a</sup>              | 4.6 <sup>a</sup>     | 0.0443 <sup>a</sup>                 | 0.0246 <sup>b</sup>                   | 4.92 <sup>b</sup>       | 0.41                                         | 0.0398                                         |
| 12/03/2015      | 1.43 <sup>a</sup>              | 4.2 <sup>a</sup>     | –                                   | –                                     | 6.47 <sup>a</sup>       | 0.41                                         | 0.0362                                         |
| 01/08/2016      | 1.33 <sup>a</sup>              | 3.8 <sup>a</sup>     | –                                   | –                                     | 6.99 <sup>a</sup>       | 0.39                                         | 0.0388                                         |
| 02/11/2016      | 1.33 <sup>a</sup>              | 6.8 <sup>b</sup>     | 0.0245 <sup>a</sup>                 | 0.0024 <sup>a</sup>                   | 8.93 <sup>a</sup>       | 0.37                                         | 0.0225                                         |
| 03/17/2016      | 1.43 <sup>a</sup>              | 5.2 <sup>b</sup>     | –                                   | –                                     | 6.70 <sup>a</sup>       | 0.30                                         | 0.0213                                         |
| 04/05/2016      | 4.00 <sup>c</sup>              | 10.8 <sup>b</sup>    | –                                   | –                                     | 6.36 <sup>a</sup>       | 0.34                                         | 0.0250                                         |
| 05/04/2016      | 2.22 <sup>a</sup>              | 9.6 <sup>b</sup>     | 0.0380 <sup>a</sup>                 | 0.0106 <sup>b</sup>                   | 5.44 <sup>a</sup>       | 0.36                                         | 0.0253                                         |
| 06/15/2016      | 1.33 <sup>a</sup>              | 6.9 <sup>b</sup>     | –                                   | –                                     | 5.03 <sup>a</sup>       | 0.40                                         | 0.0426                                         |
| 07/14/2016      | 1.33 <sup>a</sup>              | 8.8 <sup>b</sup>     | –                                   | –                                     | 5.24 <sup>a</sup>       | 0.43                                         | 0.0437                                         |
| 08/11/2016      | 1.11 <sup>a</sup>              | 9.6 <sup>b</sup>     | 0.0556 <sup>a</sup>                 | 0.0138 <sup>b</sup>                   | 5.88 <sup>a</sup>       | 0.39                                         | 0.0369                                         |
| 09/14/2016      | 1.00 <sup>a</sup>              | 12.7 <sup>b</sup>    | –                                   | –                                     | 6.43 <sup>a</sup>       | 0.33                                         | 0.0370                                         |
| 11/10/2016      | 2.50 <sup>b</sup>              | 7.1 <sup>b</sup>     | 0.0457 <sup>a</sup>                 | 0.01540 <sup>b</sup>                  | 6.27 <sup>a</sup>       | 0.29                                         | 0.0280                                         |

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

<sup>2</sup>There are no EPA condition criteria for TDN and TDP

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