



Assessment of Estuarine Water and Sediment Quality at Fort Pulaski National Monument

2018 Data Summary

Natural Resource Data Series NPS/SECN/NRDS—2019/1237





ON THIS PAGE

Coastal assessment site FOPU-22 in Oyster Creek, near Fort Pulaski National Monument.

NPS photo / SECN

ON THE COVER

View of the salt marsh and Oyster Creek from coastal assessment site FOPU-21 near Fort Pulaski National Monument.

NPS photo / SECN

Assessment of Estuarine Water and Sediment Quality at Fort Pulaski National Monument

2018 Data Summary

Natural Resource Data Series NPS/SECN/NRDS—2019/1237

Eric N. Starkey, Wendy Wright, and Christopher S. Cooper

National Park Service
Southeast Coast Inventory and Monitoring Network
135 Phoenix Drive
Athens, GA 30605

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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. 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 July 2018 the Southeast Coast Network conducted an assessment of water quality at Fort Pulaski National Monument as part of the National Park Service Vital Signs Monitoring Program.

Monitoring was conducted following methods developed by the Environmental Protection Agency (EPA) as part of the National Coastal Assessment Program (EPA 2010). Laboratory analysis measured chlorophyll *a* and total and dissolved concentrations of nitrogen and phosphorous. Field measurements included water temperature, pH, dissolved oxygen, and salinity. Water clarity, which requires a Secchi depth measurement, was obtained when possible. All measured parameters were rated as good, fair, or poor based on thresholds set by the EPA (2012).

- Water clarity was rated good at twenty-four sites (80%) and could not be sampled at six sites (20%) due to strong currents.
- Chlorophyll *a* concentration was rated fair at twenty-eight sites (93%) and poor at two sites (7%).
- Dissolved inorganic nitrogen (DIN) concentration was good at ten sites (33%), and fair at the remaining twenty sites (67%).
- Dissolved inorganic phosphorus (DIP) concentration was good at all thirty sites (100%).
- Dissolved oxygen concentration was rated good at five sites (17%) and fair at twenty-five (83%).
- A water-quality condition summary index was calculated for each site sampled in Fort Pulaski National Monument based on the categorical assessments of chlorophyll *a*, DIN and DIP concentrations, dissolved oxygen, and water clarity. This summary index indicated fair water-quality conditions at all thirty sites (100%).
- Based on the summary water-quality index rating for the monument, overall water-quality conditions at Fort Pulaski National Monument in 2018 were fair.
- For sediment, ecological condition was ranked as good at twenty-seven sites (90%) and fair at three sites (10%). As a result, no adverse effects to benthic organisms due to sediment contamination are anticipated at the majority of the sampled sites. This ranking was assigned according to the 2010 Environmental Protection Agency, National Coastal Condition Assessment (NCCA) thresholds for sediment chemistry.



View from coastal assessment site 08 in the Bull River near Fort Pulaski National Monument. NPS photo / SECN.

Introduction

Water resources are important to park management from ecological, regulatory, and visitor experience perspectives; therefore, 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 around parks and contribute to a better understanding of park ecological processes and physical systems (Gregory et al. 2013).

To effectively monitor a diverse and dynamic set of estuarine water resources, the NPS Southeast Coast I&M Network (SECN) implemented a two-pronged monitoring approach, which consists of collecting periodic discrete and continuously recorded data from fixed stations located in each park combined with periodic synoptic assessments of water quality at a larger spatial scale in the waters surrounding park areas (Gregory et al. 2013). When implemented together, these approaches give a more complete picture of physical processes, diurnal and seasonal variations, and spatial patterns during critical portions of the year.

The network identified four specific monitoring objectives for which data are collected and analyzed as part of this effort (Gregory et al. 2013):

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 nutrient concentrations (nitrogen, phosphorus, and chlorophyll *a*) 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) in estuarine waters every ten years.

This report summarizes coastal water-quality monitoring data collected during a synoptic assessment to address objectives 3 and 4 at Fort Pulaski National Monument. Data was gathered from 23 July to 26 July 2018. The purpose of this document is to report the most recently collected data from within the monument as part of an ongoing long-term water-quality monitoring program. This report was designed to provide water-quality monitoring data to managers as a concise summary in the context of applicable federal standards developed by the EPA. Previous synoptic assessment of water-quality conditions at Fort Pulaski National Monument were conducted in August 2007 and July 2014 as part of I&M monitoring efforts (Gregory et al. 2010; Wright et al. 2015).

Study Area

Fort Pulaski National Monument

Fort Pulaski National Monument (FOPU) is located in Chatham County, Georgia along the Savannah River, at the confluence of the river and the Atlantic Ocean (Figure 1). The monument consists of two islands that were primarily salt marsh until human intervention. Cockspur Island probably supported some coastal hammock forest or woodland, based on the composition of existing vegetation. Cockspur Island was selected for fortification as early as the 18th century. In the early 19th century, as part of the development of the site for defense, the island was modified by the installation of drainage canals and a dike system. The site was later affected by the deposition of dredge spoil material from the Savannah River, which continued until recent times. During the civil war period, vegetation was removed and kept in early successional stages to enhance visibility.

Since the abandonment of the fort in the late 1800s, a large portion of central Cockspur Island has reverted to maritime forest. Currently the upland portions of Cockspur Island (approximately 260 acres or 0.4 square miles [sq mi]) support a mosaic of maritime forest, maritime shrub communities, maintained grasslands, and successional spoil-deposit areas. The island also includes more than 340 acres (0.5 sq mi) of tidal shrubland and tidal herbaceous marsh.

McQueen's Island makes up the largest portion of land holdings for the national monument (about 4,900 acres [7.7 sq mi]), and the majority of the island consists of salt marsh. A railroad was constructed along the northern edge of the island in 1887 to connect the city of Savannah with Tybee Island. The railroad was operated until 1933. US Highway 80 was constructed in 1923. The highway crosses the central portion of the island and then continues east along the old railroad grade. In 1994 Chatham County converted the abandoned railroad right-of-way to a multipurpose hiking trail. Both the highway and the converted rails-to-trails areas support habitat for numerous ruderal herbaceous coastal plain species. (DeVivo et al. 2008).

Water resources at Fort Pulaski National Monument have been affected by land/waterway use in the surrounding watersheds. Examples of water-quality effects applicable to park include nonpoint source pollution from urban and agricultural areas, elevated metal concentrations in dredged sediments of the Savannah River shipping channel, effects of multiple Superfund sites and landfills, and water pollution from malfunctioning septic systems (McFarlin and Alber 2005).

Fort Pulaski National Monument Significant Waters Map

Southeast Coast Network
National Park Service
U.S. Department of the Interior



Figure 1. Map of Southeast Coast Network (SECN) fixed station sampling site and significant waters near Fort Pulaski National Monument in 2018. Indicated are areas of salt marsh (USFWS 2019), urbanized areas (USCB 2019), areas designated as having special uses or restrictions (NOAA 2018) and fixed station sites monitored by the network.

Fort Pulaski National Monument 2018 Coastal Assessment Sites

Southeast Coast Network
National Park Service
U.S. Department of the Interior



Figure 2. Map showing the location of coastal assessment sites (Table 1) sampled at Fort Pulaski National Monument in July 2018.

Table 1. Site Name, waterbody name and location, depth, coordinates, and chemical and physical attributes of sampling sites at Fort Pulaski National Monument, July 2018. The table references site names used to present data in this report (Figure 2). All coordinates are in NAD83 Datum in UTM zone 17. Salinity, pH, and water temperature were measured at a depth of 0.5 meters [m—meters; SAV—sub-aquatic vegetation; ppt—parts per thousand].

Site Name	Water Body	UTMX	UTMY	SAV	Debris	Site Depth (m)	Water Temp (°C)	pH	Salinity (ppt)
FOPU-01	Savannah River	502758	3548836	No	No	5.3	29.2	7.4	15.4
FOPU-02	Wilmington River	498964	3548675	No	No	2.3	29.1	7.3	15.9
FOPU-03	Bull River	506892	3540173	No	No	2.3	29.1	7.5	29.5
FOPU-04	South Channel	506213	3544678	No	No	1.8	29.5	7.6	19.4
FOPU-05	South Channel	510646	3542769	No	No	5.1	29.7	7.6	18.2
FOPU-06	Savannah River	504209	3548419	No	No	5.1	29.4	7.3	14.0
FOPU-07	Oyster Creek	507806	3540843	No	No	7.1	28.7	7.5	30.1
FOPU-08	Bull River	504360	3543972	No	No	4.2	29.7	7.3	21.1
FOPU-09	Lazaretto Creek	509560	3540853	No	No	4.5	29.8	7.5	27.2
FOPU-10	South Channel	501812	3548409	No	No	3.4	29.0	7.4	16.5
FOPU-11	Bull River	506002	3541959	No	No	3.8	29.5	7.4	25.1
FOPU-12	Savannah River	509210	3544750	No	No	4.5	29.5	7.8	27.5
FOPU-13	Savannah River	505540	3547068	No	No	2.9	29.6	7.4	14.6
FOPU-14	South Channel	503996	3546647	No	No	6.6	29.0	7.4	18.4
FOPU-15	Savannah River	507374	3544441	No	No	4.2	29.2	7.6	21.6
FOPU-16	South Channel	511429	3542978	No	No	1.3	30.3	7.7	20.7
FOPU-17	Bull River	503253	3545217	No	No	2.3	29.8	7.4	18.8
FOPU-18	Wilmington River	499890	3548866	No	No	7.2	28.9	7.4	15.7
FOPU-19	Bull River	506342	3539585	No	No	3.1	29.2	7.5	29.5
FOPU-20	South Channel	506733	3544374	No	No	2.0	29.7	7.5	17.6
FOPU-21	Oyster Creek	507476	3541949	No	No	2.1	29.1	7.5	29.1
FOPU-22	South Channel	501271	3548807	No	No	2.9	29.9	7.4	16.5
FOPU-23	Lazaretto Creek	507807	3539059	No	No	5.1	29.3	7.6	29.6
FOPU-24	South Channel	508240	3543380	No	No	2.6	29.6	7.5	17.7
FOPU-25	Savannah River	504904	3547027	No	No	1.5	29.6	7.5	15.8
FOPU-26	South Channel	502095	3547993	No	No	5.6	29.1	7.4	15.9
FOPU-27	Bull River	507371	3541448	No	No	4.7	29.3	7.4	27.8
FOPU-28	Savannah River	508621	3544275	No	No	3.6	29.3	7.8	22.9
FOPU-29	Savannah River	506245	3545470	No	No	5.3	29.4	7.8	25.7
FOPU-30	Elba Island Cut	501204	3547840	No	No	3.1	29.5	7.3	16.6

Methods

The water-quality assessment was conducted in estuarine and tidal creek waters in the vicinity of the monument, following the methods developed by the Environmental Protection Agency (EPA) National Coastal Assessment Program (EPA 2010). Descriptions of the water-quality parameters and the assessment criteria are from the EPA National Coastal Assessment IV Report (EPA 2012). Methods used for these assessments were partially adapted and integrated into protocols tailored specifically to parks in the Southeast Coast Network (Gregory et al. 2013). Site selection and sampling methodology are briefly outlined in the following sections.

In 2018, thirty sites in the monument's waters were randomly selected for monitoring following methods developed by the EPA (Table 1, Figure 2; Stevens 1997; Stevens and Olsen 1999; Stevens and Olsen 2004). A pool of alternate sites was selected in case any of the original sites were not accessible. This method of randomly selecting spatially-balanced sites provides managers with a statistically valid estimate of the overall conditions of the assessed resource within or around the park.

Water-Quality Data Collection

The water-quality assessment conducted during this sampling period incorporated hydrographic profiles at 0.5–1.0 meter (1.6–3.3 feet [ft]) intervals at each site, to measure temperature, pH, dissolved oxygen, and salinity. Chlorophyll *a* levels and total dissolved nutrient samples were collected from 0.5 meters (1.6 ft) below the surface. Chlorophyll *a* samples were processed using known volumes of water samples that were filtered onto glass-fiber filters then refrigerated and submitted for laboratory analysis.

Water clarity was estimated at each site using a Secchi disk to determine light extinction depths, which were converted

to light attenuation coefficients (*k*) using the equation: $K = c / \text{Secchi depth (in meters)}$, where “*c*” is a constant that corresponds to the water body’s naturally occurring clarity conditions (i.e., *c* = 1.0 for naturally turbid conditions, *c* = 1.4 for normal turbidity conditions, or *c* = 1.7 for waters supporting submerged aquatic vegetation (SAV) restoration [Smith et al. 2006; EPA 2016]). Fort Pulaski National Monument uses a coefficient of 1.0 for naturally turbid conditions. 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 network parks. Water clarity was not assessed at sites with excessive current or when they were too shallow to ascertain an accurate Secchi depth measurement. When sites were too shallow to access by boat, or when they were located in shipping channels, alternate sites were used.

Water-Quality Assessment Criteria

The categorical assessments (e.g., good, fair, poor) use measurements of chlorophyll *a*, nutrients, bottom dissolved oxygen, and water clarity (Table 2) and are intended to characterize acutely degraded water-quality conditions. The assessments do not consistently identify sites that experience occasional or infrequent hypoxia, nutrient enrichment, or decreased water clarity. Therefore, a rating of poor for the water-quality index means that the site likely exhibited consistently poor conditions before or after the assessment period. If a site is designated fair or good, the site did not experience poor conditions on the date of sampling; however, the site could be characterized by poor conditions for short time periods.

Site assessments were also made using an index that combines the ratings for each parameter into a site-specific water-quality index rating. This index allows for general

Table 2. Coastal water-quality monitoring condition criteria for water-quality parameters collected by the Southeast Coast Network. Based on thresholds set by the EPA (2012) [µg/L—micrograms per liter; mg/L—milligrams per liter].

Rating	Water Clarity (k) ¹	Chlorophyll <i>a</i> (µg/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	2.3–2.99	5–20	0.1–0.5	0.01–0.05	2–5
Poor	> 2.99	> 20	> 0.5	> 0.05	< 2

¹Light 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.

Table 3. Condition criteria used for water-quality assessment summaries at individual sampling sites and parks.

Rating	Site Water-Quality Index Rating ¹	Park Water-Quality Index Rating
Good	A maximum of one indicator is rated fair, and no indicators are rated poor.	Less than 10% of sites are in poor condition, and more than 50% of sites are in good condition.
Fair	One indicator is rated poor, or two or more indicators are rated fair.	10% to 20% of sites are in poor condition, or 50% or less of sites are in good condition.
Poor	Two or more of the five indicators are rated poor.	More than 20% of sites are in poor condition.
Missing	Two components of the indicator are missing and the available indicators do not suggest a fair or poor rating.	NA

¹Park and site water-quality index ratings are adapted from ratings established by the EPA (2012).

comparisons between sites in a park (Table 3) and can be used to summarize overall conditions in the waters around a park. This rating also allows general comparisons between parks based on the percentage of sites that fall within the good, fair, or poor categories.

Sediment Data Collection

Sediment samples were collected by taking multiple grabs at each site using a 6.8-kilogram (kg; 24-pound [lbs]) Ponar Sampler with a sample area of 152 × 152 millimeter (mm; 6 × 6 inches [in]). The top 23 centimeters (cm; 0.78–1.2 in) from each sample were composited and split into three separate samples that were analyzed for organic contaminants, metals, total organic carbon (TOC), and grain size. Samples were stored on wet ice or in a refrigerator until completion of analysis by the contracted laboratory.

Sediment Assessment Criteria

The Southeast Coast Network uses Environmental Protection Agency (EPA) National Coastal Condition Assessment (NCCA) sediment quality guidelines (SQG) for estuarine waters to assess the degree of sediment contamination. These SQGs include the mean Effects-Range Median Quotient (mERM-Q) and Logistic Regression Model (LRM). Together, the mERM-Q and LRM provide a holistic interpretation of sediment chemistry and its potential effects on benthic organisms.

The mERM-Q approach assesses the relative degree of sediment contamination and estimates the probability of toxicity to benthic organisms from sediment contaminants (EPA 2016). Calculation of mERM-Q relies upon the Effects Range Low (ERL) and Effects Range Median (ERM) values shown in Table 4. ERM is the median concentration of a contaminant observed to have adverse biological effects in the literature studies examined. While ERL is the 10th percentile concentration of a contaminant represented by studies demonstrating adverse biological effects in the literature. Ecological effects are not likely to occur at contaminate concentrations below the ERL criterion.

The LRM approach calculates the probability of observing a toxic effect based on individual contaminant concentrations and the maximum probability (P_{max}) of observing toxicity from all contaminants in a sample (EPA 2016). Values used in the LRM-P_{max} calculation (B₀ and B₁) can be found in Table 5.

Previous coastal assessments conducted by the network and the EPA used % Total Organic Carbon (TOC) as a rating factor for sediment quality. However, in 2010, the EPA updated its methods to reflect current practices and %TOC is no longer a component of the sediment quality index. As a result, %TOC has been reported below for comparison with past reports, but was not used in determination of ecological condition by site.

Table 4. Thresholds for sediment chemistry used to determine ecological condition by site (U.S. EPA 2010) [mERM-Q—mean Effects-Range Median Quotient; LRM—Logistic Regression Model; P_{max}—maximum probability].

Rank	Threshold
Good	mERM-Q < 0.1 and LRM P _{max} ≤ 0.5
Fair	mERM-Q ≥ 0.1 - ≤ 0.5 or LRM P _{max} > 0.5 - < 0.75
Poor	mERM-Q > 0.5 or LRM P _{max} ≥ 0.75

Table 5. Sediment quality guideline values used to calculate mERM-Q and LRM-Pmax (EPA 2016).

Sediment Chemicals Analyzed	Units	ERL	ERM	Used to calculate mERM-Q	B ₀	B ₁	Used to calculate LRM-Pmax
Antimony	µg/g	–	–	–	-0.9005	2.411	X
Arsenic	µg/g	8.2	70	X	-4.1407	3.1674	X
Cadmium	µg/g	1.2	9.6	X	-0.34	2.5073	X
Chromium	µg/g	81	370	X	-6.4395	2.9952	X
Copper	µg/g	34	270	X	-5.7878	2.9325	X
Lead	µg/g	46.7	218	X	-5.4523	2.7662	X
Mercury	µg/g	0.15	0.71	X	0.8041	2.5461	X
Nickel	µg/g	20.9	51.6	–	-4.6119	2.7658	X
Silver	µg/g	1	3.7	X	-0.1117	1.9684	X
Zinc	µg/g	150	410	X	-7.9834	3.342	X
Acenaphthene	ng/g	16	500	X	-3.6165	1.7532	X
Acenaphthylene	ng/g	44	640	X	-2.962	1.3797	X
Anthracene	ng/g	85.3	1100	X	-3.6574	1.4854	X
Fluorene	ng/g	19	540	X	-3.7146	1.8071	X
2-methylnapthalene	ng/g	70	670	X	-3.7579	1.7833	X
Napthalene	ng/g	160	2100	X	-3.7753	1.6152	X
Phenanthrene	ng/g	240	1500	X	-4.4576	1.6768	X
Benz(a)anthracene	ng/g	261	1600	X	-4.2013	1.5747	X
Benzo(a)pyrene	ng/g	430	1600	X	-4.3005	1.5832	X
Chrysene	ng/g	384	2800	X	-4.3241	1.5372	X
Dibenz(a,h)anthracene	ng/g	63.4	260	X	-3.6308	1.7692	X
Fluoranthene	ng/g	600	5100	X	-4.4574	1.4787	X
Pyrene	ng/g	665	2600	X	-4.708	1.5854	X
Total DDT	ng/g	1.6	46.1	X	–	–	–
Total PCB congeners	ng/g	22.7	180	X	-3.4613	1.3488	X
Total PAHs*	ng/g	4020	44800	–	–	–	–

Results

Parameter-Based Water Condition Assessments

Figures 3–7 illustrate the spatial distribution of sampling sites and the corresponding ratings for water clarity, chlorophyll *a*, dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (DIP), and bottom-reading dissolved oxygen (DO) based on each parameter's corresponding condition category. Inset graphs on Figures 3–7 show the proportion of sites in the assessed area that were placed in each rating category. The map and graph in Figure 8 summarize seashore-wide water quality. Site-specific water-quality data for each parameter are also presented in Table 6.

Water clarity was rated good at twenty-four sites (80%) and could not be sampled at six sites (20%) due to strong current.

Chlorophyll *a* concentration was rated fair at twenty-eight sites (93%) and poor at two sites (7%).

Dissolved inorganic nitrogen (DIN) concentration was good at ten sites (33%), and fair at the remaining twenty sites (67%).

Dissolved inorganic phosphorus (DIP) concentration was good at all thirty sites (100%).

Dissolved oxygen concentration was rated good at five sites (17%) and fair at twenty-five sites (83%).

A water-quality condition summary index was calculated for

each site sampled in Fort Pulaski National Monument based on the categorical assessments of chlorophyll *a*, DIN and DIP concentrations, and dissolved oxygen. This summary index indicated fair water-quality conditions at all thirty sites.

Based on the summary water-quality index rating for the monument, overall water-quality conditions at Fort Pulaski National Monument in 2018 were fair.

Sediment Condition Assessments

Metal and organic contaminant concentration data is provided in Tables 7, 8a, and 8b. Figure 9 is a map which show the spatial distribution of sampling sites and the corresponding ratings for ecological condition based on sediment chemistry. The inset graph shows the percentage of sites in each ecological condition rating category (good, fair, poor). Data used to make the map and graph are shown in Table 9. Ecological condition was ranked as good at twenty-seven sites (90%) and fair at three sites (10%). As a result, no adverse impacts to benthic organisms due to sediment contamination are anticipated at the majority of the sampled sites. Relative to other sample sites, all three locations ranked as fair showed elevated levels of Arsenic, Chromium, Copper, Lead, Nickel, and Zinc (Table 7). These rankings were assigned according to the 2010 Environmental Protection Agency, National Coastal Condition Assessment (NCCA) thresholds for sediment chemistry.

Fort Pulaski National Monument Water Clarity (k)

Southeast Coast Network
National Park Service
U.S. Department of the Interior

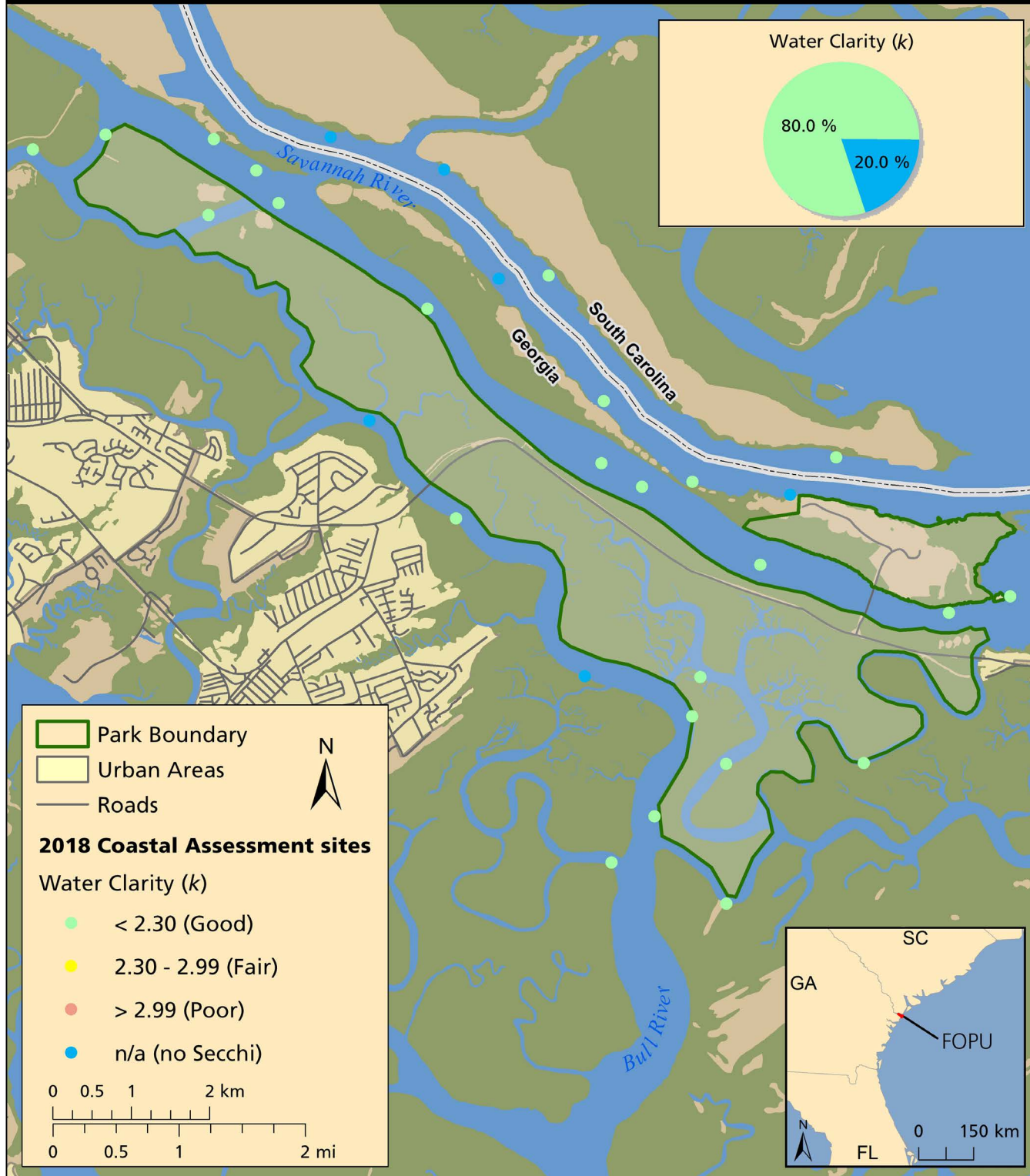


Figure 3. Water clarity ratings at sampling sites at Fort Pulaski National Monument in July 2018. Inset graph shows the percent of sites in each condition category [green—good; yellow—fair; blue—n/a].

Fort Pulaski National Monument Chlorophyll a

Southeast Coast Network
National Park Service
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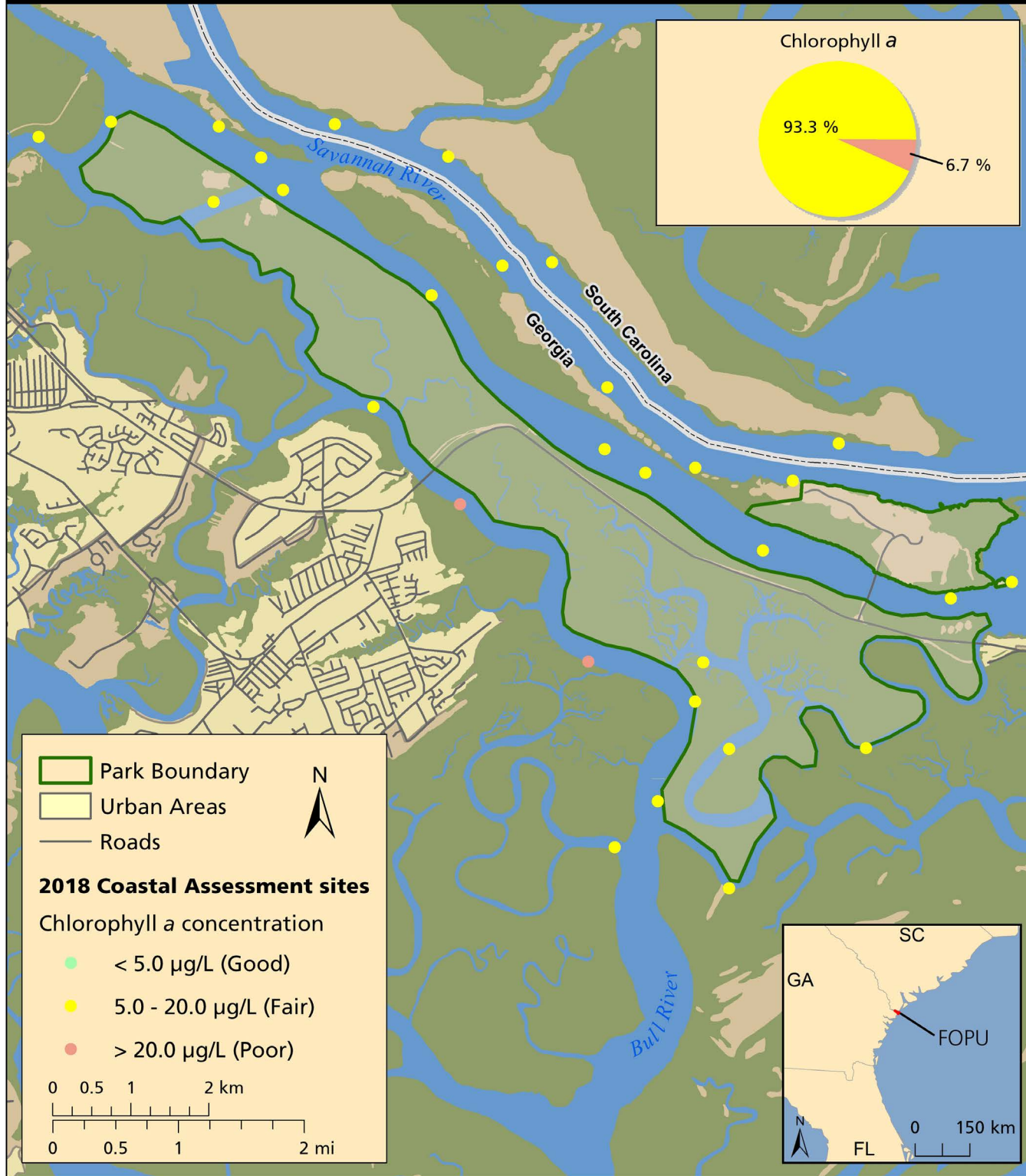


Figure 4. Chlorophyll a concentrations at Fort Pulaski National Monument in July 2018. Inset graph shows the percent of sites in each condition category [green—good; yellow—fair; red—poor].

Fort Pulaski National Monument Dissolved Inorganic Nitrogen

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National Park Service
U.S. Department of the Interior

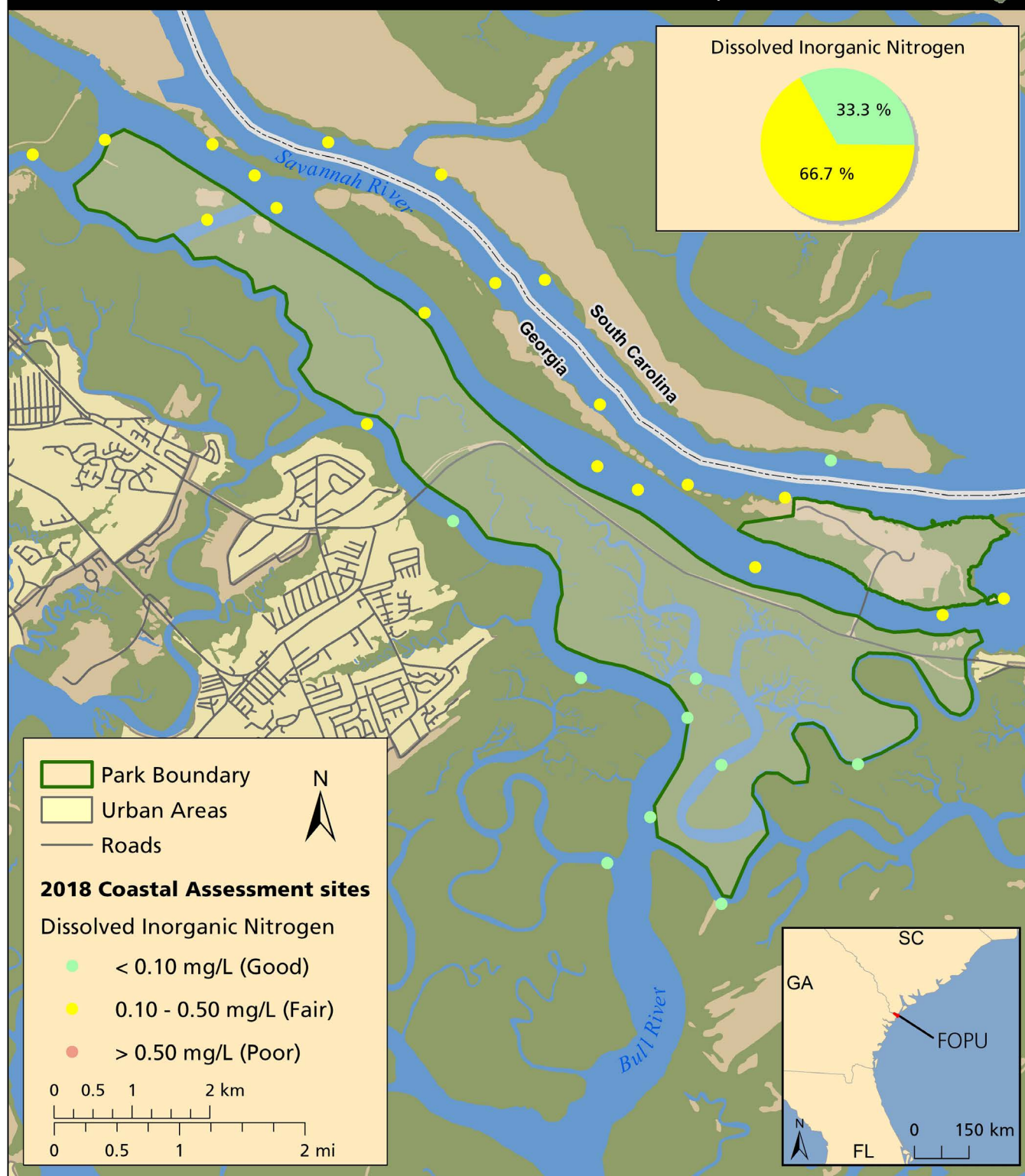


Figure 5. Dissolved inorganic nitrogen concentrations at sampling sites at Fort Pulaski National Monument in July 2018. Inset graph shows the percent of sites in each condition category [green—good; yellow—fair].

Fort Pulaski National Monument Dissolved Inorganic Phosphorus

Southeast Coast Network
National Park Service
U.S. Department of the Interior

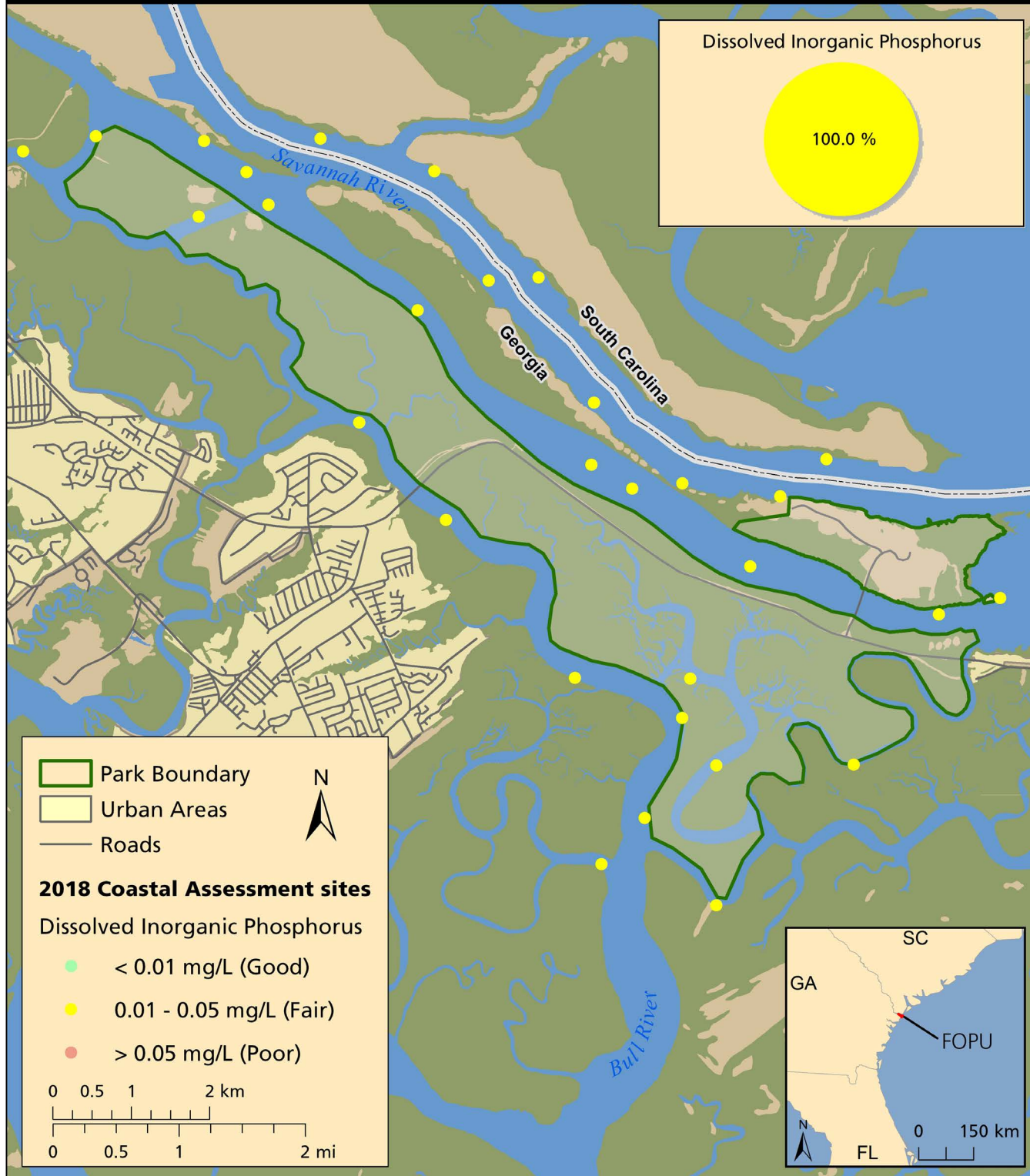


Figure 6. Dissolved inorganic phosphorus concentrations at sampling sites at Fort Pulaski National Monument in July 2018. Inset graph shows the percent of sites in each condition category [yellow—fair].

Fort Pulaski National Monument Dissolved Oxygen

Southeast Coast Network
National Park Service
U.S. Department of the Interior

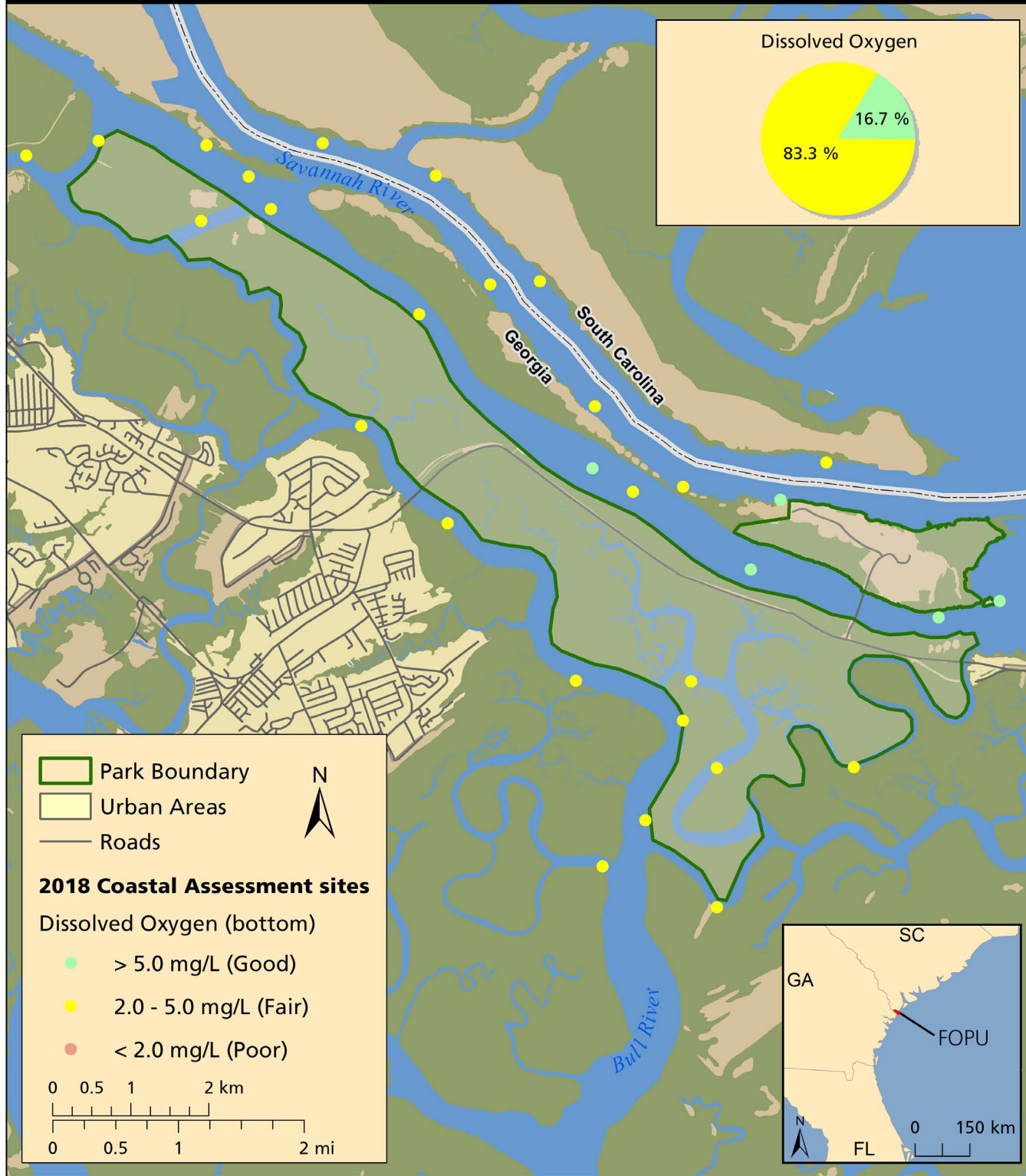


Figure 7. Dissolved oxygen concentrations at sampling sites at Fort Pulaski National Monument in July 2018. Inset graph shows the proportion of sites in each condition category [green—good; yellow—fair].

Fort Pulaski National Monument Site Water Quality Index Ratings

Southeast Coast Network
National Park Service
U.S. Department of the Interior



Figure 8. Water-quality index rating at sampling sites in the vicinity of Fort Pulaski National Monument in July 2018. Inset graph shows the proportion of sites in each condition category [yellow—fair].

Fort Pulaski National Monument Ecological Condition

Southeast Coast Network
National Park Service
U.S. Department of the Interior



Figure 9. Spatial distribution of sampling sites and the corresponding ratings for ecological condition based on sediment chemistry. Inset graph shows the proportion of sites in each condition category [green—good; yellow—fair].

Water-Quality Data

Table 6. Water-quality parameter values and assessment conditions for sampling sites in the vicinity of Fort Pulaski National Monument in July 23–26, 2018. Water clarity was assessed using light attenuation values (k) using a constant (1.0) for estuarine waters with naturally turbid conditions (Smith et al. 2006) and assessment categories that correspond to EPA (2012 and 2016). Condition of other assessed parameters based on EPA (2012) [Green^a—good; yellow^b—fair; red^c—poor; k—light attenuation coefficient; µg/L—micrograms per liter; N—Nitrogen; mg/L—milligrams per liter; P—Phosphorous; — data not collected;]. Dissolved oxygen concentrations are taken near the bottom (deepest reading).

Site Name	Water Clarity (k ¹)	Chlorophyll a (µg/L)	Dissolved Oxygen (DO, mg/L)	Dissolved Inorganic N (DIN, mg/L)	Dissolved Inorganic P (DIP, mg/L)	Total Dissolved N ² (mg/L)	Total Dissolved P ² (mg/L)
FOPU-01	—	7.74 ^b	4.0 ^b	0.245 ^b	0.0313 ^b	0.44	0.056
FOPU-02	1.1 ^a	13.70 ^b	4.3 ^b	0.229 ^b	0.0267 ^b	0.27	0.054
FOPU-03	1.3 ^a	9.49 ^b	4.4 ^b	0.031 ^a	0.0155 ^b	0.41	0.040
FOPU-04	1.7 ^a	12.43 ^b	5.0 ^a	0.195 ^b	0.0245 ^b	0.41	0.047
FOPU-05	1.3 ^a	11.86 ^b	5.8 ^a	0.181 ^b	0.0216 ^b	0.51	0.047
FOPU-06	—	6.45 ^b	3.9 ^b	0.268 ^b	0.0312 ^b	0.28	0.060
FOPU-07	1.3 ^a	6.54 ^b	4.4 ^b	0.055 ^a	0.0183 ^b	0.35	0.044
FOPU-08	1.7 ^a	20.30 ^c	4.2 ^b	0.067 ^a	0.0145 ^b	0.05	0.043
FOPU-09	1.3 ^a	8.80 ^b	4.2 ^b	0.037 ^a	0.0126 ^b	0.47	0.041
FOPU-10	1.3 ^a	6.19 ^b	3.8 ^b	0.246 ^b	0.0310 ^b	0.28	0.056
FOPU-11	—	20.73 ^c	4.9 ^b	0.032 ^a	0.0133 ^b	0.29	0.039
FOPU-12	1.3 ^a	16.47 ^b	4.6 ^b	0.088 ^a	0.0176 ^b	0.50	0.040
FOPU-13	2.0 ^a	8.29 ^b	4.9 ^b	0.264 ^b	0.0305 ^b	0.49	0.056
FOPU-14	1.3 ^a	5.36 ^b	4.5 ^b	0.221 ^b	0.0285 ^b	0.43	0.051
FOPU-15	1.7 ^a	11.05 ^b	4.9 ^b	0.180 ^b	0.0246 ^b	0.42	0.050
FOPU-16	1.7 ^a	15.25 ^b	6.4 ^a	0.143 ^b	0.0206 ^b	0.38	0.045
FOPU-17	—	12.06 ^b	4.9 ^b	0.151 ^b	0.0177 ^b	0.46	0.043
FOPU-18	1.0 ^a	5.37 ^b	4.2 ^b	0.255 ^b	0.0300 ^b	0.26	0.055
FOPU-19	1.3 ^a	9.09 ^b	4.5 ^b	0.038 ^a	0.0213 ^b	0.44	0.041
FOPU-20	1.7 ^a	12.22 ^b	4.9 ^b	0.200 ^b	0.0268 ^b	0.32	0.048
FOPU-21	1.3 ^a	9.40 ^b	4.7 ^b	0.044 ^a	0.0204 ^b	0.27	0.046
FOPU-22	1.7 ^a	5.82 ^b	3.6 ^b	0.268 ^b	0.0375 ^b	0.26	0.060
FOPU-23	1.0 ^a	7.73 ^b	4.7 ^b	0.033 ^a	0.0194 ^b	0.43	0.045
FOPU-24	1.7 ^a	12.49 ^b	5.2 ^a	0.202 ^b	0.0236 ^b	0.45	0.050
FOPU-25	—	8.24 ^b	4.5 ^b	0.248 ^b	0.0309 ^b	0.46	0.053
FOPU-26	1.3 ^a	6.37 ^b	4.1 ^b	0.245 ^b	0.0319 ^b	0.27	0.055
FOPU-27	1.3 ^a	11.76 ^b	4.6 ^b	0.033 ^a	0.0170 ^b	0.32	0.041
FOPU-28	—	9.70 ^b	5.3 ^a	0.133 ^b	0.0196 ^b	0.27	0.043
FOPU-29	1.7 ^a	12.79 ^b	5.0 ^a	0.103 ^b	0.0185 ^b	0.44	0.046
FOPU-30	1.3 ^a	9.77 ^b	4.5 ^b	0.202 ^b	0.0241 ^b	0.25	0.051

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 EPA (2012) criteria for the assessed water bodies.

² There are no EPA condition criteria for TDN and TDP.

Table 7. Concentrations of select metals for sites sampled at Fort Pulaski National Monument, July 23–26, 2018. All results are presented in mg/kg [*—result was greater than or equal to the Method Detection Limit (MDL) but below the Practical Quantitation Limit (PQL); **—result was less than the Method Detection Limit].

Site	Antimony	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
FOPU-01	0.48**	0.61**	0.05*	1.5	0.4**	0.65	0.00084**	0.66	1.8
FOPU-02	0.93**	9.7	0.68	46	9.1	14	0.024	20	43
FOPU-03	0.59**	5.1	0.23	12	2.2	3.5	0.0066*	4.9	13
FOPU-04	0.48**	0.75*	0.078*	4.6	0.61*	2	0.00082**	1.8	6.7
FOPU-05	0.5**	3.9	0.14*	5.4	1.1	2	0.004*	2.9	9.6
FOPU-06	0.92**	7.7	0.74	38	9.8	11	0.03	20	41
FOPU-07	1.5**	16	0.81	46	12	16	0.031	22	54
FOPU-08	0.97**	9.8	0.81	43	7.6	12	0.021	20	47
FOPU-09	0.57**	3.9	0.19*	11	2	2.5	0.0063*	4.6	12
FOPU-10	0.51**	1.8*	0.13*	5.1	3.2	43	0.0074	2.6	11
FOPU-11	0.64**	3.9	0.22*	13	2.7	4	0.0073*	5.4	14
FOPU-12	1**	9.7	1.2	43	30	23	0.1	29	85
FOPU-13	0.47**	0.89*	0.098*	2.8	0.67*	1	0.0011*	1.4	3.6
FOPU-14	0.65**	5.4	0.35	22	4.3	120	0.0086	11	25
FOPU-15	0.75**	4.8	0.27*	16	2.4	3.8	0.0057*	6.9	17
FOPU-16	1*	5.6	0.12*	6	0.69*	0.2**	0.0021*	3.5	14
FOPU-17	0.54**	1.7*	0.096*	4.4	0.45*	1.7	0.00094*	1.5	4.4
FOPU-18	0.48**	0.89*	0.053*	3.1	1.2	2	0.0054*	1.6	5.1
FOPU-19	1.6**	17	0.73	45	11	14	0.032	20	53
FOPU-20	0.6**	4.6	0.43	15	6.2	10	0.045	8.2	23
FOPU-21	1.1**	19	0.89	43	12	15	0.042	21	54
FOPU-22	0.61*	1.4*	0.59	4.6	0.78*	1	0.0036*	6.7	7.5
FOPU-23	1**	6.6	0.6	27	2.5	4.9	0.013	13	32
FOPU-24	0.48**	2.3*	0.097*	3.3	0.46*	0.95	0.0012*	1.9	7.4
FOPU-25	0.47**	0.59**	0.037**	1.5	0.39**	0.47*	0.0008**	0.6	1.5
FOPU-26	0.53**	1.2*	0.05*	2	0.44**	0.84	0.0028*	1.2	2.7
FOPU-27	0.52**	5.5	0.26	22	3	4.9	0.0063*	6.7	14
FOPU-28	0.66**	6	0.23*	12	2.3	1.5	0.0073*	5.5	15
FOPU-29	0.72**	5.6	0.33	19	3.5	5	0.0046*	8.7	20
FOPU-30	0.99**	9.5	0.93	47	9.8	13	0.021	24	53

Table 8a. Organic contaminant concentrations (Acenaphthene–Chrysene) for sites sampled at Fort Pulaski National Monument, July 23–26, 2018. All results are presented in mg/kg.[*—result was greater than or equal to the Method Detection Limit (MDL) but below the Practical Quantitation Limit (PQL); **—result was less than the MDL].

Site	Acenaphthene	Acenaphthylene	Anthracene	Fluorene	2-Methylnaphthalene	Naphthalene	Phenanthrene	Benzo(A) Anthracene	Benzo(A) Pyrene	Chrysene
FOPU-01	0.015**	0.02**	0.02**	0.017**	0.013**	0.014**	0.018**	0.024**	0.034**	0.025**
FOPU-02	0.031**	0.041**	0.043**	0.036**	0.028**	0.029**	0.037**	0.05**	0.071**	0.053**
FOPU-03	0.021**	0.028**	0.029**	0.024**	0.019**	0.019**	0.025**	0.033**	0.047**	0.035**
FOPU-04	0.015**	0.02**	0.021**	0.018**	0.014**	0.014**	0.018**	0.025**	0.035**	0.026**
FOPU-05	0.017**	0.023**	0.024**	0.02**	0.015**	0.016**	0.021**	0.028**	0.039**	0.029**
FOPU-06	0.032**	0.042**	0.044**	0.036**	0.028**	0.03**	0.038**	0.051**	0.072**	0.054**
FOPU-07	0.044**	0.059**	0.061**	0.051**	0.039**	0.041**	0.053**	0.071**	0.1**	0.075**
FOPU-08	0.033**	0.044**	0.045**	0.038**	0.029**	0.031**	0.039**	0.053**	0.075**	0.056**
FOPU-09	0.019**	0.025**	0.026**	0.021**	0.017**	0.017**	0.022**	0.03**	0.043**	0.032**
FOPU-10	0.017**	0.022**	0.023**	0.019**	0.015**	0.015**	0.02**	0.027**	0.038**	0.028**
FOPU-11	0.023**	0.03**	0.031**	0.026**	0.02**	0.021**	0.027**	0.037**	0.052**	0.038**
FOPU-12	0.0077**	0.01**	0.011**	0.0088**	0.0069**	0.0072**	0.0092**	0.012**	0.017**	0.013**
FOPU-13	0.016**	0.021**	0.021**	0.018**	0.014**	0.014**	0.019**	0.025**	0.035**	0.026**
FOPU-14	0.022**	0.029**	0.03**	0.025**	0.019**	0.02**	0.026**	0.035**	0.049**	0.036**
FOPU-15	0.026**	0.034**	0.036**	0.03**	0.023**	0.024**	0.031**	0.042**	0.059**	0.044**
FOPU-16	0.019**	0.026**	0.027**	0.022**	0.017**	0.018**	0.023**	0.031**	0.044**	0.033**
FOPU-17	0.019**	0.025**	0.026**	0.022**	0.017**	0.018**	0.023**	0.031**	0.044**	0.032**
FOPU-18	0.017**	0.023**	0.023**	0.019**	0.015**	0.016**	0.02**	0.027**	0.039**	0.029**
FOPU-19	0.055**	0.073**	0.075**	0.063**	0.049**	0.051**	0.065**	0.088**	0.12**	0.093**
FOPU-20	0.021**	0.027**	0.028**	0.024**	0.018**	0.019**	0.025**	0.033**	0.047**	0.035**
FOPU-21	0.039**	0.052**	0.053**	0.044**	0.035**	0.036**	0.046**	0.063**	0.088**	0.066**
FOPU-22	0.017**	0.022**	0.023**	0.019**	0.015**	0.016**	0.02**	0.027**	0.038**	0.029**
FOPU-23	0.032**	0.043**	0.044**	0.037**	0.029**	0.03**	0.038**	0.052**	0.073**	0.054**
FOPU-24	0.017**	0.023**	0.024**	0.02**	0.015**	0.016**	0.021**	0.028**	0.039**	0.029**
FOPU-25	0.016**	0.021**	0.022**	0.018**	0.014**	0.015**	0.019**	0.025**	0.036**	0.027**
FOPU-26	0.019**	0.025**	0.026**	0.022**	0.017**	0.018**	0.023**	0.031**	0.043**	0.032**
FOPU-27	0.017**	0.023**	0.023**	0.019**	0.015**	0.016**	0.02**	0.027**	0.039**	0.029**
FOPU-28	0.021**	0.028**	0.029**	0.024**	0.019**	0.019**	0.025**	0.033**	0.047**	0.035**
FOPU-29	0.025**	0.033**	0.034**	0.028**	0.022**	0.023**	0.03**	0.04**	0.056**	0.042**
FOPU-30	0.036**	0.048**	0.049**	0.041**	0.032**	0.033**	0.043**	0.058**	0.082**	0.061**

Table 8b. Organic contaminant concentrations (Dibenz(A,H)Anthracene – Total PCBs) for sites sampled at Fort Pulaski National Monument, July 23–26, 2018. All results are presented in mg/kg. [*—result was greater than or equal to the Method Detection Limit (MDL) but below the Practical Quantitation Limit (PQL); **—result was less than the Method Detection Limit].

Site	Dibenz(A,H) Anthracene	Fluoranthene	Pyrene	Low Molecular Weight PAH	High Molecular Weight PAH	Total PAHs	P,P-DDE	P,P-DDT	Total PCBs
FOPU-01	0.02**	0.022**	0.024**	0.117	0.149	0.375	0.00051**	0.0011**	0.0076**
FOPU-02	0.042**	0.046**	0.05**	0.245	0.312	0.788	0.005**	0.011**	0.073**
FOPU-03	0.028**	0.031**	0.033**	0.165	0.207	0.527	0.0032**	0.0072**	0.048**
FOPU-04	0.021**	0.023**	0.024**	0.12	0.154	0.388	0.0026**	0.0057**	0.038**
FOPU-05	0.023**	0.025**	0.027**	0.136	0.171	0.435	0.0027**	0.0059**	0.039**
FOPU-06	0.043**	0.047**	0.05**	0.25	0.317	0.803	0.0051**	0.011**	0.076**
FOPU-07	0.059**	0.065**	0.07**	0.348	0.44	1.117	0.008**	0.018**	0.12**
FOPU-08	0.044**	0.049**	0.052**	0.259	0.329	0.834	0.0051**	0.011**	0.075**
FOPU-09	0.025**	0.028**	0.03**	0.147	0.188	0.474	0.003**	0.0067**	0.045**
FOPU-10	0.022**	0.024**	0.026**	0.131	0.165	0.418	0.0027**	0.0061**	0.041**
FOPU-11	0.031**	0.033**	0.036**	0.178	0.227	0.575	0.0034**	0.0076**	0.051**
FOPU-12	0.01**	0.011**	0.012**	0.0608	0.075	0.1928	0.005**	0.011**	0.074**
FOPU-13	0.021**	0.023**	0.025**	0.123	0.155	0.394	0.0025**	0.0056**	0.038**
FOPU-14	0.029**	0.032**	0.034**	0.171	0.215	0.547	0.0035**	0.0077**	0.051**
FOPU-15	0.035**	0.038**	0.041**	0.204	0.259	0.657	0.0039**	0.0085**	0.057**
FOPU-16	0.026**	0.029**	0.031**	0.152	0.194	0.491	0.0029**	0.0065**	0.043**
FOPU-17	0.026**	0.028**	0.031**	0.15	0.192	0.484	0.00058**	0.0013**	0.0087**
FOPU-18	0.023**	0.025**	0.027**	0.133	0.17	0.429	0.00052**	0.0012**	0.0078**
FOPU-19	0.074**	0.081**	0.087**	0.431	0.543	1.381	0.0092**	0.02**	0.14**
FOPU-20	0.028**	0.03**	0.033**	0.162	0.206	0.523	0.0033**	0.0073**	0.049**
FOPU-21	0.052**	0.057**	0.062**	0.305	0.388	0.981	0.0061**	0.013**	0.09**
FOPU-22	0.023**	0.025**	0.027**	0.132	0.169	0.427	0.0027**	0.006**	0.04**
FOPU-23	0.043**	0.047**	0.051**	0.253	0.32	0.812	0.0053**	0.012**	0.078**
FOPU-24	0.023**	0.025**	0.027**	0.136	0.171	0.435	0.0026**	0.0058**	0.039**
FOPU-25	0.021**	0.023**	0.025**	0.125	0.157	0.399	0.0025**	0.0056**	0.038**
FOPU-26	0.026**	0.028**	0.03**	0.15	0.19	0.481	0.0029**	0.0065**	0.043**
FOPU-27	0.023**	0.025**	0.027**	0.133	0.17	0.43	0.00058**	0.0013**	0.0086**
FOPU-28	0.028**	0.031**	0.033**	0.165	0.207	0.527	0.0036**	0.0079**	0.053**
FOPU-29	0.033**	0.037**	0.04**	0.195	0.248	0.629	0.0039**	0.0086**	0.057**
FOPU-30	0.048**	0.053**	0.057**	0.282	0.359	0.908	0.0055**	0.012**	0.082**

Table 9. Ecological condition, based on sediment, for sites sampled at Fort Pulaski National Monument, July 23–26, 2018. Ecological condition was determined using the thresholds for sediment chemistry in U.S. EPA NCCA 2010. Total Organic Carbon % is presented for comparison with previous coastal assessments [green^a—good, yellow^b—fair].

Site	Ecological Condition by Site	Total Organic Carbon %
FOPU-01	Good ^a	0.01
FOPU-02	Good ^a	0.71
FOPU-03	Good ^a	0.14
FOPU-04	Good ^a	0.05
FOPU-05	Good ^a	0.21
FOPU-06	Good ^a	0.56
FOPU-07	Fair ^b	0.29
FOPU-08	Good ^a	0.27
FOPU-09	Good ^a	0.15
FOPU-10	Good ^a	0.12
FOPU-11	Good ^a	0.20
FOPU-12	Good ^a	0.29
FOPU-13	Good ^a	0.02
FOPU-14	Good ^a	0.30
FOPU-15	Good ^a	0.27
FOPU-16	Good ^a	0.36
FOPU-17	Good ^a	0.02
FOPU-18	Good ^a	0.14
FOPU-19	Fair ^b	0.31
FOPU-20	Good ^a	0.16
FOPU-21	Fair ^b	0.29
FOPU-22	Good ^a	0.17
FOPU-23	Good ^a	0.13
FOPU-24	Good ^a	0.05
FOPU-25	Good ^a	0.01
FOPU-26	Good ^a	0.06
FOPU-27	Good ^a	0.06
FOPU-28	Good ^a	0.27
FOPU-29	Good ^a	0.33
FOPU-30	Good ^a	0.30

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1201 Oak Ridge Drive, Suite 150
Fort Collins, Colorado 80525

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