



Assessment of Estuarine Water Quality at Cape Hatteras National Seashore and Cape Lookout National Seashore

2025 Data Summary



Cape Lookout Lighthouse and Keeper's House viewed across coastal waters.

NPS / SECN

Assessment of Estuarine Water Quality at Cape Hatteras National Seashore and Cape Lookout National Seashore: 2025 Data Summary

Science Report NPS/SR—2026/461

Eric N. Starkey 

National Park Service
Southeast Coast Network
135 Phoenix Rd.
Athens, GA 30605

Please cite this publication as:

Starkey, E.N. 2026. Assessment of Estuarine Water Quality at Cape Hatteras National Seashore and Cape Lookout National Seashore: 2025 Data Summary. Science Report NPS/SR—2026/461. National Park Service, Fort Collins, Colorado. <https://doi.org/10.36967/2318652>

The National Park Service Science Report Series disseminates information, analysis, and results of scientific studies and related topics concerning resources and lands managed by the National Park Service. The series supports the advancement of science, informed decisions, and the achievement of the National Park Service mission.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible and technically accurate.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

This report is available in digital format from the [National Park Service DataStore](#) and the [Natural Resource Publications Management website](#). If you have difficulty accessing information in this publication, particularly if using assistive technology, please email irma@nps.gov.

Contents

	Page
Figures.....	iv
Tables.....	v
Abstract.....	vi
Executive Summary.....	vii
Introduction.....	1
Overview	1
Monitoring Objectives.....	1
Study Area	3
Cape Hatteras National Seashore	3
Cape Lookout National Seashore	5
Methods.....	8
Water-Quality Data Collection.....	8
Water-Quality Assessment Criteria.....	11
Results.....	13
Parameter-Based Water Condition Assessments.....	13
Conclusions.....	25
Literature Cited	26

Figures

	Page
Figure 1. Map of fixed stations monitored by the Southeast Coast Network in Pamlico Sound and significant waters in the vicinity of Cape Hatteras National Seashore in 2025.	4
Figure 2. Map of fixed stations monitored by the Southeast Coast Network in Core Sound and significant waters in the vicinity of Cape Lookout National Seashore in 2025.	6
Figure 3. Map showing the location of park-wide assessment sites sampled in July 2025 at Cape Hatteras and Cape Lookout National Seashores.	7
Figure 4. Water clarity ratings for sites sampled at Cape Hatteras and Cape Lookout National Seashores, July 15–21, 2025.	14
Figure 5. Chlorophyll <i>a</i> concentrations for sites sampled at Cape Hatteras and Cape Lookout National Seashores, July 15–21, 2025.	15
Figure 6. Dissolved inorganic nitrogen concentrations for sites sampled at Cape Hatteras and Cape Lookout National Seashores, July 15–21, 2025.	16
Figure 7. Dissolved inorganic phosphorus concentrations for sites sampled at Cape Hatteras and Cape Lookout National Seashores, July 15–21, 2025.	17
Figure 8. Dissolved oxygen concentrations for sites sampled at Cape Hatteras and Cape Lookout National Seashores, July 15–21, 2025.	18
Figure 9. Water-quality index rating for sites sampled at Cape Hatteras and Cape Lookout National Seashores, July 15–21, 2025.	19
Figure 10. Turbidity readings at sites sampled at Cape Hatteras and Cape Lookout National Seashores, July 15–21, 2025.	23
Figure 11. Submerged aquatic vegetation presence/absence for sites sampled at Cape Hatteras and Cape Lookout National Seashores, July 15–21, 2025.	24

Tables

	Page
Table 1. Site name, waterbody name, and location, depth, coordinates, and chemical and physical attributes of sampling sites at Cape Hatteras and Cape Lookout National Seashores, July 15–21, 2025.	9
Table 2. 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].....	11
Table 3. Condition criteria used for water-quality assessment summaries at individual sampling sites and parks.	12
Table 4. Water-quality parameter values and assessment conditions for sampling sites near Cape Hatteras and Cape Lookout National Seashores, July 15–21, 2025.	20

Abstract

In July 2025, the Southeast Coast Network assessed water quality at Cape Hatteras National Seashore and Cape Lookout National Seashore as part of the National Park Service Vital Signs Monitoring Program. Monitoring was conducted at 30 sites following methods developed by the Environmental Protection Agency (EPA) as part of the National Coastal Assessment Program (EPA 2014). Laboratory analysis measured chlorophyll *a* and total and dissolved concentrations of nitrogen and phosphorus. Field measurements included water temperature, pH, dissolved oxygen, and salinity. Water clarity, which requires a Secchi depth measurement, was calculated when possible. All measured parameters were rated as good, fair, or poor based on thresholds set by the EPA (2012).

The purpose of this document is to report the most recently collected data from the seashores 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 assessments of water-quality conditions at Cape Hatteras and Cape Lookout National Seashores were conducted in July 2010, 2015, and 2021 as part of the NPS Inventory and Monitoring program's efforts.

Executive Summary

In July 2025, the Southeast Coast Network assessed water quality at Cape Hatteras and Cape Lookout National Seashores as part of the National Park Service Vital Signs Monitoring Program. Monitoring was conducted at 30 sites following methods developed by the Environmental Protection Agency (EPA) as part of the National Coastal Assessment Program (EPA 2014). Laboratory analysis measured chlorophyll *a* and total and dissolved concentrations of nitrogen and phosphorus. Field measurements included water temperature, pH, dissolved oxygen, and salinity. Water clarity, which requires a Secchi depth measurement, was calculated when possible. All measured parameters were rated as good, fair, or poor based on thresholds set by the EPA (2012).

Site-level data are summarized as follows:

- Water clarity was rated good at four sites (13%) and could not be assessed at twenty-six sites (87%) due to shallow water.
- Chlorophyll *a* concentrations were rated good at twenty-four sites (80%), and fair at six sites (20%).
- Dissolved inorganic nitrogen (DIN) concentrations were good at twenty-nine sites (97%) and missing at one site (3%) due to laboratory quality control criteria.
- Dissolved inorganic phosphorus (DIP) concentrations were good at thirty sites (100%).
- Dissolved oxygen concentrations (bottom) were rated good at twenty-six sites (87%) and fair at four sites (13%).
- A water-quality condition summary index was calculated for each site sampled at Cape Hatteras and Cape Lookout National Seashores based on the categorical assessments of chlorophyll *a*, DIN and DIP concentrations, dissolved oxygen, and water clarity. This summary index indicated good water-quality conditions at twenty-nine sites (97%) and fair water-quality conditions at one site (3%).
- See [supplemental materials](#) to compare the distribution of good, fair, and poor ratings for each parameter across the period of record.

Park-level assessments are summarized as follows:

- Based on the summary water-quality index rating, overall water-quality conditions at Cape Hatteras and Cape Lookout National Seashores during 2025 sampling were good.
- The summary water-quality index rating of good aligns with the ratings reported in 2021 and 2015. In contrast, the 2010 summary rating was fair.

Introduction

Overview

Due to the importance of water resources to park management from ecological, regulatory, and visitor experience perspectives, estuarine water and sediment quality in and around parks were selected to be monitored by the National Park Service (NPS) Inventory and Monitoring Division's Southeast Coast Network (SECN; DeVivo et al. 2008). Since 2005, the network has employed a multiscale approach to assess estuarine resources in seven park units located in North Carolina, Georgia, and Florida. Data collected as part of this effort are intended to help resource managers: (1) better understand ecological processes and impacts caused by development, (2) make informed management decisions, and (3) form/maintain strategic partnerships to monitor and improve water-quality conditions in and around park units. In addition, given the diverse and dynamic nature of estuaries, this monitoring is intended to capture the spatial and temporal variability of these systems. Monitoring at permanent fixed stations using continuous data loggers and discrete samples allow for evaluation of temporal patterns in core water-quality parameters (dissolved oxygen, pH, salinity, temperature, and turbidity) and nutrients (nitrogen and phosphorus) and chlorophyll *a*.

While fixed-station monitoring provides fine resolution data to determine diel, monthly, and seasonal fluctuations in water quality, it lacks spatial extent. To fill this gap, spatial variability of water and sediment quality is determined with park-wide assessments every five years. These assessments include discrete sampling of nutrients, water-quality parameters, and evaluation of sediment contaminants following methods developed by the Environmental Protection Agency's National Coastal Assessment Program. This monitoring approach leads to an understanding of the spatiotemporal status and variability of estuarine water quality and yields information useful to park management.

The Southeast Coast Network's monitoring approach is extensively documented in the *Protocol for Monitoring Estuarine Water and Sediment Quality in Selected Southeast Coast Network Parks: Protocol Narrative* (Starkey et al. 2023) and associated Standard Operating Procedures (SOPs). Version 1.0 of the protocol (Gregory et al. 2013a) was implemented between 2007 and 2018. Version 2.0 of the protocol was implemented in 2019 to the present and updated to align with new technology and techniques documented in revised Standard Operating Procedures. Monitoring objectives remain consistent across both versions of the protocol.

Monitoring Objectives

The Southeast Coast Network identified an overall goal of monitoring the status and trends in water and sediment quality in estuaries surrounding SECN parks. To meet this goal, data are collected and analyzed to meet four specific monitoring objectives. These objectives remain consistent across both versions of the protocol (Gregory et al. 2013a; Starkey et al. 2023) and are listed below:

1. Determine diel and seasonal water-quality patterns for five core parameters (dissolved oxygen, salinity, temperature, pH, and turbidity) at selected coastal areas near SECN parks using fixed-station continuous data loggers.

2. Determine monthly and seasonal patterns in nutrients (nitrogen and phosphorus) and chlorophyll *a* at selected coastal areas near SECN parks by collecting discrete water samples.
3. Determine status and spatial variability of water and nutrient conditions in estuarine waters every five years near SECN parks.
4. Determine status and spatial variability of benthic sediment quality (organic contaminants, carbon, and metal levels) every 10 years in estuarine waters near SECN parks.

This report summarizes water-quality monitoring data collected during a park-wide assessment to address objective 3 at Cape Hatteras and Cape Lookout National Seashores. Data were gathered July 15–21, 2025. The purpose of this document is to report the most recently collected data from the seashores 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 Environmental Protection Agency (EPA). Previous synoptic assessments of water-quality conditions at Cape Hatteras and Cape Lookout National Seashores were conducted in July 2010, 2015, and 2021 as part of SECN monitoring efforts (Gregory and Smith 2011; Starkey et al. 2022; Wright 2016).

Study Area

Cape Hatteras and Cape Lookout National Seashores are adjacently located and separately maintained park units along the Outer Banks of the North Carolina coast, stretching from Beaufort Inlet on the south to Bodie Island on the north. Together these parks encompass over 59,000 acres (23,876 hectares [ha]) of beaches, upland maritime forests, tidal creeks, and salt marshes. Cape Hatteras and Cape Lookout National Seashores share a common geological history and are composed of a chain of transgressive and regressive barrier islands, formed during the Pleistocene glacial period from a large dune ridge located east of the Outer Banks's current location. The dune ridge gradually migrated westward during the Holocene as sea levels rose until approximately 4,000 years ago when wind, waves, and currents formed the present configuration of islands. All these islands are subject to periodic inlet formation, migration, closure, and seawater overwash during severe storms (Mallin et al. 2004).

Cape Hatteras National Seashore

Cape Hatteras National Seashore contains 35,400 acres (14,326 ha) of land and includes a series of barrier islands known as Bodie Island, Hatteras Island, and Ocracoke Island (Figure 1). The establishment of Cape Hatteras National Seashore was authorized in 1937 and officially designated a national seashore in 1953. Presently, the towns adjacent to the seashore receive heavy seasonal usage by vacationers utilizing hotels, campgrounds, and rental homes, with numerous second homes owned by out-of-town and out-of-state users. There is also a seasonal fluctuation in population, with summer populations tripling those of winter due to vacationers and seasonal users. This is important in terms of nutrient and fecal bacteria loads on groundwater, because all sewage on the islands is treated by septic systems (Mallin et al. 2004). Previous research has documented potential nutrient and pathogen problems in waters near Bodie Island near Nags Head. The waters of Pamlico Sound near Hatteras Island and adjoining municipal areas that drain into the sound are potential areas for nutrient and bacterial pathogen loading and algal blooms (Mallin et al. 2004). Waters identified as impaired under Section 303(d) of the Clean Water Act do not meet state water-quality standards for one or more designated uses. In Pamlico Sound, these impaired waters are often associated with areas of higher population density or proximity to larger tributaries (Figure 1).

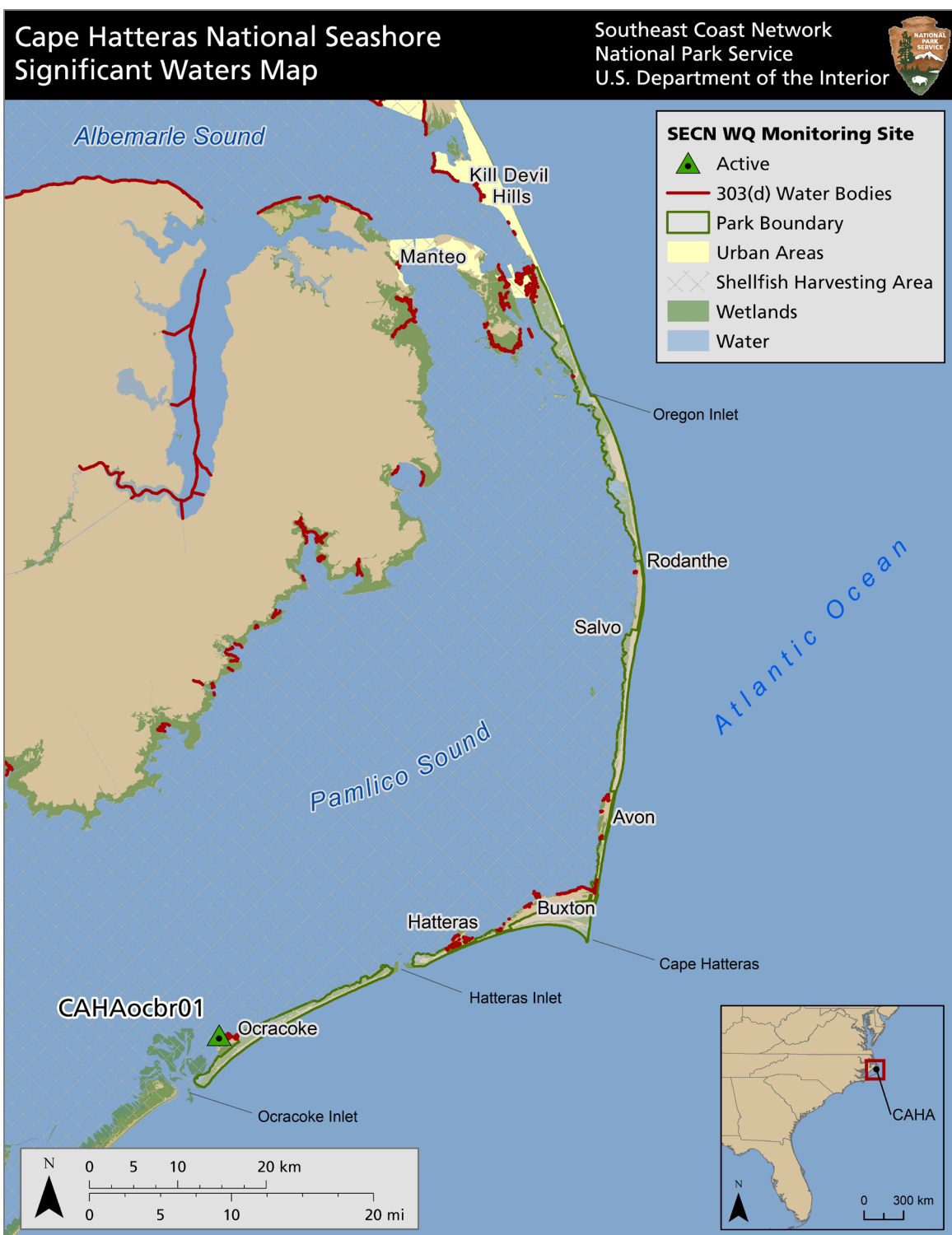


Figure 1. Map of fixed stations monitored by the Southeast Coast Network in Pamlico Sound and significant waters in the vicinity of Cape Hatteras National Seashore in 2025. Indicated are areas of salt marsh (USFWS 2024), urbanized area (USCB 2023), 303(d) listed water bodies (EPA 2022), and areas designated as having special uses or restrictions such as shellfish harvest areas (NC DENR DEH-SSRWQS 2011).

NPS / SECN

Cape Lookout National Seashore

Cape Lookout National Seashore includes approximately 24,500 acres (9,915 ha) of land and is composed of two main islands—Core Banks and Shackleford Banks (Figures 2 and 3). Cape Lookout National Seashore was authorized in 1966 and transferred to the National Park Service in 1976. Presently, its two main islands are solely used for recreational purposes. Shackleford Banks has no vehicle traffic and human use of the island consists of sport fishing, swimming, surfing, hiking, camping, and nature study. Core Banks supports these same activities, but vehicle traffic is permitted along the beaches, and there are some dirt roads in the interior of the islands. Cape Lookout is bordered to the east and south by marine waters of the Atlantic Ocean. To the north and west of the seashore are the waters of Ocracoke Inlet, Pamlico Sound, Core Sound, and Back Sound. Some of the coves and tidal creeks on the sound side of the park may be of variable estuarine salinities, depending on local rainfall.

Major threats to water quality near Core and Shackleford Banks include two facilities discharging approximately 4.5 million gallons per day (mgd) of treated effluent into Taylors Creek (Mallin et al. 2004) located several kilometers from the seashore. Nonpoint pollution is not thought to be a problem due to the lack of large urban areas or concentrated livestock. Previous data collected from the western portion of Back and Core Sounds show waters that contain low average nitrate-N and moderate total phosphorus (TP) concentrations (Mallin et al. 2004). Some estuarine waters near Cape Lookout National Seashore are identified as impaired under Section 303(d) of the Clean Water Act (Figure 2). Similar to Cape Hatteras National Seashore, these impaired waters are often associated with areas of higher population density or proximity to major tributaries.

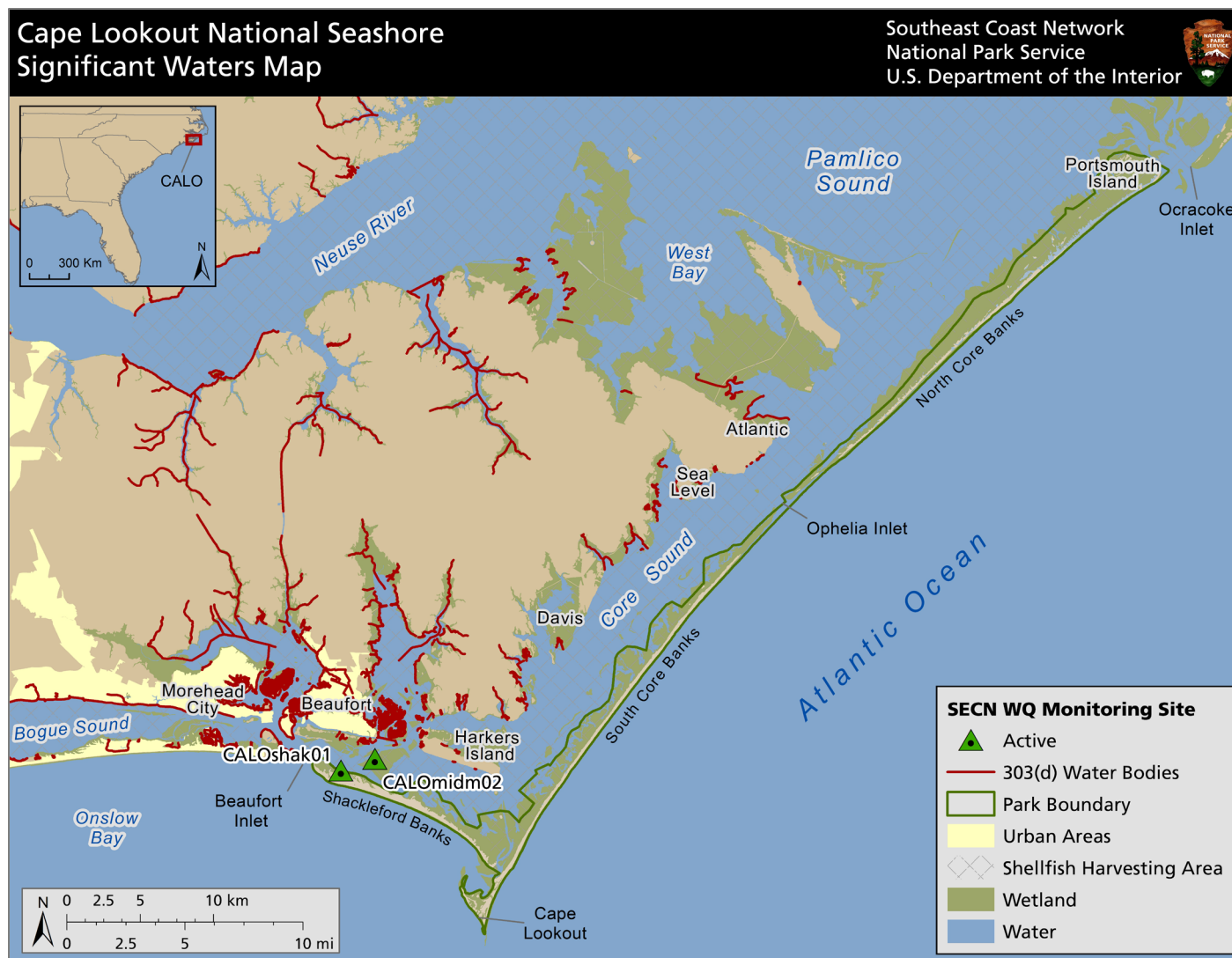


Figure 2. Map of fixed stations monitored by the Southeast Coast Network in Core Sound and significant waters in the vicinity of Cape Lookout National Seashore in 2025. Indicated are areas of salt marsh (USFWS 2024), urbanized area (USCB 2023), 303(d) listed water bodies (EPA 2022), and areas designated as having special uses or restrictions such as shellfish harvest areas (NC DENR DEH-SSRWQS 2011).

NPS / SECN

Cape Hatteras and Cape Lookout National Seashores 2025 Parkwide Assessment Sites

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

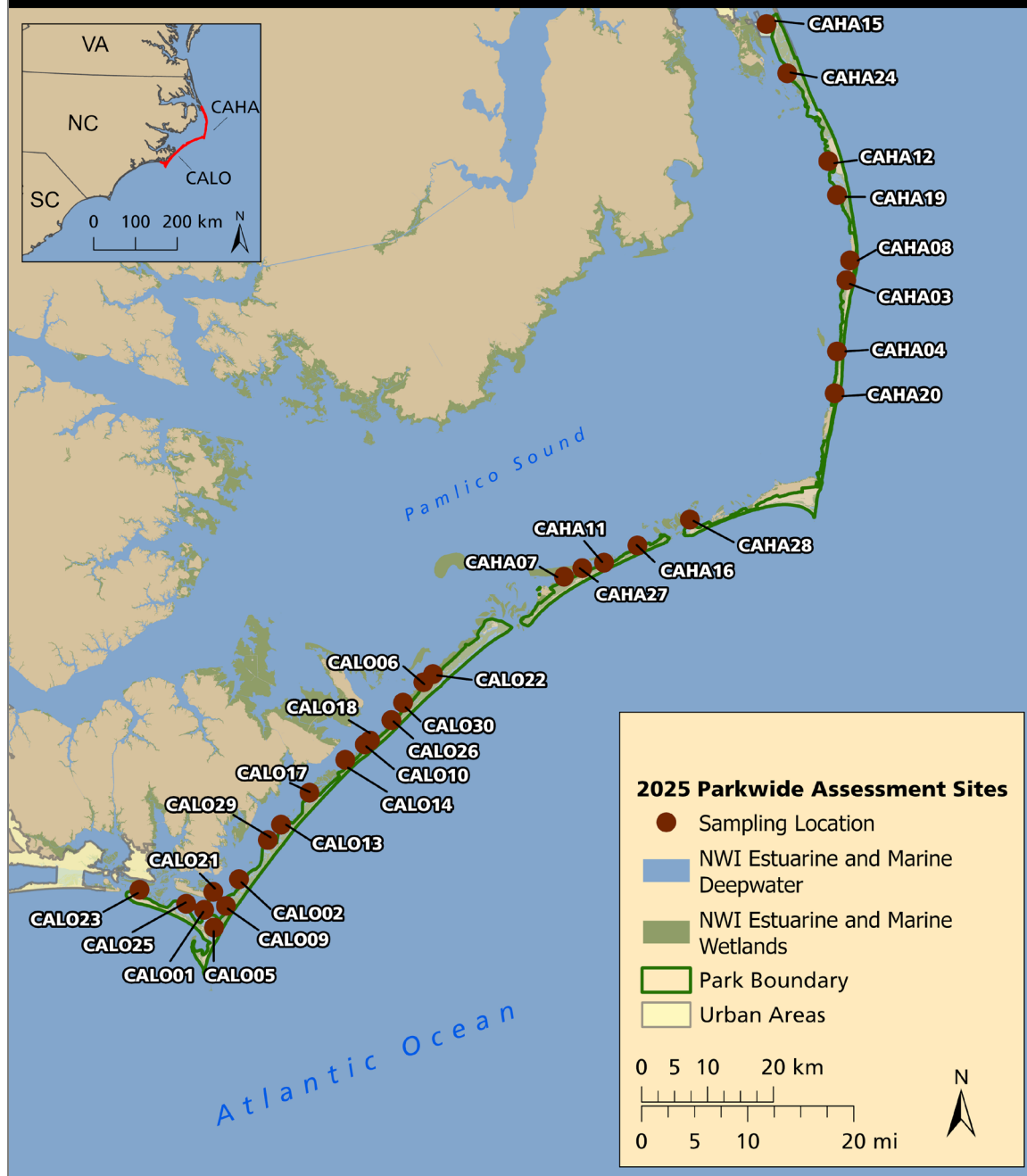


Figure 3. Map showing the location of park-wide assessment sites sampled in July 2025 at Cape Hatteras and Cape Lookout National Seashores. See the Methods section for more information about each site.

NPS / SECN

Methods

The water-quality assessment was conducted in estuarine waters of Pamlico, Core, and Back Sounds, following the methods developed by the EPA's National Coastal Assessment Program (EPA 2014). Descriptions of the water-quality parameters and the assessment criteria are from the EPA's National Coastal Assessment IV Report (EPA 2012). Methods used for these assessments were adapted and integrated into protocols tailored specifically to parks in the Southeast Coast Network (Starkey et al. 2023). Site selection and sampling methodology are briefly outlined in the following sections.

In 2025, thirty sites in Pamlico, Core, and Back Sounds were randomly selected for monitoring following methods developed by the EPA (Figure 3; Stevens 1997; Stevens and Olsen 1999, 2004). This sampling design uses a fixed sample size ($n = 30$) consistent with EPA generalized random tessellation stratified (GRTS) sampling protocols to provide a spatially balanced sample intended for park-wide inference within logistical constraints that allow completion of field sampling within a one-week period in each park unit.

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) intervals at each site, to measure temperature, pH, dissolved oxygen, salinity, and turbidity. Chlorophyll *a* and total dissolved nutrient samples were collected from 0.5 meters (1.6 feet) below the surface. Chlorophyll *a* samples were processed using known volumes of water samples 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 [EPA 2016; Smith et al. 2006]). Waters around Cape Hatteras and Cape Lookout National Seashore use a constant (c) of 1.4 because the area experiences “normal turbidity” (EPA 2016). 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 depths too shallow to ascertain an accurate Secchi measurement. Measures of turbidity from the hydrologic profile are used as a surrogate parameter when Secchi depths are not available. When sites were too shallow to access by boat or were in heavily trafficked channels where safety was a concern, alternate sites were used.

See Table 1 for the thirty sites in Pamlico, Core, and Back Sounds that were randomly selected for monitoring following methods developed by the EPA.

Table 1. Site name, waterbody name, and location, depth, coordinates, and chemical and physical attributes of sampling sites at Cape Hatteras and Cape Lookout National Seashores, July 15–21, 2025. The table references site names used to present data in this report (Figure 3). All coordinates are in NAD83 Datum, in UTM zone 18. Salinity, pH, and water temperature were measured at a depth of 0.5 meters (1.6 feet) unless water depth was too shallow in which case it was measured at 0.1 meters (0.3 feet). [SAV = submerged aquatic vegetation; m = meters; °C = degrees Celsius; PSU = practical salinity units].

Site Name	Water Body	UTMX	UTMY	SAV	Debris	Site Depth (m)	Water Temp (°C)	pH	Salinity (PSU)
CAHA03_2025	Pamlico Sound	456664	3933272	Yes	No	0.8	29.92	8.23	25.47
CAHA04_2025	Pamlico Sound	455283	3922464	Yes	No	1.0	27.71	8.09	28.99
CAHA07_2025	Pamlico Sound	413849	3888224	Yes	No	0.8	29.96	8.11	29.54
CAHA08_2025	Pamlico Sound	457236	3936293	Yes	No	0.6	30.01	7.96	26.21
CAHA11_2025	Pamlico Sound	419915	3890357	Yes	No	0.5	29.28	8.49	29.50
CAHA12_2025	Pamlico Sound	453942	3951342	Yes	No	0.6	30.70	8.12	27.69
CAHA15_2025	Roanoke Sound	444592	3972251	No	No	0.8	30.12	8.12	15.18
CAHA16_2025	Pamlico Sound	424978	3892982	Yes	No	0.6	29.35	7.93	28.02
CAHA19_2025	Pamlico Sound	455263	3946211	Yes	No	0.5	30.23	8.42	26.83
CAHA20_2025	Pamlico Sound	454913	3916097	Yes	No	0.5	28.12	8.19	28.95
CAHA24_2025	Roanoke Sound	447695	3964746	Yes	No	0.7	29.24	8.11	16.64
CAHA27_2025	Pamlico Sound	416605	3889498	Yes	No	0.9	29.47	8.08	28.50
CAHA28_2025	Pamlico Sound	432965	3896908	No	No	0.7	26.78	8.06	36.30
CALO01_2025	Core Sound	359254	3837569	No	No	1.1	31.35	8.03	36.72
CALO02_2025	Core Sound	364552	3842248	Yes	No	0.2	31.85	8.18	37.06
CALO05_2025	Light House Bay	360760	3834893	No	No	1.7	29.91	8.01	36.57
CALO06_2025	Pamlico Sound	392523	3872179	Yes	No	0.5	28.62	8.09	37.09
CALO09_2025	Core Sound	362567	3838184	Yes	No	1.9	31.40	8.11	36.74
CALO10_2025	Core Sound	383654	3862738	Yes	No	1.2	29.34	8.04	37.06
CALO13_2025	Core Sound	370922	3850550	Yes	No	1.1	29.91	8.06	37.16
CALO14_2025	Core Sound	380673	3860393	No	No	0.6	28.41	8.04	36.79
CALO17_2025	Core Sound	375244	3855396	No	No	0.4	28.01	8.05	36.85

Table 1 (continued). Site name, waterbody name, and location, depth, coordinates, and chemical and physical attributes of sampling sites at Cape Hatteras and Cape Lookout National Seashores, July 15–21, 2025. The table references site names used to present data in this report (Figure 3). All coordinates are in NAD83 Datum, in UTM zone 18. Salinity, pH, and water temperature were measured at a depth of 0.5 meters (1.6 feet) unless water depth was too shallow in which case it was measured at 0.1 meters (0.3 feet). [SAV = submerged aquatic vegetation; m = meters; °C = degrees Celsius; PSU = practical salinity units].

Site Name	Water Body	UTMX	UTMY	SAV	Debris	Site Depth (m)	Water Temp (°C)	pH	Salinity (PSU)
CALO18_2025	Core Sound	384425	3863320	Yes	No	1.1	29.52	8.06	37.05
CALO21_2025	Core Sound	360635	3840320	No	No	1.0	30.77	8.00	36.64
CALO22_2025	Pamlico Sound	393987	3873421	Yes	No	0.5	28.08	8.25	35.68
CALO23_2025	Back Sound	349447	3840625	No	No	2.5	28.68	7.97	36.54
CALO25_2025	Back Sound	356533	3838498	No	No	2.5	30.11	8.01	36.61
CALO26_2025	Core Sound	387652	3866413	Yes	No	1.0	29.25	8.08	37.12
CALO29_2025	Core Sound	368937	3848222	Yes	No	0.5	30.14	8.26	37.88
CALO30_2025	Core Sound	389426	3869062	Yes	No	1.1	29.29	8.08	37.04

Water-Quality Assessment Criteria

The categorical assessments (e.g., good, fair, poor) use measurements of water clarity, chlorophyll *a*, dissolved inorganic nitrogen, dissolved inorganic phosphorus, and bottom dissolved oxygen (Table 2) intended to characterize acutely degraded water-quality conditions at a site. 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 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.

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

^A For Rating category, “Good” is shaded green, “Fair” is shaded yellow, and “Poor” is shaded red.

^B 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.

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 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 and at the same park over time based on the percentage of sites that fall within the good, fair, or poor categories.

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

Rating ^A	Site Water-Quality Index Rating ^B	Park Water-Quality Index Rating ^B
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.	N/A

^A For Rating category, “Good” is shaded green, “Fair” is shaded yellow, “Poor” is shaded red, and “Missing” is shaded blue.

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

While not used to determine site and park condition ratings, turbidity at 0.5 meters (1.6 feet) and presence or absence of submerged aquatic vegetation (SAV) are useful parameters to gauge site health not captured by the EPA’s condition criteria. The SECN turbidity (Formazin Nephelometric Units [FNU]) condition criteria (<2.0 = good, 2.0–5.0 = fair, >5.0 = poor) are specifically for CAHA and CALO and are based on what is considered protective for North Carolina’s SAV habitat (Hall 2022). These are more restrictive criteria than the general <25 Nephelometric Turbidity Units (NTU), which is outlined in the North Carolina Administrative Code (North Carolina Department of Environmental Quality 2019). These turbidity criteria do not replace assessment of water clarity but are used as a surrogate parameter when Secchi depths are not available due to shallow water.

Results

Parameter-Based Water Condition Assessments

Figures 4–8 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 4–8 show the proportion of sites in the assessed area that were placed in each rating category. The map and graph in Figure 9 summarize Cape Hatteras and Cape Lookout National Seashores’s water-quality conditions during the assessment. Site-specific water-quality data for each parameter are also presented in Table 4. In addition to the SECN’s standard assessments based on EPA protocols, Figures 10 and 11 provide site conditions for turbidity and presence/absence of submerged aquatic vegetation (SAV). For comparison with past assessments, maps and condition rating summary graphs for sample years 2010–2021 can be found in the [supplemental materials](#). The [data package](#) contains data and associated metadata used in the preparation of this report.

Site-level data are summarized as follows:

- Water clarity was rated good at four sites (13%) and could not be assessed at twenty-six sites (87%) due to shallow water.
- Chlorophyll *a* concentrations were rated good at twenty-four sites (80%), and fair at six sites (20%).
- Dissolved inorganic nitrogen (DIN) concentrations were good at twenty-nine sites (97%) and missing at one site (3%) due to laboratory quality control criteria.
- Dissolved inorganic phosphorus (DIP) concentrations were good at thirty sites (100%).
- Dissolved oxygen concentrations (bottom) were rated good at twenty-six sites (87%) and fair at four sites (13%).
- A water-quality condition summary index was calculated for each site sampled at Cape Hatteras and Cape Lookout National Seashores based on the categorical assessments of chlorophyll *a*, DIN, and DIP concentrations, dissolved oxygen, and water clarity. This summary index indicated good water-quality conditions at twenty-nine sites (97%) and fair water-quality conditions at one site (3%).
- See [supplemental materials](#) to compare the distribution of good, fair, and poor ratings for each parameter across the period of record.

Park-level assessments are summarized as follows:

- Based on the summary water-quality index rating, overall water-quality conditions at Cape Hatteras and Cape Lookout National Seashores during 2025 sampling were good.
- The summary water-quality index rating of good aligns with the ratings reported in 2021 and 2015. In contrast, the 2010 summary rating was fair.

Cape Hatteras and Cape Lookout National Seashores 2025 Water Clarity (k)

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

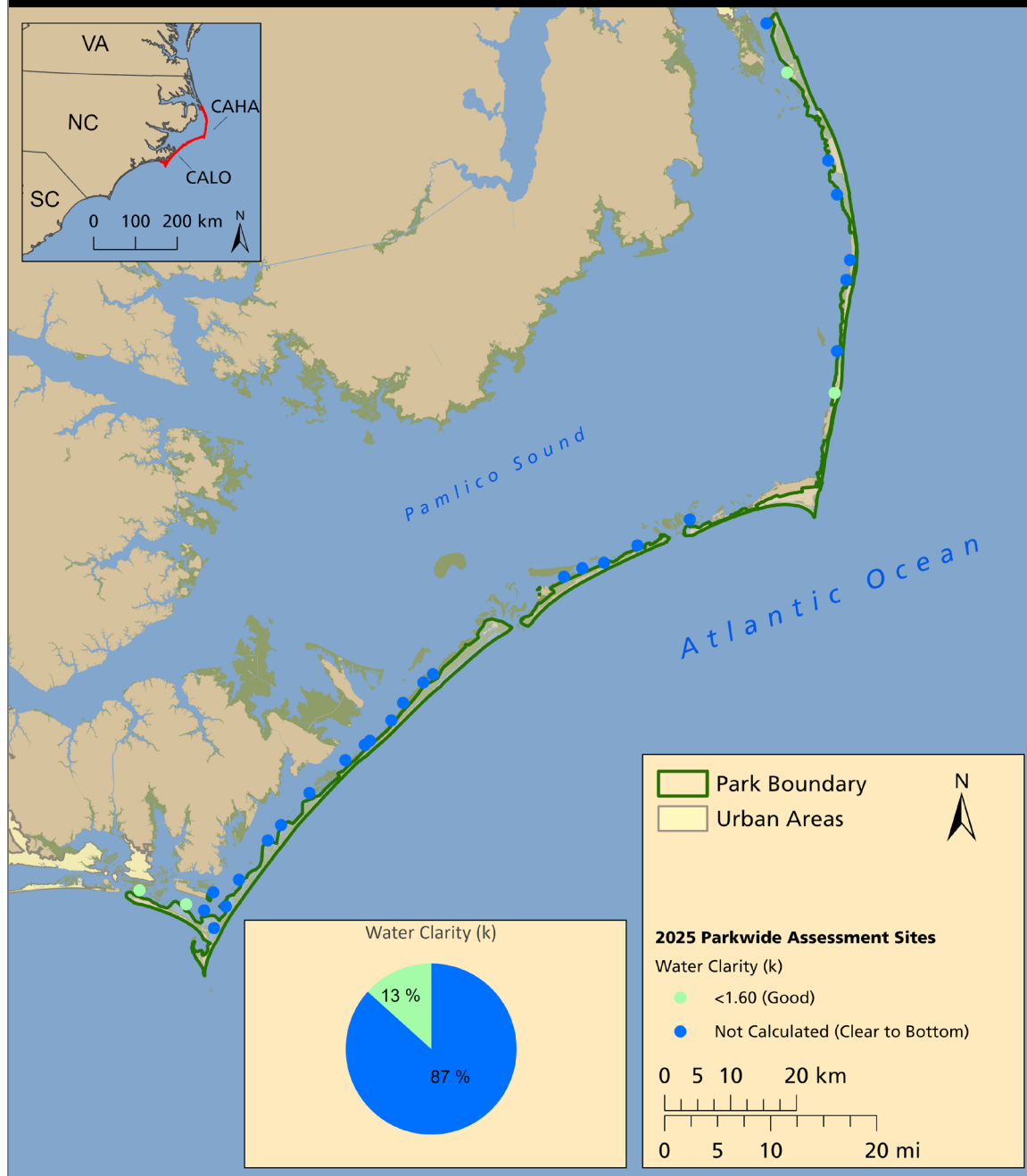


Figure 4. Water clarity ratings for sites sampled at Cape Hatteras and Cape Lookout National Seashores, July 15–21, 2025. The inset graph shows the percentage of sites in each condition category [Green = good; blue = not calculated, clear to bottom].

NPS / SECN

Cape Hatteras and Cape Lookout National Seashores 2025 Chlorophyll a

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

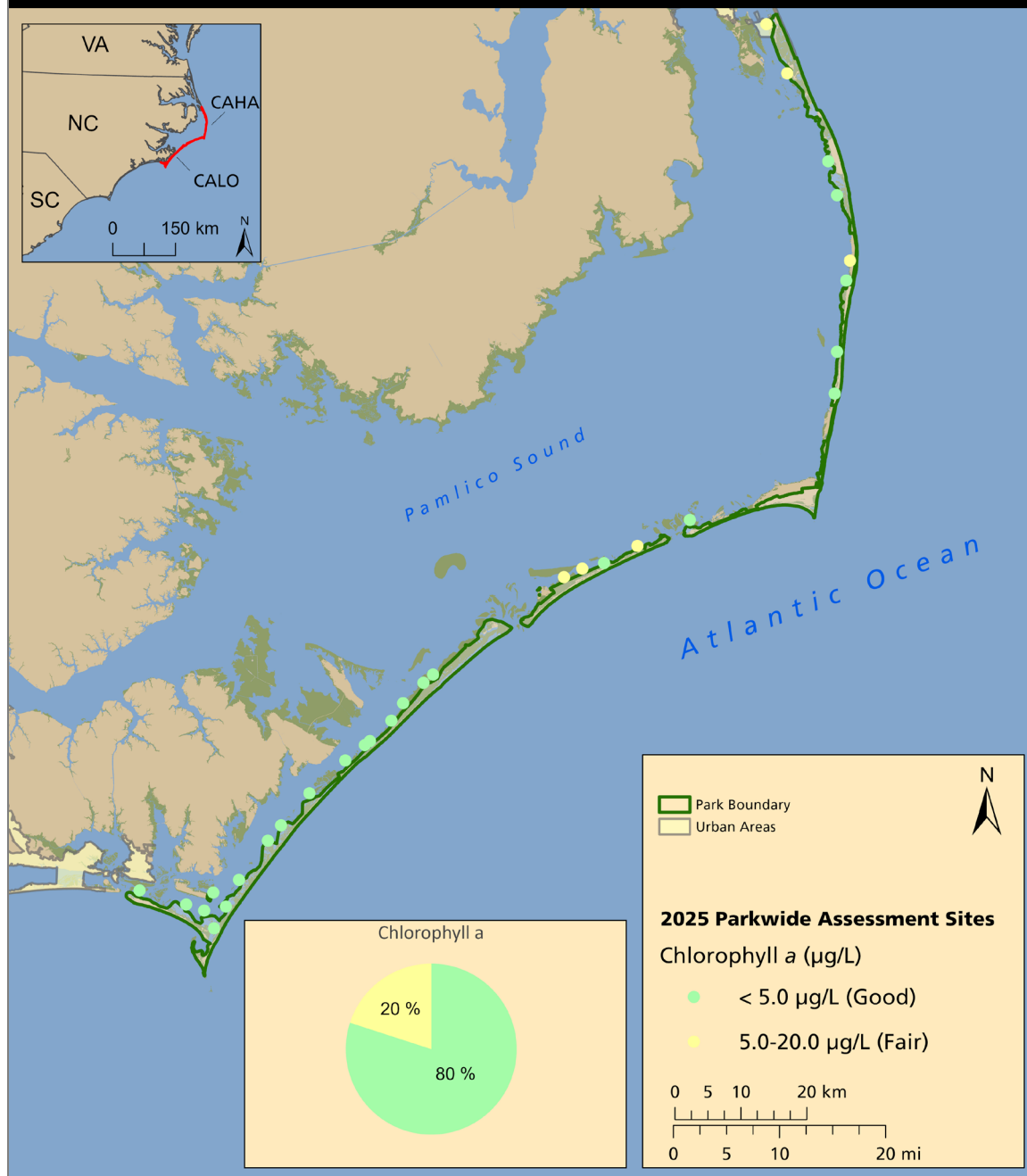


Figure 5. Chlorophyll a concentrations for sites sampled at Cape Hatteras and Cape Lookout National Seashores, July 15–21, 2025. The inset graph shows the percentage of sites in each condition category [Green = good; yellow = fair].

NPS / SECN

Cape Hatteras and Cape Lookout National Seashores 2025 Dissolved Inorganic Nitrogen

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

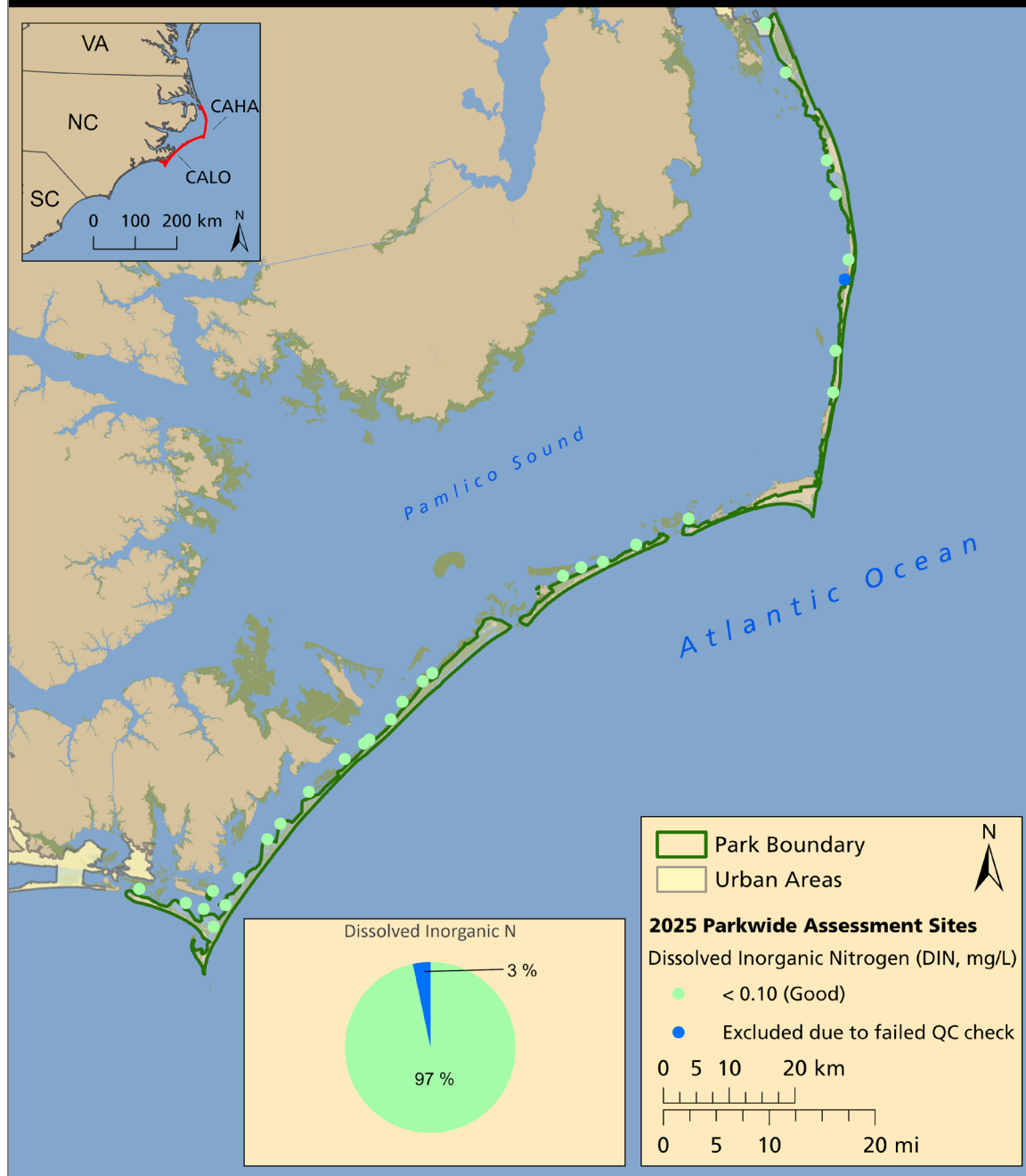


Figure 6. Dissolved inorganic nitrogen concentrations for sites sampled at Cape Hatteras and Cape Lookout National Seashores, July 15–21, 2025. The inset graph shows the percentage of sites in each condition category [Green = good; blue = not calculated due to QC issue].

NPS / SECN

Cape Hatteras and Cape Lookout National Seashores 2025 Dissolved Inorganic Phosphorus

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

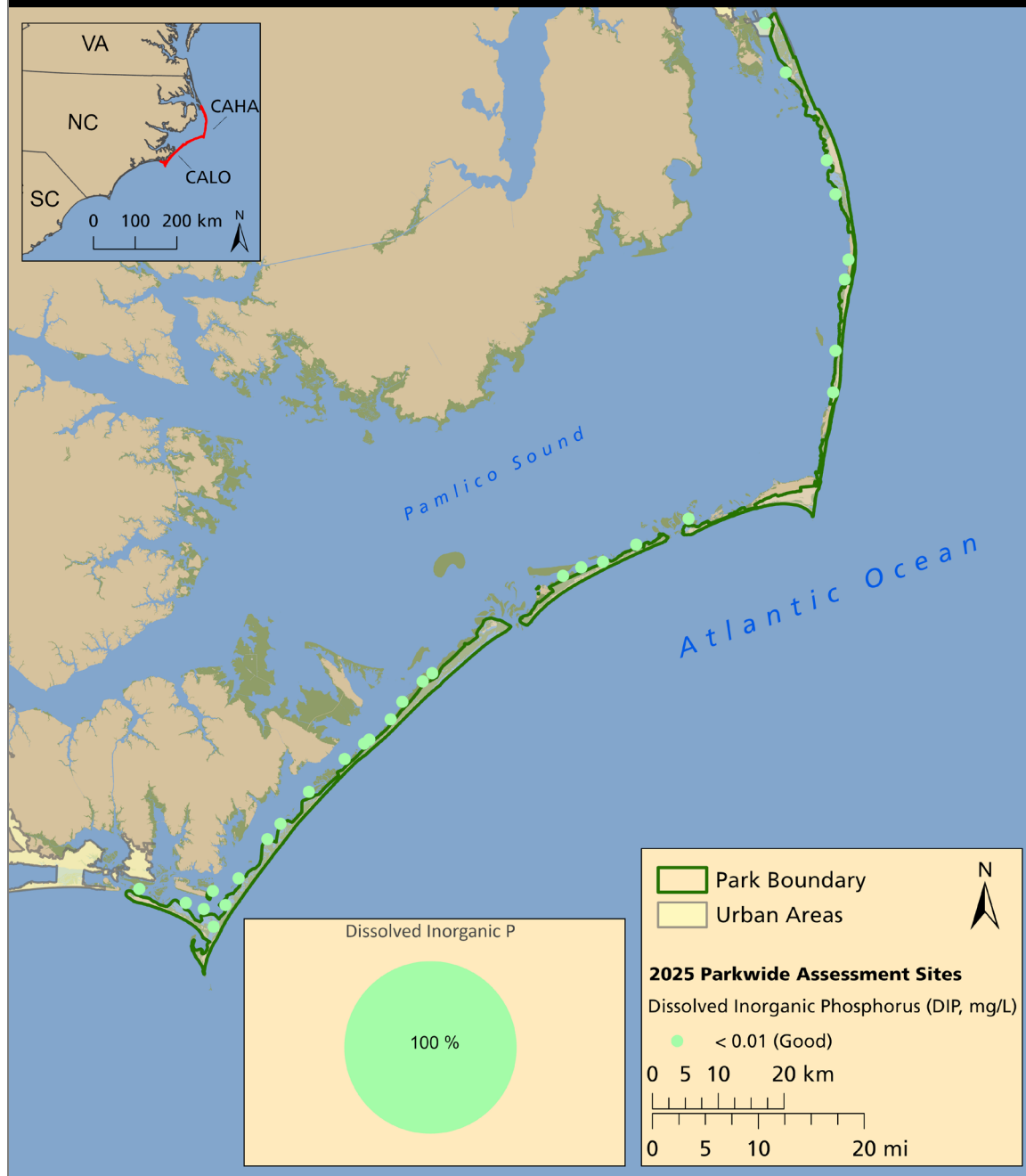


Figure 7. Dissolved inorganic phosphorus concentrations for sites sampled at Cape Hatteras and Cape Lookout National Seashores, July 15–21, 2025. The inset graph shows the percentage of sites in each condition category [Green = good].

NPS / SECN

Cape Hatteras and Cape Lookout National Seashores 2025 Dissolved Oxygen

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

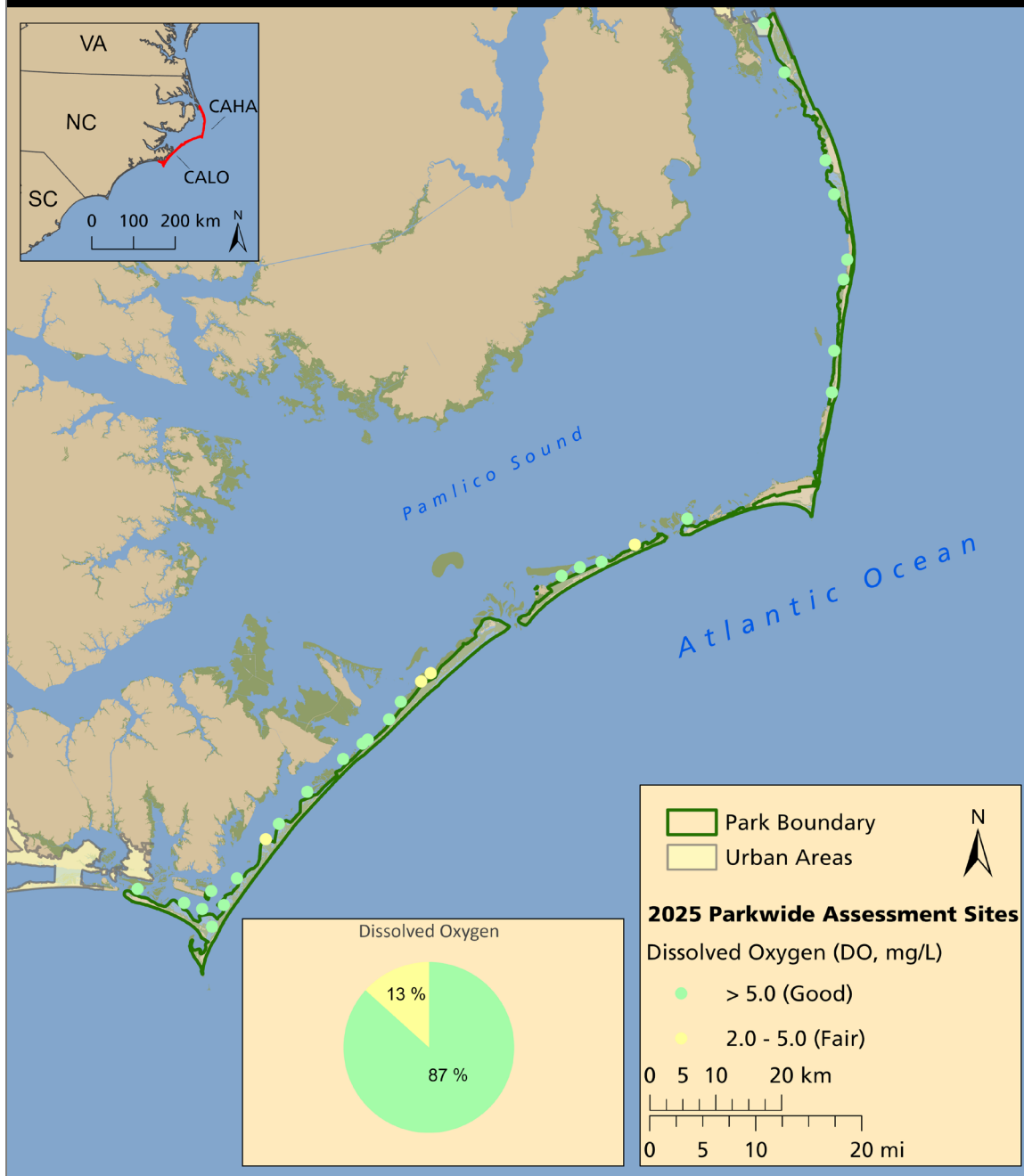


Figure 8. Dissolved oxygen concentrations for sites sampled at Cape Hatteras and Cape Lookout National Seashores, July 15–21, 2025. Inset graph shows the proportion of sites in each condition category [Green = good; yellow = fair].

NPS / SECN

Cape Hatteras and Cape Lookout National Seashores 2025 Site Water Quality Index Rating

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

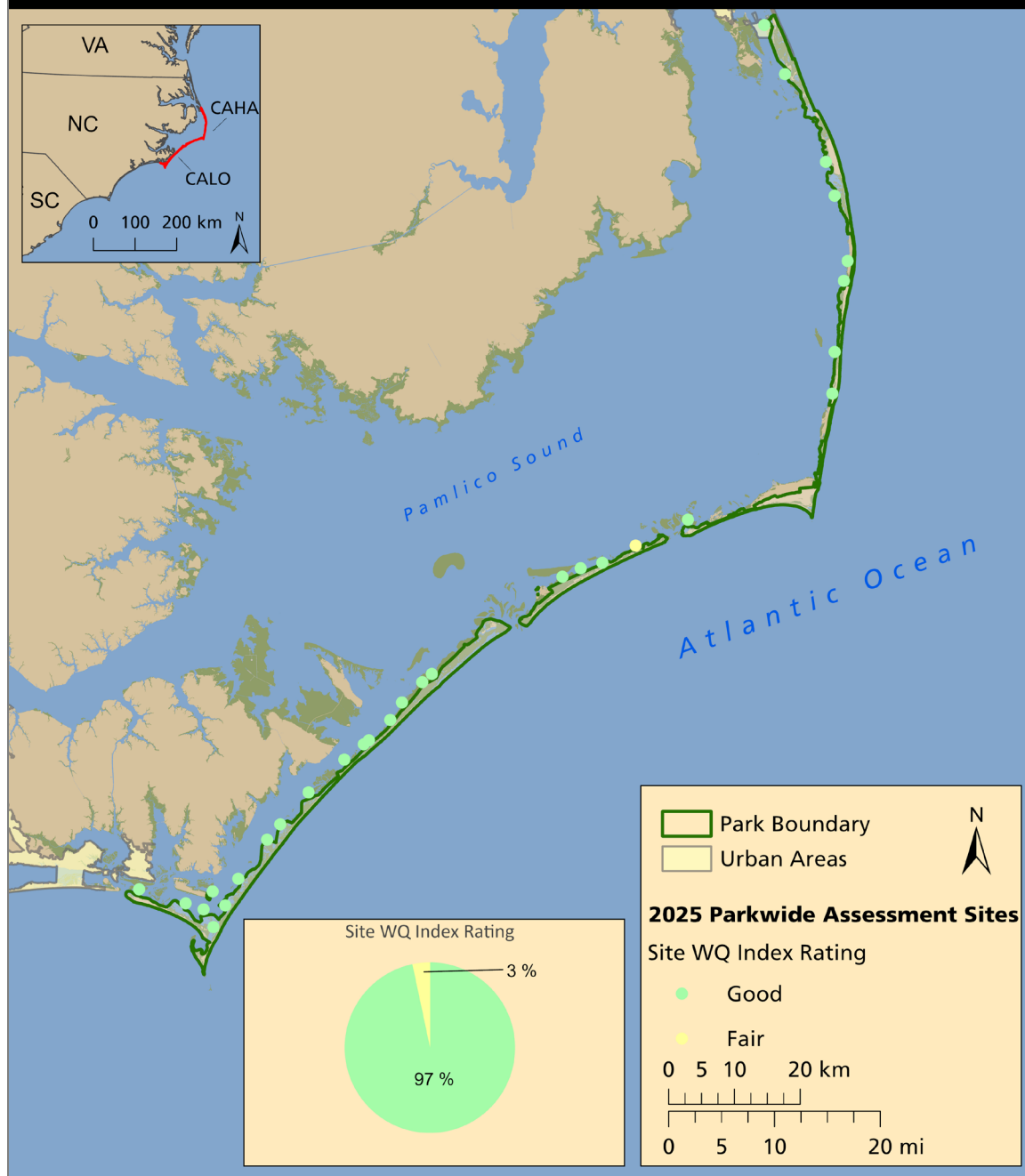


Figure 9. Water-quality index rating for sites sampled at Cape Hatteras and Cape Lookout National Seashores, July 15–21, 2025. Inset graph shows the proportion of sites in each condition category [Green = good; yellow = fair].

NPS / SECN

Table 4. Water-quality parameter values and assessment conditions for sampling sites near Cape Hatteras and Cape Lookout National Seashores, July 15–21, 2025. Water clarity was assessed using light attenuation values (k) with a constant (1.4) for estuarine waters experiencing “normal turbidity” (Smith et al. 2006) and assessment categories that correspond to EPA (2012). Conditions of the other assessed parameters are based on EPA (2012). k = light attenuation coefficient; µg/L = micrograms per liter; N = Nitrogen; mg/L = milligrams per liter; P = Phosphorus; “–” = data not collected; N/A = data not reported due to QC check issue. Dissolved oxygen concentrations are taken near the bottom (deepest reading).

Site	Water Clarity (k) ^A	Chlorophyll a (µg/L) ^B	Dissolved Oxygen (DO) (mg/L) ^B	Dissolved Inorganic Nitrogen (DIN) (mg/L) ^B	Dissolved Inorganic Phosphorus (DIP) (mg/L) ^B	Total Dissolved Nitrogen (mg/L) ^{B, C}	Total Dissolved Phosphorus (mg/L) ^{B, C}	Site WQ Index Rating
CAHA03_2025	–	1.20 ^D	5.6 ^D	N/A	0.0034 ^{D, G}	0.42	0.018	Good ^D
CAHA04_2025	–	0.83 ^D	5.7 ^D	0.015 ^D	0.0034 ^{D, G}	0.32	0.009	Good ^D
CAHA07_2025	–	5.89 ^E	6.7 ^D	0.010 ^{D, G}	0.0066 ^D	0.22	0.016	Good ^D
CAHA08_2025	–	7.96 ^E	5.5 ^D	0.011 ^D	0.0043 ^D	0.42	0.017	Good ^D
CAHA11_2025	–	3.50 ^D	7.3 ^D	0.010 ^{D, G}	0.0034 ^{D, G}	0.42	0.008	Good ^D
CAHA12_2025	–	3.73 ^D	7.3 ^D	0.025 ^D	0.0043 ^D	0.47	0.017	Good ^D
CAHA15_2025	–	8.26 ^E	5.6 ^D	0.017 ^D	0.0044 ^D	0.39	0.014	Good ^D
CAHA16_2025	–	8.13 ^E	4.4 ^E	0.010 ^{D, G}	0.0034 ^{D, G}	0.30	0.012	Fair ^E
CAHA19_2025	–	2.29 ^D	9.4 ^D	0.021 ^D	0.0034 ^{D, G}	0.39	0.011	Good ^D
CAHA20_2025	0.8 ^D	1.64 ^D	5.9 ^D	0.023 ^D	0.0034 ^{D, G}	0.40	0.014	Good ^D
CAHA24_2025	1.4 ^D	9.18 ^E	5.9 ^D	0.011 ^D	0.0034 ^{D, G}	0.41	0.008	Good ^D

^A 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.

^B Where µg/L = micrograms per liter; N = Nitrogen; mg/L = milligrams per liter; P = Phosphorus.

^C There are no EPA condition criteria for TDN and TDP.

^D Conditions are assessed as good using parameters from the EPA (2012) (also with a green background).

^E Conditions are assessed as fair using parameters from the EPA (2012) (also with a yellow background).

^F Conditions are assessed as poor using parameters from the EPA (2012) (also with a red background).

^G Result was less than or equal to the Method Detection Limit (MDL reported).

Table 4 (continued). Water-quality parameter values and assessment conditions for sampling sites near Cape Hatteras and Cape Lookout National Seashores, July 15–21, 2025. Water clarity was assessed using light attenuation values (k) with a constant (1.4) for estuarine waters experiencing “normal turbidity” (Smith et al. 2006) and assessment categories that correspond to EPA (2012). Conditions of the other assessed parameters are based on EPA (2012). k = light attenuation coefficient; µg/L = micrograms per liter; N = Nitrogen; mg/L = milligrams per liter; P = Phosphorus; “–” = data not collected; N/A = data not reported due to QC check issue. Dissolved oxygen concentrations are taken near the bottom (deepest reading).

Site	Water Clarity (k) ^A	Chlorophyll a (µg/L) ^B	Dissolved Oxygen (DO) (mg/L) ^B	Dissolved Inorganic Nitrogen (DIN) (mg/L) ^B	Dissolved Inorganic Phosphorus (DIP) (mg/L) ^B	Total Dissolved Nitrogen (mg/L) ^{B, C}	Total Dissolved Phosphorus (mg/L) ^{B, C}	Site WQ Index Rating
CAHA27_2025	–	5.27 ^E	6.3 ^D	0.016 ^D	0.0091 ^D	0.26	0.025	Good ^D
CAHA28_2025	–	1.31 ^D	7.0 ^D	0.011 ^D	0.0034 ^{D, G}	0.11	0.005	Good ^D
CALO01_2025	–	2.33 ^D	6.6 ^D	0.013 ^D	0.0034 ^{D, G}	0.16	0.010	Good ^D
CALO02_2025	–	0.80 ^D	8.4 ^D	0.011 ^D	0.0034 ^{D, G}	0.21	0.017	Good ^D
CALO05_2025	–	0.89 ^D	6.4 ^D	0.010 ^{D, G}	0.0034 ^{D, G}	0.11	0.008	Good ^D
CALO06_2025	–	1.55 ^D	4.9 ^E	0.011 ^D	0.0037 ^D	0.21	0.013	Good ^D
CALO09_2025	–	0.99 ^D	7.7 ^D	0.010 ^{D, G}	0.0034 ^{D, G}	0.13	0.007	Good ^D
CALO10_2025	–	2.67 ^D	6.3 ^D	0.010 ^{D, G}	0.0034 ^{D, G}	0.14	0.006	Good ^D
CALO13_2025	–	1.61 ^D	5.2 ^D	0.015 ^D	0.0045 ^D	0.23	0.026	Good ^D
CALO14_2025	–	1.43 ^D	7.1 ^D	0.010 ^{D, G}	0.0034 ^{D, G}	0.11	0.005	Good ^D
CALO17_2025	–	2.3 ^D	5.7 ^D	0.010 ^{D, G}	0.0034 ^{D, G}	0.15	0.007	Good ^D

^A 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.

^B Where µg/L = micrograms per liter, N = Nitrogen; mg/L = milligrams per liter; P = Phosphorus.

^C There are no EPA condition criteria for TDN and TDP.

^D Conditions are assessed as good using parameters from the EPA (2012) (also with a green background).

^E Conditions are assessed as fair using parameters from the EPA (2012) (also with a yellow background).

^F Conditions are assessed as poor using parameters from the EPA (2012) (also with a red background).

^G Result was less than or equal to the Method Detection Limit (MDL reported).

Table 4 (continued). Water-quality parameter values and assessment conditions for sampling sites near Cape Hatteras and Cape Lookout National Seashores, July 15–21, 2025. Water clarity was assessed using light attenuation values (k) with a constant (1.4) for estuarine waters experiencing “normal turbidity” (Smith et al. 2006) and assessment categories that correspond to EPA (2012). Conditions of the other assessed parameters are based on EPA (2012). k = light attenuation coefficient; µg/L = micrograms per liter; N = Nitrogen; mg/L = milligrams per liter; P = Phosphorus; “–” = data not collected; N/A = data not reported due to QC check issue. Dissolved oxygen concentrations are taken near the bottom (deepest reading).

Site	Water Clarity (k) ^A	Chlorophyll a (µg/L) ^B	Dissolved Oxygen (DO) (mg/L) ^B	Dissolved Inorganic Nitrogen (DIN) (mg/L) ^B	Dissolved Inorganic Phosphorus (DIP) (mg/L) ^B	Total Dissolved Nitrogen (mg/L) ^{B, C}	Total Dissolved Phosphorus (mg/L) ^{B, C}	Site WQ Index Rating
CALO18_2025	–	2.57 ^D	7.1 ^D	0.010 ^{D, G}	0.0034 ^{D, G}	0.14	0.007	Good ^D
CALO21_2025	–	2.89 ^D	6.3 ^D	0.046 ^D	0.0034 ^{D, G}	0.32	0.012	Good ^D
CALO22_2025	–	4.03 ^D	3.6 ^E	0.010 ^{D, G}	0.0034 ^{D, G}	0.24	0.008	Good ^D
CALO23_2025	0.7 ^D	0.82 ^D	6.3 ^D	0.013 ^D	0.0034 ^{D, G}	0.15	0.010	Good ^D
CALO25_2025	1.4 ^D	1.82 ^D	6.5 ^D	0.013 ^D	0.0034 ^{D, G}	0.16	0.013	Good ^D
CALO26_2025	–	2.53 ^D	6.0 ^D	0.010 ^{D, G}	0.0074 ^D	0.26	0.023	Good ^D
CALO29_2025	–	0.87 ^D	3.8 ^E	0.011 ^D	0.0038 ^D	0.26	0.008	Good ^D
CALO30_2025	–	2.61 ^D	6.3 ^D	0.010 ^{D, G}	0.0034 ^{D, G}	0.20	0.015	Good ^D

^A 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.

^B Where µg/L = micrograms per liter; N = Nitrogen; mg/L = milligrams per liter; P = Phosphorus.

^C There are no EPA condition criteria for TDN and TDP.

^D Conditions are assessed as good using parameters from the EPA (2012) (also with a green background).

^E Conditions are assessed as fair using parameters from the EPA (2012) (also with a yellow background).

^F Conditions are assessed as poor using parameters from the EPA (2012) (also with a red background).

^G Result was less than or equal to the Method Detection Limit (MDL reported).

Cape Hatteras and Cape Lookout National Seashores 2025 Turbidity

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

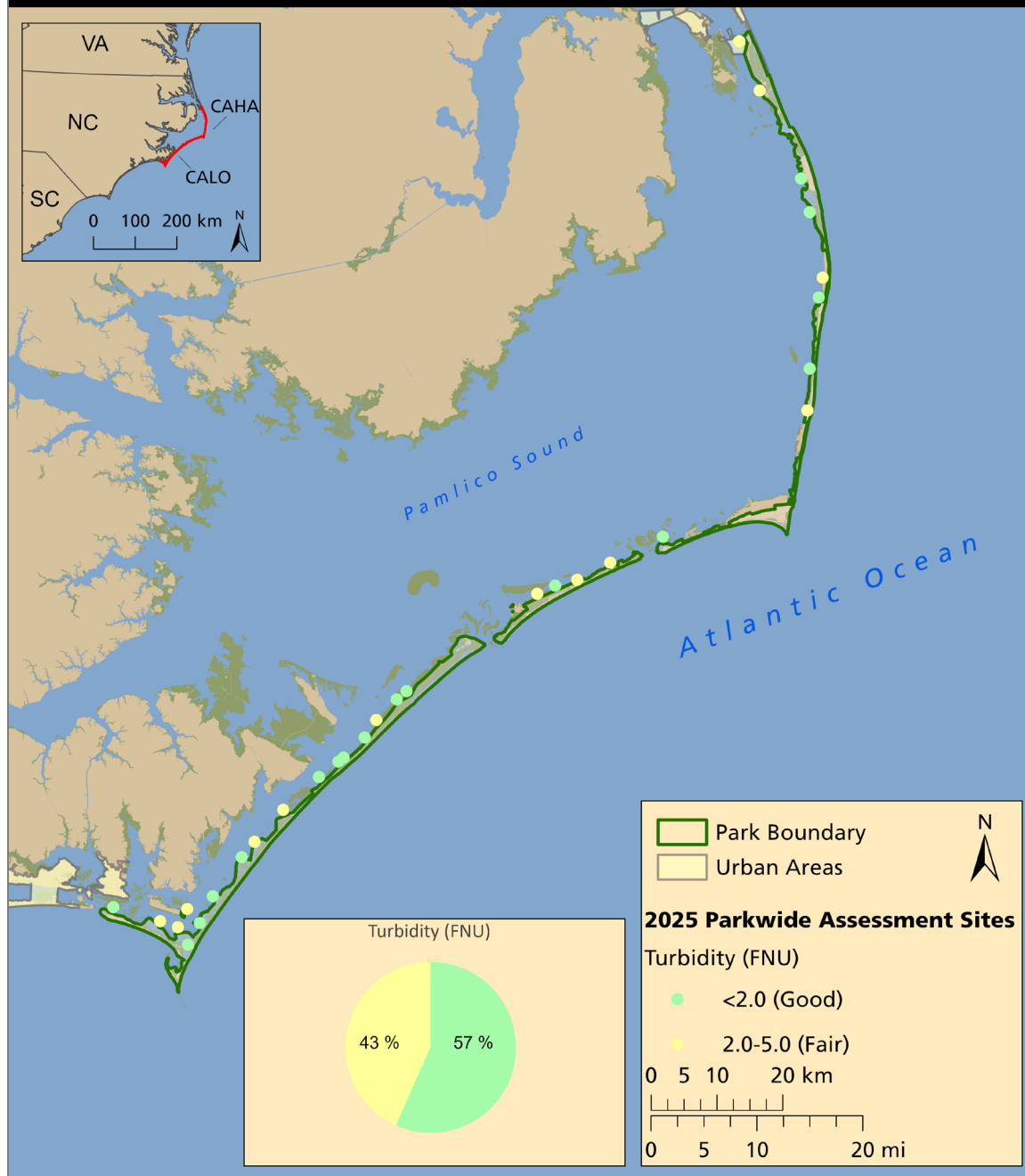


Figure 10. Turbidity readings at sites sampled at Cape Hatteras and Cape Lookout National Seashores, July 15–21, 2025. Inset graph shows the proportion of sites in each SECN condition category for turbidity at CAHA and CALO [Green = good; yellow = fair].

NPS / SECN

Cape Hatteras and Cape Lookout National Seashores 2025 Submerged Aquatic Vegetation

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

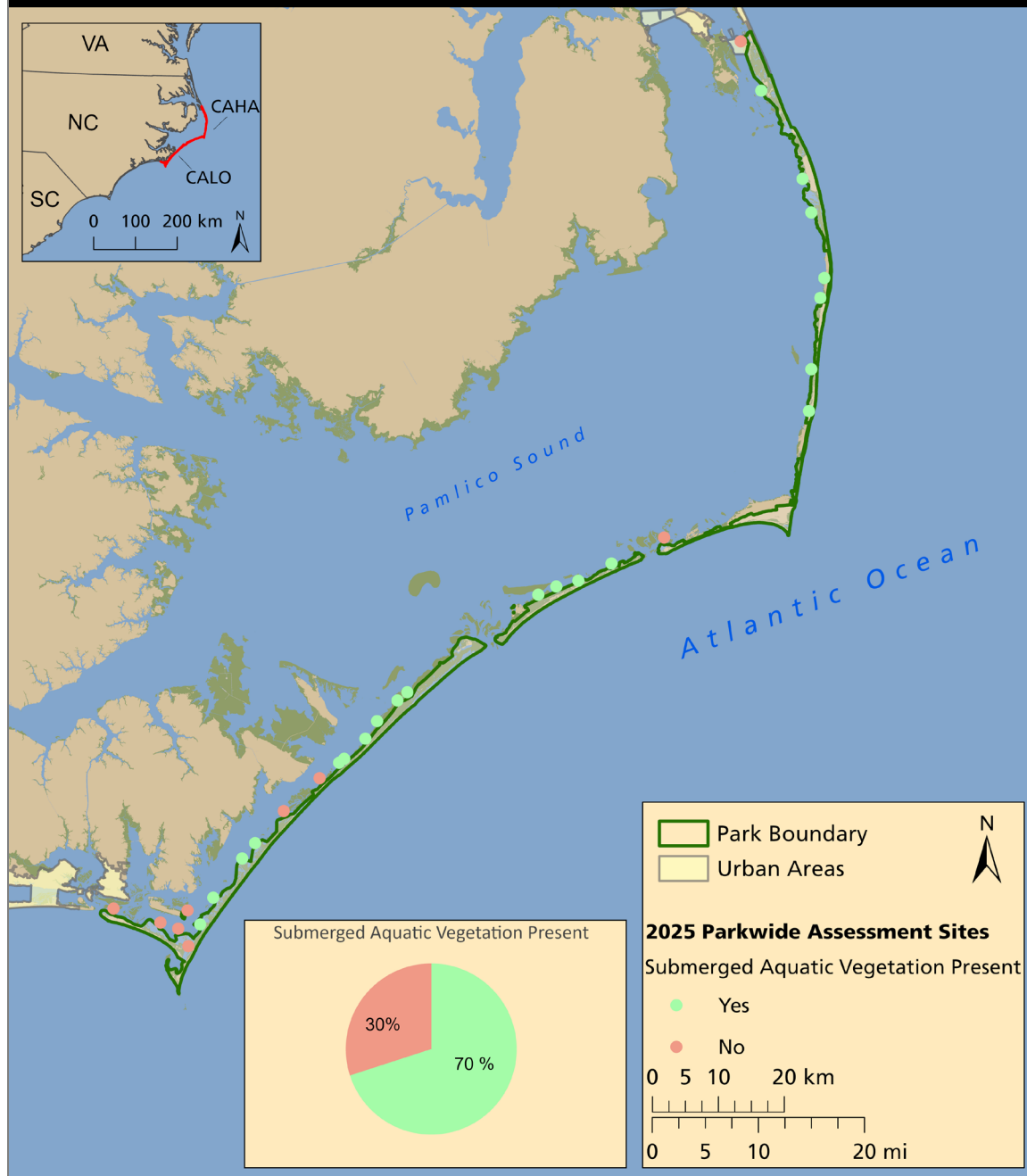


Figure 11. Submerged aquatic vegetation presence/absence for sites sampled at Cape Hatteras and Cape Lookout National Seashores, July 15–21, 2025. Inset graph shows the proportion of sites in each condition category [Green = yes; red = no].

NPS / SECN

Conclusions

Overall, estuarine water-quality conditions at Cape Hatteras National Seashore and Cape Lookout National Seashore in July 2025 were generally good, with most sites meeting EPA “good” thresholds for chlorophyll *a*, dissolved inorganic nitrogen, dissolved inorganic phosphorus, and bottom dissolved oxygen. Only one site received a water-quality index rating of “fair,” and no sites were categorized as “poor,” consistent with generally stable conditions reported in 2015 and 2021. These results indicate that during the 2025 sampling period nutrient enrichment and hypoxia were limited across most monitored sites.

The Southeast Coast Network will continue to monitor for subtle shifts in water quality, particularly in shallow areas where Secchi depth measurements were limited, increases in chlorophyll *a* at sites approaching “fair” conditions, potential declines in dissolved oxygen, and any signs of long-term change associated with climate variability, sea-level rise, or watershed-scale nutrient inputs. Maintaining consistent sampling and continuing to pair fixed-station time series with park-wide spatial assessments will remain critical for detecting emerging stressors early and supporting adaptive management at these seashores.

Literature Cited

- DeVivo, J.C., C.J. Wright, M. Byrne, E.M. DiDonato, and T. Curtis. 2008. Vital signs monitoring in the Southeast Coast Inventory and Monitoring Network. NPS/SECN/NRR—2008/061, National Park Service, Fort Collins, Colorado. <https://irma.nps.gov/DataStore/DownloadFile/153409>
- Gregory, M.B., and K.A. Smith. 2011. Assessment of estuarine water and sediment quality at Cape Lookout and Cape Hatteras National Seashores, 2010. Natural Resource Data Series Report NPS/SECN/NRR—2011/179. National Park Service, Fort Collins, Colorado. <https://irma.nps.gov/DataStore/Reference/Profile/2173641>
- Gregory, M.B., J.C. DeVivo, E.M. DiDonato, C.J. Wright, and E. Thompson. 2013a. Protocol for monitoring estuarine water and sediment quality in selected Southeast Coast Network parks. NPS/SECN/NRR—2013/644. National Park Service, Fort Collins, Colorado. <https://irma.nps.gov/DataStore/Reference/Profile/2194106>
- Hall, N.S. 2022. Evaluation of water clarity metrics for protection of submerged aquatic vegetation in the Albemarle-Pamlico Estuarine System. UNC Institute of Marine Sciences and the Albemarle-Pamlico National Estuary Partnership. <https://apnep.nc.gov/documents/2022-evaluation-water-clarity-and-sav-albemarle-pamlico-estuary/open>
- Mallin, M.A., V.L. Johnson, and M.R. McIver. 2004. Assessment of coastal water resources and watershed conditions in Cape Lookout National Seashore, North Carolina. Technical Report NPS/NRWRD/NRTR—2004/322 (NPS D-58). National Park Service, Water Resources Division. <https://irma.nps.gov/DataStore/Reference/Profile/659834>
- North Carolina Department of Environmental Quality. 2019. Classifications and Water Quality Standards Applicable to Surface Waters and Wetlands of North Carolina: 15A NCAC 02B .0100–.0300. Division of Water Resources, Raleigh, North Carolina. https://files.nc.gov/ncdeq/csrrb/tri_rev_17to19/15A_NCAC_02B_.0100-.0300.pdf
- North Carolina Department of Environment and Natural Resources Division of Environmental Health-Shellfish Sanitation and Recreational Water Quality Section (NC DENR DEH-SSRWQS). 2011. GIS coverage for shellfish areas (GIS dataset). Raleigh, North Carolina.
- Smith, L.M., V.D. Engle, and J.K. Summers. 2006. Assessing water clarity as a component of water quality in Gulf of Mexico estuaries. *Environmental Monitoring and Assessment* 115:291–305. <https://doi.org/10.1007/s10661-006-6555-3>
- Starkey, E.N., D. McCay, C.S. Cooper, and M. Hynds. 2022. Assessment of estuarine water and sediment quality at Cape Hatteras National Seashore and Cape Lookout National Seashore: 2021 data summary. Natural Resource Data Series NPS/SECN/NRDS— 2022/1373. National Park Service, Fort Collins, Colorado. <https://irma.nps.gov/DataStore/Reference/Profile/2294854>

- Starkey, E.N., M.B. Gregory, W.K. Wright, J.C. DeVivo, E.M. DiDonato, C.J. Wright, and E. Thompson. 2023. Protocol for monitoring estuarine water and sediment quality in selected Southeast Coast Network parks: Protocol narrative—version 2.0. Natural Resource Report NPS/SECN/NRR—2023/2528. National Park Service, Fort Collins, Colorado.
<https://doi.org/10.36967/2299077>
- Stevens, D.L., Jr., and A.R. Olsen. 2004. Spatially balanced sampling of natural resources. *Journal of the American Statistical Association* 99(465):262–278.
<https://doi.org/10.1198/016214504000000250>
- Stevens, D.L., Jr. 1997. Variable density grid-based sampling designs for continuous spatial populations. *Environmetrics* 8(3):167–195. [https://doi.org/10.1002/\(SICI\)1099-095X\(199705\)8:3%3C167::AID-ENV239%3E3.0.CO;2-D](https://doi.org/10.1002/(SICI)1099-095X(199705)8:3%3C167::AID-ENV239%3E3.0.CO;2-D)
- Stevens, D.L., Jr., and A.R. Olsen. 1999. Spatially restricted surveys over time for aquatic resources. *Journal of Agricultural, Biological, and Environmental Statistics* 4(4):415.
<https://doi.org/10.2307/1400499>
- U.S. Fish and Wildlife Service (USFWS). 2024. National Wetlands Inventory website.
<https://www.fws.gov/wetlands/>
- United States Census Bureau (USCB). 2023. Decennial Census of Population and Housing by Decades. 2000 Census Gateway website. <https://www.census.gov/programs-surveys/decennial-census/decade.2000.html>
- United States Environmental Protection Agency (EPA). 2012. [National Coastal Condition Report IV](#). EPA-842-R-10-003. EPA Office of Water, Washington, D.C.
- United States Environmental Protection Agency (EPA). 2014. National Coastal Condition Assessment: Field Operations Manual. EPA-841-R-14-007. U.S. Environmental Protection Agency, Washington, D.C. https://www.epa.gov/sites/default/files/2016-03/documents/national_coastal_condition_assessment_2015_field_operation_manual_version_1.0_1.pdf
- United States Environmental Protection Agency (EPA). 2016. [National Coastal Condition Assessment \(NCCA\) 2010](#) technical report. EPA 841-R-15-006. EPA Office of Water, Washington, D.C.
- United States Environmental Protection Agency (EPA). 2022. 303(d) listed water bodies (GIS coverage). [How's My Waterway](#). EPA Office of Water, Washington, D.C.

Wright, W. 2016. Assessment of estuarine water quality at Cape Hatteras and Cape Lookout National Seashores: 2015 data summary. Natural Resource Data Series NPS/SECN/NRDS—2016/1056. National Park Service, Fort Collins, Colorado.
<https://irma.nps.gov/DataStore/Reference/Profile/2235357>

National Park Service
U.S. Department of the Interior



Science Report NPS/SR—2026/461
<https://doi.org/10.36967/2318652>

Natural Resource Stewardship and Science

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525