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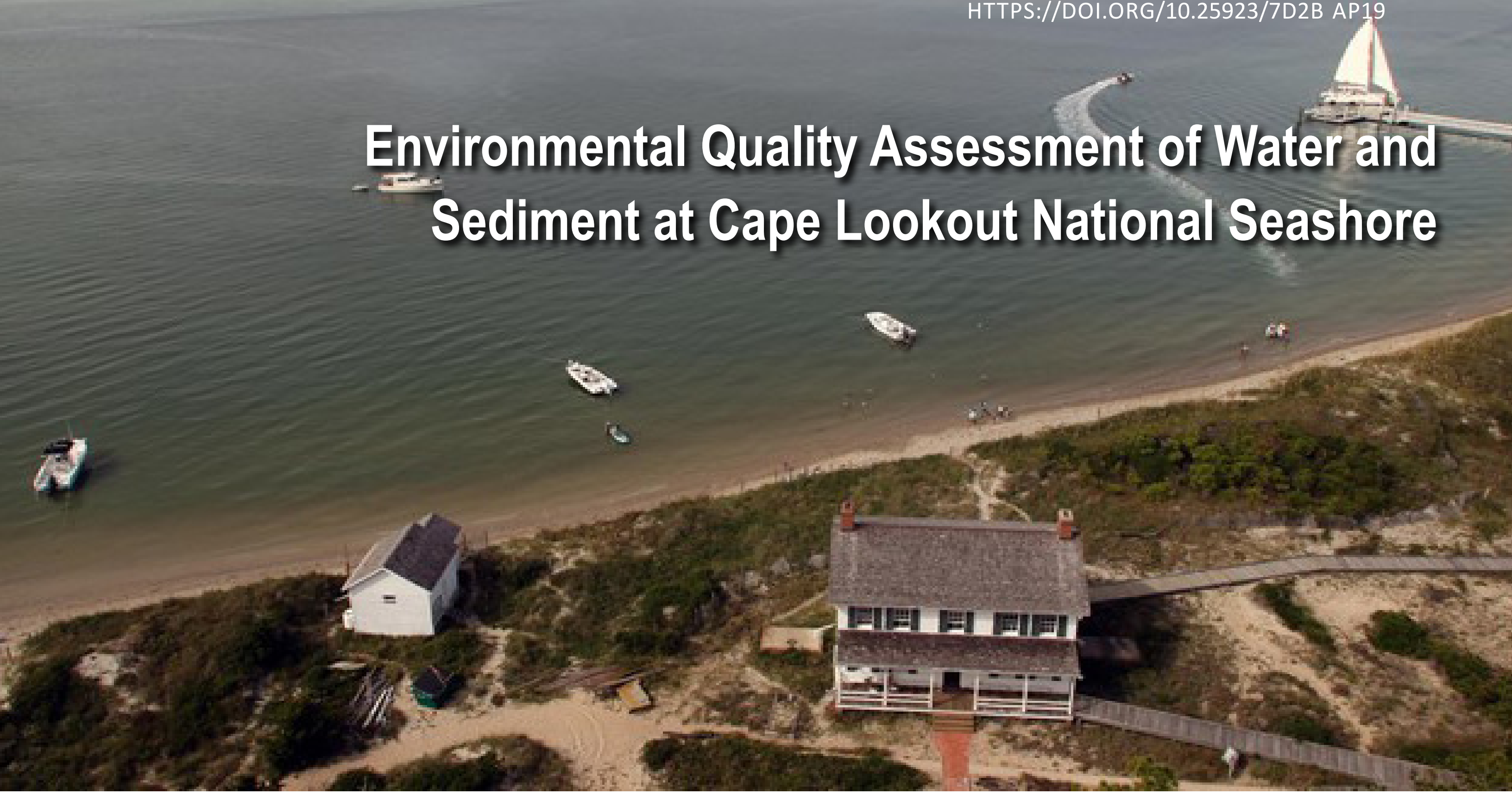
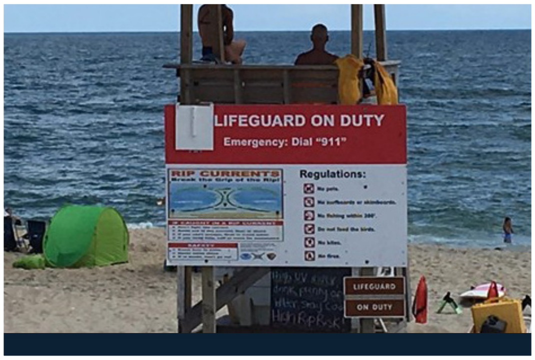
Environmental Quality Assessment of Water and Sediment at Cape Lookout National Seashore





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Executive Summary

In 2018, Hurricane Florence brought historic flooding to large regions of northern South Carolina and southern North Carolina. The sheer amount of inundation and freshwater influx into the coastal area may have had impacts on water quality and marine resources due to salinity change, redistributed chemical pollution (e.g., pesticides, polycyclic aromatic hydrocarbons, metals, nutrients), and influx of bacterial pathogens from the impacted areas. This project assessed water and sediment quality from 20 sites within Cape Lookout National Seashore, NC to determine if any floodwater inundation and runoff from mainland areas affected sediment and water quality. Oyster tissue from two sites was also sampled. The data provide a critical baseline of sediment and water quality data from which to compare any post-coastal inundation events.

Results from the analysis of water collected from 20 sites in Cape Lookout National Seashore indicated nutrient levels measured were below that of concern according to North Carolina and EPA standards. Results from the analysis of sediment from these 20 sites found at least one class of contaminant at all sites. However, contaminant levels were not high enough to be a regulatory concern. Chemical analysis of the oyster tissue collected from two of the Cape Lookout sites showed low levels of all compounds detected. The data presented in this report gives much needed current levels of water quality, sediment contaminants and oyster health in Cape Lookout National Seashore.

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INTRODUCTION

The National Centers for Coastal Ocean Science (NCCOS) is the focal point for NOAA's coastal ocean science efforts and helps NOAA meet its coastal stewardship and management responsibilities. It is responsible for executing NOAA's science mission: 1) to protect, restore and manage the use of coastal and ocean resources through an ecosystem approach to management; 2) to conserve and manage coastal and marine ecosystems and resources; 3) to recover marine and coastal species to health and productivity; and 4) share knowledge and information with others. NCCOS executes its responsibilities by providing coastal managers with scientific information to support management options for protecting environmental resources and public health, preserving valued habitats and improving community interactions with coastal ecosystems. The approach used by NCCOS to implement their scientific programs is through Marine Spatial Ecology, Stressor Impacts and Mitigation, and Coastal Change and Social Science. Marine Spatial Ecology delivers an integration of a broad spectrum of physical, biological and social factors to guide communities in balancing resource use and conservation. Stressor Impacts and Mitigation provides ecological forecasting, information on stressors and their impacts on coastal resources to support management, mitigation and protection of water and wildlife resources, seafood industries and public health. Social Science and Coastal Change are cross-cutting lines of research to understand and evaluate the ecosystem services provided by coastal marine resources to reduce vulnerabilities within coastal communities and ecosystems.

This project assessed water and sediment quality from 20 sites within Cape Lookout National Seashore, NC to determine if any floodwater inundation and runoff from mainland areas affected sediment and water quality. Oyster tissue from two sites was also sampled. Floodwaters and runoff from agricultural and industrial areas located upstream of the park boundaries are suspected of having chemical and bacterial contaminants, which could affect the environmental health of the area in addition to the health and safety of Cape Lookout National Seashore visitors. In 2018, Hurricane Florence brought historic flooding to large regions of northern South Carolina and southern North Carolina. Like many other severe coastal storms, Hurricane Florence was suspected to cause significant damage to many ecological components of estuaries and coastal systems along coastal North and South Carolina. The shear amount of inundation and freshwater influx into the coastal area may have had impacts on water quality and marine resources as result of salinity change, redistributed chemical pollution (e.g., pesticides, polycyclic aromatic hydrocarbons (PAHs), metals, nutrients), and influx of bacterial pathogens from the impacted areas. A lack of ecosystem assessment data in Cape Lookout National Seashore pre-event inhibited quantification of coastal inundation impacts post-event. These types of extreme weather events may become more frequent along the coastline of the Carolinas due to climate change. This project aims to provide critical baseline information regarding environmental quality within the National Seashore boundaries. This information will benefit environmental resource managers and coastal communities by assessing ecosystem vulnerabilities and providing a baseline for determining resource damages after an inundation event.

The work proposed in this project was to assess chemical contaminants in water and sediment at up to 20 sites in Shackleford Banks, South Core Sound, and North Core Sound within the national seashore boundaries. The anticipated outcomes were the following:

1. Provide a critical baseline of sediment and water quality data from which to compare any post-coastal inundation events. The data will be used to inform park management decisions regarding environmental and human protection.

2. Deliver a dataset for discrete sampling sites within the park boundaries of water quality to include nutrient and chlorophyll *a* levels and chemical contamination in sediments. Oyster tissue was sampled where available to provide background levels of biomarkers of contaminant exposure.

3. Develop a dataset that contributes to historical data from NOAA's Mussel Watch and other long-term monitoring programs in the region.

METHODS

Sediment, water, and oyster collection was accomplished during July - October 2021. Twenty sites were sampled as listed in Table 1 and mapped in Figure 1. These sites were chosen by National Park Service personnel. The sites were accessed using NOAA Research Vessel R1807. This is an 18-foot, Class 1 vessel built by Privateer Boat Company and equipped with a Yamaha 90 hp outboard engine and a small davit to assist with sediment bottom grabs. The vessel was trailered to the appropriate boat landings for access to the sites. After navigating the vessel to each site, a 3-person crew (composed of a small-boat driver and two field support persons) spent approximately 1.5 hours to collect necessary water and sediment and record field data. The field data recorded at each site included lat/long, surface water temperature (°C), salinity (parts per thousand [ppt]), dissolved oxygen (mg/L), pH, depth (m), and Secchi depth (m; as a measure of turbidity) at the site.

At each site, approximately 500 mL of water was sampled by dipping a glass jar into the water column and capping. These water samples were kept on ice for nutrient analysis and chlorophyll-a analysis. For nutrient analysis, at least 250 mL of site water was vacuumed filtered through a 47 mm GF/F filter membrane. The filtrate was then placed in a polypropylene bottle and frozen until analysis. Nutrient analysis for ammonia, nitrate plus nitrite, and phosphate was performed by Nutrient Analytical Services Laboratory (University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory, 146 Williams Street, P.O. Box 38, Solomons, MD 20688) using methods as posted on their website (https://www.umces.edu/nasl/methods).

For chlorophyll *a* analysis, at least 10 mL of site water was vacuumed filtered through a 25 mm GF/F filter membrane. If no color was present on the filter, then 10 mL aliquots of site water was filtered until coloration was present. The filter was removed, placed face up in a scintillation vial with 1 mL of saturated magnesium carbonate solution, and frozen at -20°C. For analysis, 9 mL of acetone was added to each vial, shaken, refrigerated for 24 h, shaken again, and refrigerated for an additional 24 h. The chlorophyll *a* extracts were then read on a Sequoia-Turner Model 450 fluorometer. Readings were calculated then converted to µg/L after taking into account the door factor, gain correction, and volume filtered (Glover and Morris, 1979).

At each site, approximately 750 mL of sediment was sampled using a Young-modified Van Veen sampler. At least three of these bottom samples were collected at each site. The surficial sediments (upper 2 cm) of each grab were homogenized on-site in a disposable Teflon liner placed inside a five-gallon plastic bucket. Sediment was then placed in pre-cleaned containers for analysis of total organic carbon (TOC), contaminants, and sediment toxicity. After enough sediment had been collected, the grab and all utensils were rinsed with the site water then cleaned with an iso-propyl saturated disposable cloth. A new liner was also placed in the five-gallon bucket ready for the next site.

All sediment samples were kept on ice while in the field and then stored frozen at -20°C until analyzed. The following contaminants were analyzed by the NOAA/NOS/NCCOS Charleston Laboratory using procedures similar to those described by Kucklick et al. (1997), Long et al. (1997), Balthis et al. (2012), Chen et al. (2012), and Apeti et al (2018): 22 metals, 80 pharmaceuticals and personal care products, 17 human hormones, 50 polycyclic aromatic hydrocarbons (PAHs), 4 alkylphenols, and 25 pesticides. Sediment was also analyzed for 28 per- and polyfluoroalkyl substances (PFAS) compounds, 51 polybrominated diphenyl ethers (PBDE), and 19 polybrominated biphenyls (PBB) by TDI Brooks/B&B Laboratories (14391B South Dowling Road, College Station, TX 77845). These analytical methods are published in Kimbrough et al (2006). TDI Brooks/B&B Laboratories also measured total organic carbon and the bacteria *Clostridium perfringens* in the sediment samples. Sediment toxicity was assessed by the Microtox® solid-phase bioassay, which uses a photoluminescent bacterium (Aliivibrio fischeri) and protocols described by the Microbics Corporation (1992) and Ringwood et al. (1997). This was performed at the NOAA/NOS National Centers for Coastal Ocean Science Charleston Laboratory.

Oysters (*Crassostrea virginica*) were collected from two sites, CL2021-007 and 019. Each site consisted of three subsamples. CL2021-007 subsamples consisted of 66 to 74 whole oysters. CL2021-019 subsamples consisted of 22 to 34 whole oysters. Oysters were not present at the other sites sampled. Whole oyster tissue was removed from the shells for each subsample, pooled within that subsample and analyzed for 22 metals, 104 pharmaceuticals and personal care products, 17 human hormones, 4 alkylphenols, 33 pesticides and organic chlorine compounds, 156 polychlorinated biphenyls (PCB), 28 PFAS compounds, 51 PBDEs, 19 PBBs, and 4 butyltin compounds. Oyster tissue analysis for metals, alkylphenols, pharmaceuticals, and personal care products were analyzed NOAA/NOS/NCCOS Charleston Laboratory using methods as described by Apeti et al (2018). PAH, pesticides, PDBEs, PBBs, PCBs, butyltins, and PFAS were analyzed by TDI Brooks/B&B Laboratories using proprietary and confidential methods.

Field crew collecting oysters at Cape Lookout National Seashore. Photo credit: Jeff West (NPS).

RESULTS and DISCUSSION

Water

The 20 sites that were sampled in Cape Lookout National seashore are listed in Table 1 along with corresponding depth, Secchi depth (as a measure of turbidity), temperature, and salinity. The current water quality standards for surface waters in North Carolina as developed by North Carolina Department of Environmental Quality, Division of Water Resources can be viewed in rules 15A NCAC 02B .0100 through .0300 (North Carolina Environmental Quality, 2024). Dissolved oxygen in tidal salt water in NC should not be less than 5.0 mg/L and pH should be between 6.8 and 8.5. All sites sampled were within the ranges for dissolved oxygen and pH. Dissolved oxygen ranged from 5.54 - 7.09 mg/L while pH at the 20 sites ranged from 7.8 - 8.3. Observations with the Secchi disk indicated that turbidity was not a problem at these sites with values ranging from 0.6 m to 2.8 m.

Nutrient and chlorophyll *a* levels in water at the sampled sites are listed in Table 2. The current water quality standards for surface waters in North Carolina for chlorophyll *a* and nitrite/nitrate can be found at the same document above (North Carolina Department of Environmental Quality, 2018). According to this document, chlorophyll *a* levels should not be greater than 40 µg/L for all waters not designated as trout waters. Nitrite/Nitrate levels for NC should not exceed 10 mg/L for any surface waters.   Ammonia standards follow that of US EPA document number 440/5-88-004; NTIS number PB89-169825. Phosphate standards could not be found for NC. EPA phosphate standards indicate levels should be no more than 0.1 mg/L for streams that do not empty into reservoirs; no more than 0.05 mg/L for streams discharging into reservoirs; and no more than 0.024 mg/L for reservoirs (EPA, 2011). All nutrients measured at the Cape Lookout sites were below NC and EPA levels of concern (Table 2). The chlorophyll *a* levels were also below levels of concern (Table 2).

Sediment

Sediment from all 20 sites was analyzed for a variety of contaminants, most of which were not detected. All pharmaceutical and personal care products (PPCPs) and human hormones for which the sediment was analyzed were below the method detection limit (Tables 3 and 4). The PPCPs listed include prescription and over-the-counter medications, synthetic fragrances, disinfectants, antimicrobial compounds, disinfectants, and insect repellants. A primary route for PPCPs and hormones to enter the environment is through wastewater discharge or direct disposal (Apeti et al., 2018). More information on the chemical group and general use of these PPCPs and hormones may be found in Apeti et al. (2018). The lack of detection of these compounds at Cape Lookout may indicate that, at the time of sampling, any wastewater discharge and/or improper disposal were not a concern.

Of the 25 pesticides that were measured (Table 5A), only three pesticides were detected (4,4'-DDD, heptachlor epoxide, cis-chlordane) but only one each at five different sites (CL2021-003, CL2021-004, CL2021-007, CL2021-018, CL2021-019) (Table 5B). The three detected are metabolites of organochlorine insecticides that were used in termite and mosquito control in addition to being used on agricultural crops. DDT was banned in 1972 (ATSDR, 2021) while chlordane and heptachlor were banned in 1988 (ATSDR, 2015; ATSDR, 2014). Their detection years after banning is testament to their persistence. However, please note that these are very low ng/g levels. The level of pesticides found in the sediment can be weighed against a series of values developed by Long et al. (1995). Effects Range Low (ERL) and Effects Range Medium (ERM) for metals and organic compounds are values for those compounds commonly found in sediments. The ERL value represents a minimal threshold below which effects to sediment dwelling estuarine organisms would be rarely observed. The ERM value represents a probable range in which adverse effects would frequently occur. Between the two values, represents a range in which effects would occasionally occur (Long et al., 1995). The ERL and ERM values that have been determined so far are seen in Table 9. The levels of 4,4'-DDD, heptachlor epoxide, and cis-chlordane found at these sites indicate that effects on sediment dwelling organisms would not be likely compared to these ERL and ERM guidelines.

Sediment was analyzed for four alkylphenols (Table 6A), but only one was detected (4-n-octylphenol) and at four different sites (CL2021-013, CL2021-015, CL2021-017, CL2021-019; Table 6B). Alkylphenols are chemicals used as detergents and surfactants that tend to be persistent in the environment. The major source of these compounds in the environment is wastewater discharge (Apeti et al., 2018). The one alkylphenol detected was at ng/g levels.

At the 20 sites, total PAH50s were detected at 18 sites (Table 7A; see Table 7B for list of total PAH50 compounds). At sites CL2021-003 and CL2021-005, total PAH50s were not detected. These 50 PAHs, including both parent and alkylated PAHs, are known as "total PAH50'' and represent a suite of target analytes in environmental petroleum samples (Boehm, 2006). PAHs are generated from the incomplete combustion of fossil fuels as well as from non-combusted fossil fuels (oil spills) and can be persistent in sediments such as marsh substrates especially when the substrates have a high organic carbon content (Vo et al., 2004). The amount of total PAHs found at site CL2021-019, 295.1 ng/g, was higher than all the other sites. Sites CL2021-002, CL2021-007, CL2021-010, CL2021-020 had the next highest measured total PAH levels. However, none of the detectable levels exceeded the ERL values for total PAHs indicating that effects on sediment dwelling organisms would not be predicted based on these concentrations.

Metals in sediments were detected in all 20 sites (Table 8). Of the 22 metals measured, 13 were found in all 20 sites. Three of the metals (silver, cadmium, antimony) were not found at any site. Metals were detected at the highest amounts at sites CL2021-019 and CL2021-020. At both of these sites, 19 metals were detected. At these two sites, aluminum was found at levels from 15,804 to 18,405 µg/g which was seven times higher than the next highest site (CL2021-002). Iron was found at CL2021-019 and CL2021-020 at levels from 13,620.8 to 14,701 µg/g which was four times higher than the next highest site (CL2021-002 again). Nine of the metals for which Cape Lookout sediments were analyzed have ERL and ERM values (Table 9). However, none of the detectable levels exceeded the ERL values for those metals indicating that effects on sediment dwelling organisms would not be predicted based on these metal concentrations.

PFAS levels and related compounds in sediments at the 20 sites were analyzed. PFAS are a group of fabricated chemicals that have been used in a variety of industries since the 1940s including food packaging, commercial household products, and electronics manufacturing. These chemicals are very persistent in the environment and have been found in fish, animals, and humans where they have the ability to build up and persist over time. The list of PFAS for which Cape Lookout sediments were analyzed are in Table 10A. All fell below method detection limits (ng/g levels) except for nine sites listed in Table 10B. The sites with the highest levels in the sediment samples were CL2021-005 and CL2021-020 with 0.105

and 0.120 ng/g respectively. PFAS regulation information is rapidly being updated by the EPA and it is recommended to peruse the EPA website for the most up to date regulations (https://www.epa.gov/pfas). As of this writing, no EPA regulations exist addressing PFAS levels in sediment.

PBDEs and PBBs are classes of chemicals used as flame retardants. They are incorporated into manufactured items such as furniture, wire insulation, rugs, computers and small appliances. These chemicals enter the environment through discharge from manufacturing and breakdown of the products containing them. PDBEs and PBBs have a high affinity for sediment particles and have been known to bioaccumulate in fish and mammals (CDC, 2017). PBDE and PBB chemicals were not found in the sediment at any of the 20 sites sampled (Tables 11 and 12).

Microtox analysis is a measure of sediment toxicity using a luminescent bacterium (*Aliivibrio fischeri*). The values reported in Table 19 are the effective concentration of a sediment dilution that caused a 50% reduction in light emission from the bacteria over a set time period. The practical use of these EC50 values depends upon the percentage of silt and clay in the sediment samples. Sediment is considered toxic if % EC50 < 0.5 and % Silt/Clay <20 or % EC50 < 0.2 and % Silt/Clay >20. In Table 11 it is seen that sites CL2021-019 and CL2021-020 approach the toxic definition but would still not be considered toxic.

Total carbon levels were measured in the sediment at all the sites sampled (Table 20) and were further divided into total organic carbon (TOC) and total inorganic carbon listed as both milligrams and %. Organic matter in sediments is an important source of food for benthic fauna, however an overabundance can lead to adverse bioeffects due to oxygen depletion and buildup of toxic by-products associated with the natural breakdown process (Hyland et al. 2005). Results of the Hyland et al. (2005) study, which looked at benthic infaunal patterns in relation to increasing TOC levels in sediments from various coastal regions around the world, suggested that risks of reduced benthic species richness from organic loading and other associated stressors in sediments should be relatively low at TOC concentrations less than about 1% (10 mg/g). All sites sampled in this study contained levels less than 0.5% except CL2021-019 and CL2021-020 at 1.17% and 1.69%, respectively (Table 20).

Oyster Tissue

Analysis of oyster tissue for human hormones (Table 4), alkylphenols (Table 6A), PBDEs (Table 11), PBBs (Table 12) found no detectable amounts of these compounds in the tissues from the two sites. Hormones, PBDEs and PBBs were also not found in the sediment from the 20 sites sampled.

PFAS (PFBA and PFOS) were found in oysters from both sites but in low ng/g wet weight (ww) amounts (Table 10C). PFAS were not found in the sediment at CL2021-007 but were found in the sediment at CL2021-019. EPA does have Draft 2022 Aquatic Life Ambient Water Quality Criteria for PFOA and PFOS which includes criteria for invertebrate whole-body tissue for freshwater organisms. For PFOA, the criteria recommend levels no higher than 1.11 mg/kg ww, while for PFOS the criteria recommend levels no higher than 0.937 mg/kg ww (EPA, 2022). As seen in Table 10C, the two PFAS (PFBA and PFOS) found in oyster tissue were in low ng/g ww amounts well below the EPA criteria. As stated previously, the EPA PFAS website will have the most up to date information on criteria and any regulations (https://www.epa.gov/pfas).

Of the 104 pharmaceutical and personal care products for which the oysters were analyzed (Table 14A), five were found in oyster tissue (Table 14B). Amphetamine, clonidine (a sedative), and cotinine (nicotine metabolite) were found in the oysters from site CL2021-007 while albuterol and DEET were found in the oysters from CL2021-019. All were found in low ng/g ww amounts. DEET, the active ingredient in insect repellants, was found in the highest amount (6.73 ng/g ww). None of these compounds were found in the sediment at any of the 20 sites sampled (amphetamine was not one of the products analyzed for in sediment; Table 3).

Butyltin analysis of oyster tissue is seen in Table 15. Butyltin compounds include tributyltin (TBT) which is an antifoulant used on boats, buoys, crab pots, fish nets, and cages that prevents the growth of mollusks and other marine organisms on treated surfaces. TBT can accumulate in shellfish and high levels are associated with marinas, boating activities, and boat yards (Harper 2005). No butyltins were measured in oysters from the two Cape Lookout sites.

Oysters from the two Cape Lookout sites were analyzed for 33 pesticide and organic chlorine compounds, and 156 PCBs (Tables 16A and 16B). Oysters from site CL2021-007 contained 4,4'-DDE and four PCB compounds at low ng/g dry weight levels. Site CL2021-019 detected only 4,4'-DDE in oyster tissue. 4,4'-DDE is a common breakdown product of the persistent DDT pesticide (banned in 1972 in the US; NPIC 1999). Sediment from site CL2021-007 contained another DDT metabolite, 4,4'-DDD. PCBs are persistent compounds, banned in 1979, formerly used in industrial and consumer products (EPA, 2024). Sediment from Cape Lookout sites were not analyzed for PCBs. Again, the pesticides and PCBS were detected in oyster tissue in low nanogram amounts.

Oyster tissue from the same two sites were analyzed for 64 PAHs and 26 alkyl isomers and hopanes (Tables 17A, 17B, and 17C). Oysters from site CL2021-007 contained 33 PAHs and 12 alkyl isomers while oysters from site CL2021-019 contained 8 PAHs and 2 alkyl isomers. Those 8 PAHS were also detected at site CL2021-007 oysters. None of the detectable levels in the sediment exceeded the ERL values (Table 9) for total or individual PAHs indicating that effects on sediment dwelling organisms would not be predicted based on these concentrations.

Metals analysis of oyster tissue collected from sites CL2021-007 and CL2021-019 is found in Table 18. Oysters from site CL2021-007 contained 18 metals; 15 different metals were detected in the sediment from that site. Oysters from site CL2021-019 contained 16 metals while 19 metals were detected in the sediment from that site. For metals, zinc was found in the highest levels followed by iron in µg/g ww amounts. Oysters are naturally high in zinc (NIH, 2022) so these amounts are not unexpected. Iron had one of the higher levels of measured amounts in the sediment at these two sites so accumulation in oysters is also not unexpected.

The USFDA (2007) lists tolerance levels allowed in shellfish for human consumption for six "deleterious substances" and 13 "toxic elements". The six metals listed (As, Cd, Cr, Pb, Ni, Hg) were found in the oyster tissue analyzed but below action levels. The DDE and PCBs found in the oyster tissue were also below action levels. No other substances on the FDA lists were found in oysters from the two sites. For guidance on shellfish harvest regulations in North Carolina, please consult this website: https://www.deq.nc.gov/about/divisions/marine-fisheries.

Bacteria

The highest occurrence of the bacteria, *Clostridium perfringens*, was found in the sediment at sites CL2021-019 (415 CFU/g dry weight) and CL2021-020 (820 CFU/g dry weight) (Table 19). *C. perfringens* is an anaerobic Gram-positive spore-forming bacillus. It can be found on raw meat and poultry, in the intestines of animals, and in the environment. C. perfringens is associated with food poisoning and non-foodborne diarrheal disease. These bacteria can also infect wounds resulting in necrosis of subcutaneous fat, muscle, or nerves (CDC, 2023). These bacteria can be used as an indicator of human fecal contamination and can be used as surrogate for the presence of protozoan parasite pathogens (Stelma, 2018).

NOAA's National Status and Trends Program (NS&T) has monitored levels of C. perfringens in sediment as part of its regular monitoring of contaminants throughout the coastal US. Values have been found as high as 41,000 CFU/g in polluted urban harbors. In North Carolina, NS&T measured C. perfringens as high as 1607 CFU/g in sediments from Beaufort Inlet in 2007 (NCCOS, 2023). At this time, regulation of *C. perfringens* levels in estuarine waters and sediment do not exist at the state or federal level.

CONCLUSIONS

Results from the analysis of water collected from 20 sites in Cape Lookout National Seashore found that the nutrient levels measured were below that of concern according to North Carolina and EPA standards. The water quality parameters measured at the time of sampling were also within normal ranges. Chlorophyll *a* analysis indicated that eutrophication is not a problem at the sites sampled.

Results from the analysis of sediment from these 20 sites found at least one class of contaminants at all 20 sites. PFAS were measured in sediments from nine of the 20 sites but at low ng/g levels.

Two sites, CL2021-019 and CL2021-020, contained the highest levels and number of metals, the highest levels of total PAH50s, contained PFAS, had the highest TOC levels, were just under the toxic threshold for the Microtox assay, and had the highest levels of C. perfringens bacteria. The field crew noted that these two sites are close to the ferry path which runs from Ocracoke to Cedar Island, as well as being close to Ocracoke Inlet through which boats may pass (Figure 2). CL2021-019 was sampled near a dock that use to service a residence in the abandoned town of Portsmouth. CL2021-020 was sampled in a channel leading to an abandoned Coast Guard station. While sediment contaminants were found at these sites, contaminant levels were not high enough to be a regulatory concern.

Chemical analysis of the oyster tissue collected from the two Cape Lookout sites showed low levels of all contaminants detected. Of those contaminants regulated by the EPA and USFDA, none were above action levels.

The data presented in this report gives much needed current levels of water quality, sediment contaminants and oyster contaminants in Cape Lookout National Seashore. Environmental monitoring of this region will help to determine effects of floodwaters from natural weather events, mainland runoff from upstream agricultural and industrial areas, and effects of recreational and commercial boating within park boundaries for future monitoring and comparison sampling. Based on the results from this report at these 20 sites, water, sediment, and oysters contain no or low contaminant levels. For background information on the state of North Carolina's coastal zone please see the list of NOAA research.

NOAA research on North Carolina coastal zone

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Abandoned village of Portsmouth at Cape Lookout National Seashore. Photo credit: NOAA.

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Table 1. List of sites sampled with water quality parameters in Cape Lookout National Seashore.

Site Name	Latitude (DD)	Longitude (DD)	Matrix	Date	Time	Depth (m)	Secchi Depth (m)	Temp (°C)	Salinity (ppt)
CL2021-001	34.68713	-76.64529	Sediment/ Water	7/27/2021	14:24	1.0	1.0	28.9	35.5
CL2021-002	34.67136	-76.59474	Sediment/ Water	7/27/2021	13.46	1.6	1.4	29.3	35.31
CL2021-003	34.63638	-76.52646	Sediment/ Water	7/27/2021	10:53	1.4	1.4	28.2	35.54
CL2021-004	34.64207	-76.52747	Sediment/ Water	7/27/2021	10:22	1.4	1.4	28.1	35.49
CL2021-005	34.64528	-76.52970	Sediment/ Water	7/27/2021	09:45	1.2	1.2	27.9	35.45
CL2021-006	34.61567	-76.52983	Sediment/ Water	7/27/2021	12:35	1.3	1.3	28.7	35.44
CL2021-007	34.61215	-76.53754	Sediment/ Water	7/27/2021	11:57	2.3	2.3	28.5	35.39
CL2021-007	34.61319	-76.53791	Oysters		NR	4	NR	22.1	32.4
CL2021-008	34.61459	-76.54798	Sediment/ Water	7/27/2021	11:25	1.3	1.3	28.4	35.54
CL2021-009	34.68687	-76.50105	Sediment/ Water	7/28/2021	14:23	0.6	0.6	29.2	35.51
CL2021-010	34.76914	-76.42194	Sediment/ Water	7/28/2021	12:30	1.7	1.7	29.6	36.14
CL2021-011	34.81447	-76.38739	Sediment/ Water	7/30/2021	10:45	1.4	1.4	27.4	35.9
CL2021-012	34.83038	-76.37008	Sediment/ Water	7/30/2021	10:00	0.8	0.8	27.6	35.98
CL2021-013	34.87738	-76.30556	Sediment/ Water	7/29/2021	14:03	1.2	1.2	29.2	34.77
CL2021-014	34.90209	-76.26803	Sediment/ Water	7/29/2021	13:22	1.1	1.1	29.2	35.44
CL2021-015	34.94987	-76.21571	Sediment/ Water	7/29/2021	12:43	0.8	0.8	29.6	22.35
CL2021-016	34.9959	-76.17521	Sediment/ Water	7/29/2021	10:25	1.3	1.3	27.8	24.26
CL2021-017	35.04943	-76.10895	Sediment/ Water	7/29/2021	09:24	1.3	1.3	27.9	21.06
CL2021-018	35.06552	-76.08483	Sediment/ Water	7/29/2021	08:41	0.8	0.8	27.1	22.68
CL2021-019	35.07090	-76.06851	Sediment/ Water/ Oysters		09:45	0.8	NR	NR	27.0
CL2021-020	35.07086	-76.05644	Sediment/ Water		10:35	0.6	NR	NR	26.0

Temp = temperature; NR = not recorded

Table 2. Measured nutrient levels and chlorophyll *a* levels in surface water at the sampled sites. MDL = method detection limit.

Site Name	Ammonia* (NH_4) [mg N/L]	Phosphate** (PO_4) [mg P/L]	Nitrite plus Nitrate*** (NO_3+NO_2) [mg N/L]	Chlorophyll *a* [µg/L]
CL2021-001	<MDL	0.0035	0.0016	2.28
CL2021-002	<MDL	<MDL	<MDL	2.34
CL2021-003	<MDL	<MDL	<MDL	0.407
CL2021-004	<MDL	<MDL	0.0038	1.29
CL2021-005	<MDL	0.0035	0.0034	1.11
CL2021-006	<MDL	<MDL	<MDL	21.90
CL2021-007	<MDL	0.0039	<MDL	1.55
CL2021-008	<MDL	<MDL	<MDL	0.78
CL2021-009	<MDL	<MDL	<MDL	2.42
CL2021-010	<MDL	<MDL	<MDL	2.05
CL2021-011	<MDL	<MDL	0.0047	3.55
CL2021-012	<MDL	<MDL	<MDL	6.20
CL2021-013	<MDL	<MDL	<MDL	3.36
CL2021-014	<MDL	<MDL	0.0021	6.22
CL2021-015	<MDL	0.0087	<MDL	9.58
CL2021-016	<MDL	<MDL	<MDL	9.07
CL2021-017	<MDL	<MDL	<MDL	9.67
CL2021-018	<MDL	<MDL	<MDL	1.07
CL2021-019	<MDL	0.0198	<MDL	11.00
CL2021-020	<MDL	0.0092	0.0026	19.20

*MDL = 0.009 mg N/L

**MDL = 0.0035 mg P/L

***MDL = 0.0015 mg N/L

Table 3. List of pharmaceutical and personal care products for which Cape Lookout sediments were analyzed. All products were below the method detection limit (ng/g levels). Method detection limits available upon request.

Acetaminophen	Sulfamerazine	Triclocarban	10-Hydroxy-Amitriptyline
Caffeine	Sulfamethazine	Triclosan	Alprazolam
Carbamazepine	Sulfamethizole	Warfarin	Amitriptyline
Clarithromycin	Sulfamethoxazole	Albuterol	Amlodipine
Cloxacillin	Sulfanilamide	Atenolol	Benzoylecgonine
Dehydronifedipine	Sulfathiazole	Atorvastatin	Benztropine
Digoxigenin	Thiabendazole	Cimetidine	Betamethasone
Diphenhydramine	Trimethoprim	Clonidine	Cocaine
Fluoxetine	Tylosin	Cotinine	Deet
Norfloxacin	2-Hydroxy Ibuprofen	Enalapril	Diazepam
Ofloxacin	Bisphenol-A	Hydrocodone	Fluocinonide
Oxacillin	Furosemide	Oxycodone	Fluticasone Propionate
Paraxanthine	Gemfibrozil	Triamterene	Hydrocortisone
Penicillin G	Glipizide	Busulfan	Meprobamate
Penicillin V	Glyburide	Citalopram	Methylprednisolone
Sulfachloropyridazine	Hydrochlorothiazide	Clotrimazole	Metprolol
Sulfadiazine	Ibuprofen	Etoposide	N-Desmethyldiltiazem
Sulfadimethoxine	Naproxen	Venlafaxine	Norfluoxetine
	Prednisone	Sertraline	Norverapamil
	Propoxyphene	Verapamil	Paroxetine
		Propranolol	Prednisolone

Table 4. List of human hormones for which Cape Lookout sediments and whole oyster tissue were analyzed. For sediments (ng/g dry mass) and oysters (ng/g wet weight), all fell below method detection limits. Method detection limits available upon request.

17a-Dihydroequilin	Allyl Trenbolone
17a-Estradiol	Androstenedione
17a-Ethynyl Estradiol	Desogestrel
17B-Estradiol	Mestranol
Diethylstilbestrol	Norethindrone
Equilenin	Norgestrel
Equilin	Progesterone
Estriol	Testosterone
Estrone	

Table 5A. List of pesticides for which Cape Lookout sediments were analyzed. All fell below method detection limits (ng/g levels) except for those in Table 5B. Method detection limits available upon request.

Aldrin	2,4'-DDD
Alpha-Hch	2,4'-DDE
Beta-Hch	2,4'-DDT
Chlorpyrifos	4,4'-DDD
Cis-Chlordane (Alpha-Chlordane)	4,4'-DDE
Cis-Nonachlor	4,4'-DDT
Dieldrin	
Endosulfan I	
Endosulfan II	
Endosulfan Sulfate	
Endrin	
Gamma-Chlordane	
Gamma-Hch (G-Bhc, Lindane)	
Heptachlor	
Heptachlor Epoxide	
Hexachlorobenzene	
Mirex	
Oxychlordane	
Trans-Nonachlor	

Table 5B. Cape Lookout sites for which pesticides were detected in sediments above the method detection limit.

Site name	Pesticide	Amount (ng/g dry mass)
CL2021-003	4,4'-DDD	0.041
CL2021-004	4,4'-DDD	0.064
CL2021-007	4,4'-DDD	0.053
CL2021-018	heptachlor epoxide	0.030
CL2021-019	cis-chlordane	0.018

Table 6A. List of alkylphenols for which Cape Lookout sediments and whole oyster tissue were analyzed. For sediments, all fell below method detection limits (ng/g dry mass) except for those in Table 6B. For oysters, all fell below method detection limits (ng/g wet weight levels). Method detection limits available upon request.

4-n-octylphenol
4-nonylphenol
NP1EO
NP2EO

Table 6B. Cape Lookout sites for which alkylphenols were detected in sediments above method detection limits.

Site Name	4-n-octylphenol (ng/g dry mass)
CL2021-013	2.71
CL2021-015	4.499
CL2021-017	1.36
CL2021-019	0.971

Table 7A. Analysis of total PAH50 in Cape Lookout sediments. MDL = method detection limit. See Table 7B below for list of total PAH50.

Site Name	Total PAH50 (ng/g dry mass)
CL2021-001	0.103
CL2021-002	37.049
CL2021-003	<MDL
CL2021-004	3.641
CL2021-005	<MDL
CL2021-006	0.978
CL2021-007	32.959
CL2021-008	3.761
CL2021-009	4.274
CL2021-010	26.882
CL2021-011	1.132
CL2021-012	0.180
CL2021-013	0.784
CL2021-014	1.269
CL2021-015	0.296
CL2021-016	3.481
CL2021-017	1.481
CL2021-018	3.021
CL2021-019	295.139
CL2021-020	139.074

Table 7B. The parent and alkylated PAH analytes measured in total PAH50 as defined by Boehm (2006).

PAH50 Analytes	
Parent PAH	Alkylated PAH
Naphthalene	C1-Naphthalenes
Biphenyl	C2-Naphthalenes
Acenaphthene	C3-Naphthalenes
Acenaphthylene	C4-Naphthalenes
Fluorene	C1-Fluorenes
Dibenzofuran	C2-Fluorenes
Dibenzothiophene	C3-Fluorenes
Phenanthrene	C1-Dibenzothiophenes
Anthracene	C2-Dibenzothiophenes
Fluoranthene	C3-Dibenzothiophenes
Pyrene	C4-Dibenzothiophenes
Benz(A)Anthracene	C1-Phenanthrenes/Anthracenes
Benzo(B)Naphtho(2,1-D)Thiophene	C2-Phenanthrenes/Anthracenes
Chrysene+Triphenylene	C3-Phenanthrenes/Anthracenes
Benzo(A)Fluoranthene	C4-Phenanthrenes/Anthracenes
Benzo(B)Fluoranthene	C1-Fluoranthenes/Pyrenes
Benzo(J)Fluoranthene	C2-Fluoranthenes/Pyrenes
Benzo(K)Fluoranthene	C3-Fluoranthenes/Pyrenes
Benzo(A)Pyrene	C4-Fluoranthenes/Pyrenes
Benzo(E)Pyrene	C1-Chrysenes/Benzanthracenes
Dibenzo(A,H)Anthracene	C2-Chrysenes/Benzanthracenes
Indeno(1,2,3-C,D)Pyrene	C3-Chrysenes/Benzanthracenes
Benzo(G,H,I)Perylene	C4-Chrysenes/Benzanthracenes
	C1-Naphthobenzothiophenes
	C2-Naphthobenzothiophenes
	C3-Naphthobenzothiophenes
	C4-Naphthobenzothiophenes

Table 8. Analysis of metals in Cape Lookout sediments. All values are µg/g dry mass. MDL = method detection limit.

MDLs: Ag ≤ 0.228; As ≤0.258; Be ≤0.073; Cd ≤0.198; Cu ≤0.721; Sb ≤1.21; Sn ≤0.24; Tl ≤0.115; U ≤0.296. Ag, Cd, Sb not detected at any site.

Site Name	Al	As	Ba	Be	Co	Cr	Cu	Fe	Hg	Li	Mn	Ni	Pb	Se	Sn	Tl	U	V	Zn
CL2021-001	693.5	1.0	4.2	0.1	0.6	4.8	<MDL	1512.6	0.002	2.5	11.5	1.0	1.5	0.3	<MDL	<MDL	<MDL	2.7	4.3
CL2021-002	2573.6	2.6	7.3	0.2	1.3	8.5	1.8	3647.9	0.007	6.7	29.8	2.8	2.8	0.7	<MDL	<MDL	0.3	7.6	10.3
CL2021-003	510.0	0.6	2.9	<MDL	0.4	3.7	0.7	937.5	0.002	2.2	10.6	0.8	1.9	0.5	<MDL	<MDL	<MDL	2.4	3.3
CL2021-004	1533.2	1.1	6.2	0.1	0.8	5.5	1.1	2086.3	0.004	4.2	18.3	1.7	2.0	0.6	<MDL	<MDL	<MDL	4.6	6.1
CL2021-005	298.8	0.8	2.1	<MDL	0.3	2.2	<MDL	536.1	0.002	1.5	4.5	0.8	0.9	0.6	<MDL	<MDL	<MDL	1.6	2.4
CL2021-006	529.3	<MDL	3.8	<MDL	0.5	3.5	<MDL	936.7	0.002	2.2	11.8	1.5	2.3	0.5	<MDL	<MDL	<MDL	2.6	3.7
CL2021-007	738.7	1.0	4.6	<MDL	0.6	3.7	1.2	1496.4	0.007	2.7	11.2	3.2	1.6	0.7	<MDL	<MDL	<MDL	3.4	4.3
CL2021-008	432.3	1.3	3.0	<MDL	0.5	2.7	<MDL	1226.1	0.002	1.9	10.4	2.6	0.8	0.7	<MDL	<MDL	<MDL	2.9	2.6
CL2021-009	672.4	0.6	4.9	<MDL	0.5	3.6	<MDL	927.0	0.003	2.5	7.8	0.7	1.0	0.3	<MDL	<MDL	<MDL	1.9	3.5
CL2021-010	1282.8	0.6	6.4	0.1	0.8	4.7	0.8	1874.9	0.006	3.9	16.2	1.3	1.6	0.3	<MDL	<MDL	<MDL	3.5	5.8
CL2021-011	866.3	0.5	5.2	0.1	0.7	4.3	2.4	1265.2	0.003	3.6	14.2	1.0	2.2	0.5	<MDL	<MDL	<MDL	2.8	5.2
CL2021-012	742.8	0.4	5.9	<MDL	0.6	4.4	<MDL	1069.9	0.003	2.9	11.7	0.8	1.7	0.3	<MDL	<MDL	<MDL	2.4	5.6
CL2021-013	603.5	0.8	4.4	0.1	0.6	3.7	<MDL	840.4	0.005	2.6	6.9	0.9	0.9	0.4	<MDL	<MDL	<MDL	1.8	3.4
CL2021-014	832.2	0.3	6.4	0.1	0.6	4.3	<MDL	1164.2	0.004	3.1	10.8	0.8	1.7	0.2	<MDL	<MDL	0.4	2.7	4.5
CL2021-015	637.5	<MDL	4.9	<MDL	0.5	4.1	<MDL	918.4	0.003	2.7	11.0	0.8	1.8	0.6	<MDL	<MDL	<MDL	2.6	3.9
CL2021-016	911.0	0.5	6.0	<MDL	0.6	3.3	0.9	1176.3	0.005	3.1	9.7	0.8	1.2	0.2	<MDL	<MDL	<MDL	2.1	7.3
CL2021-017	538.1	0.4	4.3	<MDL	0.4	2.5	<MDL	671.6	0.003	2.4	5.2	0.6	0.7	0.2	<MDL	<MDL	<MDL	1.1	2.8
CL2021-018	1606.4	0.5	4.1	0.1	0.7	4.8	<MDL	1608.1	0.005	4.0	18.9	1.0	1.5	0.3	<MDL	<MDL	<MDL	2.8	5.1
CL2021-019	15804.5	5.1	38.8	0.6	4.6	26.5	6.0	13620.8	0.016	26.6	141.0	9.5	7.1	1.3	0.7	0.2	0.8	26.3	34.7

Table 9. Effects Range Low (ERL) and Effects Range Medium (ERM) values for metals and organic compounds commonly found in sediments. Based on Long et al. (1995).

	ERL Guideline	ERM Guideline
Metals (µg/g)		
Arsenic	8.2	70
Cadmium	1.2	9.6
Chromium	81	370
Copper	34	270
Lead	46.7	218
Mercury	0.15	0.71
Nickel	20.9	46.1
Silver	1	3.7
Zinc	150	410
Organic compounds (ng/g)		
Acenaphthene	16	500
Acenaphthylene	44	640
Anthracene	85.3	1,100
Benzo[*a*]anthracene	261	1,600
Benzo[*a*]pyrene	430	1,600
Chrysene	384	2,800
Dibenz[*a,h*]anthracene	63.4	260
Fluoranthene	600	5,100
Fluorene	19	540
2-Methylnaphthalene	70	670
Naphthalene	160	2,100
Phenanthrene	240	1,500
Pyrene	665	2,600
Total PAHs	4020	44,792
Chlordane	0.5	6
4,4’-DDD	2	20
4,4’-DDE	2.2	27
Total DDTs	1.58	46.1
Total PCBs	22.7	180

Table 10A. List of PFAS compounds for which Cape Lookout sediments and whole oyster tissue were analyzed. All fell below method detection limits except for those in Table 10B for sediment (ng/g dry mass) and Table 10C for oysters (ng/g wet weight). Method detection limits available upon request.

PFBA	PFDA
PFPeA	PFNS
PFBS	PFUnA
4:2 FTS	PFDoA
6:2 FTS	PFTriA
8:2 FTS	PFTreA
PFHxA	PFOSA
PFPeS	N-EtFOSAA
PFHpA	N-MeFOSAA
PFHxS	PFDS
PFOA	HFPO-DA
PFHpS	ADONA
PFNA	9Cl-PF3ONS
PFOS	11Cl-PF3OUdS

Table 10B. Cape Lookout sites for which PFAS compounds were detected in sediments above the method detection limit.

Site name	PFAS Compound	Amount (ng/g dry mass)
CL2021-001	PFOS	0.048
CL2021-002	PFDA	0.056
CL2021-005	PFOA	0.105
CL2021-006	PFBA	0.046
CL2021-008	PFBA	0.070
CL2021-009	PFOA	0.074
CL2021-014	PFOA	0.078
CL2021-019	PFOS	0.069
CL2021-020	PFOS	0.120

Table 10C. PFAS compounds detected in whole oyster tissue from two Cape Lookout sites. Values are averages of three oysters per site. Values in parentheses are standard error.

Site name	PFAS Compound	Amount (ng/g wet weight)
CL2021-007	PFBA	0.157 (0.09)
CL2021-007	PFOS	0.054 (0.02)
CL2021-019	PFBA	0.112 (0.06)

Table 11. List of PBDE (polybrominated diphenyl ether) compounds for which Cape Lookout sediments and whole oyster tissue were analyzed. All fell below method detection limits (ng/g dry mass) for both sediment and oysters. Method detection limits available upon request.

PBDE-1	PBDE-116
PBDE-2	PBDE-118
PBDE-3	PBDE-126
PBDE-10	PBDE-85
PBDE-7	PBDE-155
PBDE-11	PBDE-154
PBDE-8	PBDE-153
PBDE-12	PBDE-138
PBDE-13	PBDE-166
PBDE-15	PBDE-183
PBDE-32	PBDE-181
PBDE-30	PBDE-190
PBDE-17	PBDE-202
PBDE-25	PBDE-201
PBDE-33	PBDE-204
PBDE-28	PBDE-197
PBDE-35	PBDE-198/199/203/200
PBDE-37	PBDE-196
PBDE-75	PBDE-205
PBDE-71/49	PBDE-194
PBDE-47	PBDE-195
PBDE-66	PBDE-208
PBDE-77	PBDE-207
PBDE-100	PBDE-206
PBDE-119	PBDE-209
PBDE-99	

Table 12. List of PBB (polybrominated biphenyl) compounds for which Cape Lookout sediments and whole oyster tissue were analyzed. All fell below method detection limits (ng/g dry mass) for both sediment and oysters. Method detection limits available upon request.

PBB 1	PBB 26
PBB 2	PBB 31
PBB 3	PBB 53
PBB 4	PBB 52
PBB 10	PBB 49
PBB 7	PBB 103
PBB 9	PBB 80
PBB 15	PBB 77
PBB 30	PBB 155
PBB 18	

Table 13. Microtox effective concentration (EC50) of sediment that causes a 50% reduction in light emission of Aliivibrio fischeri from Cape Lookout sites. EC50 corrected for dry weight of sediment.

Sediment is considered toxic if EC50 <0.5 and %Silt/Clay <20 or EC50 <0.2 and %Silt/Clay >20.

Site Name	EC50 (%)	Silt/Clay (%)
CL2021-001	>15.4402	0.286
CL2021-002	1.3795	13.220
CL2021-003	>15.3935	0.856
CL2021-004	>16.0873	4.801
CL2021-005	>16.3231	0.856
CL2021-006	3.5107	1.242
CL2021-007	3.7395	2.528
CL2021-008	2.2976	1.332
CL2021-009	>15.4160	1.077
CL2021-010	7.6729	3.873
CL2021-011	12.2821	1.530
CL2021-012	>16.0180	1.435
CL2021-013	>14.2205	1.462
CL2021-014	10.6987	1.896
CL2021-015	>15.7058	1.483
CL2021-016	>15.0999	2.408
CL2021-017	>15.0969	1.290
CL2021-018	>14.9733	2.150
CL2021-019	0.2948	43.608
CL2021-020	0.2077	44.530

Table 14A. List of pharmaceutical and personal care products for which whole oyster tissue collected from two Cape Lookout sites were analyzed. All products were below the method detection limit (ng/g wet weight), except those in Table 14B. Method detection limits available upon request.

Acetaminophen	2-Hydroxy Ibuprofen	albuterol	10-hydroxy-amitriptyline
azithromycin	Bisphenol-A	Amphetamine	Alprazolam
Caffeine	Furosemide	atenolol	Amitriptyline
Carbadox	Gemfibrozil	Atorvastatin	Amlodipine
Carbamazepine	Glipizide	Cimetidine	Benzoylecgonine
Ciprofloxacin	Glyburide	Clonidine	Benztropine
Clarithromycin	Hydrochlorothiazide	Codeine	Betamethasone
Clinafloxacin	Ibuprofen	Cotinine	Cocaine
Cloxacillin	Naproxen	Enalapril	DEET
Dehydronifedipine	Triclocarban	Hydrocodone	Diazepam
Digoxigenin	Triclosan	metformin	Fluocinonide
Digoxin	Warfarin	Oxycodone	Fluticasone propionate
Diltiazem	Penicillin G	Ranitidine	Hydrocortisone
Diphenhydramine	Penicillin V	Triamterene	Meprobamate
Enrofloxacin	Roxithromycin	Busulfan	Methylprednisolone
Flumequine	Sarafloxacin	Citalopram	Metprolol
Fluoxetine	Sulfachloropyridazine	Clotrimazole	N-Desmethyldiltiazem
Lincomycin	Sulfadiazine	Etoposide	Norfluoxetine
Lomefloxacin	Sulfadimethoxine	Venlafaxine	Norverapamil
Miconazole	Sulfamerazine	Paroxetine	Valsartan
Norfloxacin	Sulfamethazine	Prednisolone	Verapamil
Norgestimate	Sulfamethizole	Prednisone	Tylosin
Ofloxacin	Sulfamethoxazole	Promethazine	Theophylline
Ormetoprim	sulfanilamide	Propoxyphene	
Oxacillin	Sulfathiazole	Propranolol	
Oxolinic Acid	Thiabendazole	Sertraline	
Paraxanthine	Trimethoprim	Simvastatin	

Table 14B. Levels of pharmaceutical and personal care products detected in oysters above method detection limits at two Cape Lookout sites. Values are averages of three subsamples per site in ng/g wet weight except where noted. Values in parentheses are standard error.

Site name	Product	Amount (ng/g wet weight)
CL2021-007	Amphetamine	0.719 (0.34)*
CL2021-007	Clonidine	0.582**
CL2021-007	Cotinine	0.717**
CL2021-019	Albuterol	0.205**
CL2021-019	DEET	6.73 (2.04)

*average of two subsamples

**one subsample

Table 15. List of butyl tin compounds for which whole oyster tissue collected from two Cape Lookout sites were analyzed. All products were below the method detection limit (ng/g dry mass). Method detection limits available upon request.

MBT
DBT
TBT
TeBT

Table 16A. List of pesticides, organic chlorine compounds, and polychlorinated biphenyls (PCBs) for which whole oyster tissue collected from two Cape Lookout sites were analyzed. All fell below method detection limits (ng/g dry mass) except for those in Table 16B. Method detection limits available upon request.

Aldrin	Dieldrin
Endrin	Endrin Aldehyde
Endrin Ketone	Heptachlor
Heptachlor-Epoxide	Oxychlordane
Alpha-Chlordane	Gamma-Chlordane
Trans-Nonachlor	Cis-Nonachlor
Alpha-HCH	Beta-HCH
Delta-HCH	Gamma-HCH
DDMU	2,4’-DDD
4,4’-DDD	2,4’-DDE
4,4’-DDE	2,4’-DDT
4,4’-DDT	1,2,3,4-Tetrachlorobenzene
1,2,4,5-Tetrachlorobenzene	Hexachlorobenzene
Pentachloroanisole	Pentachlorobenzene
Endosulfan II	Endosulfan I
Endosulfan Sulfate	Mirex
Chlorpyrifos	PCBs - 156 compounds (list upon request)

Table 16B. Levels of pesticides, organic chlorine compounds, and polychlorinated biphenyls (PCBs) detected in oyster tissue above method detection limits at two Cape Lookout sites. Values are averages of three subsamples per site in ng/g dry mass except where noted. Values in parentheses are standard error.

Site name	Product	Amount (ng/g dry mass)
CL2021-007	4,4’-DDE	0.545 (0.58)*
CL2021-007	PCB 66/80	0.300**
CL2021-007	PCB 153/168	0.579 (0.022)
CL2021-007	PCB 138/164/163	0.286 (0.014)*
CL2021-007	PCB 187/182	0.284 (0.0)*
CL2021-019	4,4’-DDE	0.423 (0.004)*

*average of two subsamples

**one subsample

Table 17A. List of PAHs, alkyl isomers and hopanes for which whole oyster tissue collected from two Cape Lookout sites were analyzed. All fell below method detection limits (ng/g dry mass) except for those in Table 17B. Method detection limits available upon request.

cis/trans Decalin	C1-Fluoranthenes/Pyrenes	2-Methylnaphthalene
C1-Decalins	C2-Fluoranthenes/Pyrenes	1-Methylnaphthalene
C2-Decalins	C3-Fluoranthenes/Pyrenes	2,6-Dimethylnaphthalene
C3-Decalins	C4-Fluoranthenes/Pyrenes	1,6,7-Trimethylnaphthalene
C4-Decalins	Naphthobenzothiophene	1-Methylfluorene
Naphthalene	C1-Naphthobenzothiophenes	4-Methyldibenzothiophene
C1-Naphthalenes	C2-Naphthobenzothiophenes	2/3-Methyldibenzothiophene
C2-Naphthalenes	C3-Naphthobenzothiophenes	1-Methyldibenzothiophene
C3-Naphthalenes	C4-Naphthobenzothiophenes	3-Methylphenanthrene
C4-Naphthalenes	Benz(a)anthracene	2-Methylphenanthrene
Benzothiophene	Chrysene/Triphenylene	2-Methylanthracene
C1-Benzothiophenes	C1-Chrysenes	4/9-Methylphenanthrene
C2-Benzothiophenes	C2-Chrysenes	1-Methylphenanthrene
C3-Benzothiophenes	C3-Chrysenes	3,6-Dimethylphenanthrene
C4-Benzothiophenes	C4-Chrysenes	Retene
Biphenyl	Benzo(b)fluoranthene	2-Methylfluoranthene
Acenaphthylene	Benzo(k,j)fluoranthene	Benzo(b)fluorene
Acenaphthene	Benzo(a)fluoranthene	C29-Hopane
Dibenzofuran	Benzo(e)pyrene	18a-Oleanane
Fluorene	Benzo(a)pyrene	C30-Hopane
C1-Fluorenes	Perylene	C20-TAS
C2-Fluorenes	Indeno(1,2,3-c,d)pyrene	C21-TAS
C3-Fluorenes	Dibenzo(a,h)anthracene	C26(20S)-TAS
Carbazole	C1-Dibenzo(a,h)anthracenes	C26(20R)/C27(20S)-TAS
Anthracene	C2-Dibenzo(a,h)anthracenes	C28(20S)-TAS
Phenanthrene	C3-Dibenzo(a,h)anthracenes	C27(20R)-TAS
C1-Phenanthrenes/Anthracenes	Benzo(g,h,i)perylene	C28(20R)-TAS
C2-Phenanthrenes/Anthracenes	C1-Dibenzothiophenes	
C3-Phenanthrenes/Anthracenes	C2-Dibenzothiophenes	
C4-Phenanthrenes/Anthracenes	C3-Dibenzothiophenes	
Dibenzothiophene	C4-Dibenzothiophenes	
	Fluoranthene	
	Pyrene	

Table 17B. Levels of PAHs detected in oyster tissue above method detection limits at two Cape Lookout sites. Values are averages of three subsamples per site in ng/g dry mass except where noted. Values in parentheses are standard error.

Site name	Product	Amount (ng/g dry mass)
CL2021-007	C1-Naphthalenes	4.54 (0.24)
CL2021-007	Biphenyl	2.53 (0.21)
CL2021-007	Acenaphthylene	6.17 (0.35)
CL2021-007	Acenaphthene	20.48 (0.85)
CL2021-007	Dibenzofuran	8.42 (0.39)
CL2021-007	Fluorene	19.08 (0.51)
CL2021-007	Carbazole	5.59 (1.00)*
CL2021-007	Anthracene	40.13 (5.43)
CL2021-007	Phenanthrene	101.37 (5.60)
CL2021-007	C1-Phenanthrenes/Anthracenes	44.98 (3.64)
CL2021-007	C2-Phenanthrenes/Anthracenes	33.49 (3.30)
CL2021-007	C3-Phenanthrenes/Anthracenes	11.17 (0.37)
CL2021-007	Dibenzothiophene	5.80 (0.24)
CL2021-007	C1-Dibenzothiophenes	4.44 (0.12)
CL2021-007	C2-Dibenzothiophenes	8.30 (0.03)
CL2021-007	C3-Dibenzothiophenes	5.90 (0.32)
CL2021-007	Fluoranthene	189.57 (16.97)
CL2021-007	Pyrene	103.86 (10.3)
CL2021-007	C1-Fluoranthenes/Pyrenes	70.94 (4.54)
CL2021-007	C2-Fluoranthenes/Pyrenes	12.97 (1.09)
CL2021-007	Naphthobenzothiophene	26 (0.58)
CL2021-007	C1-Naphthobenzothiophenes	6.09 (0.61)
CL2021-007	Benz(a)anthracene	71.52 (5.88)
CL2021-007	Chrysene/Triphenylene	74.54 (5.29)
CL2021-007	C1-Chrysenes	15.07 (1.44)
CL2021-007	Benzo(b)fluoranthene	36.69 (4.72)
CL2021-007	Benzo(k,j)fluoranthene	27.46 (2.66)
CL2021-007	Benzo(a)fluoranthene	5.47 (0.48)
CL2021-007	Benzo(e)pyrene	22.55 (3.18)
CL2021-007	Benzo(a)pyrene	10.09 (1.23)
CL2021-007	Perylene	16.9**
CL2021-007	Indeno(1,2,3-c,d)pyrene	4.21 (0.30)
CL2021-007	Benzo(g,h,i)perylene	3.77 (0.39)
CL2021-019	C1-Naphthalenes	5.39 (3.02)
CL2021-019	Biphenyl	7.21**
CL2021-019	Fluorene	7.15 (1.11)
CL2021-019	Phenanthrene	3.80**
CL2021-019	Fluoranthene	4.71 (0.30)
CL2021-019	Pyrene	4.57 (0.70)
CL2021-019	Benz(a)anthracene	1.55 (0.17)
CL2021-019	Chrysene/Triphenylene	2.72 (0.15)

*average of two subsamples

**one subsample

Table 17C. Levels of alkyl isomers detected in oyster tissue above method detection limits at two Cape Lookout sites. Values are averages of three subsamples per site in ng/g dry mass except where noted. Values in parentheses are standard error. No hopanes were detected in oyster tissue.

Site name	Product	Amount (ng/g dry mass)
CL2021-007	2-Methylnaphthalene	3.77 (0.20)
CL2021-007	1-Methylnaphthalene	3.15 (0.24)
CL2021-007	4-Methyldibenzothiophene	2.33 (0.17)
CL2021-007	2/3-Methyldibenzothiophene	2.68 (0.03)
CL2021-007	3-Methylphenanthrene	16.95 (0.94)
CL2021-007	2-Methylphenanthrene	17.95 (1.47)
CL2021-007	2-Methylanthracene	8.35 (1.06)
CL2021-007	4/9-Methylphenanthrene	9.98 (0.90)
CL2021-007	1-Methylphenanthrene	9.16 (0.68)
CL2021-007	3,6-Dimethylphenanthrene	3.67 (0.25)
CL2021-007	2-Methylfluoranthene	13.10 (1.06)
CL2021-007	Benzo(b)fluorene	29.44 (1.71)
CL2021-020	2-Methylnaphthalene	2.69 (0.39)
CL2021-020	1-Methylnaphthalene	14.5*

*one subsample

Table 18. Analysis of metals in whole oyster tissues from two Cape Lookout sites. Values are averages of three oysters per site in µg/g wet weight. Values in parentheses are standard error. MDL = method detection limit.

MDLs: Ag ≤0.038; Be ≤0.014; Sb ≤0.234; Sn ≤0.0346; Tl ≤0.021; U ≤0.054

Below MDL for all oysters tested: Be, Sb, Tl, U

Site Name	Ag	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Hg	Li	Mn	Ni	Pb	Se	Sn	V	Zn
CL2021-007	0.100	15.792	3.528	0.153	0.093	0.090	0.365	5.472	29.750	0.014	0.162	1.084	0.267	0.052	0.526	0.028	0.174	87.437
	(0.01)	(0.72)	(0.04)	(0.05)	(0.01)	(0.01)	(0.15)	(0.76)	(3.26)	(0.00)	(0.01)	(0.05)	(0.03)	(0.01)	(0.01)	(0.03)	(0.02)	(7.15)
CL2021-019	<MDL	27.532	1.493	0.112	0.069	0.098	0.161	3.887	48.326	0.011	0.154	1.703	0.229	0.125	0.405	<MDL	0.111	82.052
		(1.4)	(0.03)	(0.01)	(0.01)	(0.00)	(0.01)	(0.68)	(0.57)	(0.00)	(0.00)	(0.09)	(0.01)	(0.02)	(0.01)		(0.00)	(6.75)

Table 19. Analysis of sediment for the bacteria *Clostridium perfringens* from Cape Lookout sites.

Site Name	CFU/g dry wt.
CL2021-001	<1
CL2021-002	40.4
CL2021-003	<1
CL2021-004	23.9
CL2021-005	<1
CL2021-006	<1
CL2021-007	7.31
CL2021-008	11.5
CL2021-009	5.04
CL2021-010	<1
CL2021-011	<1
CL2021-012	<1
CL2021-013	<1
CL2021-014	18.3
CL2021-015	<1
CL2021-016	<1
CL2021-017	<1
CL2021-018	<1
CL2021-019	415
CL2021-020	804

Table 20. Analysis of sediment for carbon from Cape Lookout sites. MDL = method detection limit

Site Name	Total Carbon (%)	Total Organic Carbon (%)	Total Inorganic Carbon (%)
CL2021-001	0.2	0.05	0.15
CL2021-002	0.56	0.36	0.2
CL2021-003	0.12	0.04	0.07
CL2021-004	0.41	0.18	0.24
CL2021-005	0.21	0.03	0.18
CL2021-006	0.39	0.05	0.34
CL2021-007	1.5	0.2	1.3
CL2021-008	0.81	0.08	0.73
CL2021-009	0.05	0.05	<MDL
CL2021-010	0.18	0.15	0.03
CL2021-011	0.11	0.05	0.05
CL2021-012	0.08	0.04	0.04
CL2021-013	0.06	0.04	<MDL
CL2021-014	0.09	0.06	<MDL
CL2021-015	0.05	0.04	<MDL
CL2021-016	0.1	0.07	0.04
CL2021-017	0.06	0.05	<MDL
CL2021-018	0.08	0.06	<MDL
CL2021-019	1.62	1.17	0.45
CL2021-020	1.64	1.69	0.00

Figure 1. Sites sampled in Cape Lookout National Seashore.

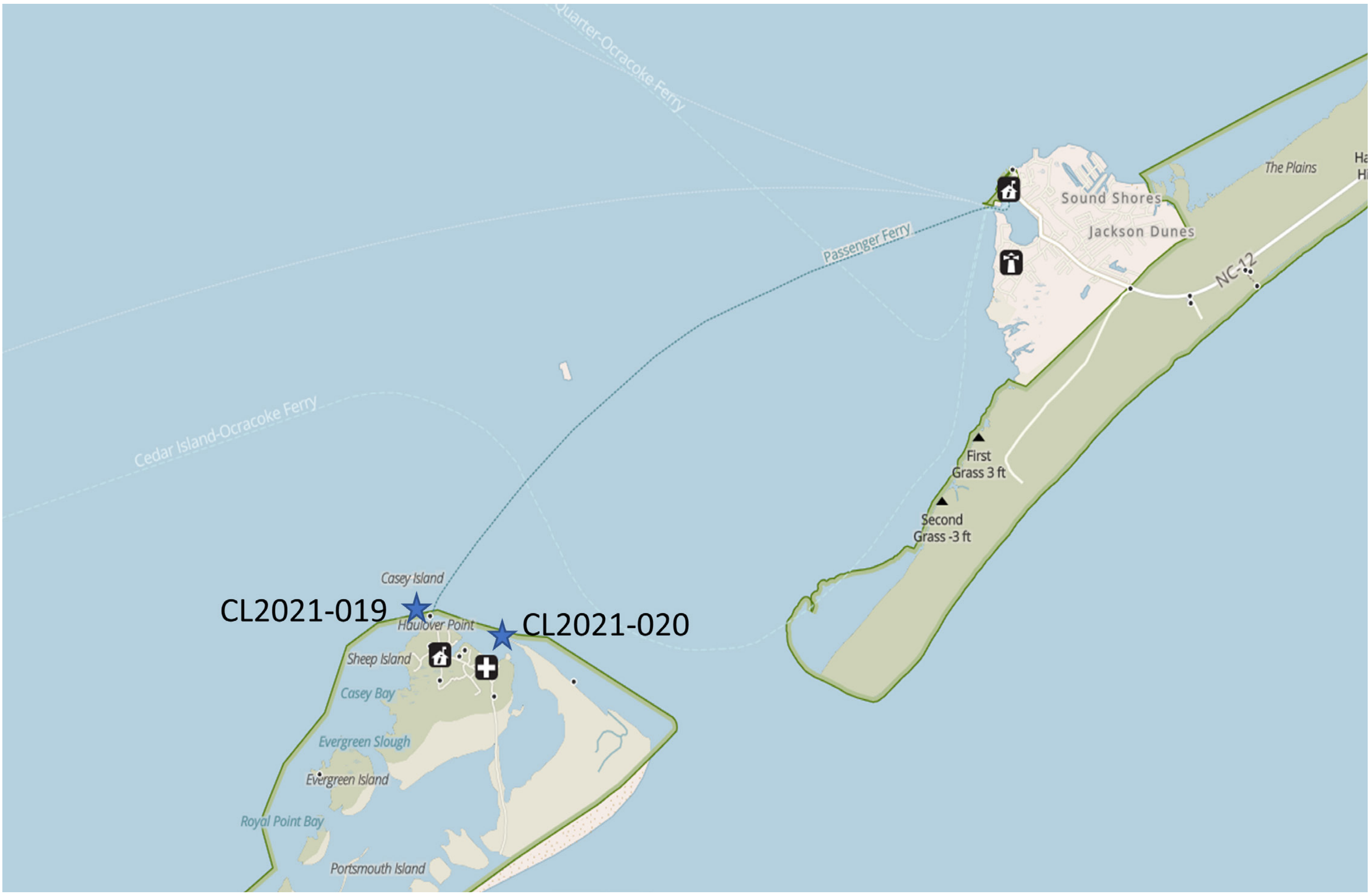

Figure 2. Close up of sites CL2021-019 and CL2021-020 showing ferry routes and abandoned village of Portsmouth.

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