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Terrestrial Vegetation Monitoring at Cape Hatteras National Seashore

2023 Data Summary—Cycle 2 and Newly Established Cycle 1 Plots

The Southeast Coast Network (SECN) surveyed long-term vegetation monitoring plots within Cape Hatteras National Seashore in July and August 2023. Above, Mallorie Davis (SECN Biological Science Technician) and Scott Ward (North Carolina Botanical Garden) use survey tape to establish plot boundaries within a typical graminoid- and herbaceous-dominated backdune swale. Dark green clumps in the background are stunted individuals of southern red cedar (*Juniperus silicicola*).

NPS / M. FORBES BOYLE

Terrestrial Vegetation Monitoring at Cape Hatteras National Seashore: 2023 Data Summary—Cycle 2 and Newly Established Cycle 1 Plots

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Abstract

Parks within the Southeast Coast Network (SECN) support diverse terrestrial vegetation communities, and long-term monitoring is essential for detecting trends and assessing ecosystem condition. Vegetation within SECN parks is sampled using 20 × 20 meter (65.6 × 65.6 ft) plots. This report summarizes vegetation status at Cape Hatteras National Seashore in 2023, representing the second monitoring cycle following baseline data collection in 2019. In 2019, 52 plots were established across four habitat types—nontidal wetlands, tidal wetlands, upland forests, and upland open grasslands—and four management units: Bodie Island, North Hatteras Island, South Hatteras Island, and Ocracoke Island. All plots were resampled in 2023, and 19 additional plots were established, increasing the total sample size to 71. Across all plots, 294 vascular plant taxa were documented, including 21 taxa not previously recorded in park species lists, including the invasive *Rosa multiflora*. Nineteen taxa are designated as rare within North Carolina, including two state-threatened species: blue witchgrass (*Dichanthelium caerulescens)* and Gulf Coast spikerush (*Eleocharis cellulosa*). Live tree basal area (m^2/ha) increased between 2019 and 2023 for all species except swamp bay (*Persea palustris*) in upland forest plots. Within the South Hatteras Island unit, 25% of swamp bay individuals classified as alive in 2019 were dead in 2023, and an additional 50% exhibited severe decline or were functionally dead. Observed symptoms are consistent with laurel wilt disease, a fungal pathogen vectored by an invasive ambrosia beetle that has caused extensive mortality of Lauraceae species across the southeastern United States. Aside from impacts associated with laurel wilt disease, very few widespread disturbances and threats were detected within sampled plots in 2023. A vegetation health scorecard was developed for each management unit and habitat type. Invasive plant species occurred across all habitats, representing a consistent stressor; however, native species diversity was rated as “Good” across all monitored habitats. Despite ongoing coastal development and accelerating rates of sea-level rise, Cape Hatteras National Seashore continues to function as a protected refuge for diverse plant assemblages along the Outer Banks of North Carolina.

Acknowledgments

Field crew members who assisted with data collection in 2023 on Cape Hatteras National Seashore (CAHA) included Wylie Paxton (NPS Appalachian-Piedmont-Coastal [APC] Zone Lead Fire Effects Monitor), Alyssa Sanderson (former Southeast Coast Network Scientist in Parks Intern), Scott Ward (North Carolina Botanical Garden, NPS contractor), and this report's two authors—Forbes Boyle (Southeast Coast Network Botanist and Terrestrial Vegetation Monitoring Protocol Lead) and Mallorie Davis (Southeast Coast Network Biological Science Technician). Scott also provided unknown plant identification support following the field season. Thanks to Matt Wood (NPS APC Zone Fire Ecologist) for supporting this monitoring effort and lending APC Zone staff to assist with fieldwork. CAHA resource staff provided logistical support and reviewed safety plans both prior to and during the field season. A special thanks to Meaghan Johnson (CAHA Chief of Resource Management and Science), Michelle Tongue (CAHA Deputy Chief of Resource Management and Science), and Paul Doshkov (CAHA Biological Science Technician) for their support throughout the field season. We are grateful to Paul for helping pull our field truck out of the roadside ditch one of our field monitoring mornings. Bruce Sorrie (retired botanist with the North Carolina Natural Heritage Program) provided images of state rare species featured in the "Preserve-Scale Species Diversity and Notable Species Information" subsection of the Results section of this report. Finally, thanks to Mark Hynds (Southeast Coast Network Editor) for editorial support and development of photopoint array images, which are available in the Supplemental Materials (Boyle and Davis 2026) accompanying this report.

The 2023 vegetation monitoring fieldwork at Cape Hatteras included support from multiple NPS divisions and partners. Left, field crew members pictured above from left to right included Mallorie Davis (SECN, Biotech), Alyssa Sanderson (SECN, former Scientist in Parks intern), Forbes Boyle (SECN, Botanist), and Wylie Paxton (APC Zone Lead Fire Effects Monitor). Right, Scott Ward (North Carolina Botanical Garden) and Alyssa Sanderson.
NPS / MALLORIE DAVIS (left); NPS / M. FORBES BOYLE (right)

Summary and Key Findings

The Southeast Coast Network (SECN) conducts long-term terrestrial vegetation monitoring as part of the National Park Service's (NPS) Inventory and Monitoring Program. The vegetation community vital sign is one of the primary-tier resources identified by SECN park managers, and monitoring is conducted at 14 network parks. Monitoring plants and their associated communities over time allows for targeted understanding of ecosystems within the SECN geography, which provides managers with information about the degree of change within their parks' natural vegetation.

2023 marked the second year of conducting this monitoring effort at Cape Hatteras National Seashore (NS). From July through August, 52 vegetation plots established in 2019 were resampled ("plot revisits," "Cycle 2") and 19 plots were established during this monitoring year ("plot establishment," "Cycle 1"). Data collected in each plot included a list of species present and cover of each species, woody stem seedling/sapling counts and adult tree (greater than 10 centimeters [3.9 inches]) diameters at breast height (DBH), overall tree health, observed disturbance, and woody biomass (i.e., fuel load) estimates. For Cycle 1 plots established in 2023, landform and soil data were also collected.

Plot summaries and analyses were stratified across four broad habitat types within four non-contiguous management units of the seashore. Habitat types included nontidal wetlands, tidal wetlands, upland forests and shrublands, and upland open grasslands; management units included Bodie Island, North Hatteras Island, South Hatteras Island, and Ocracoke Island. The four broad habitat types represented the dominant terrestrial natural and semi-natural vegetation types of the seashore. Vegetation communities of the nontidal wetland type included interdune marshes dominated by common threesquare (*Schoenoplectus pungens* var. *pungens*), cattails (*Typha* sp.), and other herbaceous and graminoid species; flats and interdune swales dominated by 2 to 8 meter (6.6 to 26.2 ft) tall common wax-myrtle (*Morella cerifera*) with a scattered, emergent canopy of southern red cedar (*Juniperus silicicola*); and shrub swamps located in old dune swales and depressions surrounded by upland maritime forests. Collectively, this broad habitat type exhibited the highest range of variation of vegetation structure and diversity among all habitat types of the seashore. Its distribution is generally evenly distributed across all four management units owing to the constant presence of common wax-myrtle shrub swales on the outer edge of backdune habitat across the seashore. Graminoid-dominated tidal wetlands occurred on the estuarine side of Bodie, North Hatteras, and Ocracoke Islands. This habitat type differed from nontidal wetlands due to routine overland flooding of estuarine or sea water. Flooding can occur daily, brought on by lunar-driven tidal fluctuations, or flooding can be irregular, brought on by wind events. Water sources of nontidal wetland habitat types are restricted to rainfall, groundwater, and occasional overland flow during high storm surge events. Tidal wetlands of Cape Hatteras NS occur across a salinity gradient from hypersaline to freshwater. A site's vegetation diversity and structure typically correspond to these salinity ranges. Marshes on low geomorphic landscape positions that experience daily flooding of full saline water are dominated by smooth cordgrass (*Spartina alterniflora*), while those that experience routine flooding of brackish water (from mixing of sea water from the ocean and riverine

water from the estuary) are dominated by black needle rush (*Juncus roemerianus*). These "low" salt and brackish marshes are not included in this monitoring effort. Other tidal wetland community types that are monitored include brackish marshes and stunted shrublands that occur on higher topographic positions within estuarine marshes. Species present in these "high" tidal marshes include small saltmeadow cordgrass (*Spartina patens*), saltgrass (*Distichlis spicata*), silver seaside oxeye (*Borrichia frutescens*), maritime marsh-elder (*Iva frutescens*), and other salt-tolerant herbaceous plants. Freshwater tidal marshes are also present within the seashore. These occur along the upper fringe of brackish marshes where salt-content within the water is minimal. They are typically permanently saturated and exhibit patchy, zonal vegetation. Species present within these freshwater marshes can include giant cordgrass (*Spartina cynosuroides*), sawgrass (*Cladium jamaicense*), cattails, black needle rush, common threesquare, and a host of other wetland species tolerant of small degrees of salinity. Maritime-influenced upland forests and shrublands of Cape Hatteras NS include evergreen forests of stable dune ridges and slopes. They are dominated by loblolly pine (*Pinus taeda*) with occasional oaks (e.g., live oak [*Quercus virginiana*] and sand laurel oak [*Quercus hemisphaerica*]) and southern red cedar. Maritime evergreen forests represent the dominant matrix upland community of the seashore's South Hatteras Island management unit. The herbaceous stratum can vary from sparse to dense. Upland shrublands dominated by stunted live oak and yaupon (*Ilex vomitoria*) are found scattered across the South Hatteras Island unit and to a smaller degree other units (e.g., Bodie Island and North Hatteras Island) of the seashore. These communities typically occur on the ocean-facing edge of maritime forests and generally have very few herbaceous species. Planted and semi-natural stands of pine-dominated forests occur across Cape Hatteras NS. Some of these stands are dominated by non-native pines (e.g., slash pine [*Pinus elliottii*]) and probably occur on sites that naturally would have supported shrub-dominated nontidal wetlands. However, for this monitoring effort, these areas were included in the upland forest and shrubland broad habitat type due to their structural similarity with other more naturally occurring forests of the Outer Banks landscape. Upland open grasslands are the first vegetated habitat encountered heading away from the ocean, past open beach, across all management units of the seashore. It is thought of as the charismatic vegetation type of barrier islands and ocean-facing mainland of the southeastern coast, with waving stalks of sea oats (*Uniola paniculata*) and other grasses supporting dune structure. Across Cape Hatteras NS, this habitat includes graminoid- and herbaceous-dominated vegetation communities of foredunes, backdunes, and occasional openings within stable dunes of island interiors. As noted above, sea oats typically dominate the ocean-edge and ridges of foredunes, while occasionally seaside little bluestem (*Schizachyrium littorale*) can be found on rear slopes of foredunes and backdune slopes. Pockets of shrubs and stunted trees are found across upland open grasslands, including common wax-myrtle, northern bayberry (*Morella pensylvanica*), and southern red cedar; these shrub-zones also can include sprawling, dense tangles of woody vines such as dune greenbriar (*Smilax auriculata*) and maritime catbriar (*Smilax bona-nox* var. *littoralis*). Within flat swales of backdunes, they can intergrade with wetland communities. These areas can be vegetatively abundant with little open sand cover. In drier swales, species include small saltmeadow cordgrass, blanketflower (*Gaillardia pulchella*), dune fingergrass (*Eustachys petraea*), and southern seaside goldenrod (*Solidago mexicana*). Mesic to hydric swales also include small saltmeadow cordgrass, as

well as sweet grass (*Muhlenbergia sericea*), narrowleaf whitetop sedge (*Rhynchospora colorata*), and annual sea-pink (*Sabatia stellaris*).

Noteworthy findings from 2023 include:

- Long-term SECN vegetation plots of Cape Hatteras NS are in a spatially-balanced pattern across four broad habitat types within four of the seashore's primary management units—Bodie Island, North Hatteras Island, South Hatteras Island, and Ocracoke Island. Plot sample size by broad habitat type was as follows:
    - Nontidal wetlands: 21 plots
    - Tidal wetlands: 14 plots
    - Upland forests and shrublands: 14 plots
    - Upland open grasslands: 22 plots
- Photopoints of each plot from 2019 and 2023 are available to view in the *2019–2023 CAHA Vegetation Plot Photopoints* (Supplemental Materials [Boyle and Davis 2026]).
- Across all 71 monitoring plots sampled in 2023, 294 vascular plant taxa were detected. Sixty-two species present in 2019 were not detected in 2023, including four species listed as invasive by the North Carolina Native Plant Society—Japanese stiltgrass (*Microstegium vimineum*), dallis grass (*Paspalum dilatatum* ssp. *dilatatum*), Kentucky bluegrass (*Poa pratensis* ssp. *pratensis*), and common chickweed (*Stellaria media*). There were 12 species present in 2023 not on previous park taxa lists, including the invasive multiflora rose (*Rosa multiflora*).
- The most frequently occurring species across the seashore were small saltmeadow cordgrass, southern red cedar, common wax-myrtle, maritime catbriar, yaupon, and eastern poison ivy (*Toxicodendron radicans* var. *radicans*). Over one-third of the species detected within these plots were single occurrence records (i.e., only found in one plot).
- There were 17 non-native species and two species of unknown nativity observed within these monitoring plots in 2023, 6% of the species list. Seven of these species are listed as invasive by the North Carolina Native Plant Society. The most frequently occurring invasive species were centipede grass (*Eremochloa ophiuroides*) which was found in 36% of the upland open grassland plots; Japanese honeysuckle (*Lonicera japonica*) found in 33% of the nontidal wetland plots; and common reed (*Phragmites australis*) found in 24% of the nontidal wetland plots. Other invasive species found within these plots included thorny-olive (*Elaeagnus pungens*), bahia grass (*Paspalum notatum*), Vasey grass (*Paspalum urvillei*), and the aforementioned multiflora rose.
- Most species detected in 2023 are common across eastern North Carolina and the Southeastern United States. However, there were 19 species listed as rare and tracked by the state of North Carolina observed within 2023 monitoring plots (6% of the species list). Rare species included the state threatened blue witchgrass (*Dichanthelium caerulescens*) and Gulf

Coast spikerush (*Eleocharis cellulosa*). Sixteen of the 19 species of rare plants were found within nontidal wetland habitat of the seashore.

- The average number of species across all plant growth forms and within all broad habitat types monitored within the seashore remained similar to values reported in 2019. Furthermore, total native and non-native richness values remained similar between the two sampling years within all broad habitat types.
- The most frequent species recorded in each of the broad habitat types were as follows:
    - nontidal wetlands
        - common wax-myrtle
        - small saltmeadow cordgrass
        - groundsel tree (*Baccharis halimifolia*)
        - eastern poison ivy
        - maritime catbriar
    - tidal wetlands
        - small saltmeadow cordgrass
        - saltgrass (*Distichlis spicata*)
    - upland forests and shrublands
        - yaupon
        - swamp bay (*Persea palustris*)
        - eastern poison ivy
        - maritime catbriar
        - Virginia creeper (*Parthenocissus quinquefolia*)
    - upland open grasslands
        - sea oats
        - camphorweed (*Heterotheca subaxillaris*)
        - seabeach evening-primrose (*Oenothera humifusa*)
- Basal area is defined as the cross-sectional area of trees at a given height (typically 1.37 meters [4.5 ft], or breast height) and is a common metric used to assess woody stem density. Basal area (m^2/ha) of live trees increased from 2019 to 2023 in both nontidal wetland and upland forest and shrubland plots of the seashore. Dominant canopy species within nontidal wetlands included southern red cedar and Carolina willow (*Salix caroliniana*); dominant canopy species within upland forests and shrublands included loblolly pine, live oak, southern red cedar, and sand laurel oak. Tree-sized species were not a significant component of tidal wetland nor upland open grassland habitats.

- Most tree-sized swamp bay stems measured during this monitoring effort exhibited symptoms like Laurel Wilt Disease (LWD), a fungal disease spread by an exotic ambrosia beetle and responsible for the die-off of hundreds of millions of bay trees (*Persea* sp.) across the Southeastern U.S. since 2002. Of the 10 live swamp bay trees measured within SECN vegetation monitoring plots of the seashore in 2019, eight had died or had decreased vigor and increased canopy dieback in 2023. Swamp bay trees present in newly established plots in 2023 were either dead or had significantly reduced vigor.
- Regeneration rates of sapling-sized canopy-forming species were low across maritime forests of the South Hatteras Island unit. In other parts of the eastern U.S., regeneration failure has been attributed to over-browsing by white-tailed deer (*Odocoileus virginianus*). Deer population estimates are currently not well known across Dare County, North Carolina barrier islands. It is possible a low abundance of sapling-sized individuals is typical within maritime upland forests of South Atlantic barrier islands and regeneration growth is slow due to low light penetration. Regeneration rates of canopy-forming seedlings were high within these plots and likely represent the next cohort of adult-sized trees when canopy gaps form. Long-term monitoring will be used to assess these trends.
- Very few widespread disturbances and threats to vegetation resources were observed within vegetation plots of Cape Hatteras NS in 2023.
- A vegetation health scorecard was developed for each of the seashore's broad habitat types. Growth and expansion of invasive species was a stressor to vegetation resources that occurred across all habitats of the preserve. However, native species diversity scores were rated as "Good" for all monitored habitats. This is a remarkable feature of the vegetation communities within Cape Hatteras NS. Despite continued growth and development across the Outer Banks and impacts related to accelerated rates of sea-level rise, the seashore offers sanctuary and protected space for a diverse assemblage of plant species and their associations in eastern North Carolina.
- Vegetation monitoring occurs every four years within each park of the Southeast Coast Network. The next monitoring year for Cape Hatteras NS is 2027.

Project Background

The Southeast Coast Inventory and Monitoring Network (SECN) monitors the status of vegetation and vegetation communities in 14 National Park Service (NPS) parks in the southeastern U.S. (DeVivo et al. 2008). Tracking vegetation conditions over time is critical to determining park health and making informed management decisions to protect and preserve this vital park resource for future generations. Plant species and their associations integrate the biological and physical environment, serve as the foundation for food webs, provide wildlife habitat for many species, function as a carbon sink, produce oxygen, and cycle nutrients and energy through an ecosystem. They also provide the backdrop of the natural world for park visitors.

The Southeast Coast Network uses a terrestrial vegetation monitoring approach (Boyle et al. 2019) similar to other Inventory and Monitoring Networks in the NPS Southeast Region, including the Cumberland Piedmont Network (White et al. 2011), Gulf Coast Network (Carlson et al. 2018), and South Florida/Caribbean Network (Whelan et al. 2020). The standard sampling unit for these networks is a 20 × 20 meter (65.6 × 65.6 ft) vegetation plot. Data collected from each plot include a vascular species list, species cover, tree health and abundance, woody species regeneration metrics, and other environmental, abiotic, and disturbance information. Data are synthesized across sampling years to answer the following questions:

- How does species richness vary across terrestrial vegetation communities?
- What is the status of composition and abundance among native versus non-native, invasive species?
- What are the most common plants encountered during the monitoring effort, and conversely, were rare species detected?
- What is the relative frequency of woody seedlings, saplings, and subcanopy or canopy species; what are the growth and mortality rates of dominant trees?
- Do observable stressors appear to impact vegetation communities?
- How are forest fuels changing over time?

The current data summary report for Cape Hatteras National Seashore (Cape Hatteras NS, “the seashore”) describes the status of these plot elements in 2023 and represents the second iteration of monitoring. Baseline data were collected from 52 of these plots in the summer of 2019. Plots were established across four broad habitat types of the seashore (nontidal wetlands, tidal wetlands, upland forests and shrublands, and upland open grasslands) and across four management units (Bodie Island, North Hatteras Island, South Hatteras Island, and Ocracoke Island). In the first data summary report published for Cape Hatteras NS, the South Hatteras Island unit was labeled as the Buxton unit and the North Hatteras Island unit was labeled as the Hatteras Island unit (Boyle and Rico 2021). However, after conversations with the park resource management staff, the report authors decided to change to the current naming convention for consistency with other reports and clarity for park managers (Meaghan Johnson, Chief of Resource Management and Science, Cape Hatteras National

Seashore, personal communication). Each of these 52 plots was resampled in 2023. An additional 19 plots were established in 2023 to increase overall sample size across habitats and management units. Vegetation, environmental, and disturbance information are summarized below at different scales (e.g., plot, broad habitat type) to provide managers added context of site-scale and landscape-scale conditions that can be used in combination to make informed decisions. Raw data exports from all sampling years are available at: DataStore—Data Package: Terrestrial Vegetation Monitoring in National Parks of the Southeast Coast Network, 2019–2023 (https://irma.nps.gov/DataStore/Reference/Profile/2305052).

Study Area

Physical Description

Cape Hatteras NS covers approximately 9,903 hectares (24,470 acres [ac]) along a 70-mile (112.7 kilometers [km]) chain of three barrier islands in eastern North Carolina—Bodie, Hatteras, and Ocracoke Islands (Figure 1). These islands form a substantial portion of the northern Outer Banks and are separated from mainland North Carolina by the Pamlico Sound. Bodie Island is separated from Hatteras Island to the south by Pea Island National Wildlife Refuge. Although located within the seashore's administrative boundary, it is managed by the U.S. Fish and Wildlife Service. The Southeast Coast Network conducts long-term vegetation monitoring on four primary management units of the preserve under federal ownership: Bodie Island, North Hatteras Island, South Hatteras Island (which includes a substantial portion of the Buxton Woods ecosystem), and Ocracoke Island (Figure 1). These units serve as the sampling frame for this project.

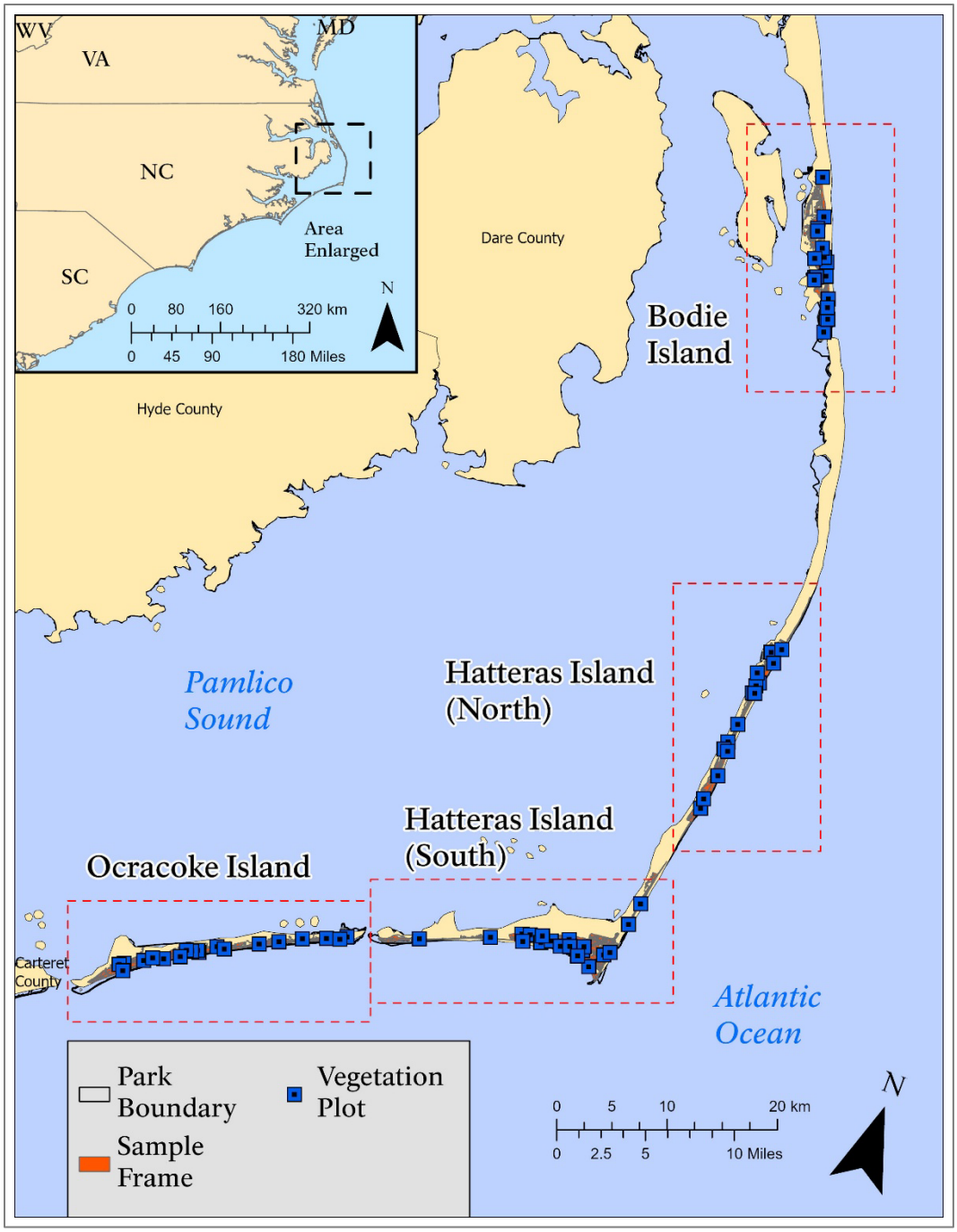

Figure 1. Southeast Coast Network's vegetation monitoring sampling frame and plot locations across Cape Hatteras National Seashore.

NPS / SECN

General Vegetation Features

Cape Hatteras NS falls entirely within the Environmental Protection Agency's (EPA) Level III Middle Atlantic Coastal Plain Ecoregion (Omernik and Griffith 2014) and includes one EPA Level IV Ecoregion—Carolinian Barrier Islands and Coastal Marshes (Griffith et al. 2002). The seashore

makes up a large portion of the northern Outer Banks landscape of coastal North Carolina. The Outer Banks were formed following the most recent glaciation and are composed of relatively young coarse sand substrates deposited over limestone and unconsolidated soil materials. The topography is fairly flat except for undulating dune fields and beach dunes, ranging from 3 meters (10 ft) to 9 meters (30 ft); the highest elevation is on Jockey's Ridge—a live unstable dune that reaches 35 meters (115 ft). Like most barrier islands along the southeastern coast, the vegetation communities along Cape Hatteras NS range from open beach and foredune grasslands on the ocean-facing side to tidal marshes on the sound-facing side. Between the open beach and tidal marshes is a mixture of interdune swales, backdunes, and enclosed wetlands. Wide sections within the seashore—like those found within Buxton Woods—also contain a mixture of upland maritime forests on side slopes and older dune ridges and swamp forests in older dune swales. The canopy of maritime upland forests is dominated by various combinations of live oak (*Quercus virginiana*), Darlington oak (*Quercus hemisphaerica*), loblolly pine (*Pinus taeda*), and swamp bay (*Persea palustris*). Swamp forests and shrublands located within old dune swales are dominated by swamp tupelo (*Nyssa biflora*), southern swamp dogwood (*Swida foemina*), swamp bay, supplejack (*Berchemia scandens*), and sweetgum (*Liquidambar styraciflua*). Open upland vegetation is found on foredunes and occasional backdunes. Dominant species within these dune habitats include sea oats (*Uniola paniculata*) and American beachgrass (*Calamagrostis breviligulata* ssp. *breviligulata*). Shrub-dominated backdunes can contain stunted trees such as live oak and loblolly pine along with common wax-myrtle (*Morella cerifera*), northern bayberry (*Morella pensylvanica*), and yaupon (*Ilex vomitoria*). Tidally influenced, graminoid-dominated wetlands on the sound-side of these barrier islands are composed of smooth cordgrass (*Spartina alterniflora),* black needle rush (*Juncus roemerianus*), small saltmeadow cordgrass (*Spartina patens*), giant cordgrass (*Spartina cynosuroides*), cattails (*Typha* sp.), and common threesquare (*Schoenoplectus pungens* var. *pungens*).

The most recent catalog of vascular plants of the North Carolina Outer Banks was completed in 2021 and includes species accounts reported from Emerald Isle to the North Carolina-Virginia border—a landscape snapshot that includes, but is bigger than, Cape Hatteras NS (Sorrie 2021). The documented totals from this report include 1,020 species and infraspecific taxa, 770 which are native (75%) and 250 which are non-native or adventive (25%). Roughly 75% of these taxa are "current," i.e., they have been observed or collected within the Outer Banks landscape since 2000 (Sorrie 2021). Another source of species inventory information is the NPSpecies database. Currently, NPSpecies documents over 1,100 vascular species and infraspecific taxa as present within Cape Hatteras NS (NPS 2025). Regardless of the accuracy of total species counts from these reports, the seashore provides habitat for many native flora, some of which are rare or protected. Sorrie (2021) documents 55 taxa listed as rare in North Carolina, one of which is federally protected (seabeach amaranth [*Amaranthus pumilus*]). Many of these 55 species occur within the boundaries of Cape Hatteras NS, including seabeach amaranth and state endangered Georgia sunrose (*Crocanthemum georgianum*), blue witchgrass (*Dichanthelium caerulescens*), salt-meadow grass (*Diplachne maritima*), Gulf Coast spikerush (*Eleocharis cellulosa*), Virginia pinweed (*Lechea maritima* var. *virginiana*), and seabeach knotweed (*Polygonum glaucum*).

Cape Hatteras NS is home to nearly 30 known U.S. National Vegetation Classification System (USNVCS) vegetation associations, and these were used as map units for the seashore's most recent vegetation mapping project (McManamay et al. 2014). Many of these associations are listed as vulnerable, imperiled, or critically imperiled across their range by NatureServe, including Mid-Atlantic Maritime Shrub Swamp (Red Bay Type), Mid-Atlantic Coastal Maritime Forest, Atlantic Coast Interdune Swale, Southern Atlantic Interdune Swale, and Sea-oats Dune Grassland (NatureServe 2025).

Land Use History and Vegetation Management Issues

Due to its extreme location between Pamlico Sound and the Atlantic Ocean, Cape Hatteras NS ecosystems have always been subjected to high frequencies of storm-, wind-, tide-, and wave-driven processes. Historic and current vegetation composition and structure are largely a result of these highly dynamic processes. In the early 20th century, two major land use changes were implemented due to increased human growth and visitation along the coast. First was the construction of artificial water control structures and drainage ditches for advancing mosquito control and increasing waterfowl habitat. This led to a shift in hydrological patterns within the interior of the park's landscape. The second was the construction and build-up of primary dunes along the length of the seashore. Vegetation was also planted on these sites to facilitate stabilization. American beachgrass, rather than the more historically dominant sea oats, was planted extensively in the 1930s and 1950s across the constructed dune system of the Outer Banks (van der Valk 1975). American beachgrass reaches its southern range limit within eastern North Carolina. Due to its extensive planting in the early-mid 20th century, it is difficult to determine the exact natural southern limit of this species. A third widespread impact to the seashore's ecological processes resulted in the construction and continued maintenance of North Carolina Highway 12, which runs through the middle of the seashore and impacts hydrologic patterns from storm overwash. Current vegetation patterns and processes across the Outer Banks are impacted and will continue to be impacted by rising sea levels. Vegetation communities are vulnerable to overwash—which moves sand from the island's ocean-side to the sound-side—brought on by more frequent and higher intensity storms. Rising global air and sea temperatures are thought to increase the frequency of these storms (IPCC 2019). Erosion and accretion patterns, including the island's natural westward (inland) migration patterns, brought on by rising seas and intense storms will also impact vegetation communities on both sides of these barrier islands. Sorrie (2021) outlines the most vulnerable vegetation communities of the Outer Banks based on their propensity to harbor rare plants and likeliness to be impacted from such stressors as sea level rise, storm overwash, dune migration, vehicular traffic, and other factors. These communities include Upper Beach and Sand Flat, Maritime Wet Grassland, Estuarine Fringe Pine Forest, Tidal Freshwater Marsh, Brackish Marsh, and Interdune Marsh and Interdune Pond.

Other threats to the seashore's terrestrial vegetation have historically included over-browsing by white-tailed deer (*Odocoileus virginianus*), root damage caused by feral hogs (*Sus scrofa*), and the expansion of non-native, invasive plants. Species categorized as invasive by the North Carolina Native Plant Society and North Carolina Invasive Plant Council that have significant impact across Cape Hatteras NS vegetation communities include alligator-weed (*Alternanthera philoxeroides*), centipede grass (*Eremochloa ophiuroides*), Japanese honeysuckle (*Lonicera japonica*), and common

reed (*Phragmites australis*). The full list of invasive species present within the seashore is available in NPSpecies (NPS 2025) and Sorrie (2021). Exotic insect pests and diseases that have widespread impacts on native trees across North Carolina include emerald ash borer beetle (*Agrilus planipennis*), hemlock woolly adelgid (*Adelges tsugae*), and laurel wilt. Of these, laurel wilt disease (LWD) is the most proximate threat to vegetation ecosystems of Cape Hatteras NS. The most recent distribution maps of LWD detection published by the USDA Forest Service (USFS 2024) document LWD as far north along the North Carolina coast as Carteret County. The disease is comprised of a fungal pathogen (*Raffaelea lauricola*) spread by an invasive, non-native ambrosia beetle (*Xyleborus glabratus*) and affects several species within the Lauraceae Family, including swamp bay and red bay (*Persea borbonia*; Fraedrich et al. 2008). Both species are present on the seashore, although only swamp bay is dominant across most forest and shrub habitat types. Infected bay trees typically die within months after succumbing to the disease. These individuals exhibit crowns of brownish-red dead leaves. Since it was first detected in the United States over 20 years ago, LWD has caused profound loss of tree- and sapling-sized bay trees—a subcanopy dominant species in most maritime forests across the Southeast. Individual swamp bay trees within the Southeast Coast Network vegetation monitoring plots in the seashore in 2019 exhibited symptoms similar to those caused by LWD (Boyle and Rico 2021). It is possible the declining swamp bay trees observed were impacted by another type of ambrosia beetle—there are other species that cause crown and branch dieback—or another disturbance altogether. Another set of forest pests, albeit native, that have impacted forested ecosystems of the seashore are pine beetles (e.g., southern pine beetle [*Dendroctonus frontalis*] and ips beetle [*Ips* sp.]). Pine beetle damage was not detected within vegetation plots during the 2019 Southeast Coast Network vegetation monitoring effort (Boyle and Rico 2021).

Although many vegetation communities across the southeastern coast are shaped by and often dependent on fire disturbance for their maintenance, the role of fire across the Outer Banks (including Cape Hatteras NS) is not as clear as it is for other park units within this region. The 2001 Fire Management Plan for Cape Hatteras NS, Fort Raleigh National Historic Site, and Wright Brothers National Memorial discusses the historical role of fire within the seashore, describing a landscape where human-initiated burning may have had more of an impact than lightning-ignited fires (NPS 2001). Within Buxton Woods, Bratton and Davison (1987) found charcoal and charred tree trunks that suggest evidence of historical wildland fire. In more recent times, prescribed fire along with mechanical and chemical treatments have been used as tools within Cape Hatteras NS to reduce hazardous fuel loads near developed areas and to "maintain and/or restore plant communities, cycle nutrients and reduce or remove exotic plants, and to protect and enhance cultural landscapes" (NPS 2001). These treatments have largely been focused within the Bodie Island unit of the seashore. Resource goals related to prescribed fire within the Bodie Island unit are to (1) reduce brush species from marsh habitat, (2) improve marsh habitat for waterfowl and wading birds, (3) maintain herbaceous species diversity and cover in marsh and forest communities, (4) maintain and improve shrub scrub habitat for migratory birds, and (5) maintain maritime forests to provide quality wildlife habitat and visitor experiences (Klein et al. 2015).

Methods

Plot Selection

USNVCS vegetation associations were described for Cape Hatteras NS and used as map units during the latest park-wide vegetation mapping project (McManamay et al. 2014). Vegetation associations present within the park were then grouped into broader-scale classification types (broad habitat types) by this report's lead author to maintain adequate sample sizes of plot distribution across classification units useful for park management decisions. While mapped vegetation associations could be incorrect—McManamay et al. (2014) reports an overall accuracy assessment within the overall project as 80%—the cross-walked broadly defined habitats they nest under are typically correct. Four broad habitat types were defined for Cape Hatteras NS: nontidal wetlands, tidal wetlands, upland forests and shrublands, and upland open grasslands.

The number of plots within broad habitat types of the four targeted management units of the seashore were determined by a combination of factors. First, a sample size of between two and four plots per 100 hectares (247 ac) was targeted for habitats that cover more than 30% of the total area of a park unit's natural and semi-natural vegetation. In habitats that cover less than 30% of the total area, four plots were established. Only three plots were established in upland forests and shrublands of Bodie Island and Ocracoke Island due to the small area this habitat type occurs across these management units and to prevent plots from spatially overlapping. Number of plots by broad habitat type for each unit is as follows:

- Bodie Island
    - nontidal wetlands: 6 plots
    - tidal wetlands: 4 plots
    - upland forests and shrublands: 3 plots
    - upland open grasslands: 4 plots
- North Hatteras Island
    - nontidal wetlands: 4 plots
    - tidal wetlands: 4 plots
    - upland open grasslands: 7 plots
- South Hatteras Island
    - nontidal wetlands: 6 plots
    - upland forests and shrublands: 8 plots
    - upland open grasslands: 6 plots
- Ocracoke Island
    - nontidal wetlands: 5 plots

- tidal wetlands: 6 plots
- upland forests and shrublands: 3 plots
- upland open grasslands: 5 plots

Plot locations by management unit are illustrated in Figure 2. Broad habitat type polygons derived from vegetation map data did not always reveal the correct, on-the-ground habitat. This explains why some vegetation plots classified as one type appear to occur in a different mapped type. Plant community classifications are useful models for understanding natural phenomena, but they misleadingly imply hard boundaries between classes. Each vegetation class, type, or association is a spectrum of intergrading groups of plants, with each species responding independently, for the most part, to environmental conditions and chance events. Because of this, plots can have features of more than one class, and some plots are a better match to their assigned class than others. Accepting that most classification models are an imperfect fit, the class assignments used for this project are based on each plot's dominant class (i.e., >50% of the plot).

Plot locations were determined using the generalized random-tessellation stratified (GRTS) sampling methodology, which creates a spatially balanced array of sample points across an area of interest while maintaining flexibility in a project's sample size (Stevens and Olsen 2004). Plots were selected for sampling based on the order listed within the GRTS output. For a full description of the site selection approach used by the Southeast Coast Network for terrestrial vegetation monitoring, refer to Boyle (2024).

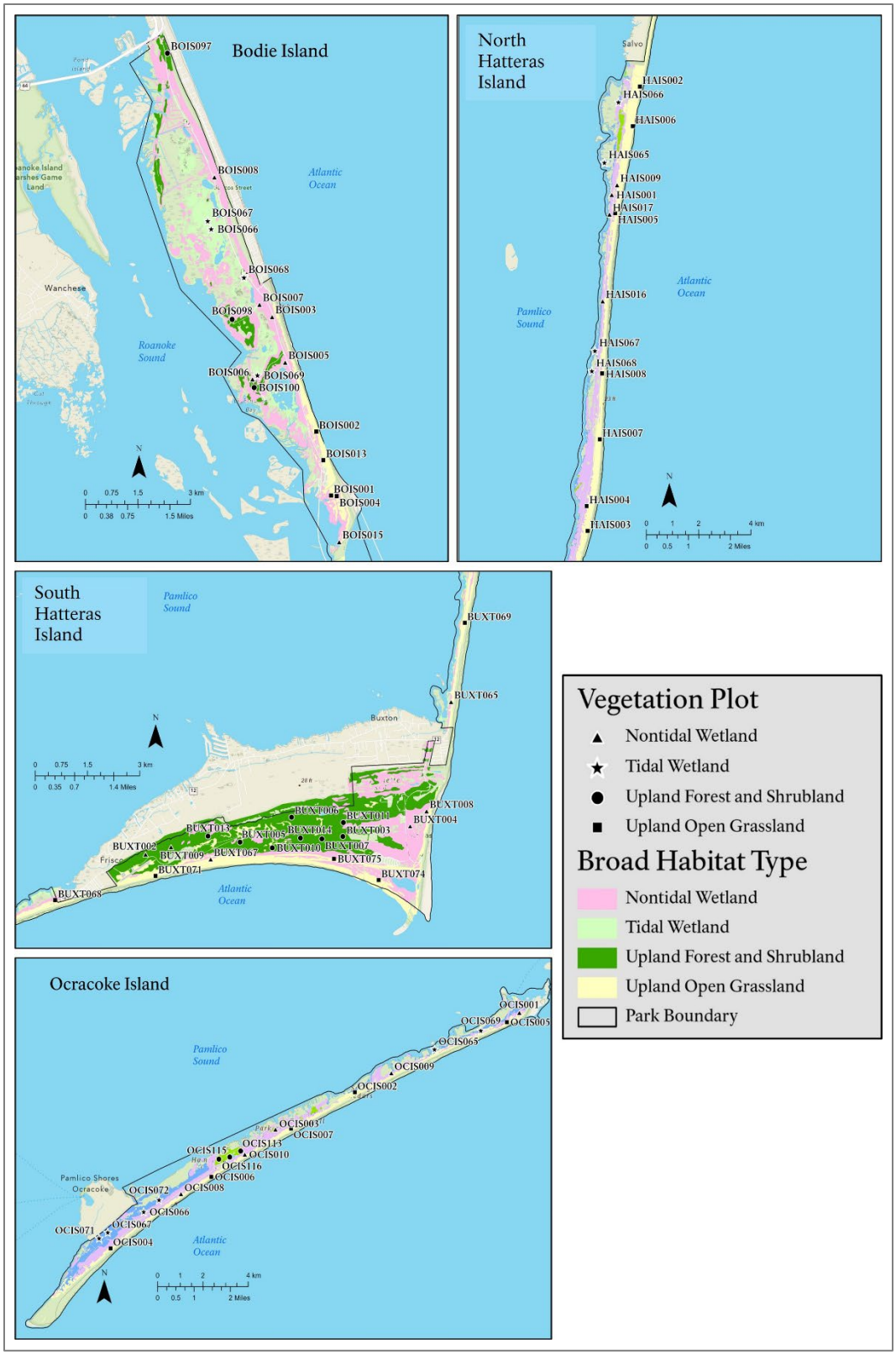

Figure 2. Broad habitat types of Cape Hatteras National Seashore management units and Southeast Coast Network vegetation plot locations.

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Field Methodology

Vegetation monitoring fieldwork at Cape Hatteras NS in 2023 began in July and ended in August. The vegetation plot layout for this monitoring effort is based upon the plot design used by the Carolina Vegetation Survey (Peet et al. 1998) and the Cumberland Piedmont Network (White et al. 2011). The plot array consists of a 20 × 20 meter (65.6 × 65.6 ft) bounded square with multiple nested sampling frames ranging from 1 square meter (10.8 square feet [ft^2]) to 400 square meters (4,305.5 ft^2), three 25 meter (82.0 ft) fuel transects that cross through the bounded square, and three soil sample frames adjacent to the bounded square (Figure 3).

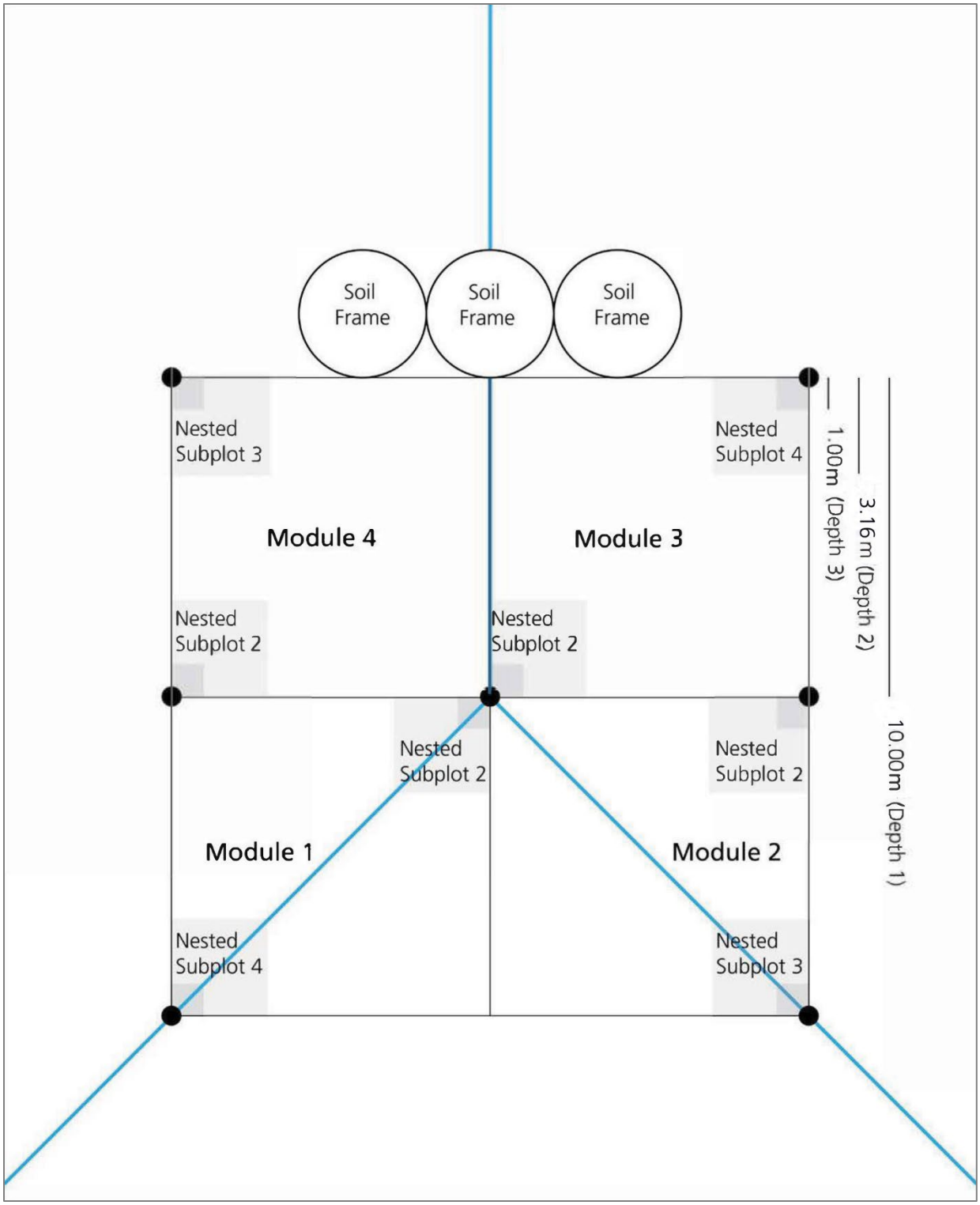

Figure 3. The layout of a vegetation monitoring plot for the Southeast Coast Network, which is a modified version of the standard Level 5 Carolina Vegetation Survey plot. Ideal locations of rebar used as permanent structures to monument the plot are represented by black shaded circles. Blue lines represent locations of the three 25-meter (82-foot) fuel transects.

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Vascular plant species lists were compiled at the 1 m^2 and 10 m^2 depths of each nested subplot as well as for each 100 m^2 module. Areal cover of each species present or overhanging each module was recorded using the 10 point cover class scale from Peet et al. (1998). Every attempt was made to identify all plants to species, variety, or subspecies; when this was not possible, the lowest level of identifiable taxa (e.g., genera, family) was used. Once the final list was determined, each species was cross-referenced with the USDA Plants Database (USDA NRCS 2025) and the Flora of the Southeastern United States (Weakley 2020) to determine growth form, nativity status, and to provide a unique common name. The species list was also cross-referenced with North Carolina plant lists to determine the state and federal conservation status (e.g., Endangered, Threatened, Rarity) of each species (Walker et al. 2024) and the list of non-native invasive plants in North Carolina to determine the degree of invasiveness (NCNPS 2023).

All woody stems greater than or equal to 10 centimeter (3.9 in) diameter at breast height (or 1.37 meter [4.5 ft] in height, DBH) were classified as trees. Each standing dead tree that reached DBH within each module was mapped on gridded paper and its decay class and height were recorded. For each living tree present within the plot, its position within a module was also mapped on gridded paper and the following values were recorded:

- Species
- DBH
- Presence of harmful insects, disease, or other damages
- Status (live versus dead)
- Crown class
- Vigor
- Dieback

Woody stems greater than or equal to 1.37 meters in height and less than 10 centimeters DBH were classified as saplings and tallied by species and diameter class within each 10 m^2 depth of the eight nested subplots. Woody stems less than 1.37 meters in height were classified as seedlings and tallied by species and height class within each 1 m^2 depth of the same nested subplots. Seedlings between 5–15 centimeters in height were classified as germinants. Basal area, or the cross-sectional area of an individual tree based on its diameter, was calculated for each tree and sapling species. This metric as well as total counts (density) of woody individuals classified as either trees, saplings, or seedlings were used to determine growth rates and relative dominance of species classified as canopy or subcanopy species within vegetation plots and broad habitat types.

Surface fuels were assessed at each nontidal wetland and upland forest and shrubland plot site using the planar transect method for the standard fuel size classes: 1-hour (0–0.6 cm), 10-hour (0.6–2.5 cm), 100-hour (2.5–7.6 cm), and 1000-hour (>7.6 cm), and duff and litter depths (Brown 1974). Counts of each fuel size class were tallied across three fuel transects, with diameter and decay class recorded for each piece of 1000-hour fuel. These field data were incorporated into equations using

constant multipliers defined by Brown (1974)—including quadratic mean diameter, nonhorizontal correction factor, specific gravity, and bulk density—to estimate fuel load weight (unit = tons/acre) within each plot.

Site characteristics were also measured at each plot, including coverage of standing water, presence and cover of disturbances, canopy cover, and canopy height. Photopoints were also collected from each plot. Additional data were collected at newly established plots (Cycle 1). These include dominant slope, aspect, terrain shape, basic hydrological condition, collection of soil samples from the three soil sample frames, and assignment to one or two USNVCS vegetation association types. These same data were collected in 2019 for plots revisited in 2023 (Cycle 2).

Finally, sampling lasted an average of 1.8 hours per plot and ranged from one to five hours. A complete description of all field methods is located within this protocol's implementation plan and its associated field standard operating procedures (SOPs; Boyle et al. 2019 and references therein).

Results

Seventy-one vegetation plots were sampled across Cape Hatteras NS during this monitoring event in 2023, including 52 plots originally established in 2019. Nineteen plots were established in 2023 to increase the sample size of broad habitat types within each management unit of the seashore. Data are summarized below at the seashore, management unit, broad habitat, and plot scale. Occasionally, 2023 data are compared with data collected within the seashore in 2019. However, trend analysis is not presented within this data summary report. Trend analytics will not be applied to vegetation monitoring data until at a minimum of three cycles of sampling have occurred on these plots. Data summaries are provided for multiple elements collected across plots—species richness and cover, tree growth and regeneration metrics, tree health, environmental attributes, observed disturbances, and fuel loads. Collectively, these elements were qualitatively assessed to provide an overall condition scorecard for broad habitat types within the seashore. The scorecard is presented at the end of this report.

Environmental Attributes and Broad Habitat Type Descriptions

The four broad habitat types sampled during this monitoring effort comprised a wide range of topographic, elevation, hydrologic, and soil moisture conditions. These environmental differences coupled with a site's disturbance history function to create unique vegetation composition and structure conditions at each plot (Figure 4). All Cycle 2 plots were classified to a USNVCS association in 2019, and all Cycle 1 plots established in 2023 were classified to an association during this current monitoring effort. Brief descriptions of environmental attributes for each broad habitat type are provided below and summaries of USNVCS associations sampled during this monitoring effort are available in Appendix 1.

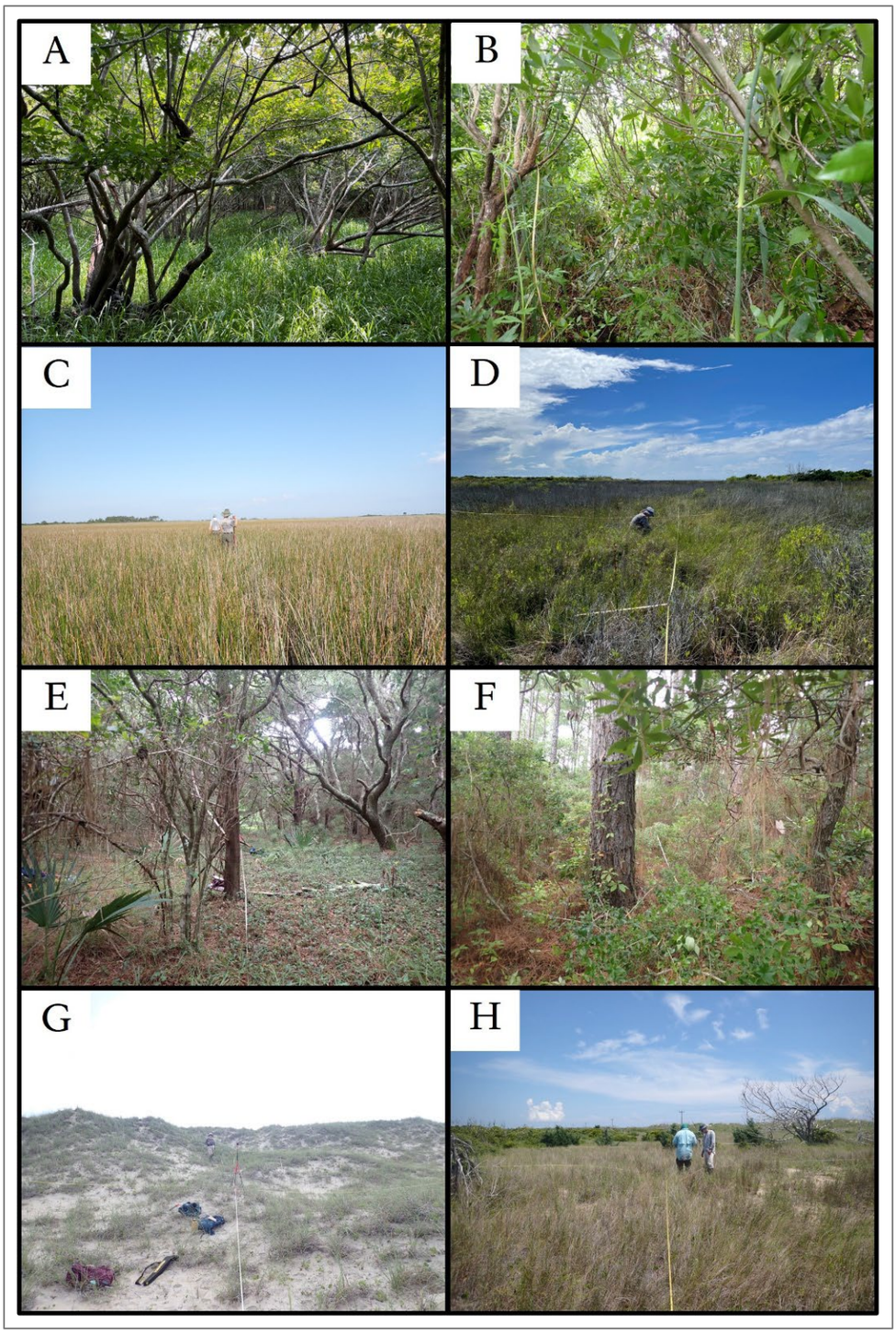

Figure 4. Representative photos of the four broad habitat types monitored within Cape Hatteras National Seashore. U.S. National Vegetation Classification Standard associations sampled within nontidal wetlands included Maritime Shrub Swamp (A) and Interdune Swale (B); associations sampled within tidal wetlands included Cattail Tidal Oligohaline Marsh (C) and High Salt Marsh (D); associations sampled within upland forests and shrublands included Maritime Evergreen Forest (E) and Slash Pine Plantation (F); and associations sampled within upland open grasslands included Sea-Oats Dune Grassland (G) and Overwash Dune Grassland (H).

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Nontidal Wetlands

Fifteen vegetation plots associated with the seashore's nontidal wetlands were established in 2019 and re-surveyed during this monitoring effort, including five plots on Bodie Island, six plots within South Hatteras Island, one plot on North Hatteras Island, and three plots on Ocracoke Island. Another six plots were established within the seashore in 2023 to ensure an adequate sample per management unit in future monitoring efforts. Plot photos are Figures 1–21 in the *2019–2023 CAHA Vegetation Plot Photopoints* (Supplemental Materials [Boyle and Davis 2026]). This habitat type includes a broad category of herbaceous-, shrub-, and forested-dominated wetlands not tidally influenced within the seashore. Examples of vegetation communities sampled within the seashore for this monitoring effort include interdune marshes dominated by common threesquare, cattails, and other herbaceous and graminoid species; flats and interdune swales dominated by 2 to 8 meter (6.6 to 26.2 ft) tall common wax-myrtle with a scattered, emergent canopy of southern red cedar (*Juniperus silicicola*); and shrub swamps in old dune swales and depressions surrounded by upland maritime forests. Interdunal swales and flats dominated by shrubs and stunted trees are one of the most frequently occurring terrestrial ecosystems of Cape Hatteras NS and found across all management units. Maritime swamp forests, on the other hand, are rare across the Outer Banks of North Carolina, with the best examples located off the seashore within Nags Head Woods and Kitty Hawk Woods. Shrub-dominated swamplands are found scattered across both Bodie Island and South Hatteras Island.

Nontidal wetlands occur in closed basins hydrologically controlled by rainfall, slope seepage, groundwater seepage, and storm overwash. Timing of standing water on these sites can vary from perennial to seasonal. Slopes were flat within plots of this broad habitat type occurring on flat plain landforms. Most plots did not have standing water present at the time of sampling. Soil pH ranged from slightly acidic to slightly alkaline within these soils and typically had lower organic matter content than tidal wetland soils (Tables 1–2 in *Plot- and Species-Scale Summary Tables* [Supplemental Materials {Boyle and Davis 2026}]).

Tidal Wetlands

Seven vegetation plots associated with the seashore's tidal wetland habitat were established in 2019 and re-surveyed during this latest monitoring effort, including one plot on Bodie Island and six plots on Ocracoke Island. Another seven plots were established on Bodie Island and North Hatteras Island to ensure a minimum of four plots per management unit in future monitoring efforts. Plot photos include Figures 22–35 in *2019–2023 CAHA Vegetation Plot Photopoints* (Supplemental Materials [Boyle and Davis 2026]). Within Cape Hatteras NS, this broad habitat type includes both graminoid- and herbaceous-dominated marshes and occasionally southern red cedar forests that are influenced by tidal patterns, salinity fluctuations, and sediment deposition. Although not sampled during this monitoring effort, tidal salt marshes along with their embedded salt pans exhibit the highest salinity levels among tidal wetland vegetation associations due to daily fluctuations of sea water. Brackish tidal marshes within the park are dominated by needlegrass rush and experience daily fluctuations of lower salinity water—often a combination of sea water and freshwater from the Pamlico and Albemarle Sounds. These marshes also were not sampled during this monitoring effort. For an explanation of why these higher salinity marshes ("low" marshes) were excluded from this effort, despite their dominance across the sound side of Cape Hatteras NS, refer to Boyle et al. (2019). Tidal

wetlands sampled within the park included freshwater sites at the upper margins of brackish marsh, where salinity levels are minimal. These sites are typically saturated throughout the year and can experience frequent or infrequent flooding from tidal fluctuations—either lunar- or wind-driven. Unlike tidal salt and brackish marshes which are fairly homogenous in vegetation composition, tidal freshwater wetlands are often characterized by a patchy mosaic of vegetation diversity. They can be composed of zones of tall or short graminoids, or an array of herbaceous plants. Management units of the seashore where tidal wetland habitat zones targeted for this monitoring effort were present included Bodie, North Hatteras, and Ocracoke Islands.

Plots of this broad habitat type occurred on very flat landforms where standing water was typically present at the time of sampling. Soils were typically high in organic matter content except in tidal wetlands of Ocracoke Island. Tidal wetlands of Ocracoke Island were slightly more alkaline and had less sodium content than tidal wetlands of Bodie and North Hatteras Island (Tables 1–2 in *Plot- and Species-Scale Summary Tables* [Supplemental Materials {Boyle and Davis 2026}]).

Upland Forests and Shrublands

Eight vegetation plots associated with the seashore's upland forest and shrubland habitat were established in 2019 and resurveyed during this latest monitoring effort. All these plots are within the South Hatteras Island unit. An additional six upland forest and shrubland plots were established across Bodie and Ocracoke Islands in 2023. Plot photos include Figures 36–49 in *2019–2023 CAHA Vegetation Plot Photopoints* (Supplemental Materials [Boyle and Davis 2026]). Upland forests and shrublands of the outer Coastal Plain of the Carolinas occur on dry to mesic sites typically more stable and protected from maritime-influenced disturbances (e.g., flooding) than other maritime habitats of the same landscape. However, these communities are still influenced and shaped by aerosol salt spray and strong winds due to their proximity to the ocean. Impacts from wind and salt spray are more pronounced along the forest edges where these communities border dune or salt marsh habitat. Although flooding is less common within upland forests and shrublands than other maritime habitats, inundation can occur during extreme storm events.

The South Hatteras Island unit of Cape Hatteras NS contains the most widespread and diverse maritime upland forest habitat across the seashore. These communities are located on well- to excessively-drained sandy soils of stable dunes and sheltered flats. The source of plant nutrients for these forests is largely from oceanic aerosol spray and occasionally shell deposits within the soil. The presence and persistence of natural forests across the North Carolina Outer Banks, including those within Buxton Woods, have long been a source of debate for ecologists and land managers. Contradictions by Brown (1959) and others, noted in Schafale (2024), include statements of the prevalence of forest habitat across the Outer Banks until human actions such as grazing, farming, and burning destroyed them; Brown (1959) and later researchers, however, also suggest that plantings of grasses and sand fencing to stabilize dunes by the NPS in the mid-20th century promoted woody development across these barrier islands. Ancient pollen records from roughly 900 years ago to the early 1700s within the South Hatteras Island unit suggest a stable forested landscape, with about 50% oak and 30% pine pollen (Brown 1983). Recent records, on the other hand, find pine at 80% and oak at less than 10%. Selective logging of live oak beginning in the early 18th century has factored in the

shift from live oak to pine within Buxton Woods, as have impacts from extreme storms. Bratton and Davison (1987) suggest the presence of pines in the canopy with sand laurel oak (*Quercus hemisphaerica*) as a co-dominant rather than live oak is indicative of previous extreme disturbance events.

Another upland forest type of Cape Hatteras NS has developed on sites formerly planted with non-native slash pine (*Pinus elliottii*), as well as other pine species. Pines were planted to reduce the migration of sand. These human-directed forests likely occur on sites that would have naturally supported nontidal wetland shrubs and grasslands; however, due to their current hydrologic condition (~ fairly mesic to subxeric) and because many of the vegetation communities identified as nontidal wetlands occur on sites that do not clearly fit as a true "wetland" or true "upland," these planted forests have been included in the upland forest and shrubland habitat type. These communities are found scattered across all management units of the seashore, from Ocracoke Island to Bodie Island.

Plots within upland forests and shrublands occurred on both flat and sloping landforms, ranging from 0 to 14°, and exhibited either flat or concave terrain shapes. Standing water was not observed on any of these sites. Soil pH values ranged from acidic to alkaline, with an average of 6.2 (Tables 1–2 in *Plot- and Species-Scale Summary Tables* [Supplemental Materials {Boyle and Davis 2026}]).

Upland Open Grasslands

This characteristic habitat type of the South Atlantic coast, with swaying culms of sea oats, represents graminoid- and occasionally forb-dominated foredune and back dune sites directly adjacent to the open beach and on higher, more exposed ridges of barrier island interiors. It is found across Cape Hatteras NS from Ocracoke Island to Bodie Island. Twenty-two vegetation plots associated with the seashore's foredunes and backdunes were established in 2019 and re-surveyed during this monitoring effort, including four plots on Bodie Island, six plots within South Hatteras Island, seven plots on North Hatteras Island, and five plots on Ocracoke Island. Plot photos include Figures 50–71 in *2019–2023 CAHA Vegetation Plot Photopoints* (Supplemental Materials [Boyle and Davis 2026]). Upland open grasslands occur on sites strongly influenced by shifting sands and high levels of salt spray from the adjacent ocean. Plants that colonize these sites are typically short-lived and salt-tolerant. The primary grass that stabilizes maritime dunes is sea oats, which produce many adventitious roots from the main culm that capture sand and allow dunes to form. Other grasses that stabilize dunes within the seashore include American beachgrass, bitter seabeach grass (*Panicum amarum*), and seaside little bluestem (*Schizachyrium littorale*). Tree and shrub development is limited in these sites because of extreme salt spray and frequent storm overwash, although occasional salt-pruned, low-lying shrub zones may be found in protected dune swales. Upland grassland flats with dense vegetation and less open sand occur on the island interior flats of stabilized dunes.

The topography of sites where these plots occur is characterized by complex landforms with rolling hills and swales. However, a few upland open grassland sites within backdunes occurred on flat landforms. Soil horizon development is minimal in these sites and organic material in the upper soil layer is minimal. Soil pH values were highest in this broad habitat type of the seashore, likely due to

the elevated presence of seashell material (Tables 1–2 in *Plot- and Species-Scale Summary Tables* [Supplemental Materials {Boyle and Davis 2026}]).

Preserve-Scale Species Diversity and Notable Species Information

Across all 71 monitoring plots sampled in 2023, 294 vascular plant taxa were detected including 100 graminoids, 124 herbs/forbs, 16 shrubs, 28 trees, and 26 vines. (Table 4 in *Plot- and Species-Scale Summary Tables* [Supplemental Materials {Boyle and Davis 2026}]). In contrast, the 52 monitoring plots established in 2019 yielded 261 species (Boyle and Rico 2021). Sixty-two species present in 2019 were not detected in 2023, including four species listed as invasive by the North Carolina Native Plant Society (NCNPS 2023)—Japanese stilt-grass (*Microstegium vimineum*), dallis grass (*Paspalum dilatatum* ssp. *dilatatum*), Kentucky bluegrass (*Poa pratensis* ssp. *pratensis*), and common chickweed (*Stellaria media*). There were 12 species present in the 2023 monitoring plots not on previous park taxa lists, including one species listed as invasive—multiflora rose (*Rosa multiflora*; NCNPS 2023). This species was observed in a single upland forest monitoring plot within the South Hatteras Island unit. The occurrences of five of these 21 "new-to-park" species have likely not been described for Dare and/or Hyde County, North Carolina. These species include common spikerush (*Eleocharis palustris*), leafy elephant's-foot (*Elephantopus carolinianus*), eastern anglepod (*Gonolobus suberosus* var. *suberosus*), bur-cucumber (*Sicyos angulatus*), and southern highbush blueberry (*Vaccinium formosum*).

Most species detected within 2023 monitoring plots are common across the North Carolina Outer Banks and the Southeastern United States. The most frequently occurring species across the seashore included small saltmeadow cordgrass, southern red cedar, common wax-myrtle, maritime catbriar (*Smilax bona-nox* var. *littoralis*), yaupon, and eastern poison ivy (*Toxicodendron radicans* var. *radicans*). Conversely, 102 of the 294 plant taxa detected (35% of the total) within these plots were single occurrence records (i.e., only found in one plot). Seashore-wide average species richness at the full-plot scale (400 m^2) was 27.2 across all plots sampled in 2023. Average richness in 2023 for the 52 plots established in 2019 (Cycle 2) was 29.6; average richness in 2019 for these plots was 28.6.

Nineteen of the 294 taxa observed within these monitoring plots are listed as rare within the state of North Carolina, including two species—blue witchgrass and Gulf Coast spikerush—listed as Threatened (Figure 5; Walker et al. 2024). Other rare species with high global risk of imperilment observed in 2023 within Cape Hatteras NS vegetation plots included nerved witchgrass (*Dichanthelium neuranthum*), dune blue curls (*Trichostema nesophilum*), and maritime thoroughwort (*Eupatorium maritimum*).

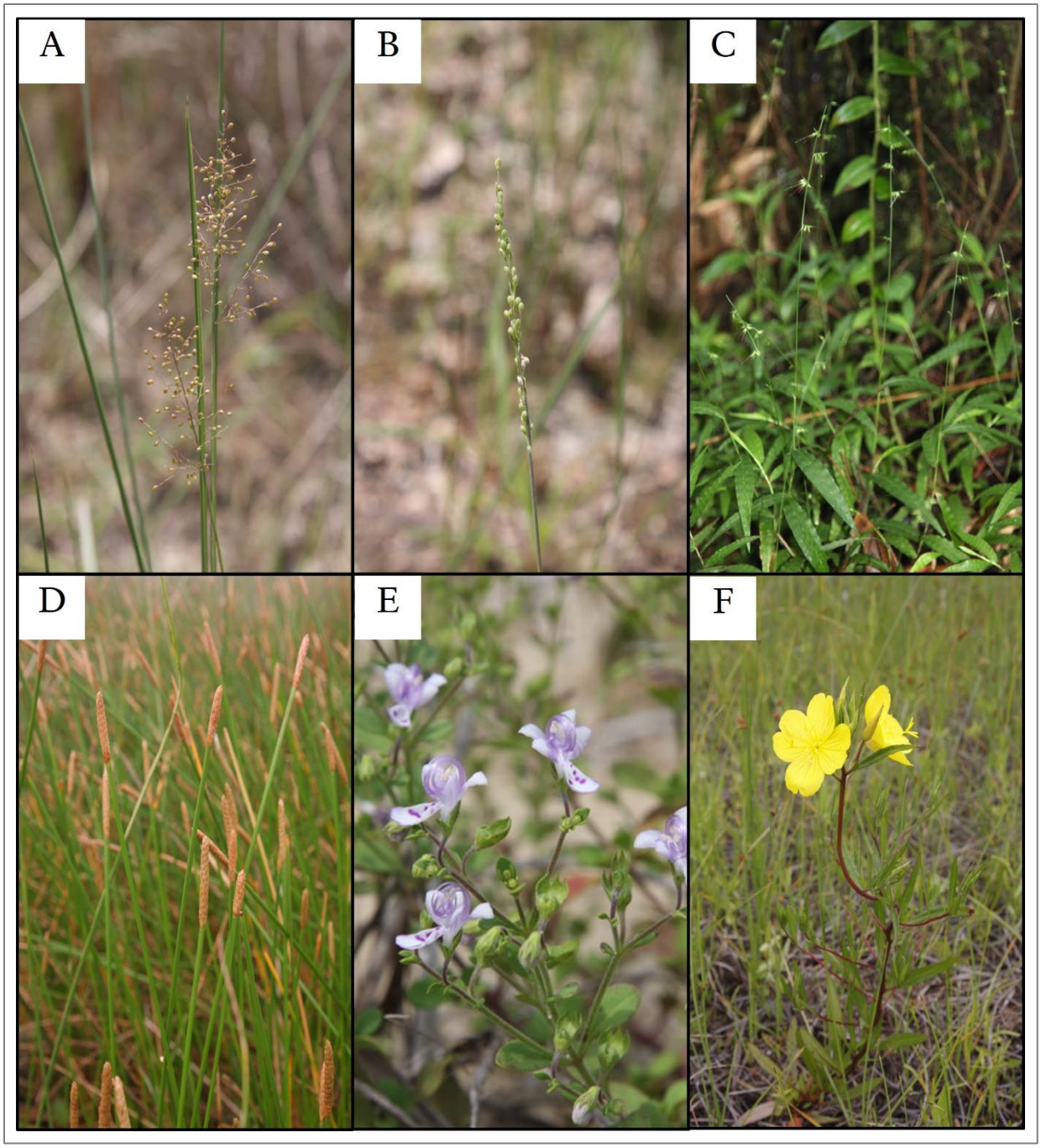

Figure 5. Nineteen vascular plants listed as rare and tracked by the North Carolina Natural Heritage Program (Walker et al. 2024) were observed during this 2023 monitoring effort within Cape Hatteras National Seashore. Species included blue witchgrass (*Dichanthelium caerulescens*; state threatened; A), nerved witchgrass (*Dichanthelium neuranthum*; significantly rare; B), woods-grass (*Oplismenus setarius*; significantly rare; C), Gulf Coast spikerush (*Eleocharis cellulosa*; state threatened; D), dune blue curls (*Trichostema nesophilum*; special concern; E), and coastal sundrops (*Oenothera unguiculata*; significantly rare; F).

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94% of taxa observed within 2023 plots across the seashore are categorized as native while the remaining 6% are categorized as non-native or whose nativity status is unknown. Seven of the non-native species are listed as invasive by NCNPS (2023) and include the aforementioned multiflora rose as well as common reed, Japanese honeysuckle, thorny-olive (*Elaeagnus pungens*), centipede grass, bahia grass (*Paspalum notatum*), and Vasey grass (*Paspalum urvillei*). 2023 plot-specific presence of invasive species is provided in Figures 6–9.

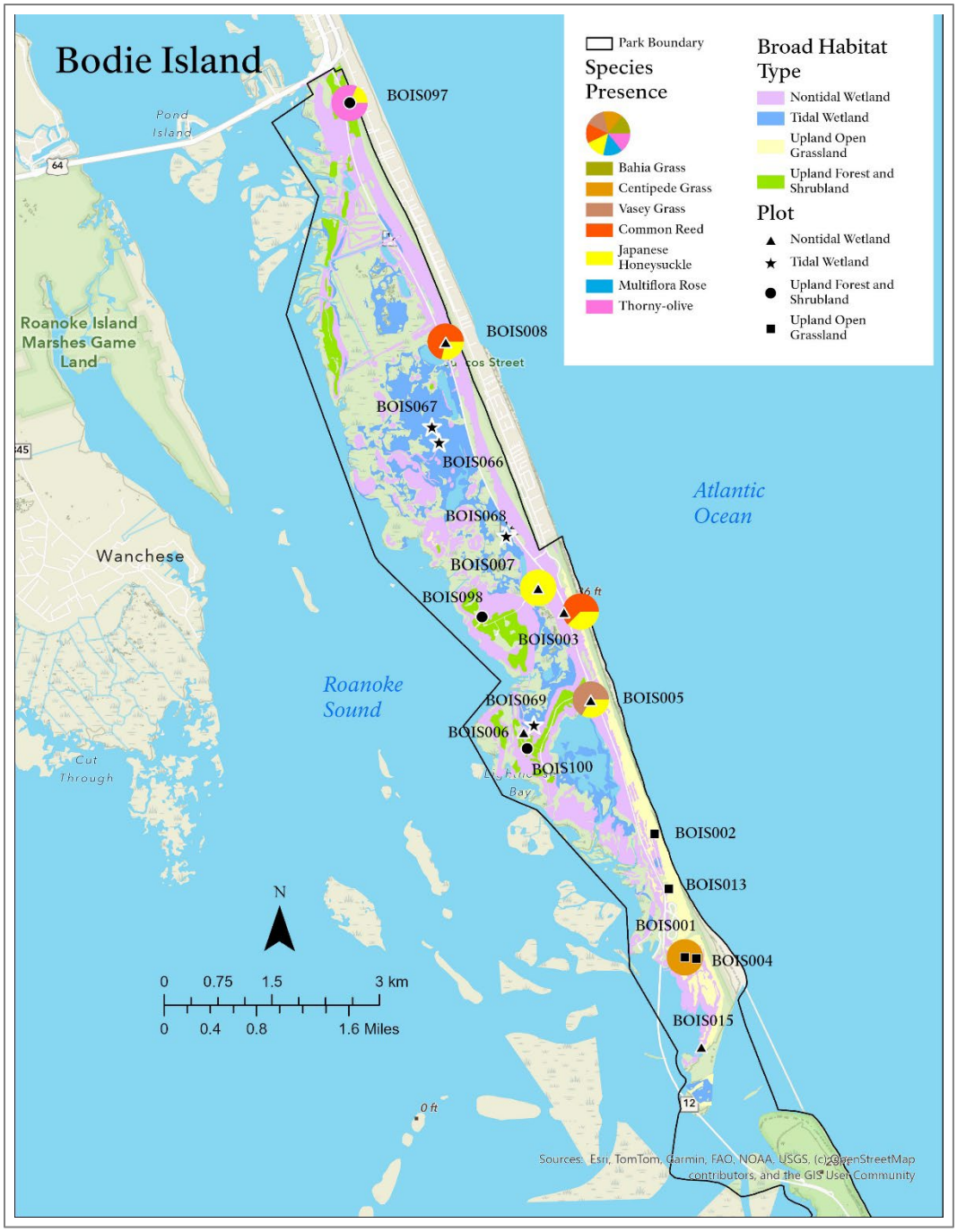

Figure 6. Invasive species presence by plot within the Bodie Island unit of Cape Hatteras National Seashore from the most recent sampling event in 2023. Where multiple species are present, pie slices represent relative cover values among species. Plots with no overlaying pie charts shown indicate that no invasive species were detected.

NPS / SECN

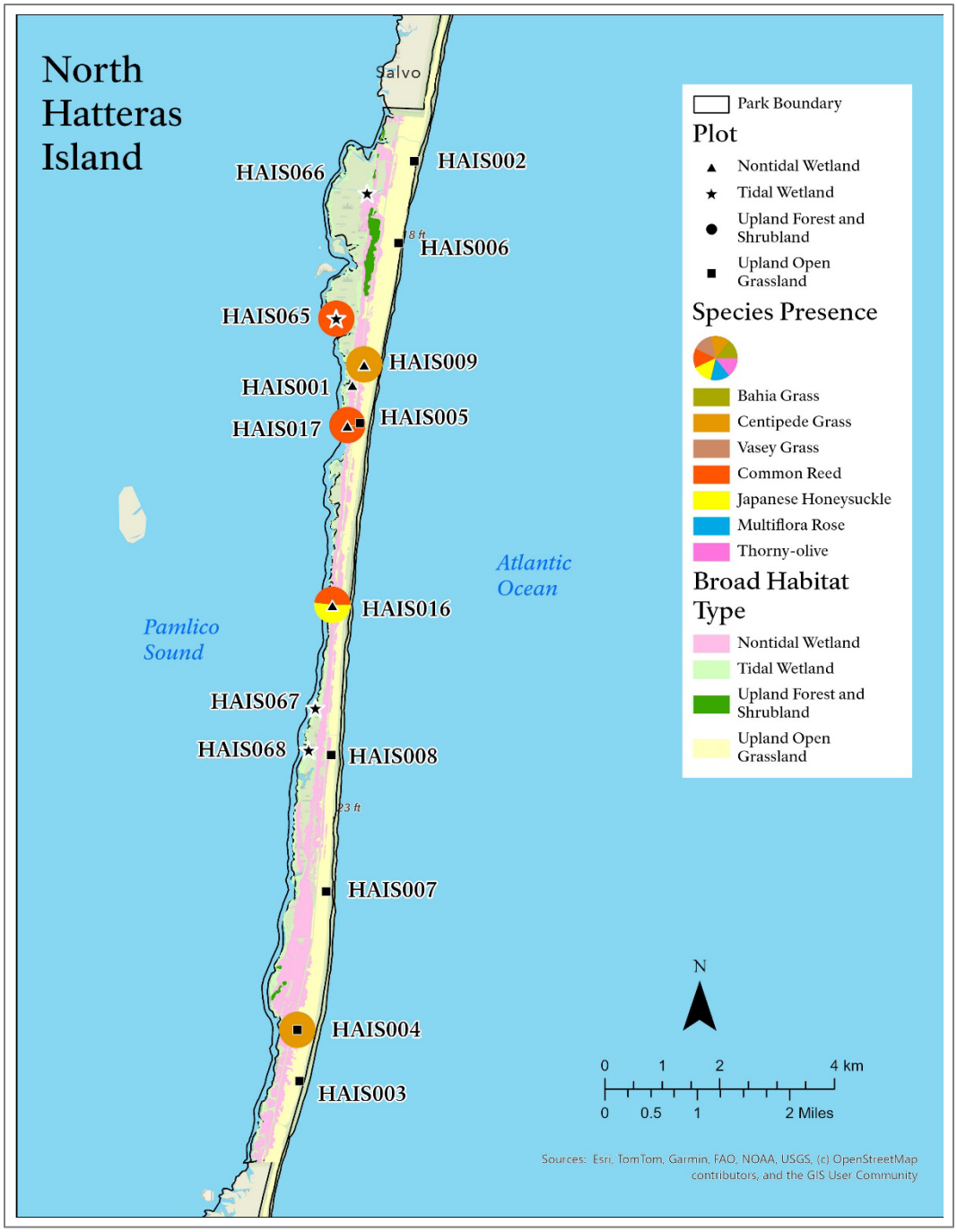

Figure 7. Invasive species presence by plot within the North Hatteras Island unit of Cape Hatteras National Seashore from the most recent sampling event in 2023. Where multiple species are present, pie slices represent relative cover values among species. Plots with no overlaying pie charts shown indicate that no invasive species were detected.

NPS / SECN

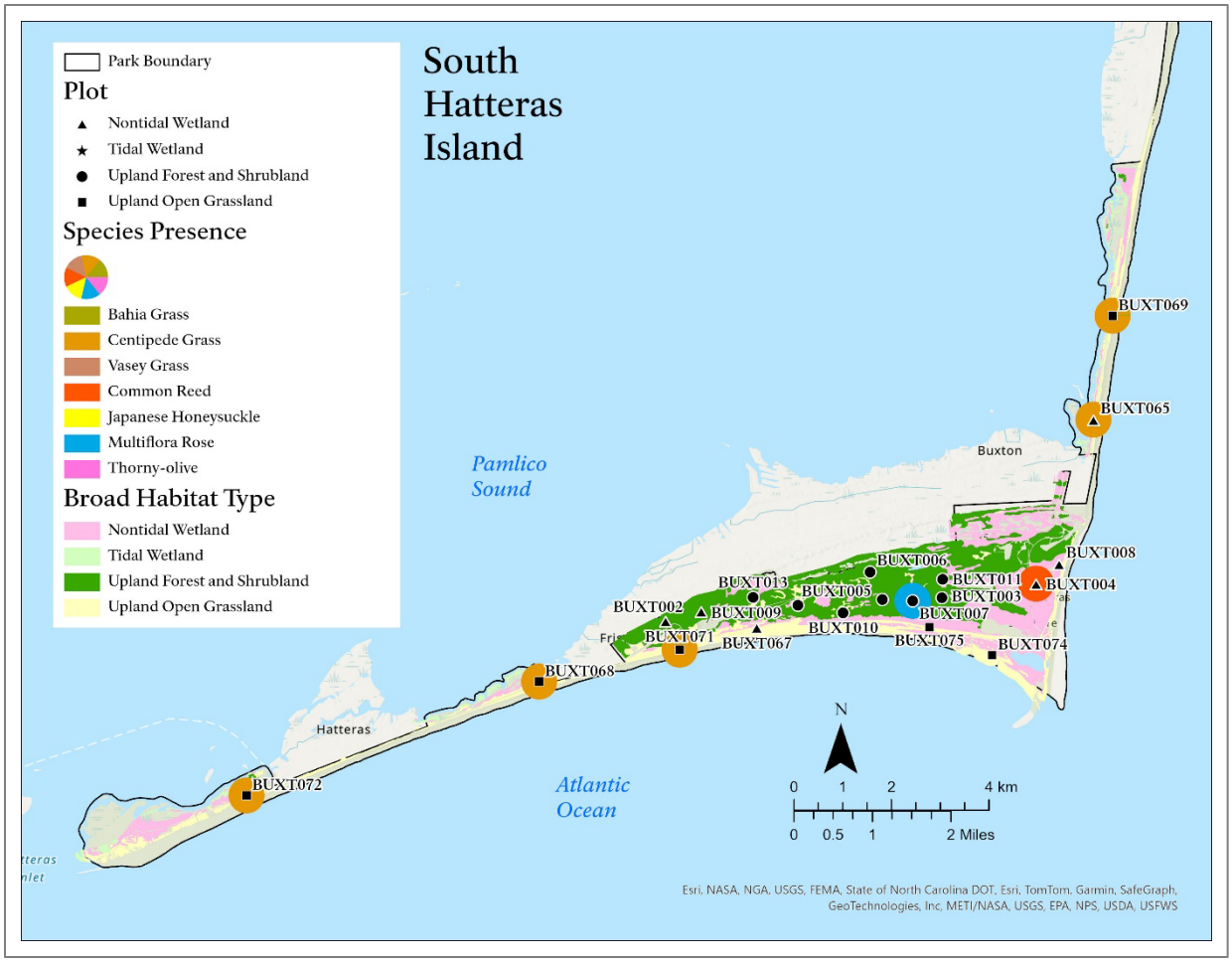

Figure 8. Invasive species presence by plot within the South Hatteras Island unit of Cape Hatteras National Seashore from the most recent sampling event in 2023. Where multiple species are present, pie slices represent relative cover values among species. Plots with no overlaying pie charts shown indicate that no invasive species were detected.

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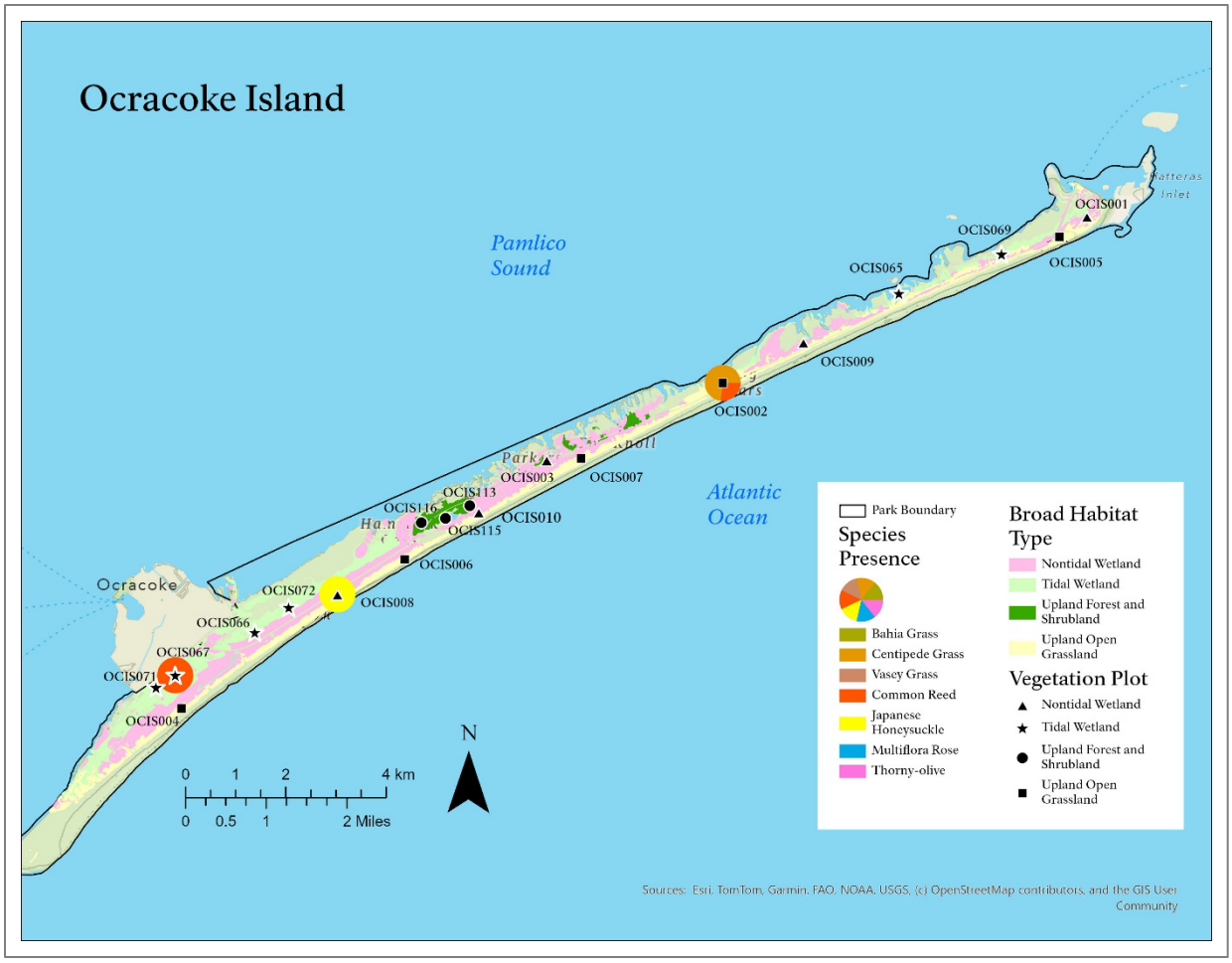

Figure 9. Invasive species presence by plot within the Ocracoke Island unit of Cape Hatteras National Seashore from the most recent sampling event in 2023. Where multiple species are present, pie slices represent relative cover values among species. Plots with no overlaying pie charts shown indicate that no invasive species were detected.

NPS / SECN

Species Richness and Abundance by Broad Habitat Type

Total species numbers (i.e., species richness) at the full plot scale (400 m^2) were expectedly variable in 2023 across broad habitat types in Cycle 2 vegetation plots (Figures 10 and 11). Tidal wetlands typically had fewer species than other broad habitat types across the seashore. Average species numbers were similar in 2023 and 2019 from these same plots of all broad habitat types across growth forms and nativity classifications (Figures 12 and 13). Detailed summaries of presence and abundance for each vascular plant species within each broad habitat type are provided below and within (Table 6 in *Plot- and Species-Scale Summary Tables* [Supplemental Materials {Boyle and Davis 2026}]).

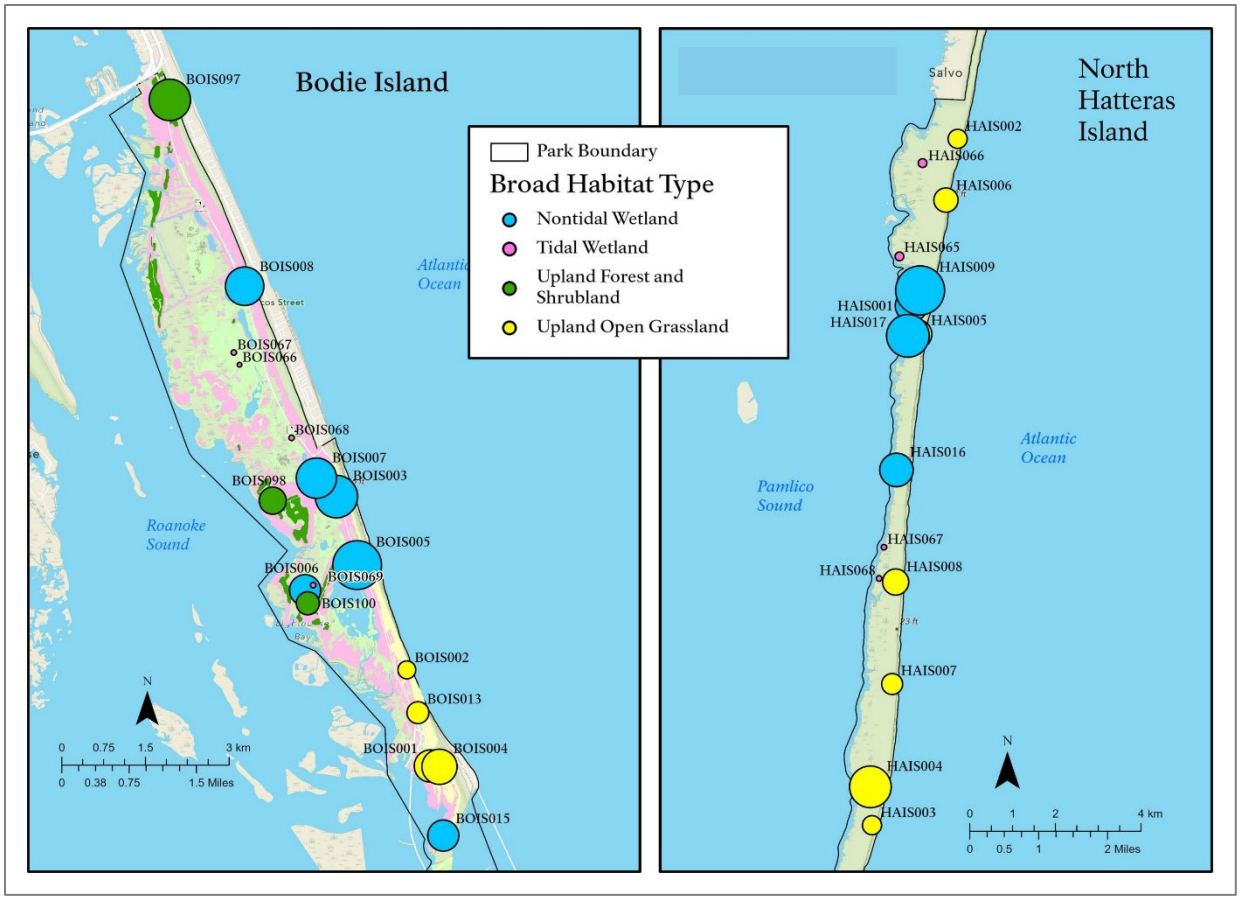

Figure 10. Vegetation plots within the Bodie Island and North Hatteras Island units of Cape Hatteras National Seashore scaled in size by 2023 species richness estimates. Richness values ranged from four to 47 species per plot across all broad habitat types.

NPS / SECN

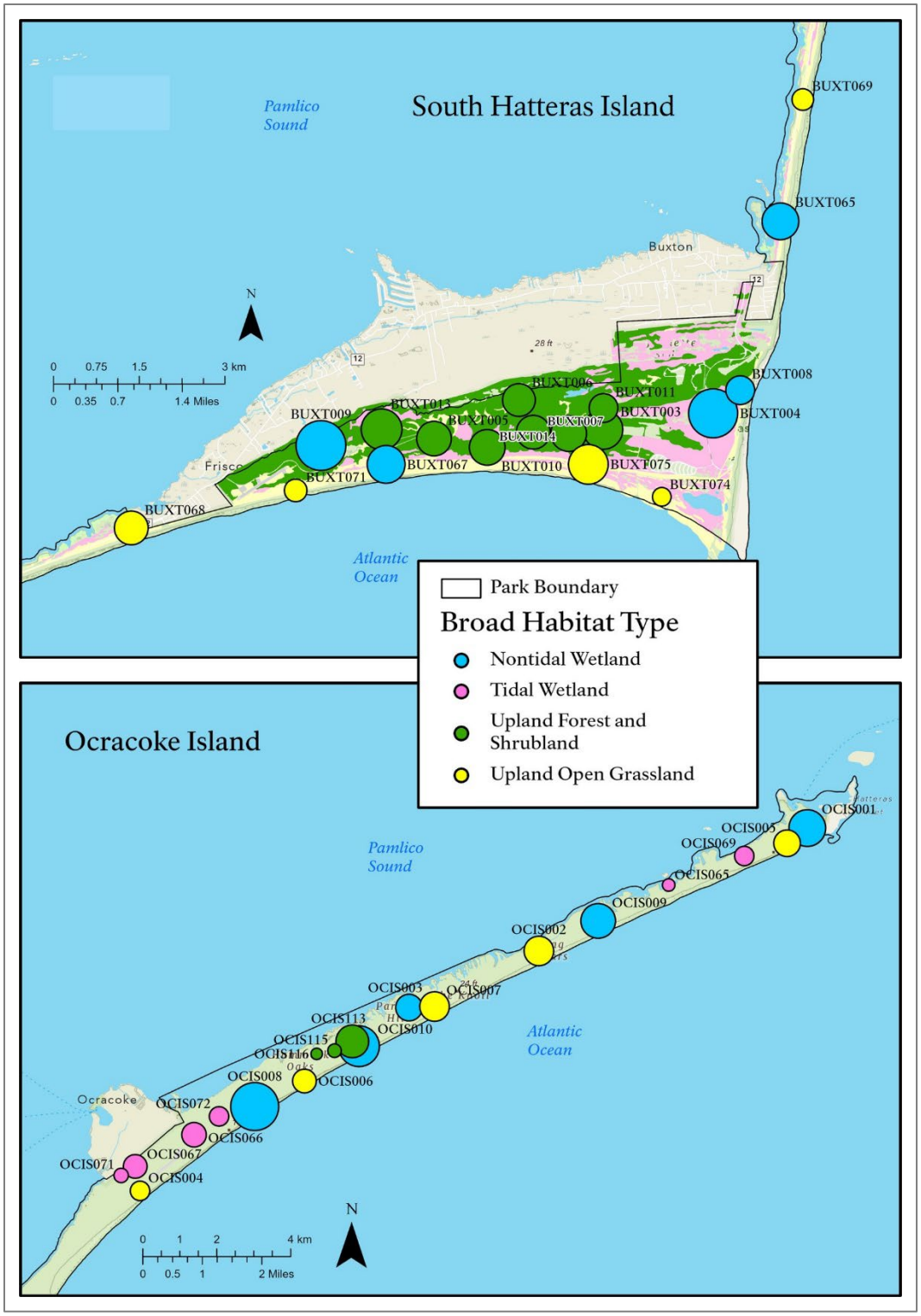

Figure 11. Vegetation plots within the South Hatteras Island and Ocracoke Island units of Cape Hatteras National Seashore scaled in size by 2023 species richness estimates. Richness values ranged from 11 to 49 species per plot across all broad habitat types.

NPS / SECN

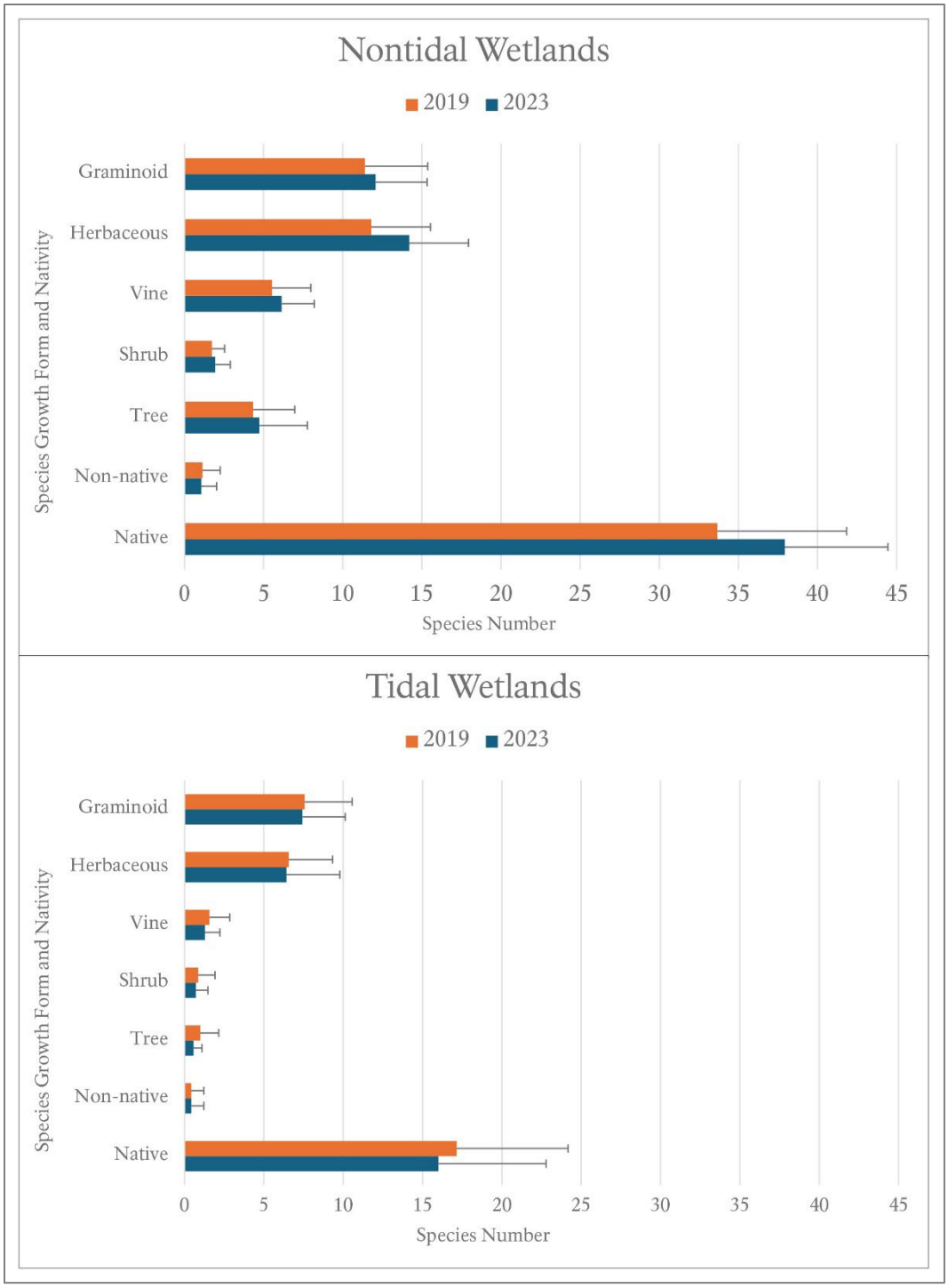

Figure 12. Average species richness at the full plot scale (400 m^2) by growth form and nativity within wetland broad habitat types of Cape Hatteras National Seashore. Data are summarized for plots monitored in both sampling years only—2019 and 2023. Error bars represent standard deviation. *NPS / SECN*

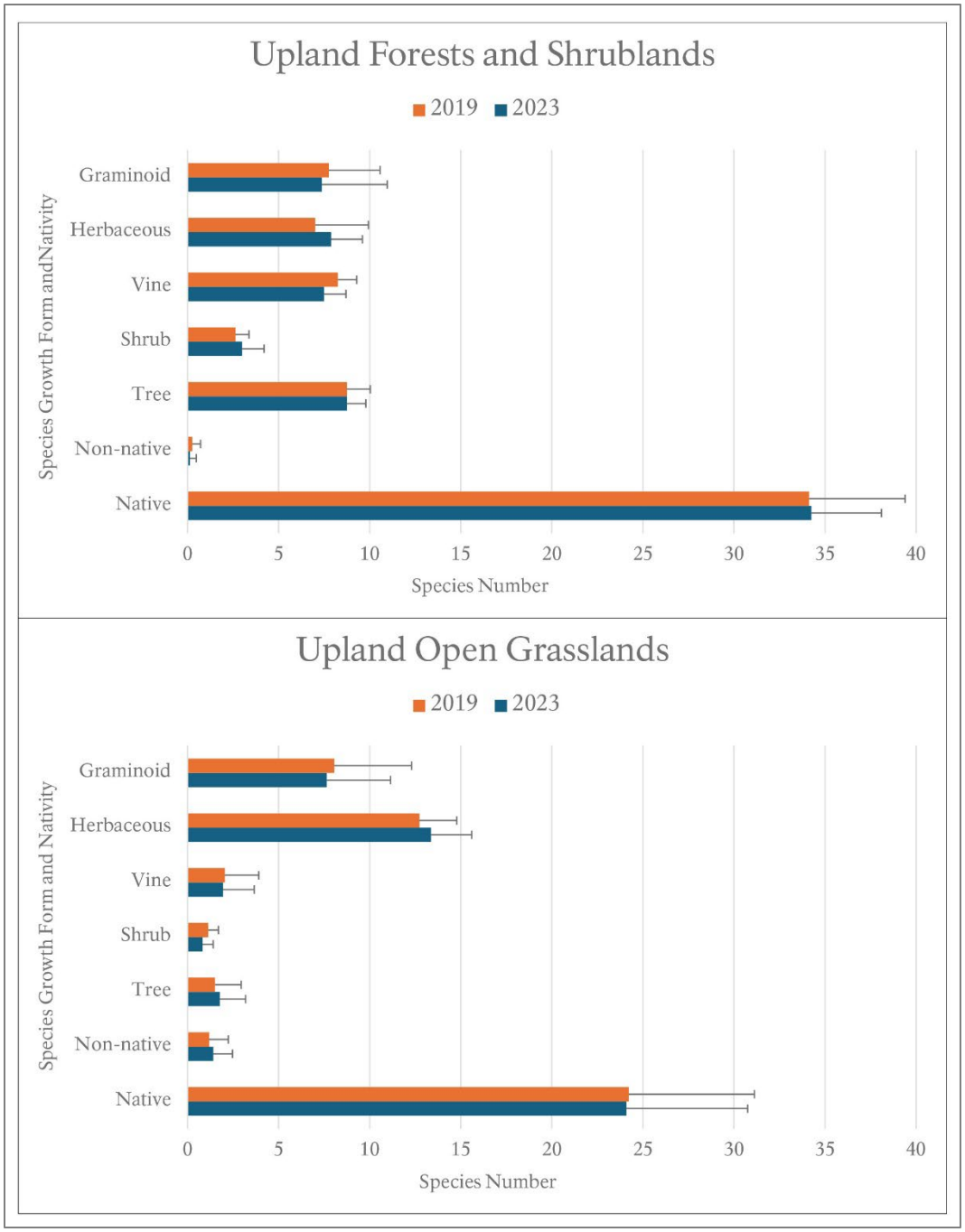

Figure 13. Average species richness at the full plot scale (400 m^2) by growth form and nativity within upland broad habitat types of Cape Hatteras National Seashore. Data are summarized for plots monitored in both sampling years only—2019 and 2023. Error bars represent standard deviation. *NPS / SECN*

Nontidal Wetlands

During this monitoring year, native species richness ranged from 26 to 49 species per plot within newly established Cycle 1 and revisited Cycle 2 nontidal wetland plots of the seashore, with an average of 36.6 (Figures 10–12; Table 5 in *Plot- and Species-Scale Summary Tables* [Supplemental

Materials {Boyle and Davis 2026}]). Collectively, plots of this habitat had the highest richness values among all other broad habitat types of the seashore. Herbs and graminoids were typically the most abundant growth form by species count across all spatial scales within these plots. Of the 19 species of rare plants observed during this monitoring effort, 16 were found within nontidal wetland plots. Six species were only found within this habitat of the seashore, including maritime thoroughwort, bloodleaf (*Iresine rhizomatosa*), winged seedbox (*Ludwigia alata*), coastal sundrops (*Oenothera unguiculata*), grassleaf arrowhead (*Sagittaria graminea*), and Simmond's aster (*Symphyotrichum simmondsii*). Where rare plants were present, canopy cover ranged from open to fairly patchy to even occasionally closed. Nontidal wetlands include the maritime wet grassland natural community type described by Sorrie (2021) as home to "a number of rare plant species." This habitat type of Cape Hatteras NS, as defined by this monitoring effort, has complex structural diversity features and a high frequency of occurrence across the seashore. It is highly valuable for plant conservation along the South Atlantic Coast for providing protected space for imperiled and rare plant species to grow and flourish.

The mean number of species (i.e., richness) within Cycle 2 nontidal wetland plots of Cape Hatteras NS was similar when comparing 2019 to 2023 monitoring events across most growth forms (trees, shrubs, vines, and graminoids) and slightly higher in 2023 within the herbaceous growth form (Figure 12). Plot level species richness data are provided for all growth forms and plot spatial scales (400 m^2, 100 m^2, 10 m^2, and 1 m^2) within (Table 5 in *Plot- and Species-Scale Summary Tables* [Supplemental Materials {Boyle and Davis 2026}]).

Of the 21 nontidal wetland plots monitored on the seashore in 2023, 14 had at least one non-native species present. These 14 plots were distributed across all four management units—Bodie Island, North Hatteras Island, South Hatteras Island, and Ocracoke Island. Non-native species composition remained similar between sampling years—2019 and 2023—within this broad habitat type (Figure 12). Invasive species were found in 10 of the 21 nontidal wetland plots (Figures 1–4). These species included common reed, Japanese honeysuckle, Vasey grass, and centipede grass. When present, these species often exhibited high abundances within plots. Within Bodie Island, common reed abundance increased substantially from 2019 to 2023; however, this species did not establish itself within plots it was not present in during the 2019 sampling period.

There were 224 total vascular plant taxa observed in the 21 nontidal wetland plots of Cape Hatteras NS during this monitoring effort in 2023. Seventy-eight of those were exclusively found within this broad habitat of the seashore. Constancy and average areal cover of each taxa record from 2023 vegetation plots are summarized by broad habitat type and found in (Table 6 in *Plot- and Species-Scale Summary Tables* [Supplemental Materials {Boyle and Davis 2026}]). Constancy is defined as the proportion of plots a certain taxon occurs in and is expressed as a percentage; a species with 100% constancy occurs in all plots of a given broad habitat type. Species with high constancy in nontidal wetland plots of the seashore in 2023 are listed below along with their average cover range:

Trees

- Groundsel tree/silverling (*Baccharis halimifolia*); constancy = 81%, mean cover = 5–10%

- Southern red cedar; constancy = 76%, mean cover = 10–25%
- Yaupon; constancy = 76%, mean cover = 5–10%
- Swamp bay; constancy = 76%, mean cover = 2–5%

Shrubs

- Common wax-myrtle; constancy = 95%, mean cover = 25–50%

Vines

- Eastern poison ivy; constancy = 81%, mean cover = 5–10%
- Maritime catbriar; constancy = 81%, mean cover = 2–5%
- Virginia creeper (*Parthenocissus quinquefolia*); constancy = 71%, mean cover = 1–2%

Herbs/Graminoids

- Small saltmeadow cordgrass; constancy = 86%, mean cover = 10–25%
- Centella/coinleaf; constancy = 71%, mean cover = 0–1%

Tidal Wetlands

During this monitoring year, native species richness ranged from four to 24 species per plot within newly established Cycle 1 and revisited Cycle 2 tidal wetland plots of the seashore, with an average of 10.9 (Figures 10–12; Table 5 in *Plot- and Species-Scale Summary Tables* [Supplemental Materials {Boyle and Davis 2026}]). Collectively, plots of this habitat had the lowest richness values among all other broad habitat types of the seashore. Herbs and graminoids were typically the most abundant growth form by species count across all spatial scales within these plots. Tidal wetland plots on Ocracoke Island were more species rich than plots of this same habitat type across the other management units of the seashore. Tidal wetlands across Bodie Island and North Hatteras Island consistently had fewer than 10 species/plot whereas there were consistently greater than 10 species/plot across Ocracoke Island. As mentioned above under the Environmental Attributes and Broad Habitat Type Descriptions section, Ocracoke Island tidal wetland plot soils exhibited much lower sodium content and higher pH values than plots within the other two management units. These edaphic features of seashore monitored tidal wetlands (e.g., high salt marsh and oligohaline marshes) are likely a primary factor impacting vascular plant species diversity and abundance.

Of the 19 species of rare plants observed during this monitoring effort, five were found within tidal wetland plots—compared to 16 rare species found in nontidal wetland plots. Most rare species observed within this broad habitat type were in monitoring plots of Ocracoke Island. Rare species found within Ocracoke Island tidal wetland plots included the state threatened Gulf Coast spikerush, significantly rare creeping spikerush (*Eleocharis fallax*) and beaked spikerush (*Eleocharis rostellata*), and rare false-willow (*Baccharis angustifolia*).

The mean number of species within Cycle 2 tidal wetland plots of Cape Hatteras NS was similar when comparing 2019 to 2023 monitoring events across most growth forms (shrubs, vines, herbs, and graminoids) and was slightly lower in 2023 within the tree growth form (Figure 12). Slightly lower tree species diversity was due to the loss of swamp bay from two plots between 2019 and 2023. It should be noted that individuals of this species occurred in 2019 plots as small statured plants (i.e., seedlings) and likely are waifs in this habitat type of the seashore. It is not surprising they were not relocated in 2023. Plot level species richness data are provided for all growth forms and plot spatial scales (400 m^2, 100 m^2, 10 m^2, and 1 m^2) within Table 5 in *Plot- and Species-Scale Summary Tables* (Supplemental Materials [Boyle and Davis 2026]).

Of the 14 tidal wetland plots monitored on the seashore in 2023, only three had at least one non-native species present. Two of these occurrences, however, were the invasive common reed. This species was found in relatively high abundance within one tidal wetland plot of North Hatteras Island and one plot of Ocracoke Island. Although the 2023 frequency of non-native and invasive species occurrence was low in tidal wetland plots, species like common reed have the capability of rapidly taking over these sites and outcompeting native species. Within the Ocracoke Island plot, common reed has increased in abundance between 2019 and 2023. The 2019 data are not available for the North Hatteras Island plot because it was not established in then.

There were 49 vascular plant taxa observed in the 14 tidal wetland plots of Cape Hatteras NS during this monitoring effort in 2023, including 10 species only found within this broad habitat of the seashore. Species that were only present within this habitat included smooth cordgrass, Gulf Coast spikerush, and Olney threesquare (*Schoenoplectus americanus*). Constancy and average areal cover value of each taxa record from 2023 vegetation plots are summarized by broad habitat type and found in Table 6 in *Plot- and Species-Scale Summary Tables* (Supplemental Materials [Boyle and Davis 2026]). Species with high constancy in tidal wetland plots of the seashore in 2023 are listed below along with their average cover range:

Herbs/Graminoids

- Small saltmeadow cordgrass; constancy = 100%, mean cover = 25–50%
- Saltgrass (*Distichlis spicata*); constancy = 79%, mean cover = 5–10%
- Black needle rush; constancy = 57%; mean cover = 5–10%
- Silver seaside oxeye (*Borrichia frutescens*); constancy = 57%; mean cover = 5–10%

Tree, shrub, and vine species were occasionally present within tidal wetlands of Cape Hatteras NS but occurred in low frequencies across the landscape.

Upland Forests and Shrublands

Native species richness ranged from 11 to 40 species per plot within newly established Cycle 1 and revisited Cycle 2 upland forest and shrubland plots of Cape Hatteras NS, with an average of 29.7 (Figures 10, 11, and 13; Table 5 in *Plot- and Species-Scale Summary Tables* [Supplemental Materials {Boyle and Davis 2026}]). Species classified as trees were slightly more dominant across all spatial

scales within these plots, although vines occurred in high abundance as well. Five rare species were observed within these plots, including the state threatened blue witchgrass. The significantly rare woods-grass (*Oplismenus setarius*) was in five of the 14 upland forest and shrubland plots of the seashore.

The only plots of this broad habitat type sampled in both 2019 and 2023 occurred on the South Hatteras Island management unit of the seashore. Average plot-level species numbers were similar among monitoring years across all species growth forms within these plots. Plot level species richness data are provided for all growth forms and plot spatial scales (400 m^2, 100 m^2, 10 m^2, and 1 m^2) within Table 5 in *Plot- and Species-Scale Summary Tables* (Supplemental Materials [Boyle and Davis 2026]).

Of the 14 upland forest and shrubland plots monitored on the seashore in 2023, only two had at least one non-native species present. This habitat type had the lowest frequency of non-native species among all broad habitat types monitored within the seashore. All non-native species present within the two plots are listed as invasive by North Carolina (NCNPS 2023). Two invasive species—Japanese honeysuckle and thorny-olive—were found within one of the newly established upland forest and shrubland plots of Bodie Island (BOIS097; Figure 1). Multiflora rose was newly observed in 2023 within one of the 2019-established plots of South Hatteras Island (BUXT007; Figure 3).

There were 126 vascular plant taxa observed in the 14 upland forest and shrubland plots of Cape Hatteras NS during this monitoring effort in 2023, including 32 species only found within this broad habitat of the seashore. Constancy and average areal cover value of each taxa record from 2023 vegetation plots are summarized by broad habitat type and found in Table 6 in *Plot- and Species-Scale Summary Tables* (Supplemental Materials [Boyle and Davis 2026]). Species with high constancy in these plots are listed below along with their average cover range:

Trees

- Yaupon; constancy = 100%, mean cover = 10–25%
- Swamp bay; constancy = 100%, mean cover = 5–10%
- Southern red cedar; constancy = 93%, mean cover = 10–25%
- Loblolly pine; constancy = 71%, mean cover = 10–25%
- Live oak; constancy = 64%, mean cover = 10–25%

Shrubs

- Common wax-myrtle; constancy = 93%, mean cover = 10–25%

Vines

- Eastern poison ivy; constancy = 100%, mean cover = 5–10%
- Maritime catbriar; constancy = 100%, mean cover = 2–5%

- Virginia creeper; constancy = 100%, mean cover = 2–5%
- Muscadine (*Muscadinia rotundifolia* var. *rotundifolia*); constancy = 86%, mean cover = 2–5%

Herbaceous and graminoid plants occurred within this broad habitat of the seashore, but no species occurred in high constancy rates among these plots.

Upland Open Grasslands

Native species richness was quite variable among upland open grassland plots of Cape Hatteras NS in 2023, ranging from 17 to 39 species per plot (Figures 10, 11, and 13; Table 5 in *Plot- and Species-Scale Summary Tables* [Supplemental Materials {Boyle and Davis 2026}]). Species classified as herbs were the dominant growth form across all spatial scales within these plots, although graminoids occurred in high abundance as well. Five rare species were observed within plots of this broad habitat type of the seashore. Another rare species—southern seaside spurge (*Euphorbia bombensis*)—was lumped together with the morphologically similar northern seaside spurge (*Euphorbia polygonifolia*). Northern seaside spurge is not tracked as rare within the state of North Carolina. This combined taxon was frequent within these plots across the seashore, as was the special concern-vulnerable dune blue curls.

Average plot-level species numbers were similar among monitoring years across all species growth forms within these plots (Figure 13). Plot level species richness data are provided for all growth forms and plot spatial scales (400 m^2, 100 m^2, 10 m^2, and 1 m^2) within Table 5 in *Plot- and Species-Scale Summary Tables* (Supplemental Materials [Boyle and Davis 2026]).

Of the 22 upland open grassland plots monitored on the seashore in 2023, 19 had at least one non-native species present. This habitat type had the highest frequency of non-native species among all broad habitat types monitored within the seashore. Non-native species composition remained similar between sampling years—2019 and 2023—within this broad habitat type (Figure 13). The most frequently occurring non-native, invasive species within these plots was centipede grass (Figures 1–4). This species is commonly planted across the southeastern U.S. as a lawn and roadside grass, and according to Sorrie (2021) has recently colonized roadsides across Bodie and Hatteras Island.

There were 110 vascular plant taxa observed in the 22 upland open grassland plots of Cape Hatteras NS during this monitoring effort in 2023, including 21 species only found within this broad habitat of the seashore. Constancy and average areal cover value of each taxa record from 2023 vegetation plots are summarized by broad habitat type and found in Table 6 in *Plot- and Species-Scale Summary Tables* (Supplemental Materials [Boyle and Davis 2026]). Species with high constancy in these plots are listed below along with their average cover range:

Trees

- Southern red cedar; constancy = 82%, mean cover = 5–10%

Herbs/Graminoids

- Sea oats; constancy = 100%, mean cover = 25–50%
- Camphorweed (*Heterotheca subaxillaris*); constancy = 100%, mean cover = 2–5%
- Seabeach evening-primrose (*Oenothera humifusa*); constancy = 100%, mean cover = 0–1%
- Dune pennywort (*Hydrocotyle bonariensis*); constancy = 91%, mean cover = 2–5%
- Southern horseweed (*Erigeron pusillus*); constancy = 91%, mean cover = 0–1%
- Small saltmeadow cordgrass; constancy = 86%, mean cover = 2–5%
- Dune prickly-pear (*Opuntia drummondii*); constancy = 86%, mean cover = 0–1%
- Southern + northern seaside spurge; constancy = 86%, mean cover = 0–1%
- Sand dayflower (*Commelina erecta* var. *angustifolia*); constancy = 82%, mean cover = 0–1%

Although shrub and vine species were present within this broad habitat type, they occurred in lower frequencies than the species listed above. Common shrubs and vines within upland open grasslands included common wax-myrtle, yaupon, dune greenbriar (*Smilax auriculata*), and maritime catbriar.

Tree Abundance, Health, and Growth Metrics by Broad Habitat Type

There were 503 live trees present within 71 SECN vegetation plots across Cape Hatteras NS in 2023, although trees were not present in all plots. The total basal area of all live trees was 460 m^2/ha. Dominant species across the seashore included loblolly pine, slash pine, southern red cedar, live oak, and sand laurel oak. There were 14 woody species with a large enough diameter at breast height (≥10 cm) to be considered a tree. Forty-seven trees were present within monitoring plots coded as dead or missing from the 2019 monitoring effort. Summaries of tree presence, abundance, and health status observed during the 2023 monitoring effort are provided below for nontidal wetland and upland forest and shrubland habitats. Tree-sized individuals were expectedly not observed in tidal wetland nor upland open grassland habitat. Woody stem basal area and density for all tree-, sapling-, and seedling-classes are summarized by species within all broad habitat types in Table 8 in *Plot- and Species-Scale Summary Tables* (Supplemental Materials [Boyle and Davis 2026]).

Nontidal Wetlands

Live tree basal area within nontidal wetland plots of Cape Hatteras NS in 2023 ranged from 0 to 13 m^2/ha with an average of 3 m^2/ha, while live tree density ranged from 0 to 21 stems/plot. Six of the 21 nontidal wetland plots did not have tree-sized woody stems present. The most dominant tree within this broad habitat type was southern red cedar (Figures 14–17). Canopy heights were less than 10 meters (32.8 ft) and canopy cover was highly variable—ranging from 0 to 92%—owing to the differences in tree densities between plots (Table 7 in *Plot- and Species-Scale Summary Tables* [Supplemental Materials {Boyle and Davis 2026}]).

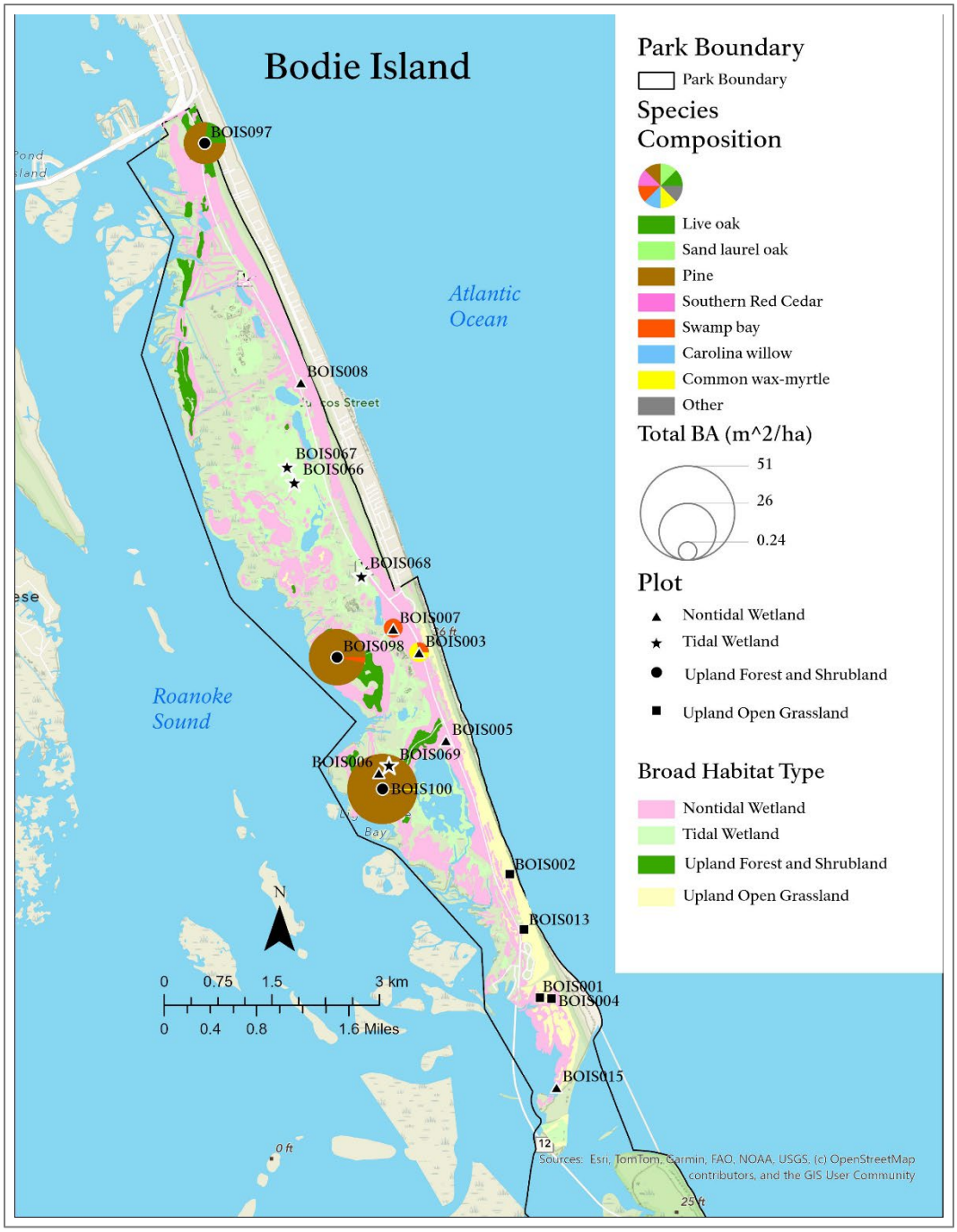

Figure 14. 2023 basal area estimates per plot by species within the Bodie Island unit of Cape Hatteras National Seashore. “Pine” represents loblolly, pond, and slash pine; “Other” represents coastal American hornbeam, American holly, American persimmon, flowering dogwood, and southern swamp dogwood. Pie size is proportional to the total plot level basal area (range: 0 to 35 m^2/ha). Plots without corresponding pie graphs lacked trees.

NPS / SECN

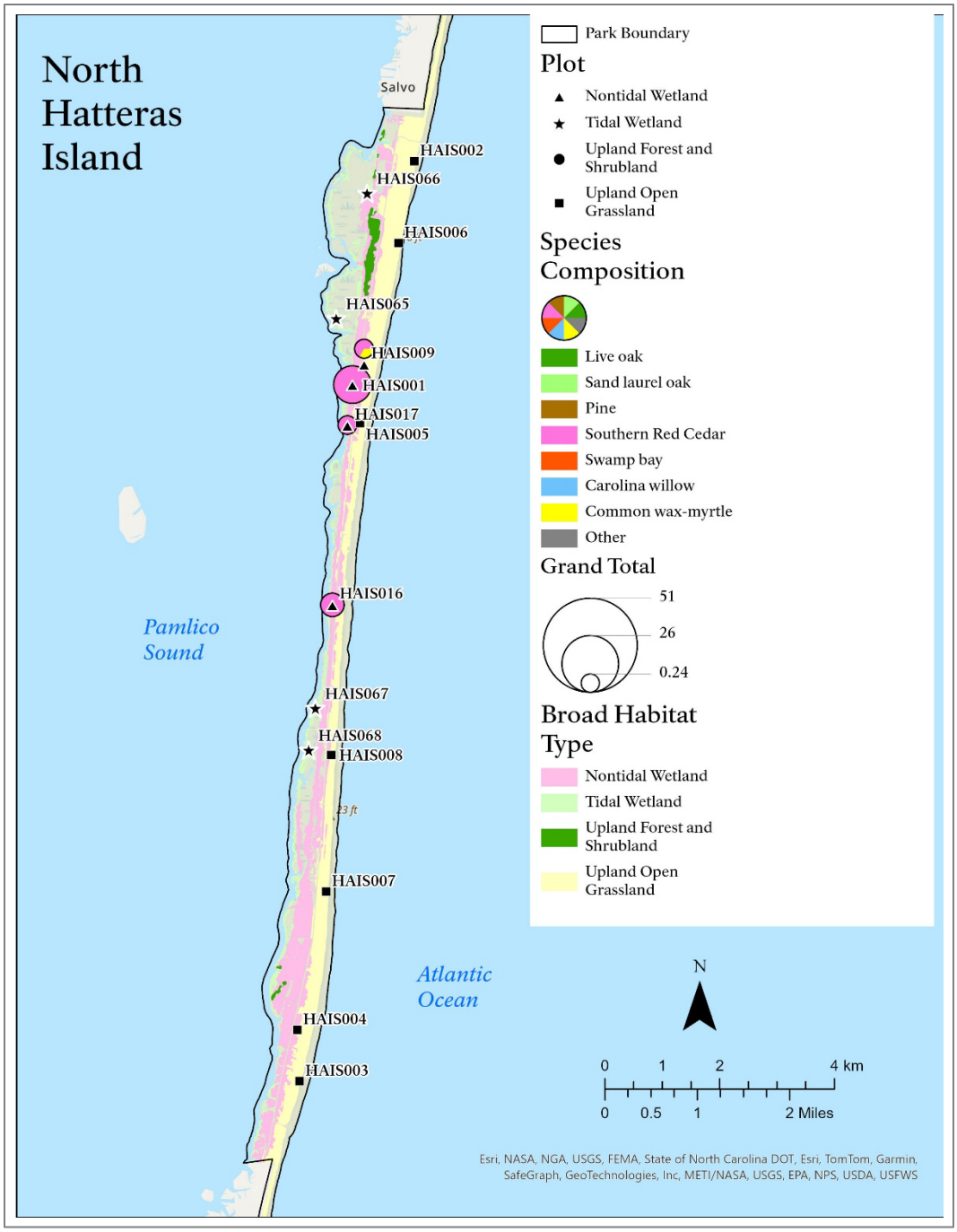

Figure 15. 2023 basal area estimates per plot by species within the North Hatteras Island unit of Cape Hatteras National Seashore. “Pine” represents loblolly, pond, and slash pine; “Other” represents coastal American hornbeam, American holly, American persimmon, flowering dogwood, and southern swamp dogwood. Pie size is proportional to the total plot level basal area (range: 0 to 13 m^2/ha). Plots without corresponding pie graphs lacked trees.

NPS / SECN

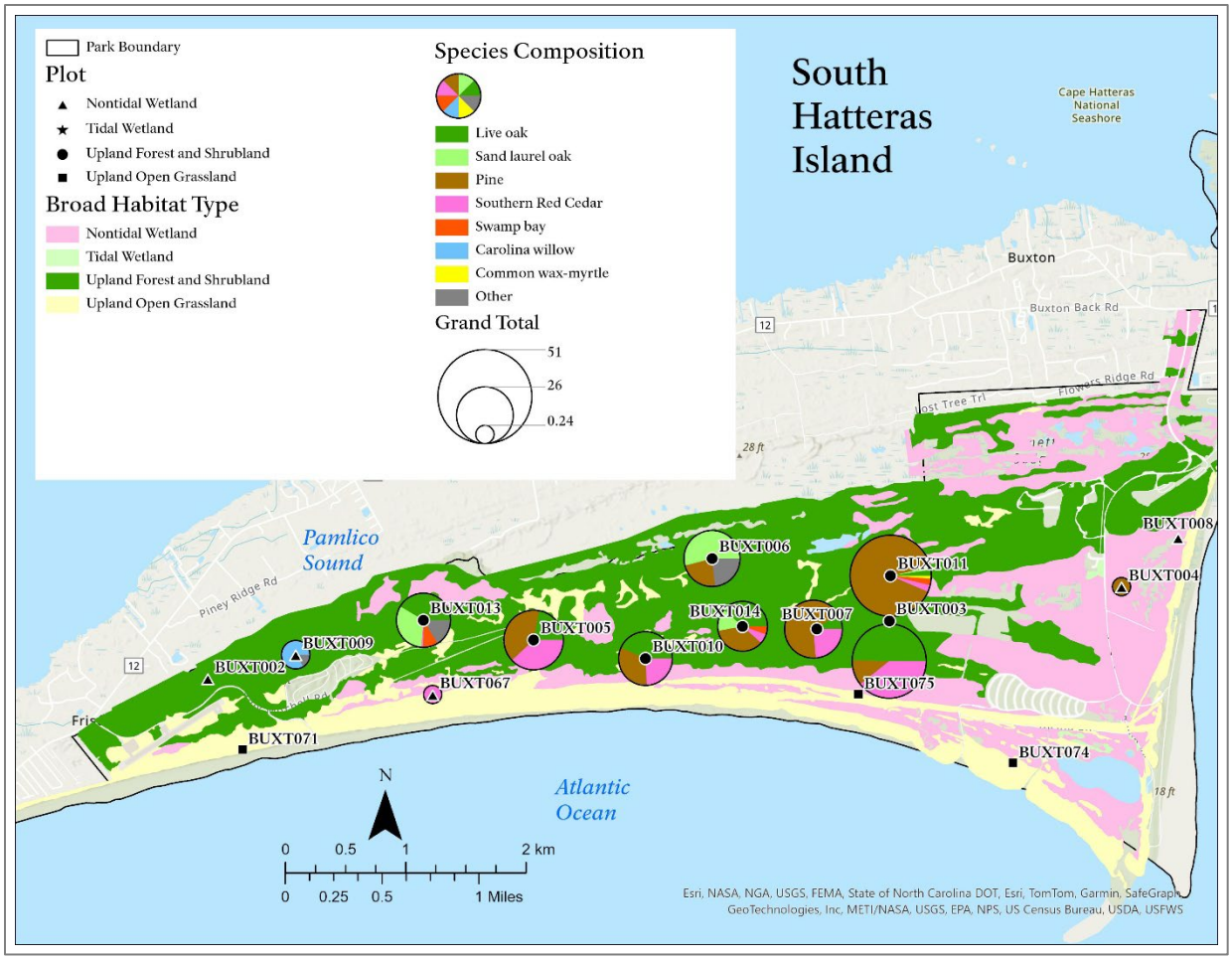

Figure 16. 2023 basal area estimates per plot by species within the South Hatteras Island unit of Cape Hatteras National Seashore. “Pine” represents loblolly, pond, and slash pine; “Other” represents coastal American hornbeam, American holly, American persimmon, flowering dogwood, and southern swamp dogwood. Pie size is proportional to the total plot level basal area (range: 0 to 42 m^2/ha). Plots without corresponding pie graphs lacked trees.

NPS / SECN

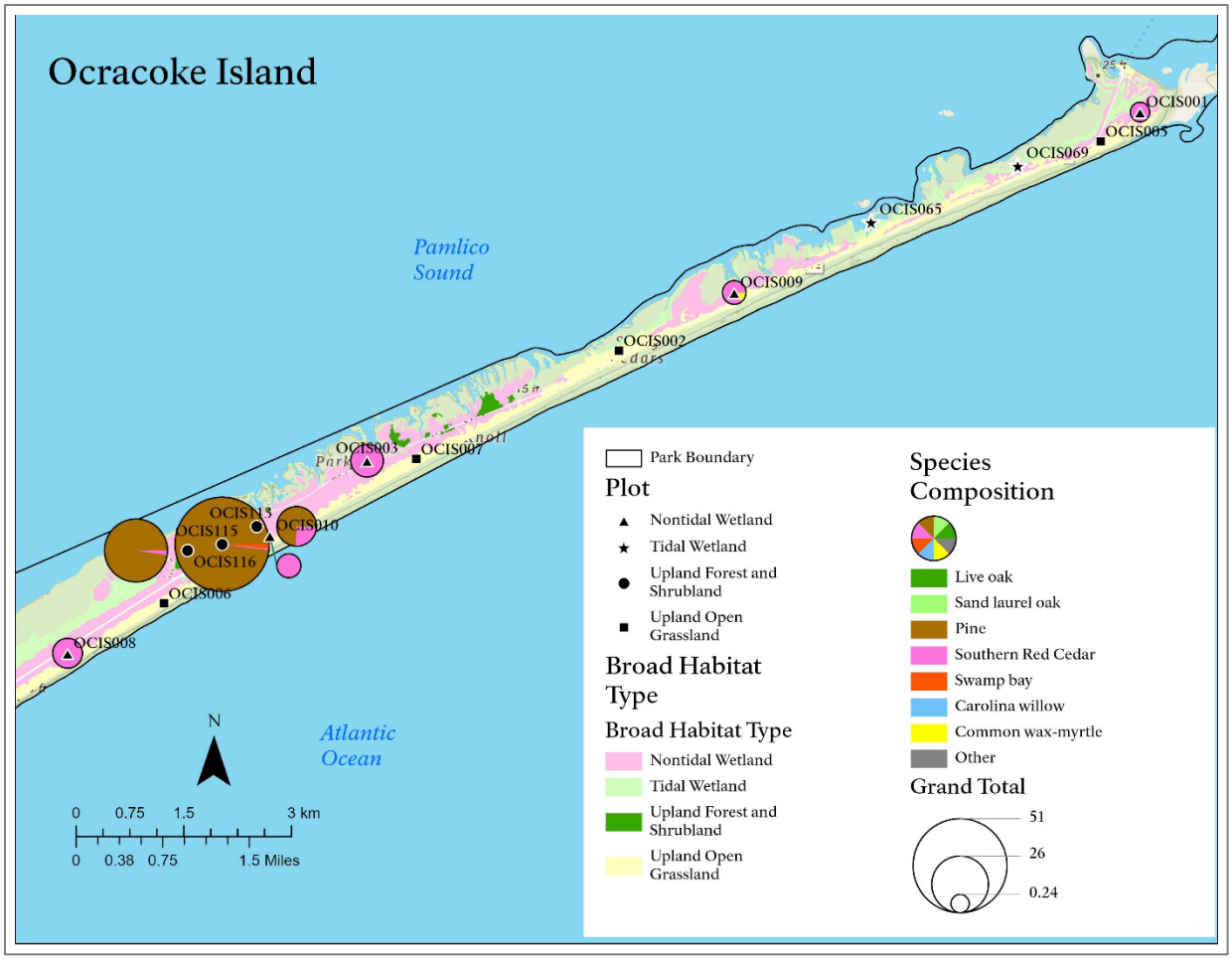

Figure 17. 2023 basal area estimates per plot by species within the Ocracoke Island unit of Cape Hatteras National Seashore. “Pine” represents loblolly, pond, and slash pine; “Other” represents coastal American hornbeam, American holly, American persimmon, flowering dogwood, and southern swamp dogwood. Pie size is proportional to the total plot level basal area (range: 0 to 51 m^2/ha). Plots without corresponding pie graphs lacked trees.
NPS / SECN

Of the 136 trees measured within these plots in 2023, 120 were living (88%), 13 were dead (10%), and three had fallen since the previous monitoring effort in 2019 (2%; Table 1). Nine of the 13 dead trees were southern red cedar, which is not surprising since southern red cedar represented the most dominant species within this broad habitat type of the seashore. Most of the live trees measured during this monitoring year were healthy or experiencing light decline (i.e., less than 25% of a stems crown is damaged or missing; Table 1).

Table 1. Total counts of live, dead, and fallen trees and vigor estimates by species within nontidal wetland vegetation plots of Cape Hatteras National Seashore.

Species	Grand Total	Status			Vigor				
		Live	Dead	Fallen	Healthy	Light Decline	Moderate Decline	Severe Decline	Functionally Dead
Carpinus caroliniana var. *caroliniana*	1	1	0	0	1	0	0	0	0
Diospyros virginiana	2	2	0	0	1	1	0	0	0
Juniperus silicicola	99	90	9	0	76	10	0	3	1
Morella cerifera	6	5	1	0	2	2	1	0	0
Persea palustris	4	3	1	0	0	0	1	2	0
Pinus taeda	2	1	1	0	1	0	0	0	0
Salix caroliniana	16	14	0	2	11	1	2	0	0
Swida foemina	6	4	1	1	1	0	2	0	0
Grand Total	**136**	**120**	**13**	**3**	**93**	**14**	**6**	**5**	**2**

Only the 15 plots established in 2019 within this broad habitat type could be used to assess tree growth. Overall, average basal area of canopy species within these plots increased, with common wax-myrtle exhibiting the slowest growth rate (Figure 18).

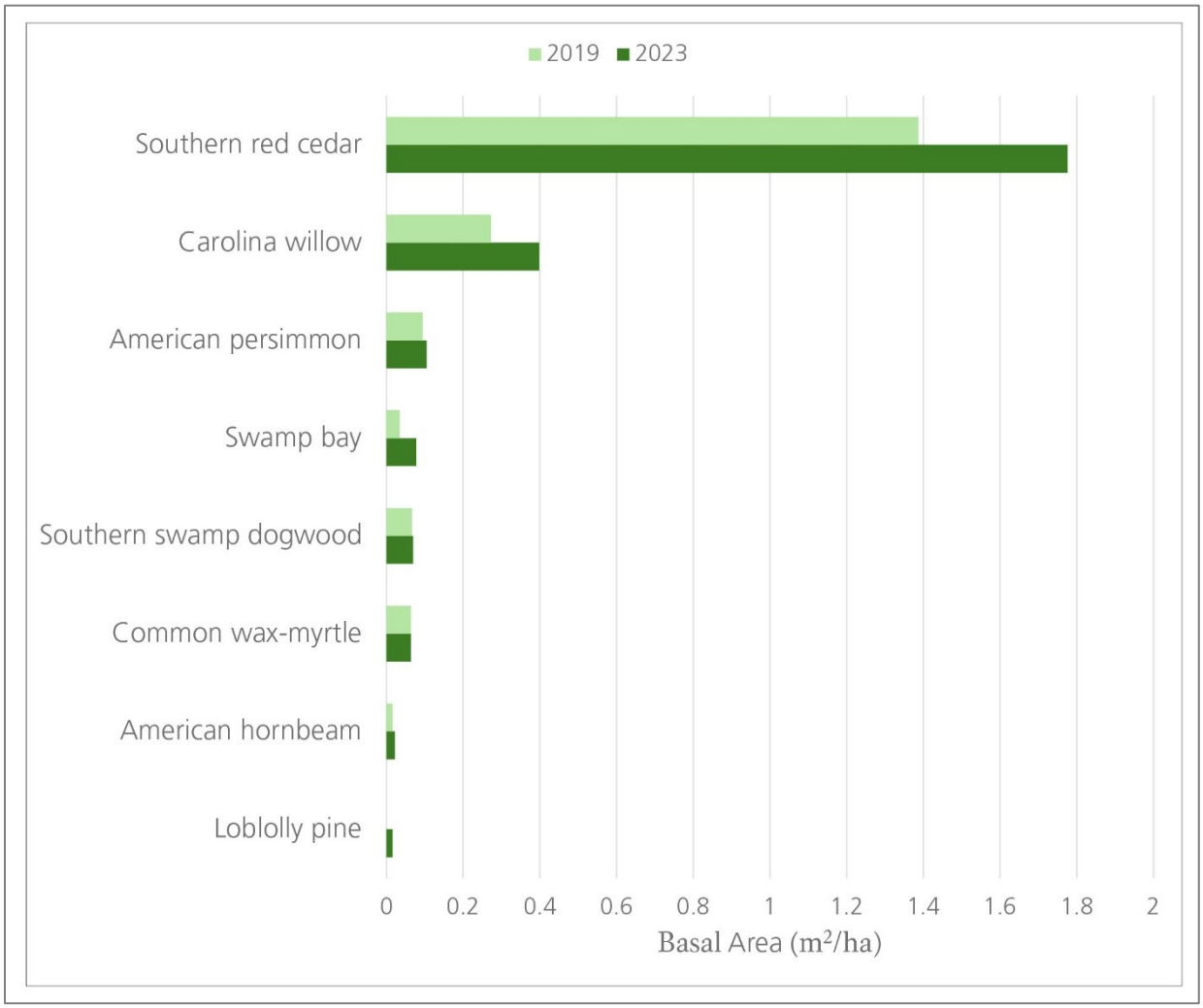

Figure 18. Mean basal area of live canopy species within nontidal wetland plots of Cape Hatteras National Seashore sampled in 2019 and 2023.

NPS / SECN

Upland Forests and Shrublands

Total live tree basal area within upland forest and shrubland plots of Cape Hatteras NS was highly variable, ranging from 15 to 51 m^2/ha with an average of 29 m^2/ha, while tree density ranged from 11 to 52 stems/plot (Table 7 in *Plot- and Species-Scale Summary Tables* [Supplemental Materials {Boyle and Davis}]). Wentworth et al. (1993) reports an average live tree basal area of 32.5 m^2/ha from vegetation plots in oak-dominated maritime forests across the coast of North Carolina, while they report an average live tree basal of 32.4 m^2/ha in pine-dominated maritime forests. Across all 2023 SECN vegetation monitoring plots, the most dominant tree within this broad habitat type was

loblolly pine, which had an average basal area of 9.3 m^2/ha; slash pine, which was in upland forest and shrubland plots of Bodie Island and Ocracoke Island, had an average basal area of 8.9 m^2/ha; finally, other dominant species included live oak, southern red cedar, and sand laurel oak (Figures 5–8). Lesser dominant and understory tree-sized species included American hornbeam (*Carpinus caroliniana* var. *caroliniana*), swamp bay, American holly (*Ilex opaca*), pond pine (*Pinus serotina*), flowering dogwood (*Benthamidia florida*), and common wax-myrtle (Table 8 in *Plot- and Species-Scale Summary Tables* [Supplemental Materials {Boyle and Davis 2026}]).

Most of these plots had closed canopies, with average canopy cover typically >75% (Table 7 in *Plot- and Species-Scale Summary Tables* [Supplemental Materials {Boyle and Davis 2026}]). A closed canopy is typical of maritime upland forests, although small-scale canopy gaps brought on by localized wind and storm events do occur naturally. Canopy height ranged from 10 to 22 meters (32.8 to 72.2 ft), with an overall average of 16.3 meters (53.5 ft; Table 7 in *Plot- and Species-Scale Summary Tables* [Supplemental Materials {Boyle and Davis 2026}]). Plots closer to the ocean-side (south-side) of the South Hatteras Island unit typically had a shorter canopy than plots closer to the estuarine side of the unit (north-side). Of the 411 trees measured within these plots in 2023, 382 were living (93%), 20 were dead (5%), and nine had fallen since the previous monitoring effort in 2019 (2%; Table 2). Most of the live trees measured during this monitoring year were healthy or experiencing only slight decline (i.e., less than 25% of a stems crown is damaged or missing; Table 2). Of the 14 swamp bay trees measured in the upland forest and shrubland plots of the South Hatteras Island unit in 2019, six were dead and five had visual symptoms similar to trees infected with LWD. In 2023, two of the eight swamp bays alive in 2019 were dead (25%) and four exhibited severely declining vigor or were functionally dead (50%). As discussed above, LWD has been detected as far north as Carteret County and has not yet been officially detected within Dare County (USFS 2026). It is possible that another ambrosia beetle, or other forest pest, has caused swamp bay decline. Based on these monitoring data, it does appear that swamp bay trees are declining in both upland forest and shrubland and nontidal wetland habitat of the seashore.

Table 2. Total counts of live, dead, and fallen trees and vigor estimates by species within upland forest and shrubland vegetation plots of Cape Hatteras National Seashore.

Species	Grand Total	Status			Vigor				
		Live	Dead	Fallen	Healthy	Light Decline	Moderate Decline	Severe Decline	Functionally Dead
Benthamidia florida	3	2	0	1	0	2	0	0	0
Carpinus caroliniana var. *caroliniana*	12	11	0	1	3	5	3	0	0
Ilex opaca	4	4	0	0	3	0	1	0	0
Juniperus silicicola	75	74	1	0	54	15	2	3	0
Morella cerifera	3	2	1	0	2	0	0	0	0
Persea palustris	22	13	5	4	4	3	2	2	2
Pinus elliottii	84	75	9	0	66	7	2	0	0
Pinus serotina	1	1	0	0	1	0	0	0	0
Pinus taeda	101	97	4	0	90	5	2	0	0
Quercus hemisphaerica	22	22	0	0	17	0	2	1	2
Quercus virginiana	84	81	0	3	63	13	4	1	0
Grand Total	**411**	**382**	**20**	**9**	**303**	**50**	**18**	**7**	**4**

As discussed within the “Environmental Attributes and Broad Habitat Type Descriptions” section above, the upland forests found within the South Hatteras Island unit of Cape Hatteras NS largely represents the best example of maritime forests formed and shaped by natural processes across the northern Outer Banks, while the slash (and other) pine-dominated “forests” of Bodie Island and Ocracoke Island represent a remnant of past human manipulation (e.g., tree planting). Within the South Hatteras Island unit, the eight upland forest and shrubland plots varied in compositional dominance of canopy species. Two plots were co-dominated by live oak, southern red cedar, and loblolly pine; two plots were dominated solely by loblolly pine; one plot was co-dominated by live oak and southern red cedar; one plot was dominated by sand laurel oak; one plot was co-dominated by sand laurel oak and live oak; and one was co-dominated by live oak and loblolly pine. Disturbance from storms and impacts from historical land-use (e.g., logging) can have confounding effects on the distribution of canopy species within maritime forests. Live oak is more tolerant to salt spray than other canopy forming species. Wentworth et al. (1993) suggest there is a compositional shift along the salt-spray gradient (ocean to sound) of barrier islands, with live oak favoring the ocean-side and sand laurel oak favoring the sound-side. In the SECN monitoring plots within the South Hatteras Island unit, this same trend was observed.

Bratton and Davison (1987) describe the overall conversion of an oak-dominated to pine-dominated upland landscape within Buxton Woods since the early 1700s because of grazing, logging, and shifting fire regimes. They suggested sand laurel oaks are a better colonizer than live oak in these maritime forests following extensive logging, grazing, and fire. During their study, they also established vegetation plots within Buxton Woods and documented loblolly pine as the most abundant canopy species. Schafale (2024) recognizes three variants of the mid-Atlantic evergreen maritime forest (including those forests of the Outer Banks) based on primary successional age, with the Live Oak-Red Cedar variant occurring on successionally younger, more exposed sites and the Laurel Oak-Pine variant occurring on older sites protected from impacts from the ocean (e.g., erosion, salt spray). Live oak occasionally is found within the older, Laurel Oak-Pine variant. His third variant is not known to occur within the seashore. The occasional presence of live oak within Schafale’s (2024) Laurel Oak-Pine variant, coupled with the pre-colonial accounts of live oak dominance described in Bratton and Davison (1987), suggest that live oak historically was much more dominant within the Buxton Woods ecosystem as it is currently.

Based on data from SECN vegetation monitoring plots, loblolly pine continues to remain the most dominant species within this habitat type of the South Hatteras Island unit and was dominant in 2019 and 2023. Live oak, southern red cedar, and sand laurel oak are also co-dominant, secondarily to pine, within these forests. Basal area has increased between 2019 and 2023 for all these species, suggesting a healthy, growing forest (Figure 19). The canopy composition with the South Hatteras Island unit has been altered from its pre-colonial condition, and, as Bratton and Davison (1987) suggest, will likely never return to its pre-colonial condition. However, as older pines die off, natural succession of oak regeneration should be promoted—albeit sand laurel oak—within these forests, especially if fire and other soil disturbance events that promote pine regeneration are withheld (Bratton and Davison 1987).

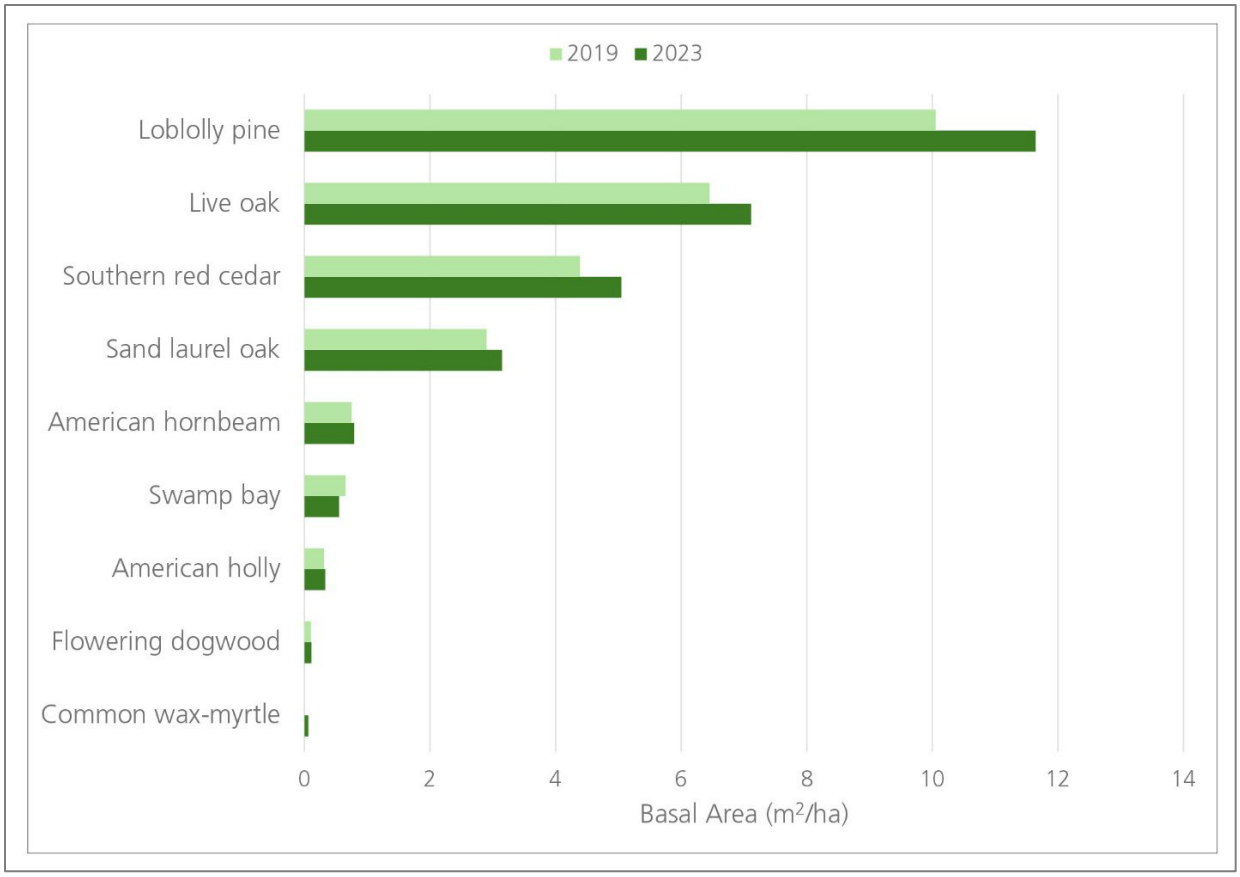

Figure 19. Mean basal area of live canopy species within upland forest and shrubland plots of Cape Hatteras National Seashore (South Hatteras Island unit) sampled in 2019 and 2023.
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Woody Stem Regeneration Metrics

Data collected from sapling and seedling counts were used to assess woody stem regeneration within individual plots and broad habitat types of Cape Hatteras NS. Abundances of saplings and seedlings of canopy- and subcanopy-forming species were highly variable among plots and habitats of the seashore. Within all plots sampled in 2023, total sapling basal area ranged from 0 to 16 m^2/ha while density ranged from 0 to 135 stems/80 m^2. Seedling density (excluding recent germinants, i.e., height class = 5–15 cm) ranged from 0 to 74 stems/8 m^2. Saplings and seedlings were not present within any of the tidal wetland plots and were infrequent in upland open grassland plots. Across the seashore, dominant woody species (including canopy and non-canopy trees, shrubs, woody vines, and Smilax spp.) within the sapling stratum included common wax-myrtle, southern red cedar, yaupon, and southern swamp dogwood; dominant seedlings included eastern poison ivy, yaupon, maritime catbriar, swamp bay, and common wax-myrtle (Table 8 in *Plot- and Species-Scale Summary Tables* [Supplemental Materials {Boyle and Davis 2026}]). Regeneration metrics of canopy- and subcanopy-forming species are summarized below by broad habitat types of the seashore characterized by a significant woody stem component (e.g., nontidal wetlands and upland forests and shrublands).

Nontidal Wetlands

Basal area of canopy and subcanopy saplings within the 21 nontidal wetland vegetation plots of Cape Hatteras ranged from 0 to 16 m^2/ha. Dominant sapling species included common wax-myrtle, southern red cedar, and southern swamp dogwood. Seedling density (excluding recent germinants) of canopy and subcanopy species ranged from 0 to 74 stems/8 m^2. Dominant seedlings included common wax-myrtle, swamp bay, and southern red cedar (Table 8 in *Plot- and Species-Scale Summary Tables* [Supplemental Materials {Boyle and Davis 2026}]).

Relative densities of trees and canopy and subcanopy saplings and seedlings remained relatively similar between sampling years within the 15 nontidal wetland plots sampled in 2019 and 2023 (Figure 20). The high abundance of small- to medium-sized southern red cedar trees within a few nontidal wetland plots of North Hatteras Island and Ocracoke Island certainly had an impact on the relative density results across this habitat. For most nontidal wetland plots, tree-sized individuals were infrequent. More often, the canopy was formed by sapling-sized individuals of common wax-myrtle and a host of other species. The hydrologic range of variation was high across this habitat type—with some sites frequently inundated and some sites exhibiting upland-like hydrologic characteristics throughout the year. It is not surprising a combination of upland (e.g., yaupon, sparkleberry [*Vaccinium arboreum*]), wetland (e.g., Carolina willow [*Salix caroliniana*]), and intermediate (e.g., common wax-myrtle) woody species were found within this broad habitat type.

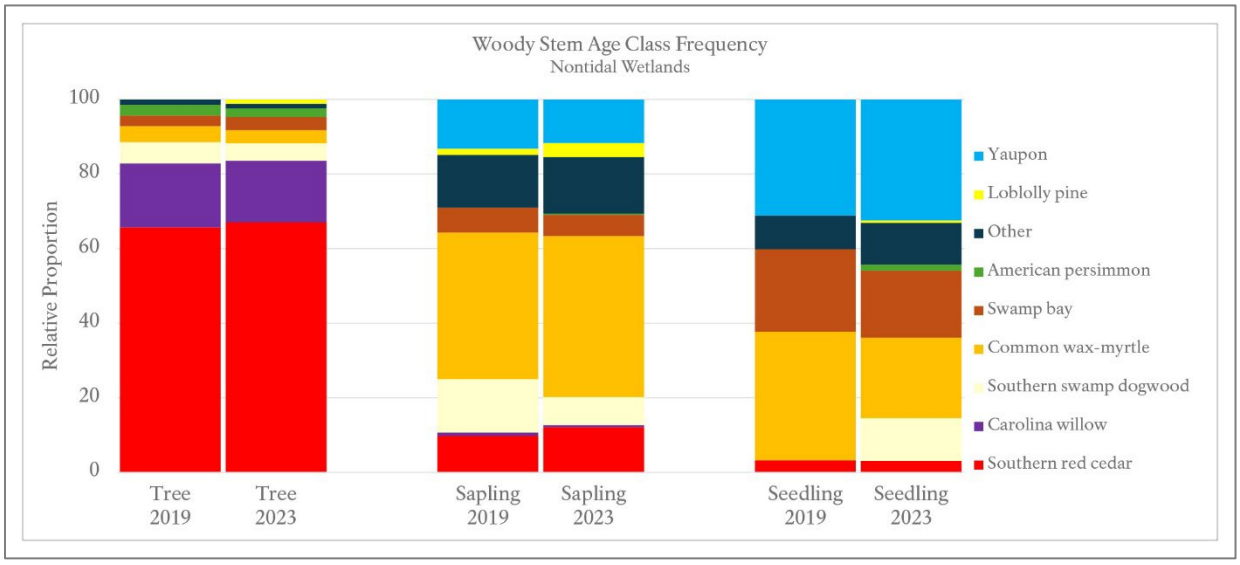

Figure 20. Relative proportion of canopy species across tree, sapling, and seedling strata within 2019 Cycle 1 and 2023 Cycle 2 nontidal wetland plots of Cape Hatteras National Seashore. Seedlings excluded recent germinants (stems 5–15 cm in height). Species in the "Other" category include red maple (*Acer rubrum*), eastern serviceberry (*Amelanchier canadensis*), groundsel tree/silverling, American hornbeam, American holly, sand laurel oak, live oak, sparkleberry, and hairy highbush blueberry (*Vaccinium fuscatum*).

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Upland Forests and Shrublands

Basal area of canopy and subcanopy saplings within the 14 upland forest and shrubland vegetation plots of Cape Hatteras NS ranged from 0.1 to 7.9 m^2/ha; dominant sapling species included, southern red cedar, common wax-myrtle, and live oak. Seedling density of canopy and subcanopy seedlings ranged from 0 to 47 stems/8 m^2; dominant seedlings included swamp bay, common wax-myrtle, sand laurel oak, and live oak. Other non-canopy forming woody species abundant in the sapling and seedling strata of these plots included yaupon, eastern poison ivy, maritime catbriar, Virginia creeper, muscadine, and Carolina jessamine (*Gelsemium sempervirens*; Table 8 in *Plot- and Species-Scale Summary Tables* [Supplemental Materials {Boyle and Davis 2026}]).

Relative densities of trees and canopy and subcanopy saplings and seedlings remained relatively similar between sampling years for most species within the eight upland forest and shrubland plots sampled in 2019 and 2023 (Figure 21). There was a slight decrease in the relative density of live oak and an increase in southern red cedar and swamp bay within the sapling stratum of this habitat type between 2019 and 2023. However, more sampling cycles will be needed to determine if there is an ecological trend in relative abundances within these groups.

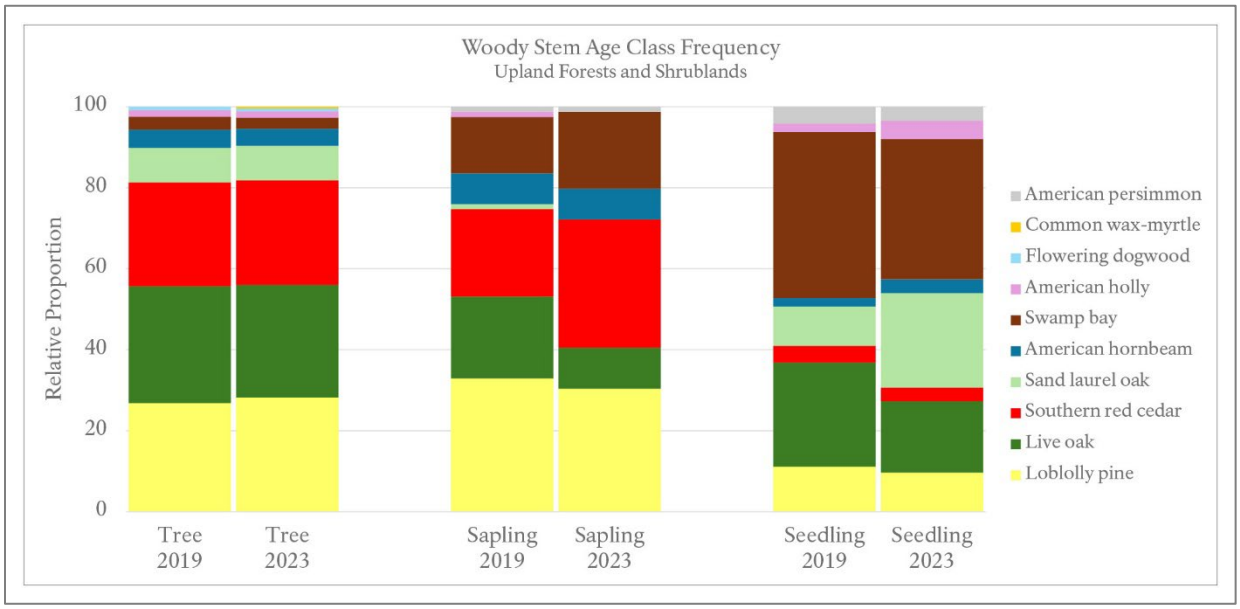

Figure 21. Relative proportion of canopy species across tree, sapling, and seedling strata within 2019 Cycle 1 and 2023 Cycle 2 upland forest and shrubland plots of Cape Hatteras National Seashore. Seedlings excluded recent germinants (stems 5–15 cm in height).
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The sustainability of forests over time is largely dependent upon the composition and abundance of desirable canopy species within a forest's seedling and sapling strata—collectively, the regeneration stratum. In the eastern United States, natural regeneration is primarily a function of canopy gaps formed by the die-off of a few older trees (Lorimer and White 2003). Species present in the regeneration stratum of these gaps typically represent the future composition of a forest's canopy

(Yamamoto 2000). Miller and McGill (2019) defined the concept of regeneration debt in eastern forests to describe differences in composition between canopy species and the regeneration stratum that could cause significant shifts in future canopy composition and abundance, and overall canopy loss in extreme situations. Regeneration debt was assessed across 39 national parks in the Mid-Atlantic and Northeast regions of the U.S. from long-term forest monitoring plots over a 12-year period (Miller et al. 2023). Their study documented imminent or probable failure in regeneration of canopy species across 27 of 39 parks with white-tailed deer (*Odocoileus virginianus*) browse impact as the strongest predictor of regeneration debt. Regeneration dynamics within oak-dominated maritime forests of the Middle Atlantic and Southern Coastal Plain are less understood than other forests of the eastern U.S, as are the mechanisms and stressors acting upon potential regeneration debt. White-tailed deer have been shown to negatively impact live oak seedling abundances in barrier island forests of Georgia (Bratton and Kramer 1992; Thyroff et al. 2019). However, in a 2007 study on Bald Head Island, North Carolina, white-tailed deer was shown not to impact understory oak survival, even though survival was low across deer exclosure and control plots (Taggart and Long 2015). These authors propose that light availability was the most probable factor in oak regeneration success.

As noted above, regeneration data from 2023 upland forest and shrubland monitoring plots of Cape Hatteras NS was highly variable. However, collectively, seedling counts of canopy and sub-canopy forming species were well above critical thresholds for regeneration failure as defined by Miller et al. (2023) across all management units monitored (Figure 22). Sapling abundance, however, was low and at the critical threshold value across all management units (Figure 22). It is unknown at this time whether impacts to regeneration across the preserve are due to factors described in Miller et al. (2023; e.g., white-tailed deer browse), other regional factors impacting Southeastern forested ecosystems, or represent natural fluctuations in canopy regeneration density. However, long-term monitoring can be used to assess trends in canopy species abundance in the regeneration stratum and determine ancillary stressors that could be impacting these trends.

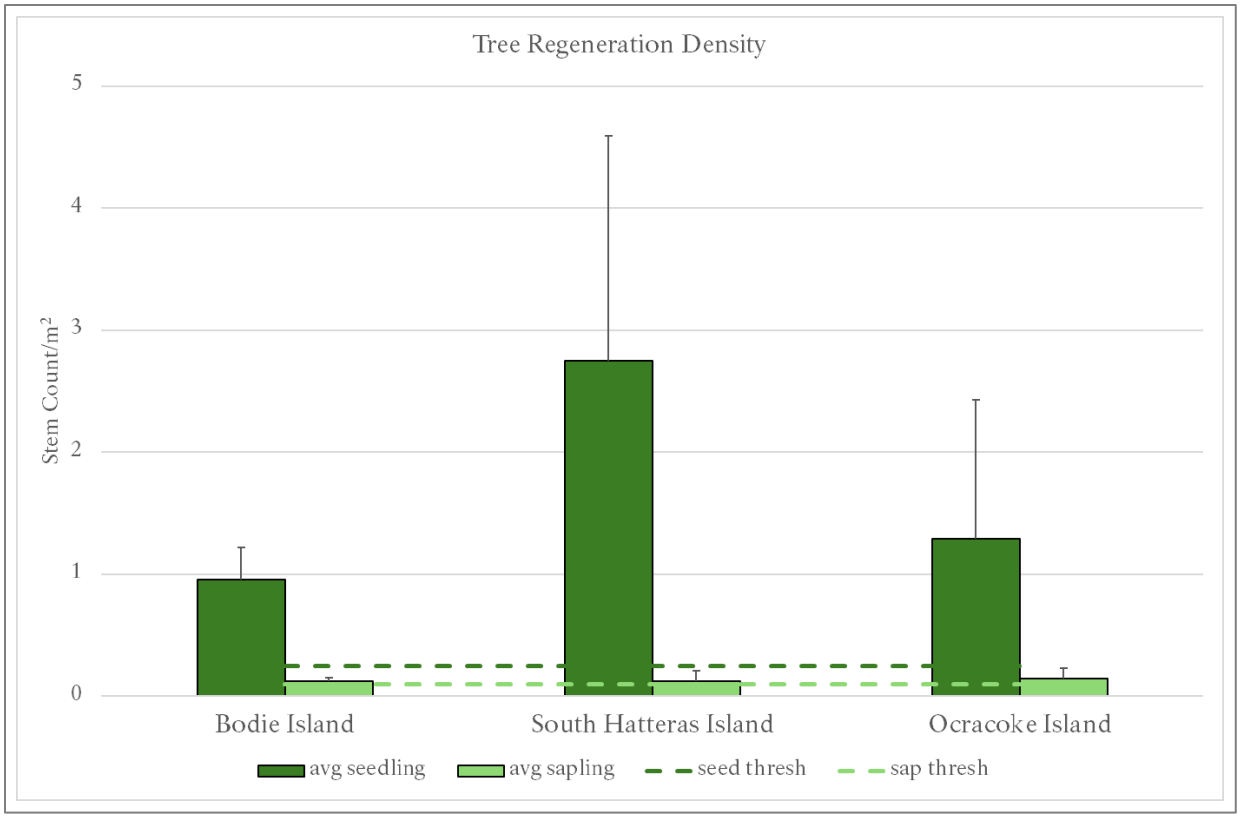

Figure 22. 2023 stem regeneration density within upland forests and shrublands of Cape Hatteras National Seashore by management unit. Sapling counts were collected at the 80 m^2 scale from each plot (sum of eight 10 m^2 nested subplots) and seedling counts, excluding recent germinants (stems 5–15 cm in height), were collected at the 8 m^2 scale from each plot (sum of eight 1 m^2 nested subplots). The values illustrated above include the average count per 1 m^2 of each stratum among plots of the same management unit. Vertical error bars represent standard deviation. The dotted horizontal lines represent the critical threshold for seedling and sapling regeneration debt based on Miller et al. 2023.
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Observed Disturbances and Threats

There were few disturbances and threats to vegetation resources observed within long-term monitoring plots of Cape Hatteras NS in 2023. Except for prescribed fire events on Bodie Island, no single disturbance was found to be prevalent across any of the broad habitat types nor management units of the seashore. Plot-level summaries of disturbances are available in Table 3 in *Plot- and Species-Scale Summary Tables* (Supplemental Materials [Boyle and Davis 2026]).

As discussed above, invasive species were observed in relatively high frequencies across nontidal wetland and upland open grassland plots. The impacts of invasive species on native ecosystems and biodiversity are well-documented and increased rates of habitat alteration and climate change are providing more opportunities for invasion (Chornesky and Randall 2003; Vitousek et al. 1996). Furthermore, management efforts that target reduction of certain non-native species can lead to increased abundances of undesirable native species, other non-native species, or the targeted non-native species (see Royo and Carson 2006), which may have consequences for forest regeneration

and ground cover diversity. It is difficult to predict how an invasive species, like common reed, will respond to both local-scale management efforts and landscape-scale changes (e.g., climate change). However, data from vegetation monitoring plots tracking trends over time of non-native and native species abundance and forest regeneration patterns with regards to specific non-native control efforts, can provide keen insights to park managers on the condition of their forest and non-forest vegetation resources.

Across most SECN parks and habitats, fire is an essential natural process that has historically shaped vegetation patterns and diversity. Fire suppression and other human-induced changes to natural fire regimes (e.g., reduced frequency, seasonality of burns) have had profound impacts to vegetation and forest resources across the Southeastern U.S., including reduction in biodiversity, lack of desirable tree regeneration, and higher threats from forest disease and insect outbreak. The role of fire within maritime and barrier island vegetation communities is not as well documented or understood as its role within the mainland of the Mid-Atlantic and Southern Coastal Plain. Based on the lack of flammability of live oak litter, the overall patchiness of flammable material within natural vegetation types, the high frequency of bare sand, and the prevalence of non-flammable tidal wetlands bisecting the landscape, it is unlikely fire was a factor in shaping ecosystems across Cape Hatteras NS. However, as discussed above, prescribed fire is currently being used as a management tool within the Bodie Island unit to reduce fuel loads and improve conditions for wildlife. Most SECN plots on this unit of the seashore west of North Carolina Highway 12 have likely been impacted (i.e., burned) at least one to three times by either prescribed fire or wildfire events over the past 30 years (W. Paxton, personal communication, 28 July 2025). Evidence of fire, however, was difficult to discern during monitoring field activities. It is too early in the monitoring cycle to determine from these data how fire has impacted vegetation structure and native versus non-native species diversity within this management unit of the seashore.

The only large-scale species-specific impact from a forest pest noted during this monitoring effort was the likely detection of LWD within tree-sized individuals of swamp bay. Based on its deleterious impact on red and swamp bay trees in geographies south of the seashore, this disease is likely to cause continued decline of this species across Cape Hatteras NS and the northern Outer Banks for the foreseeable future.

Finally, although not documented directly within these plots, accelerated rates of sea-level rise across the Outer Banks has profound implications on overall vegetation patterns across the seashore. Increased erosion rates and storm surges moving salt water into upland and freshwater ecosystems will likely increase abundance rates of salt-water, disturbance-tolerant species. Conversion of estuarine forests to open water and marsh habitat and creation of large-scale zones of dead trees (i.e., “ghost forests”) is already being observed across much of North Carolina’s Albemarle-Pamlico estuary (Gorczynski et al. 2024). Long-term monitoring data from SECN vegetation plots provide detailed information on species presence, abundance, and vegetative structure and can be used to assess change related to factors brought on by sea-level rise and other landscape-scale disturbances.

Fuel Load Estimates by Management Unit

The distribution and volume of dead and downed woody debris, duff, litter, and live vegetation is collectively referred to as surface fuel. Surface fuels can be used by managers to predict fire behavior and fire impacts (i.e., fire effects) within terrestrial ecosystems (Lutes et al. 2006). Smaller pieces of dead and downed woody debris are less than 8 centimeters (3.2 in) diameter and collectively referred to as fine woody debris (FWD). Volume of FWD is generally associated with having a stronger influence on fire behavior since smaller pieces of wood reach ignition temperature quicker than larger pieces. Coarse woody debris (CWD) includes pieces of dead and downed woody debris greater than 8 centimeters in diameter and associated with fire effects to a site since they generally burn longer during all phases of combustion. Litter represents dead grasses, recently fallen leaves, and pine needles, while duff includes decomposed litter material no longer identifiable between the litter layer and mineral soil. Like dead and downed woody debris, volume of duff and litter influences fire behavior and can influence fire effects on a site. Surface fuels can be tallied by individual class or collectively to determine total fuel load—the amount of available flammable material at a given site typically expressed in tons per acre. Fire managers for the National Park Service in the Southeast have a targeted goal to reduce and maintain fuel loads for non-living fuels below 10 tons/acre for most forested ecosystem types to reduce risk and maintain healthy habitat (Rob Klein, NPS SER Fire Ecologist, personal communication). Fire, as a landscape defining feature of plant community assembly, is not a major feature of Cape Hatteras NS. However, natural fire from lightning strikes and human-influenced burning has occurred throughout the park's history. These fire events, unlike those that occur on the North Carolina mainland, are typically small in size.

Total surface fuel load volume was highly variable among 2023 vegetation monitoring plots of Cape Hatteras NS, ranging from 2.5 to 98.4 tons/acre. Factors influencing surficial fuel volume at a site can include time since last fire, overall fire history, climate, soil, topography, or other disturbance events besides fire (e.g., ice storms, hydrology, windfall). Duff and litter were generally the largest component of surface fuels across the seashore regardless of habitat type. Duff accumulation may be high in nontidal wetlands, but it may not be the best metric to determine if fire is likely to occur at a site. Regardless of accumulation, duff may not carry fire during periods of prolonged hydroperiods. Because the surfaces of nontidal wetlands are hydric most of the year, they typically will not burn no matter the depth of duff. Standing live vegetation, which is not measured by the Southeast Coast Network, and CWD probably have more influence on both the ability of a site to burn and the impacts fire will have on a site. Patterns of fuel loads are discussed below for each of the seashore's management units.

Bodie Island

Total fuel loads increased or remained similar between 2019 and 2023 within this management unit's four nontidal wetland plots sampled during both monitoring cycles, while fuel loads were relatively high across the three upland forest and shrubland plots established in 2023, ranging from 24.2 to 30.7 tons/acre (Figures 23 and 24). Duff and litter contributed the most to total fuel loads among all fuel types, particularly within nontidal wetland plots (Figure 23).

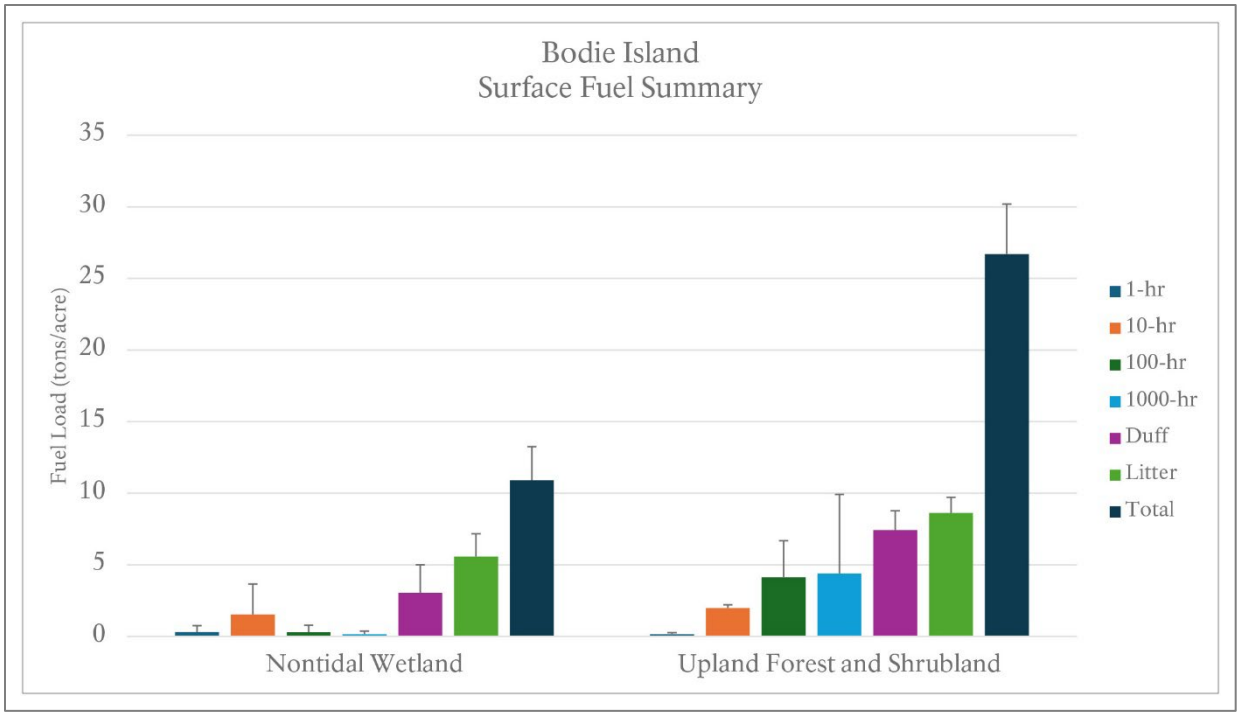

Figure 23. 2023 average fuel load values of surface fuel types within nine Southeast Coast Network vegetation monitoring plots in the Bodie Island unit of Cape Hatteras National Seashore. Fuel types labeled as 1-hr, 10-hr, and 100-hr (hr = hour) are collectively defined as fine woody debris and represent downed woody material across the forest floor less than 8 centimeters in diameter. The 1-hr category represents woody material 0–0.64 centimeters in diameter; the 10-hr category represents woody material 0.64–2.54 centimeters in diameter; and the 100-hr category represents woody material 2.54–8 centimeters in diameter. 1000-hr surface fuels are defined as coarse woody debris and represent woody material greater than 8 centimeters in diameter. The Litter category represents dead grasses, recently fallen leaves, and pine needles. The Duff category represents the area below the litter layer and above mineral soil and is composed of litter material no longer identifiable. The Total category is a sum of all surface fuel types. Vertical error bars represent standard deviation.

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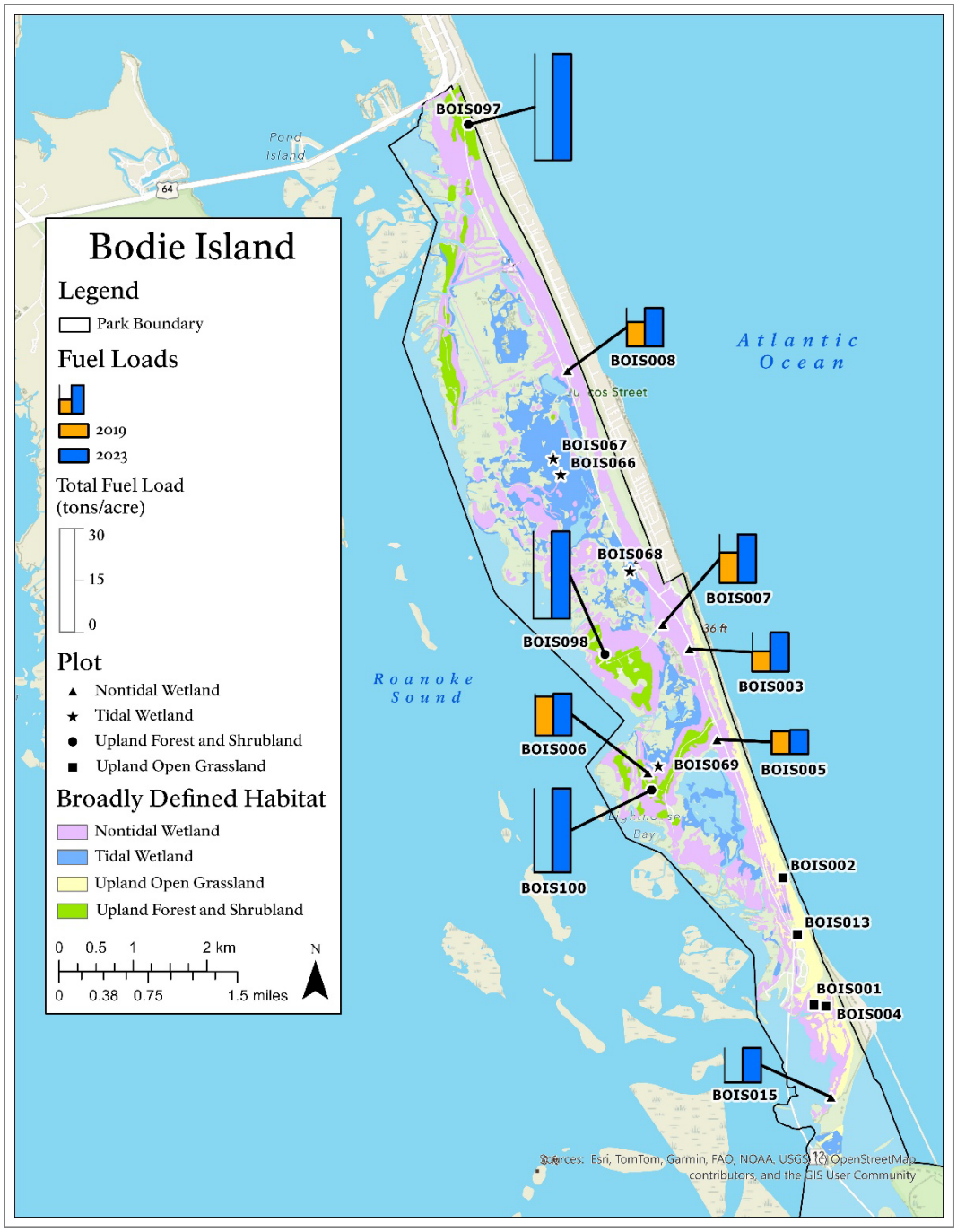

Figure 24. Total fuel loads from Southeast Coast Network vegetation plots within the Bodie Island unit of Cape Hatteras National Seashore. The following plots were established and monitored for the first time in 2023, thus no data were available in 2019—BOIS015, BOIS097, BOIS098, and BOIS100. Fuel loads were not measured in tidal wetland nor upland open grassland habitat types. Bar graph ranges are from 2.3 to 30.7 tons/acre.

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North Hatteras Island

Total fuel loads on North Hatteras Island in 2023 were highly variable across all nontidal wetland plots, ranging from 2.5 to 26.34 tons/acre (Figure 25). Duff and litter contributed the most among fuel types across these plots (Figure 26).

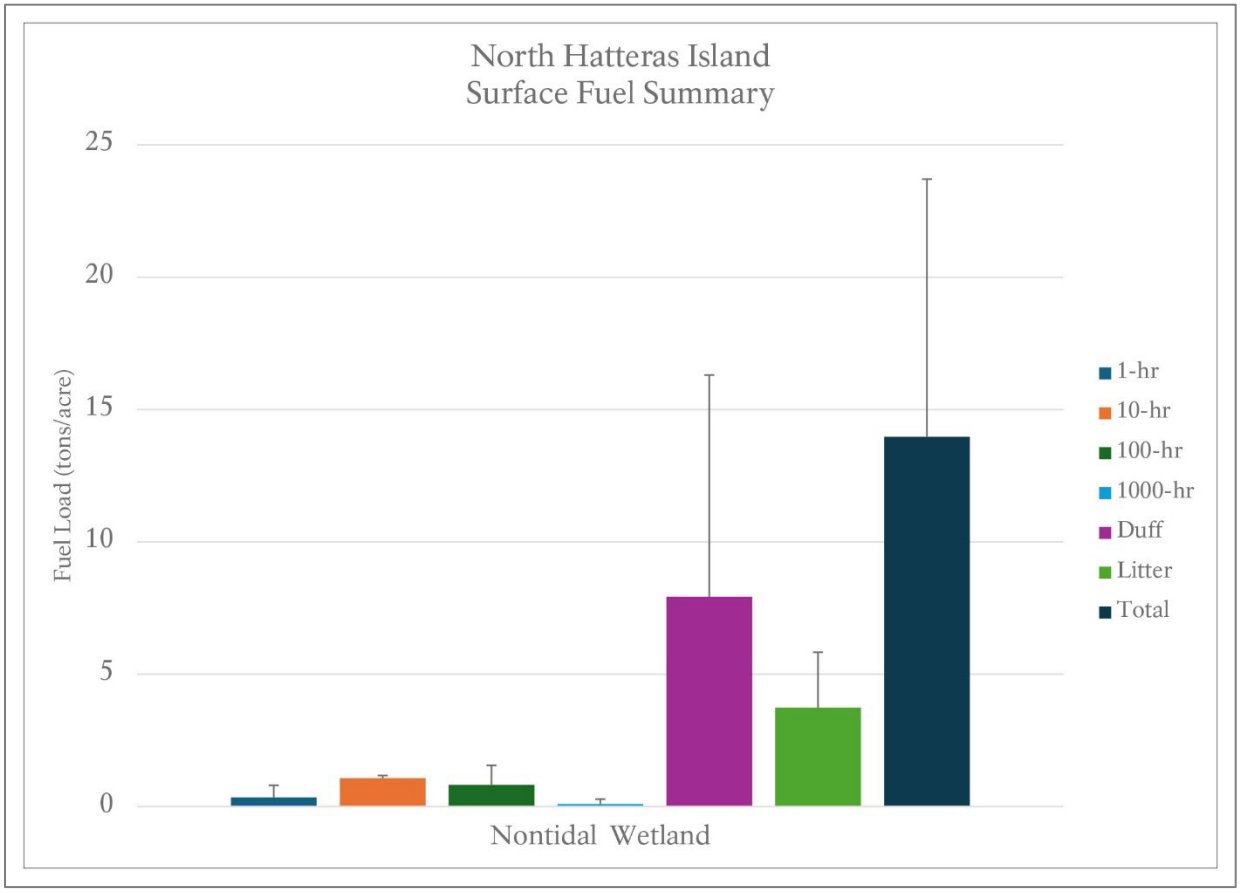

Figure 25. 2023 average fuel load values of surface fuel types within four Southeast Coast Network vegetation monitoring plots in the North Hatteras Island unit of Cape Hatteras National Seashore. Fuel types labeled as 1-hr, 10-hr, and 100-hr (hr = hour) are collectively defined as fine woody debris and represent downed woody material across the forest floor less than 8 centimeters in diameter. The 1-hr category represents woody material 0–0.64 centimeters in diameter; the 10-hr category represents woody material 0.64–2.54 centimeters in diameter; and the 100-hr category represents woody material 2.54–8 centimeters in diameter. 1000-hr surface fuels are defined as coarse woody debris and represent woody material greater than 8 centimeters in diameter. The Litter category represents dead grasses, recently fallen leaves, and pine needles. The Duff category represents the area below the litter layer and above mineral soil and is composed of litter material no longer identifiable. The Total category is a sum of all surface fuel types. Vertical error bars represent standard deviation.

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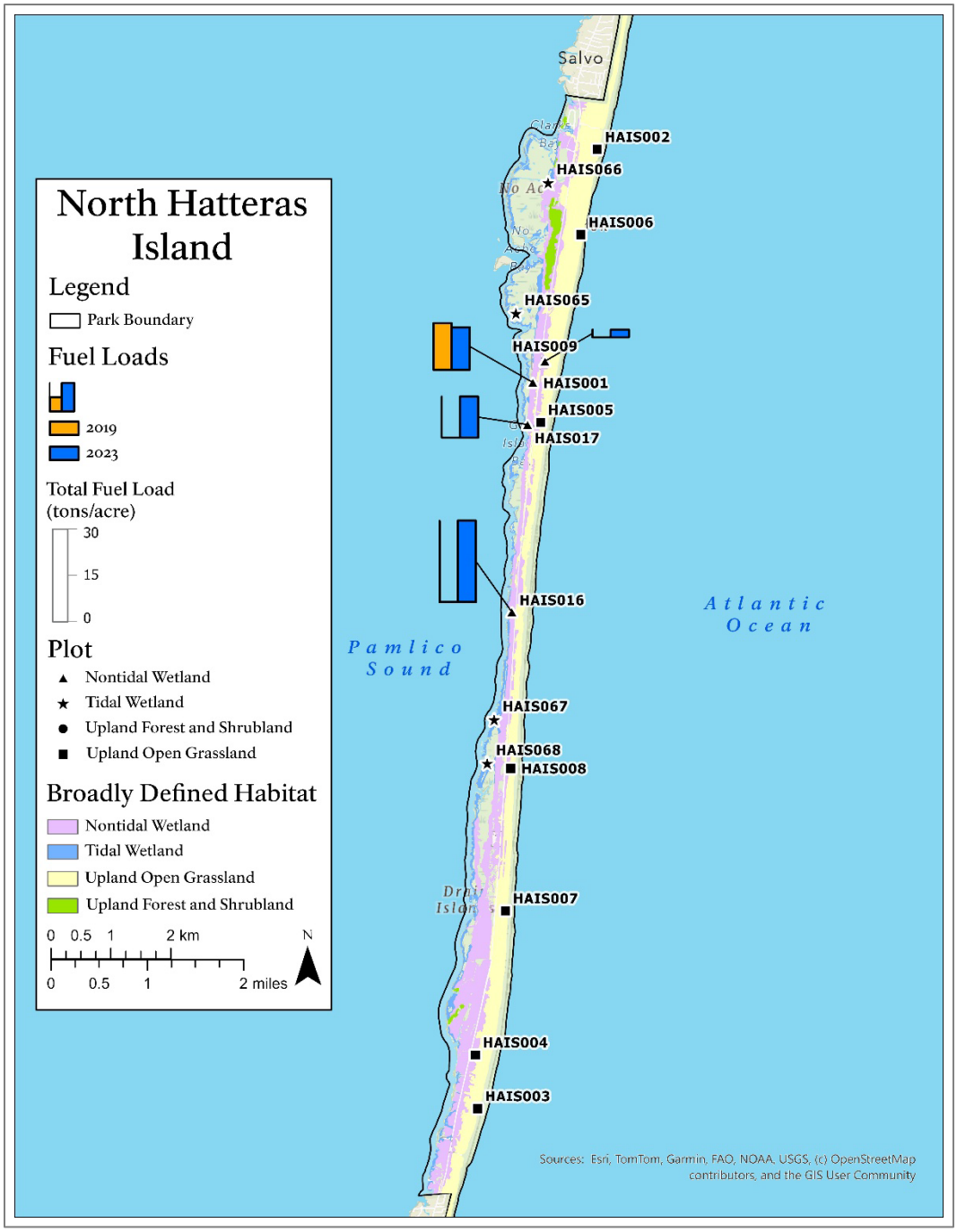

Figure 26. Total fuel loads from Southeast Coast Network vegetation plots within the North Hatteras Island unit of Cape Hatteras National Seashore. The following plots were established and monitored for the first time in 2023, thus no data were available in 2019—HAIS009, HAIS016 and HAIS017. Fuel loads were not measured in tidal wetland nor upland open grassland habitat types. Bar graph ranges are from 2.5 to 26.3 tons/acre.

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South Hatteras Island

Nontidal wetland plots within the South Hatteras Island unit had relatively high total fuel loads compared with other nontidal wetland plots of the other management units of the seashore due to the high volume of CWD. Likewise, upland forest and shrubland plots of this unit had the highest total fuel loads among the same habitat type in the Bodie Island and Ocracoke units. Total fuel loads averaged 42.9 tons/acre within nontidal wetland plots and 68.6 tons/acre within upland forest and shrubland plots (Figure 27). Total fuel loads substantially increased from 2019 to 2023 within most of the monitoring plots in the South Hatteras Island unit (Figure 28).

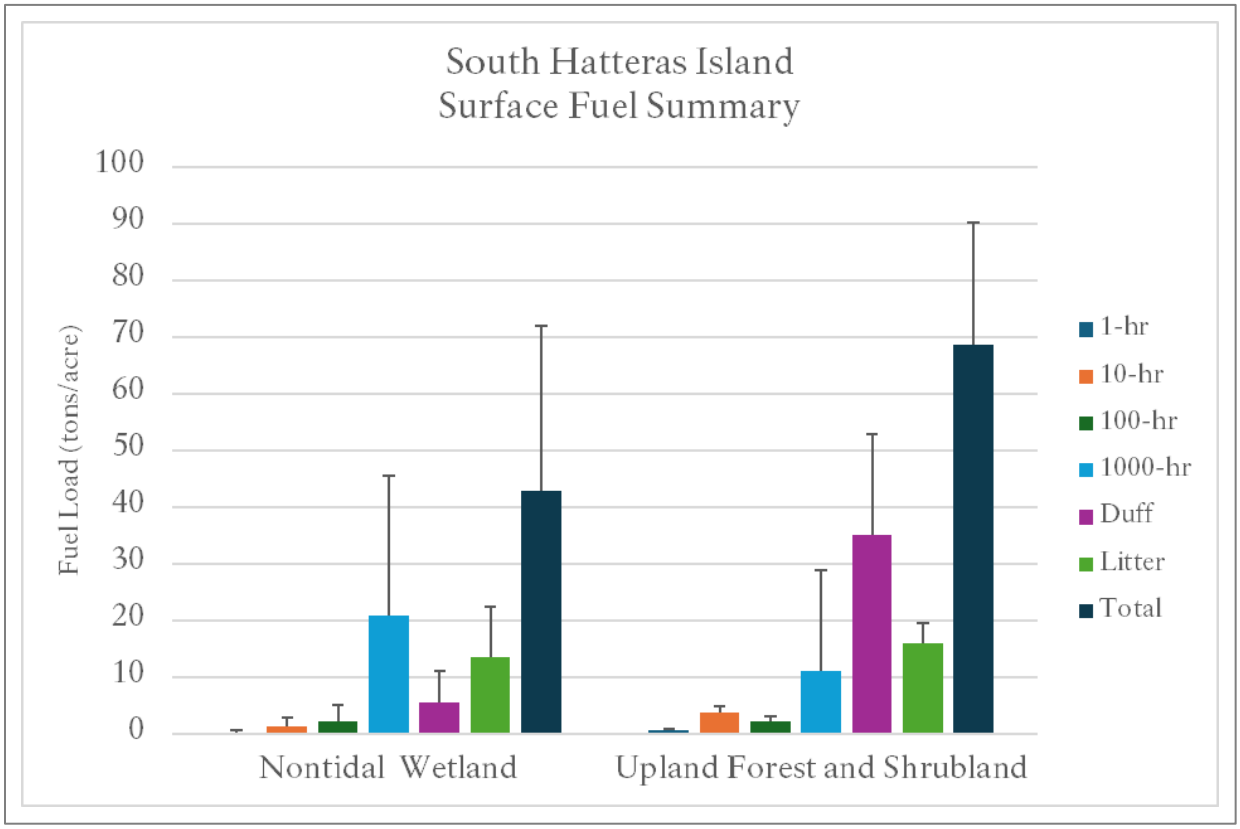

Figure 27. 2023 average fuel load values of surface fuel types within 14 Southeast Coast Network vegetation monitoring plots in the South Hatteras Island unit of Cape Hatteras National Seashore. Fuel types labeled as 1-hr, 10-hr, and 100-hr (hr = hour) are collectively defined as fine woody debris and represent downed woody material across the forest floor less than 8 centimeters in diameter. The 1-hr category represents woody material 0–0.64 centimeters in diameter; the 10-hr category represents woody material 0.64–2.54 centimeters in diameter; and the 100-hr category represents woody material 2.54–8 centimeters in diameter. 1000-hr surface fuels are defined as coarse woody debris and represent woody material greater than 8 centimeters in diameter. The Litter category represents dead grasses, recently fallen leaves, and pine needles. The Duff category represents the area below the litter layer and above mineral soil and is composed of litter material no longer identifiable. The Total category is a sum of all surface fuel types. Vertical error bars represent standard deviation.

NPS / SECN

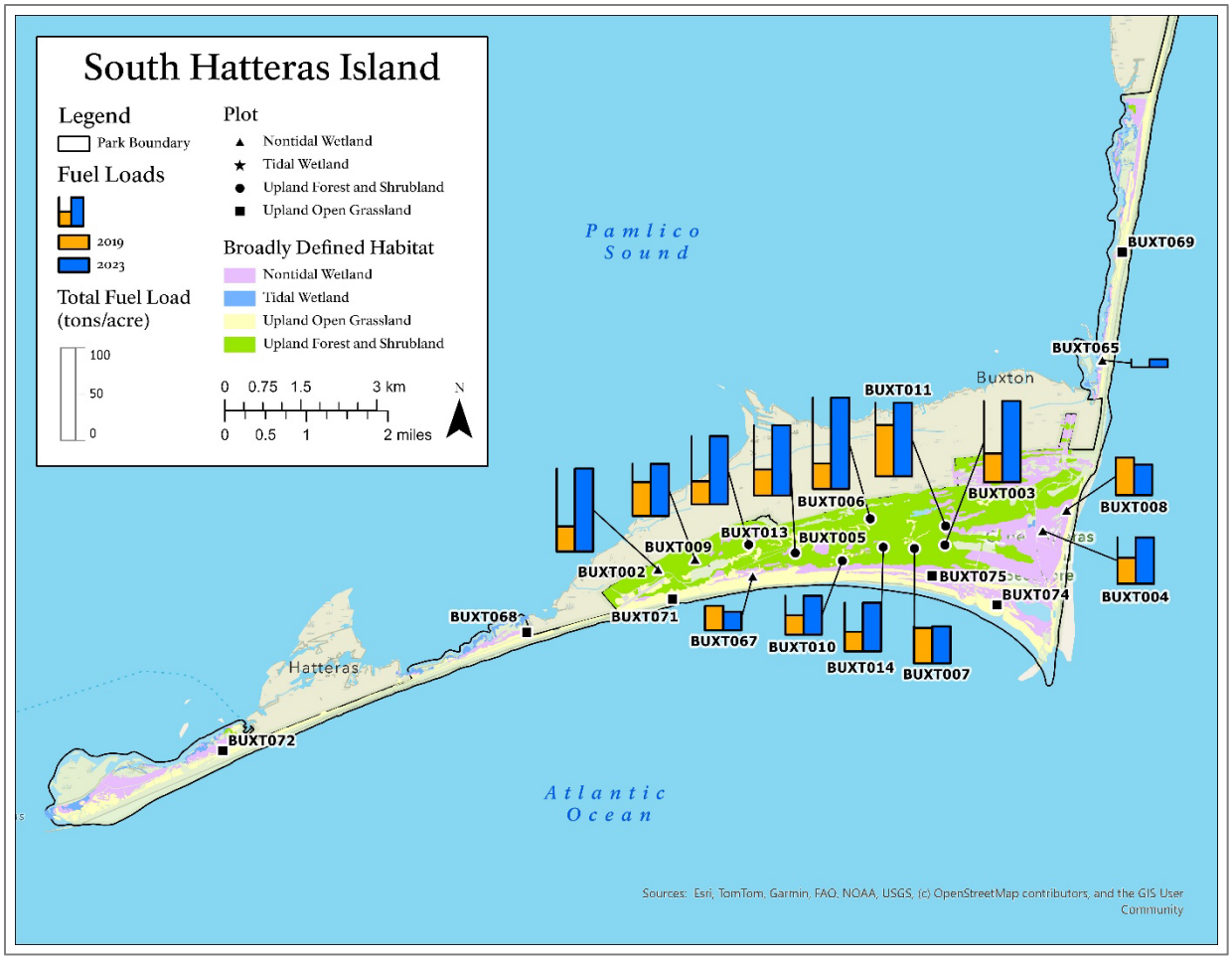

Figure 28. Total fuel loads from Southeast Coast Network vegetation plots within the South Hatteras Island unit of Cape Hatteras National Seashore. Fuel loads were not measured in upland open grassland habitat types. Bar graph ranges are from 8.6 to 98.4 tons/acre.

NPS / SECN

Ocracoke Island

Duff and litter fuel types contributed the most to total fuel loads within both nontidal wetland and upland forest and shrubland plots of the Ocracoke Island unit (Figure 29). Within this unit, fuel loads were highest within upland forest and shrubland plots near the Hammock Hill Trail system (Figure 30).

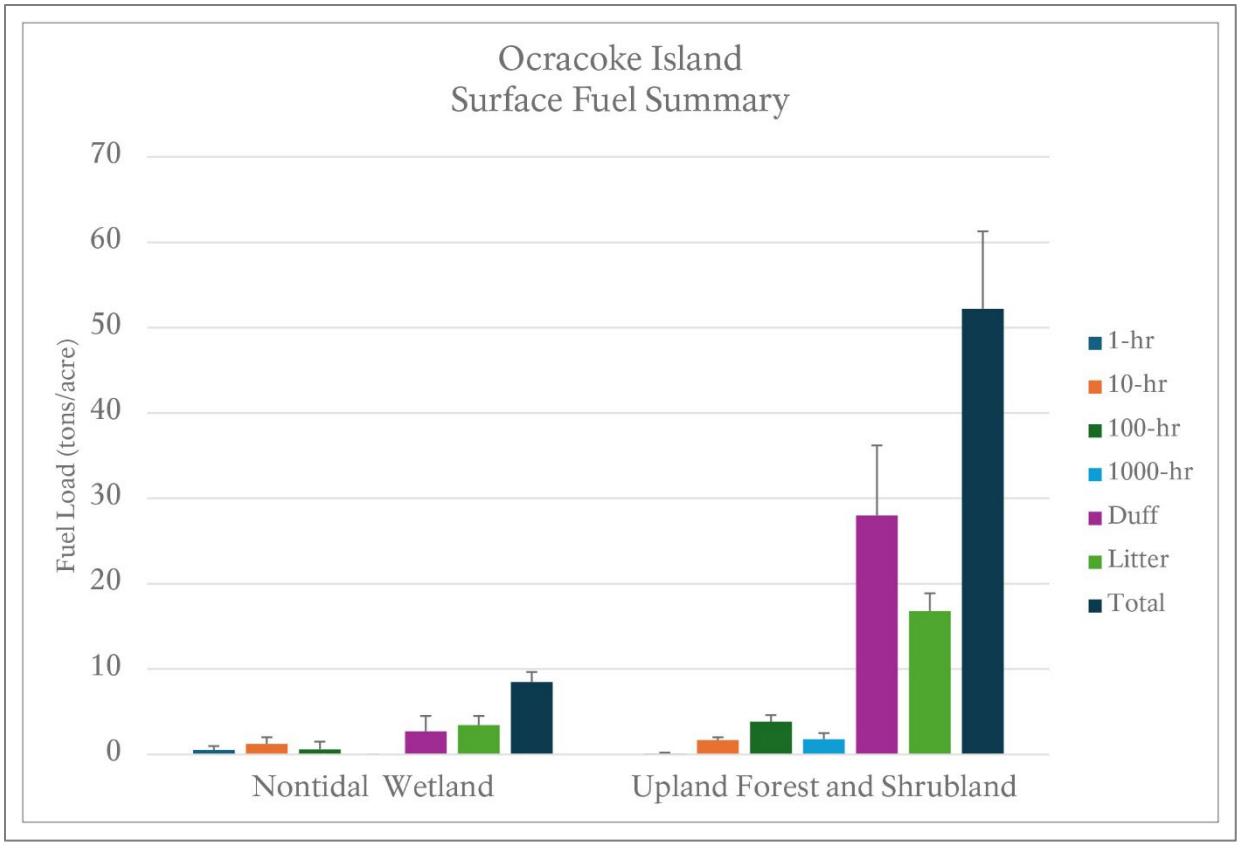

Figure 29. 2023 average fuel load values of surface fuel types within eight Southeast Coast Network vegetation monitoring plots located within the Ocracoke Island unit of Cape Hatteras National Seashore. Fuel types labeled as 1-hr, 10-hr, and 100-hr (hr = hour) are collectively defined as fine woody debris and represent downed woody material across the forest floor less than 8 centimeters in diameter. The 1-hr category represents woody material 0–0.64 centimeters in diameter; the 10-hr category represents woody material 0.64–2.54 centimeters in diameter; and the 100-hr category represents woody material 2.54–8 centimeters in diameter. 1000-hr surface fuels are defined as coarse woody debris and represent woody material greater than 8 centimeters in diameter. The Litter category represents dead grasses, recently fallen leaves, and pine needles. The Duff category represents the area below the litter layer and above mineral soil and is composed of litter material no longer identifiable. The Total category is a sum of all surface fuel types. Vertical error bars represent standard deviation.

NPS / SECN

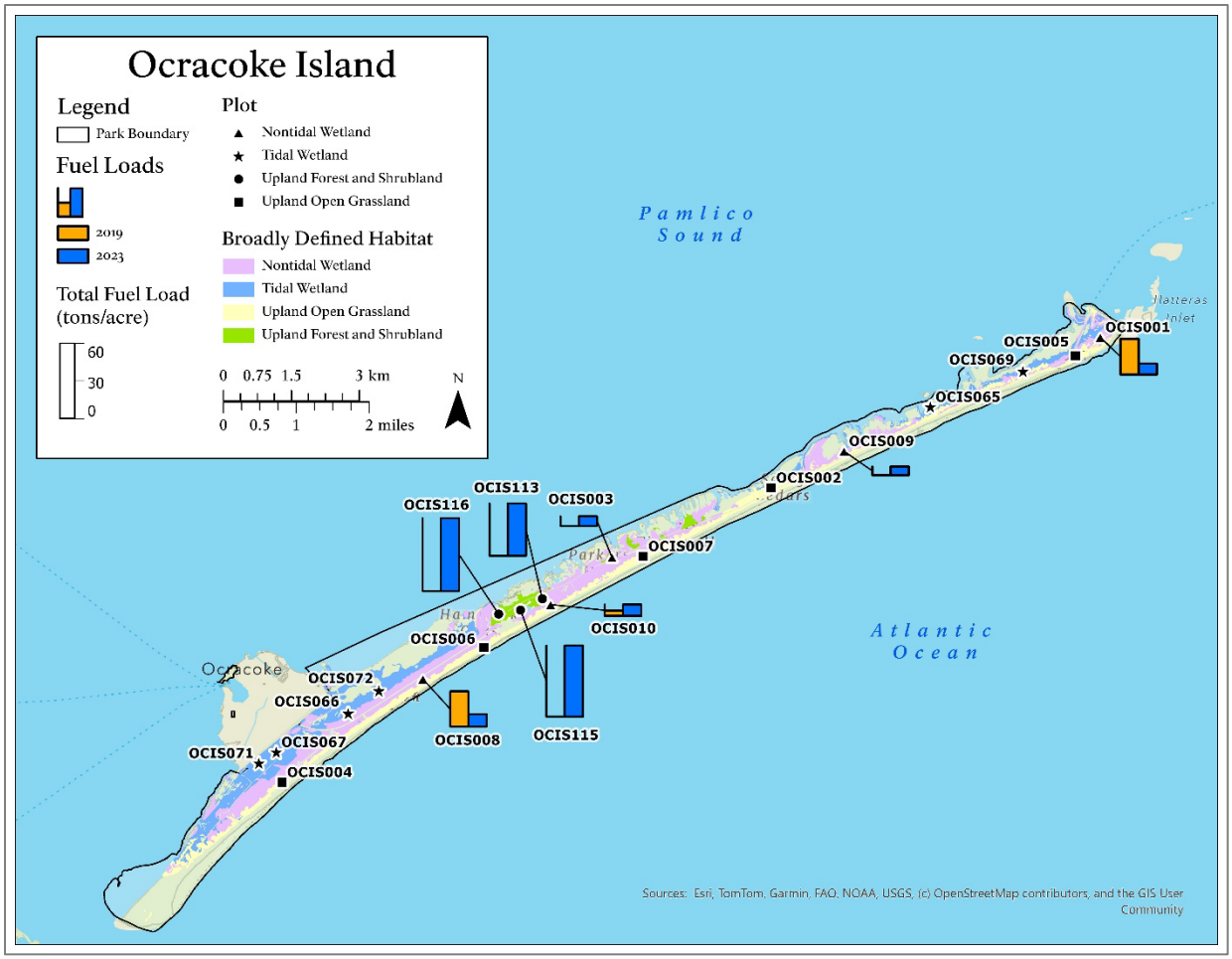

Figure 30. Total fuel loads from Southeast Coast Network vegetation plots within the Ocracoke Island unit of Cape Hatteras National Seashore. The following plots were established and monitored for the first time in 2023, thus no data were available in 2019—OCIS003, OCIS009, OCIS113, OCIS115, and OCIS116. Fuel loads were not measured in tidal wetland nor upland open grassland habitat types. Bar graph ranges are from 1.2 to 58.2 tons/acre.

NPS / SECN

Broad Habitat Type and Management Unit Scorecard

A condition scorecard using multiple monitoring elements was developed for each of the broad habitat types within each of Cape Hatteras NS's four management units (Table 3). A four-point rating system was utilized—Good, Caution, Concern, Significant Concern—to determine overall ecological health. A rating of Significant Concern implies the habitat is in imminent danger of failing due to a certain category that describes either vegetation condition (e.g., native diversity, tree growth rates, tree recruitment) or threats to native vegetation (e.g., invasive species); a rating of Good implies the habitat is healthy and stable in relation to those same categories. Canopy and fuel elements were not ranked for certain broad habitat types due to the absence of woody vegetation. Finally, it should be noted that ratings were assigned qualitatively using best judgement by this report's lead author.

Table 3. Terrestrial vegetation scorecard for broad habitat types of Cape Hatteras National Seashore's management units based on data collected from 2023 monitoring plots.

Broad Habitat Type	Unit	Native Diversity	Invasive Species	Canopy Growth Rate	Canopy Mortality Rate	Canopy Recruitment	Disturbance/ Threats	Fuel Load
Nontidal Wetlands	Bodie Island	Good [A]	Concern [C]	Good [A]	Caution [B]	Not Ranked	Good [A]	Good [A]
	South Hatteras Island	Good [A]	Caution [B]	Good [A]	Good [A]	Not Ranked	Good [A]	Good [A]
	North Hatteras Island	Good [A]	Concern [C]	Good [A]	Good [A]	Not Ranked	Good [A]	Good [A]
	Ocracoke Island	Good [A]	Caution [B]	Good [A]	Good [A]	Not Ranked	Good [A]	Good [A]
Tidal Wetlands	Bodie Island	Good [A]	Good [A]	Not Ranked	Not Ranked	Not Ranked	Good [A]	Not Ranked
	North Hatteras Island	Good [A]	Caution [B]	Not Ranked	Not Ranked	Not Ranked	Good [A]	Not Ranked
	Ocracoke Island	Good [A]	Caution [B]	Not Ranked	Not Ranked	Not Ranked	Good [A]	Not Ranked
Upland Forests and Shrublands	Bodie Island	Good [A]	Caution [B]	Good [A]	Caution [B]	Caution [B]	Good [A]	Caution [B]
	South Hatteras Island	Good [A]	Good [A]	Good [A]	Caution [B]	Caution [B]	Good [A]	Caution [B]
	Ocracoke Island	Good [A]	Good [A]	Good [A]	Caution [B]	Caution [B]	Good [A]	Caution [B]
Upland Open Grasslands	Bodie Island	Good [A]	Caution [B]	Not Ranked	Not Ranked	Not Ranked	Good [A]	Not Ranked
	South Hatteras Island	Good [A]	Caution [B]	Not Ranked	Not Ranked	Not Ranked	Good [A]	Not Ranked
	North Hatteras Island	Good [A]	Caution [B]	Not Ranked	Not Ranked	Not Ranked	Good [A]	Not Ranked
	Ocracoke Island	Good [A]	Caution [B]	Not Ranked	Not Ranked	Not Ranked	Good [A]	Not Ranked

[A] Shaded green for good.

[B] Shaded yellow for caution.

[C] Shaded red for concern.

Nontidal Wetlands

Invasive species detections were frequent within this broad habitat type of the seashore, particularly within the Bodie Island and North Hatteras Island management units. Conversely, nontidal wetlands are home to a high diversity of rare, native vascular plants across the seashore. Growth rates of canopy-forming woody species were good; however, reduced vigor and high mortality rates of swamp bay were observed in nontidal wetlands of Bodie Island.

Tidal Wetlands

Tidal wetlands of Cape Hatteras NS are relatively healthy and in stable condition based on the data collected from SECN monitoring plots. Invasive species were detected, although in low frequencies, within tidal wetlands of North Hatteras Island and Ocracoke Island.

Upland Forests and Shrublands

As discussed above, this broad habitat type of the seashore included oak- and pine-dominated maritime forests on the South Hatteras Island management unit as well as planted pine stands of Bodie Island and Ocracoke Island. Canopy mortality rates across all management units were given a Caution rating due to the prevalence of dead and unhealthy swamp bay trees. Furthermore, recruitment rates were given a Caution rating due to the low abundance of sapling-sized canopy species. Overall, however, the maritime forests within the South Hatteras Island unit are relatively healthy and stable.

Upland Open Grasslands

This habitat type is relatively healthy across Cape Hatteras NS. The one concern observed within these monitoring plots is the prevalence of non-native, invasive, centipede grass.

Conclusions

This is the second data summary report from SECN terrestrial vegetation monitoring for Cape Hatteras NS. Vegetation monitoring using the protocol published in Boyle et al. (2019) began on the seashore in 2019. The third cycle of monitoring is scheduled for summer 2027. After this third monitoring iteration, vegetation diversity and woody stem metrics will be analyzed for trends and changes will be compared with conditions of and changes in notable environmental variables, land use, climate, and resource stressors. Highlights from this current monitoring effort are listed in the Summary and Key Findings section above and not repeated here.

Literature Cited

Boyle, M.F., and M. Davis. 2026. Terrestrial Vegetation Monitoring at Cape Hatteras National Seashore 2023 Data Summary: Supplemental Materials. National Park Service. https://irma.nps.gov/DataStore/Reference/Profile/2317796 (last accessed April 2026).

Boyle, M.F. 2024. Site selection, plot establishment and return visits—Version 1.2. Southeast Coast Network Standard Operating Procedure NPS/SECN/SOP—1.4.10. Southeast Coast Network, Athens, Georgia. https://irma.nps.gov/DataStore/Reference/Profile/2304969

Boyle, M.F., and E. Rico. 2021. Terrestrial vegetation monitoring at Cape Hatteras National Seashore: 2019 data summary. Natural Resource Data Series NPS/SECN/NRDS—2022/1341. National Park Service, Fort Collins, Colorado. https://irma.nps.gov/DataStore/Reference/Profile/2290019 (last accessed February 2026).

Boyle, M.F., M.B. Gregory, M.W. Byrne, P. Capece, and S. Corbett. 2019. Terrestrial vegetation monitoring in Southeast Coast Network parks: Protocol implementation plan. Natural Resource Report NPS/SECN/NRR—2019/1930. National Park Service, Fort Collins, Colorado. https://irma.nps.gov/DataStore/Reference/Profile/2263392 (last accessed February 2026).

Bratton, S.P., and E.A. Kramer. 1992. Recovery of live oak sprouts after release from browsing on Cumberland Island National Seashore, Georgia. Pages 47–57 *in*: C.A. Cole and F.K. Turner, editors. Barrier island ecology of the mid-Atlantic coast: a symposium. Technical Report NPS/SERCAHA/NRTR—93/04. National Park Service, Washington, D.C.

Bratton, S.P., and K.L. Davison. 1987. Disturbance and succession in Buxton Woods, Cape Hatteras, North Carolina. Castanea 52(3): 166–179.

Brown, C.A. 1959. Vegetation of the Outer Banks of North Carolina. Louisiana State University Press. Baton Rouge, Louisiana.

Brown, C.W. 1983. A palynological study of peat layers from Jeanette Sedge, North Carolina Outer Banks. Master's Thesis, Smith College.

Brown, J.K. 1974. Handbook for inventorying downed woody material. USDA, Forest Service. Gen. Tech. Rep. INT-16, 24 p. Intermt. Forest and Range Experiment Station, Ogden, Utah.

Carlson, J.E., J. Bracewell, W. Granger, and M. Segura. 2018. Monitoring vegetation in Gulf Coast Network parks: Protocol implementation plan. Natural Resource Report NPS/GULN/NRR—2018/1746. National Park Service, Fort Collins, Colorado. https://irma.nps.gov/DataStore/Reference/Profile/2256507 (last accessed February 2026).

Chornesky, E.A., and J.M. Randall. 2003. The threat of invasive alien species to biodiversity: setting a future course. Annals of the Missouri Botanical Garden 90(1):67–76.

DeVivo, J.C., C.J. Wright, M.W. Byrne, E. DiDonato, and T. Curtis. 2008. Vital signs monitoring in the Southeast Coast Inventory & Monitoring Network. Natural Resource Report NPS/SECN/NRR—2008/061. National Park Service, Fort Collins, Colorado. https://irma.nps.gov/DataStore/Reference/Profile/660552 (last accessed February 2026).

Fraedrich, S.W., T.C. Harrington, R.J. Rabaglia, M.D. Ulyshen, A.E. Mayfield, III, J.L. Hanula, J.M. Eickwort, and D.R. Miller. 2008. A fungal symbiont of the redbay ambrosia beetle causes a lethal wilt in redbay and other Lauraceae in the southeastern USA. Plant Disease 92:215–224.

Gorczynski, L.E., A.R. Wilson, B.K. Odhiambo, and M.C. Ricker. 2024. Coastal forest change and shoreline erosion across a salinity gradient in a micro-tidal estuary system. Forests 15(6) 1069. https://doi.org/10.3390/f15061069

Griffith, G.E., J.M. Omernik, J.A. Comstock, M.P. Schafale, W.H. McNab, D.R. Lenat, T.F. MacPherson, J.B. Glover, and V.B. Shelburne. 2002. Ecoregions of North Carolina and South Carolina, (color poster with map, descriptive text, summary tables, and photographs). Reston, Virginia, U.S. Geological Survey (map scale: 1:1,500,000).

Intergovernmental Panel on Climate Change (IPCC). 2019. Choices made now are critical for the future of our ocean and cryosphere. https://www.ipcc.ch/2019/09/25/srocc-press-release/ (last accessed February 2026).

Klein, R.N., E.W. Paxton, and J.M. Wood. 2015. Appalachian/Piedmont Fire Ecology annual report: calendar year 2014. https://irma.nps.gov/DataStore/Reference/Profile/2220260 (last accessed February 2026).

Lorimer, C.G., and A.S. White. 2003. Scale and frequency of natural disturbances in the Northeastern US: implications for early successional forest habitats and regional age distributions. Forest Ecology and Management 185: 41–64.

Lutes, D.C., R.E. Keane, J.F. Caratti, C.H. Key, N.C. Benson, S. Sutherland, and L.J. Gangi. 2006. FIREMON: fire effects monitoring and inventory system. Gen. Tech. Rep. RMRS-GTR-164-CD. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado.

McManamay, R.H., S.C. Heath, and L. Baron. 2014. Vegetation mapping at Cape Hatteras National Seashore. Natural Resource Data Series NPS/SECN/NRR—2014/710. National Park Service, Fort Collins, Colorado.

Miller, K.M., and B.J. McGill. 2019. Compounding human stressors cause major regeneration debt in over half of eastern US forests. Journal of Applied Ecology 56(6): 1355–66.

Miller, K.M., S.J. Perles, J. Schmit, E.R. Matthews, A.S. Weed, J.A. Comiskey, M.R. Marshall, P. Nelson, and N.A. Fisichelli. 2023. Overabundant deer and invasive plants drive widespread regeneration debt in eastern United States national parks. Ecological Applications 33(4): 1–24.

National Park Service (NPS). 2001. NPS Outer Banks Group: fire management plan, including: Cape Hatteras National Seashore, Fort Raleigh National Historical Site, Wright Brothers National Memorial. ParkPlanning - Outer Banks Group Fire Management Plan (last accessed February 2026).

National Park Service (NPS). 2025. NPSpecies: Information on species in national parks. https://irma.nps.gov/NPSpecies (last accessed February 2026).

NatureServe. 2025. NatureServe Explorer 2.0: an online encyclopedia of life [web application]. NatureServe, Arlington, Virginia. https://explorer.natureserve.org (last accessed February 2026).

North Carolina Native Plant Society (NCNPS). 2023. Invasive, non-native plant species list – revised 11/7/2023. https://ncwildflower.org/invasive-exotic-species-list/ (last accessed February 2026).

Omernik, J.M., and G.E. Griffith. 2014. Ecoregions of the conterminous United States: evolution of a hierarchical spatial framework. Environmental Management 54(6):1249–1266.

Peet, R.K., T.R. Wentworth, and P.S. White. 1998. The North Carolina Vegetation Survey protocol: a flexible, multipurpose method for recording vegetation composition and structure. Castanea 63:262–274.

Royo, A.A., and W.P. Carson. 2006. On the formation of dense understory layers in forests worldwide: consequences and implications for forest dynamics, biodiversity, and succession. Canadian Journal of Forest Research 36:1345–1362.

Schafale, M.P. 2024. Classification of the natural communities of North Carolina, fourth approximation; Volume 1: uplands. North Carolina Natural Heritage Program, N.C. Department of Natural and Cultural Resources, Raleigh, North Carolina.

Sorrie, B.A. 2021. Vascular flora of the Outer Banks, North Carolina, U.S.A. Journal of the Botanical Institute of Texas 15(2):607–710.

Stevens, D.L., and A.N. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of American Statistical Association 99(465):262–278.

Taggart, J., and Z. Long. 2015. Effects of white-tailed deer (*Odocoileus virginianus*) on the maritime forest of Bald Head Island, North Carolina. American Midland Naturalist 173:283–293.

Thyroff, E.C., O.T. Burney, and D.F. Jacobs. 2019. Herbivory and competing vegetation interact as site limiting factors in maritime forest restoration. Forests 10, 950.

U.S. Department of Agriculture, Natural Resources Conservation Service (USDA NRCS). 2025. The PLANTS Database. National Plant Data Team, Greensboro, North Carolina. 27401-4901 USA. https://plants.sc.egov.usda.gov (last accessed February 2026).

U.S. Forest Service (USFS). 2026. Distribution of counties with Laurel Wilt Disease by year of initial detection (map), February 20, 2025. USDA Forest Service Forest Inventory and Analysis Program. https://www.arcgis.com/apps/dashboards/d43391c8fdb741b597e6ccf1236d2a02 (last accessed February 2026).

van der Valk, A.G. 1975. The floristic composition and structure of foredune plant communities of Cape Hatteras National Seashore. Chesapeake Science 16(2):115–126.

Vitousek, P.M., C.M. D'Antonio, L.L. Loope, and R. Westbrooks. 1996. Biological invasions as global environmental change. American Scientist 84(5): 468–478.

Walker, A.S., J. Amoroso, and M. East. 2024. Natural Heritage Program list of rare plant species of North Carolina. North Carolina Natural Heritage Program, N.C. Department of Natural and Cultural Resources. https://www.ncnhp.org/2024-rare-plant-list (last accessed February 2026).

Weakley, A.S. 2020. Flora of the southeastern United States. University of North Carolina Herbarium (NCU), North Carolina Botanical Garden, Chapel Hill, North Carolina.

Wentworth, T.R., M.P. Schafale, A.S. Weakley, R.K. Peet, P.S. White, and C.C. Frost. 1993. A preliminary classification of North Carolina barrier island forests. Pages 31–46 *in*: C.A. Cole and F.K. Turner, editors. Barrier island ecology of the mid-Atlantic coast: a symposium. Technical Report NPS/SERCAHA/NRTR—93/04. National Park Service, Atlanta, Georgia.

Whelan, K.R., R.B. Shamblin, M. Prats, J.M. Patterson, M. Londono, and R. Muxo. 2020. South Florida/Caribbean Network forest vegetation monitoring: protocol implementation plan. Natural Resource Report NPS/SFCN/NRR—2020/2064. National Park Service, Fort Collins, Colorado. https://irma.nps.gov/DataStore/Reference/Profile/2271719 (last accessed February 2026).

White, R., C. Nordman, L. Smart, T. Leibfreid, B. Moore, R. Smyth, and T. Govus. 2011. Vegetation monitoring protocol for the Cumberland Piedmont Network, Version 1. Natural Resource Report NPS/CUPN/NRR—2011/XXX. National Park Service. Fort Collins, Colorado. https://irma.nps.gov/DataStore/Reference/Profile/2192468 (last accessed February 2026).

Yamamoto, S.I. 2000. Forest gap dynamics and tree regeneration. Journal of Forest Research 5: 223–9.

Appendix 1. National Vegetation Classification Standard Associations Monitored in Cape Hatteras National Seashore

Descriptions of each vegetation association are from McManamay et al. (2014) and NatureServe (2025), while conservation status estimates are from NatureServe (2025).

Broad Habitat Type – Nontidal Wetlands

Marsh Fimbry – Common Threesquare Marsh (CEGL003790)

Plots (1): BUXT008

Brief Description: Herbaceous-dominated wetlands of intermittently flooded interdunal flats; standing water is generally present on these sites in spring. Diagnostic species include marsh fimbry (*Fimbristylis castanea*), common threesquare (*Schoenoplectus pungens*), and small saltmeadow cordgrass (*Spartina patens*). Within Cape Hatteras National Seashore, this community is home to many species on the North Carolina rare plant list.

Global Conservation Status: No Status Rank

Atlantic Coast Interdune Swale (CEGL003839)

Plots (17): BOIS003, BOIS005, BOIS006, BOIS008, BOIS015, BUXT004, BUXT065, BUXT067, HAIS001, HAIS009, HAIS016, HAIS017, OCIS001, OCIS003, OCIS008, OCIS009, OCIS010

Brief Description: This community type is very common across Cape Hatteras National Seashore; however, it is characterized by a wide range of shrub and herbaceous cover. Vegetation condition can include a tall (2–5 meters [6.6–16.4 ft]) shrub stratum that is sparse to moderate in cover (20–60%) growing over a moderate to dense (30–80%) short (1–2 meters [3.3–6.6 ft]) shrub stratum; or it can include a moderate to dense (30–95%) short shrub stratum without the tall stratum. Herbaceous cover is dependent on shrub cover, with higher herbaceous cover in sites with lower shrub cover. This community type typically occurs on flat interdunal swales or depressions that are not tidally flooded but may be irregularly flooded or seasonally saturated with freshwater from heavy rains or saltwater from storm surge. They are impacted, like most maritime vegetation communities, by salt spray. Soils are variable and range from rapidly draining sand to poorly to well-drained sandy loam to poorly drained muck. Common wax-myrtle (*Morella cerifera*) is almost always present within the shrub stratum; other shrubs or small trees can include eastern baccharis (*Baccharis halimifolia*), yaupon (*Ilex vomitoria*), and/or southern red cedar (*Juniperus silicicola*). Woody vine density can occasionally be high, and includes maritime catbriar (*Smilax bona-nox* var. *littoralis*) and eastern poison ivy (*Toxicodendron radicans* var. *radicans*). Small saltmeadow cordgrass is characteristic within the herbaceous stratum.

Global Conservation Status: G3—Vulnerable

Mid-Atlantic Maritime Shrub Swamp (Carolina Willow Type) (CEGL004222)

Plots (1): BUXT009

Brief Description: Shrub- and small tree-dominated seasonally flooded wetlands occupying swales within older dune fields and dominated by Carolina willow (*Salix caroliniana*). They typically cover areas up to one hectare. Other characteristic species can include American cupscale (*Sacciolepis striata*), small-spike false nettle (*Boehmeria cylindrica*), and redtop panic grass (*Coleataenia rigidula* ssp. *rigidula*).

Global Conservation Status: G2—Imperiled

Mid-Atlantic Maritime Shrub Swamp (Red Bay Type) (CEGL004635)

Plots (1): BOIS007

Brief Description: Wetland forests occurring on peaty soils of swales and seepage-fed zones adjacent to sand dunes. The canopy is occasionally open depending on hydrology and disturbance history. Swamp bay (*Persea palustris*) is the canopy dominant. The shrub stratum includes common wax-myrtle, yaupon, swamp bay, and southern red cedar. The herbaceous layer typically includes cinnamon fern (*Osmundastrum cinnamomeum* ssp. *cinnamomeum*), royal fern (*Osmunda spectabilis*), Virginia chain fern (*Anchistea virginica*), and netted chain fern (*Lorinseria areolata*). Woody vine density can be high in these sites. This wetland forest is extremely rare and is known from only a few sites across the North Carolina Outer Banks—including the site within the Bodie Island management unit.

Global Conservation Status: G1—Critically Imperiled

Mid-Atlantic Maritime Shrub Swamp (Dogwood Type) (CEGL007384)

Plots (1): BUXT002

Brief Description: Wetland forests occurring on peaty soils of swales and seepage-fed zones adjacent to sand dunes dominated by a 4–10 meter (13.1–32.8 ft) tall canopy of southern swamp dogwood (*Swida foemina*) and moderate to dense thickets of supplejack (*Berchemia scandens*). Various species of wetland grasses and forbs can occur, including small-spike false nettle, rice cutgrass (*Leersia oryzoides*), and southern wild-rice (*Zizania aquatica* var. *aquatica*). This association is only known to occur within Buxton Woods.

Global Conservation Status: G1—Critically Imperiled

Broad Habitat Type – Tidal Wetlands

Seaside-Tansy Tidal Shrub Flat (CEGL003924)

Plots (2): OCIS065, OCIS069

Brief Description: This association occurs along upper marsh edges and tidal flats. Soils are poorly to very poorly drained muck and sand. A sparse to very dense (20–100%) short (0.5 to 2 meters [1.6 to 6.6 ft]) shrub layer of seaside tansy (*Borrichia frutescens*) is characteristic of this community type. Additional shrubs include false-willow (*Baccharis angustifolia*) and maritime marsh-elder (*Iva*

frutescens). The herbaceous stratum can include black needle rush (*Juncus roemerianus*), small saltmeadow cordgrass, swallow-wort (*Pattalias palustris*), and marsh fimbry.

Global Conservation Status: G4—Apparently Secure

Mid-Atlantic High Salt Marsh (CEGL004197)

Plots (9): BOIS069, HAIS065, HAIS066, HAIS067, HAIS068, OCIS066, OCIS067, OCIS071, OCIS072

Brief Description: This community represents the dominant irregularly flooded tidal herbaceous marsh of the North Carolina Outer Banks. It is located on slightly higher elevations adjacent to regularly tidally flooded marshes dominated by monotypic stands of black needle rush or smooth cordgrass (*Spartina alterniflora*). High salt marsh, on the other hand, is dominated by dense cover of small saltmeadow cordgrass and saltgrass (*Distichlis spicata*), along with lesser amounts of marsh fimbry, black needle rush, common threesquare, and Carolina sea-lavender (*Limonium carolinianum*). Shrub species can occur, but the shrub stratum is typically sparse.

Global Conservation Status: No Status Rank

Cattail Tidal Oligohaline Marsh (CEGL004201)

Plots (2): BOIS066, BOIS067

Brief Description: This wetland community occurs within oligohaline to mesohaline zones (salinity range 0.5 to 18 ppt) of tidal marshes along the eastern U.S. coast. Vegetation includes a mixture of freshwater and saltwater species such as narrowleaf cattail (*Typha angustifolia*), giant cordgrass (*Spartina cynosuroides*), common threesquare, eastern rose-mallow (*Hibiscus moscheutos*), and salt marsh fleabane (*Pluchea odorata*). Other species from the adjacent high salt marsh can also be present.

Global Conservation Status: G4—Apparently Secure

Transitional Tidal Marsh (CEGL006612)

Plots (1): BOIS068

Brief Description: This vegetation type occurs in wet depressions of high salt marshes and also within the ecotone between low and high salt marsh zones. It is irregularly flooded and floods less than small saltmeadow cordgrass-dominated high salt marsh. This community is dominated by Olney threesquare (*Schoenoplectus americanus*), with lesser amounts of small saltmeadow cordgrass, salt marsh fleabane, black needle rush, and cattail species.

Global Conservation Status: G3—Vulnerable

Broad Habitat Type – Upland Forests and Shrublands

Mid-Atlantic Coastal Maritime Forest (CEGL006040)

Plots (3): BOIS098, BUXT007, BUXT011

Brief Description: This community includes loblolly pine (*Pinus taeda*)-dominated forests of sheltered backdunes protected from salt spray and overwash. Soils are nutrient poor, rapidly draining sands or sandy loams. Hardwood species may occasionally be present in the canopy and subcanopy. These species include live oak (*Quercus virginiana*), water oak (*Quercus nigra*), eastern wild black cherry (*Prunus serotina* var. *serotina*), sassafras (*Sassafras albidum*), and American persimmon (*Diospyros virginiana*). The shrub layer is typically sparse and includes canopy and subcanopy species as well as yaupon, swamp bay, common wax-myrtle, and blueberry (*Vaccinium sp*.). The herbaceous layer is also typically sparse, but slender spikegrass (*Chasmanthium laxum*) can be locally abundant. Other herbs can include partridge-berry (*Mitchella repens*) and various species of witchgrass (*Dichanthelium sp.*). This association differs from other maritime forests of the seashore due to the relative dominance of loblolly pine.

Global Conservation Status: G2—Imperiled

Atlantic Coast Maritime Evergreen Forest (CEGL007027)
Plots (6): BUXT003, BUXT005, BUXT006, BUXT010, BUXT013, BUXT014

Brief Description: This is the classic oak-dominated maritime forest of barrier islands from coastal Virginia to South Carolina. The canopy is low- to moderate-statured and is often, but not always, sculpted by wind-borne salt spray. Canopy species include live oak and sand laurel oak (*Quercus hemisphaerica*), with lesser amounts of loblolly pine and southern red cedar. Subcanopy species can include canopy species as well as red bay (*Persea borbonia*), flowering dogwood (*Benthamidia florida*), coastal American hornbeam (*Carpinus caroliniana* var. *caroliniana*), wild olive (*Cartrema americanum*), and American holly (*Ilex opaca*). The shrub and vine strata are typically well developed and include such species as common wax-myrtle, yaupon, eastern poison ivy, muscadine (*Muscadinia rotundifolia* var. *rotundifolia*), cross-vine (*Bignonia capreolata*), peppervine (*Nekemias arborea*), and Carolina jessamine (*Gelsemium sempervirens*). The herbaceous stratum is sparse and diversity is low. This forest occurs on sand flats, lower slopes, and stabilized dunes of barrier islands that are typically protected from saltwater flooding. However, because of its location on barrier islands, this association does experience routine catastrophic disturbance from high intensity storm events. Disturbance from coastal storms can include saltwater flooding, high winds, and erosion.

Global Conservation Status: G2—Imperiled

Slash Pine Plantation (CST007170)
Plots (5): BOIS097, BOIS100, OCIS113, OCIS115, OCIS116

Brief Description: These forests occupy sites that have been impacted by recent human activity in the form of planting slash pine (*Pinus elliottii*), a species of pine not native to North Carolina. In the past, it is likely that these sites could have supported either nontidal wetland vegetation associations or upland forests with native tree species. The canopy of these “semi-natural” forests are dominated by slash pine with a subcanopy of southern red cedar and occasionally pond pine (*Pinus serotina*). The shrub stratum is dominated by common wax-myrtle, yaupon, and swamp bay. The vine stratum can be well-formed and occasionally dense. The herbaceous stratum is typically sparse, and made up of

canopy, subcanopy, and woody vine species. It is unclear if slash pine will persist in these forests, if they will convert back to more natural shrublands, or native trees will outcompete the non-native pine to convert to a more natural maritime forest.

Global Conservation Status: G2—Imperiled

Broad Habitat Type – Upland Open Grasslands

Sea-Oats Dune Grassland (CEGL004040)

Plots (16): BOIS001, BOIS002, BOIS004, BUXT068, BUXT069, BUXT071, BUXT072, BUXT074, HAIS002, HAIS003, HAIS004, HAIS006, HAIS007, HAIS008, OCIS005, OCIS006

Brief Description: This is the characteristic, wide-ranging foredune vegetation type of the southern Atlantic Coast from northeast Florida to North Carolina. Sea-oats (*Uniola paniculata*) is the dominant and prominent grass. Other common species include dune pennywort (*Hydrocotyle bonariensis*), dune marsh-elder (*Iva imbricata*), camphorweed (*Heterotheca subaxillaris*), and seabeach grass (*Panicum amarum*). Like most dune grasslands of the southern Atlantic Coast, this association occurs almost exclusively on unstable, sandy, droughty soil substrates with little to no profile development. Litter accumulation from plant debris is typically absent. Sand deposition and erosion are caused by eolian (wind) processes.

Global Conservation Status: G3—Vulnerable

Overwash Dune Grassland (CEGL004097)

Plots (5): BOIS013, BUXT075, OCIS002, OCIS004, OCIS007

Brief Description: This community type is found along small, young dunes, back sides of beaches, or interdunal flats and swales of Atlantic Coast barrier islands. These sites experience occasional storm- or tide-driven overwash flooding. Unlike the Sea-oats Dune Grassland association whose soils are deposited exclusively by eolian processes, soils of this association are also deposited by flooding. Both wetland and upland plants can be found within this community type. Small saltmeadow cordgrass is typically dominant and cover of this species ranges from sparse (less than 25%) to dense (greater than 75%). Other species found in this vegetation type include purple lovegrass (*Eragrostis spectabilis*), common threesquare, seabeach grass, dune pennywort, and beach blanket-flower (*Gaillardia pulchella*). This community potentially represents an intermediate successional phase between interdunal herbaceous wetlands and interdunal shrub-dominated uplands.

Global Conservation Status: G2—Imperiled

Mid-Atlantic Coast Backdune Shrub Grassland (CEGL004240)

Plots (1): HAIS005

Brief Description: This mid-Atlantic maritime grassland occurs within the influence of offshore winds and salt spray on deep, well-drained sands of backdunes and interdune flats. They are highly variable in species composition but are typically characterized by some combination of bunchgrasses

(e.g., seaside little bluestem [*Schizachyrium littorale*], bluestem [*Andropogon virginicus*], seabeach grass, and witchgrass) and/or small saltmeadow cordgrass. Shrubs, such as common wax-myrtle and northern bayberry (*Morella pensylvanica*), are typically present but sparse. Dense tangles of eastern poison ivy are also common within this community type.

Global Conservation Status: G2—Imperiled

Literature Cited

McManamay, R.H., S.C. Heath, and L. Baron. 2014. Vegetation mapping at Cape Hatteras National Seashore. Natural Resource Data Series NPS/SECN/NRR—2014/710. National Park Service, Fort Collins, Colorado. https://irma.nps.gov/DataStore/Reference/Profile/2216475 (last accessed February 2026).

NatureServe. 2025. NatureServe Explorer 2.0: an online encyclopedia of life [web application]. NatureServe, Arlington, Virginia. https://explorer.natureserve.org (last accessed February 2026).

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