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Assessment of Natural Resource Conditions

Fire Island National Seashore

Natural Resource Report NPS/NRPC/NRR—2009/139

ON THE COVER
Looking across the frozen Great South Bay from Talisman boardwalk, Fire Island National Seashore
Photograph by: Diane Abell, R.L.A.

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Executive Summary

Congress, in its FY 2003 Appropriations Act, instructed and funded the National Park Service (NPS) to assess environmental conditions in watersheds where national park units are located. Threats from nutrient enrichment, sedimentation, exotic species, water pollution, and development are management concerns for many coastal parks. Consequently, there is a need for NPS to better understand and evaluate natural resource conditions within coastal park units and then use this information to further guide data collection and broader watershed assessment efforts. The Watershed Condition Assessment Program (WCA) will inform efforts to address threats and issues on a watershed or regional oceanographic scale and guide development of actions to reduce and prevent impairment of waters of coastal parks through NPS and partnership efforts.

The aim of this project was to compile a large-scale assessment of the natural resources associated with Fire Island National Seashore (FIIS) off the south shore of Long Island, New York. Our focus was to identify both the state of knowledge regarding individual resources and the degree to which they are affected by natural and anthropogenic factors. This report summarizes the condition and state of knowledge for natural resources, identifies information gaps where data are insufficient to assess resource condition, and makes recommendations for future studies to fill information gaps and to facilitate resource management. While the focus of this effort is on natural resources within the FIIS boundary, resources and threats proximate to FIIS were considered as they might affect FIIS park resources. A wide range of sources was reviewed to obtain information on natural resources in the park. Of particular interest were georeferenced datasets that could be used to provide a spatial perspective on condition. Georeferenced datasets were assembled into a geographic information system (GIS) that was used to create the maps included in this report.

This report provides a basic description of FIIS, including the geomorphology of the island and basic processes governing the oceanography of surrounding waters, hydrology, and groundwaters. Habitats and associated natural communities are described and stressors and threats to these resources and their impacts identified and discussed. A summary of overall condition and trends in status is also presented.

Fire Island is a 22.8 km^2 barrier island located in southeastern New York, approximately 80 km east of New York City and from 1.6 to 8 km off the southern shore of Long Island (Figure 1). The south coast of Fire Island is a continuous strip of beaches facing the ocean, whereas the north coast is a network of salt marshes, small beaches, bulkheaded private property, marinas, and related structures. Ecological communities associated with Fire Island include marine areas such as offshore benthic and pelagic zones; intertidal areas (beaches, salt marshes, and tidal creeks); and upland areas (dunes, forests, and shrublands). Fire Island contains areas that are both pristine (the Wilderness Area) and highly developed (marinas and numerous communities).

FIIS also includes the William Floyd Estate, a 2.5 km^2 property on the south shore of Long Island. Although the upland vegetative resources of the estate are included in the assessment of FIIS, because it represents a small portion of the FIIS area, is physically separated from the

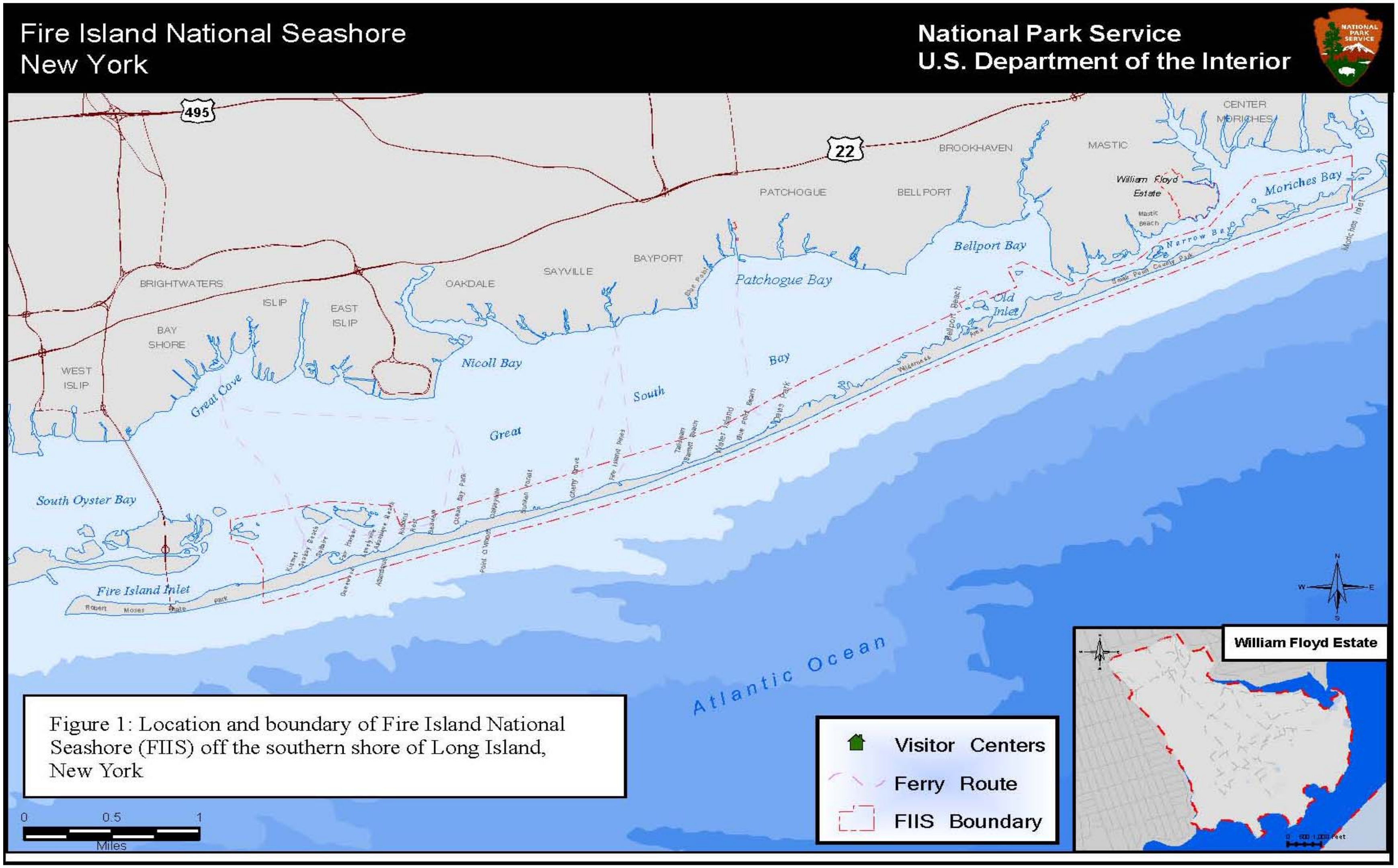

Figure 1: Location and boundary of Fire Island National Seashore (FIIS) off the southern shore of Long Island, New York

majority of the park, and due to being on the mainland is subject to different stressors and threats, a detailed condition of this portion of FIIS is not included in this report.

There are many potential threats to the natural resources of FIIS. These can be categorized into five main types: a) pollution, b) habitat alteration, c) human overuse, d) invasive exotic and problematic native species, and e) global climate change. In this report each is discussed separately, although human overuse is clearly linked to all the other stressor categories. Within each category, sub-categories of specific existing or potential threats as well as indicators of degraded condition have been identified. The status of each FIIS resource evaluated (marine benthic and pelagic, intertidal beach and salt marsh, upland dune, forest and freshwater marsh as well as groundwater) has then been assessed with respect to specific stressors, with each categorized as being an existing, potential, or not a problem (EP, PP, or NP, respectively).

Fire Island's proximity to New York City and other highly urbanized areas of the northeastern United States would appear to make it particularly vulnerable to natural resource degradation. Despite this, natural resource conditions in FIIS remain relatively intact. Nevertheless, the fragile nature of this barrier island ecosystem and its vulnerability to human-made and natural stressors requires careful management of existing resources and monitoring of existing and potential threats and stressors.

Erosion and accretion are natural processes on a barrier island, and shore line changes are expected. However, erosional hot spots associated with shore-line hardening on the bay side of Fire Island are a significant threat to the resources of FIIS. Sea-level rise will undoubtedly amplify this threat. Nutrient enrichment of the bayside waters of FIIS (Great South Bay - GSB) remains a potential problem. Despite growing populations on the south shore of Long Island, nutrient concentrations in GSB have remained stable or decreased since the 1960s. However, delivery of excess nutrients to local areas along the north shore, particularly in Moriches Bay, has led to poor water quality that could impact pelagic and benthic resources. Brown tide continues to be a sporadic problem in GSB. The decline of shellfish populations in GSB and loss of filtration capacity further exacerbate water quality problems and may be linked to declines in eelgrass beds within the bay. There is a need for more quantitative information on the status of shellfish and finfish populations (particularly those that use GSB as a breeding ground). Non-nutrient chemical contamination does not appear to be a large problem, but there are little data to support this conclusion. Invasive species, such as *Phragmites australis,* are a problem within intertidal salt marsh communities. Upland resources are vulnerable to impacts from overexploitation by humans and nuisance species such as deer. Of particular concern are the maritime holly forest, piping plovers, and seabeach amaranth, all of which have very specific habitat requirements and are subject to negative effects of natural and man-made disturbance.

Finally, sea-level rise will become an important problem for FIIS. The NPS needs to consider its potential impacts in any long-range plan. Direct physical damage and loss of habitat due to erosion and flooding are likely effects of rising sea level. Secondary effects, such as increased nutrient and chemical contamination, leading to further water quality degradation are also likely.

Acknowledgments

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Introduction

The aim of this project is to compile an assessment of the natural resources associated with Fire Island National Seashore off the south shore of Long Island, New York. Our focus is to identify both the state of knowledge regarding individual resources and the degree to which they are affected by natural and anthropogenic factors. This report summarizes the condition and state of knowledge for individual natural resources, identifies information gaps where data are insufficient to assess resource condition, and makes recommendations for future studies to fill information gaps and to facilitate resource management. While the focus of this effort is on natural resources within the FIIS boundary, resources and threats proximate to FIIS were considered as they might affect FIIS park resources. The vegetative communities of the William Floyd Estate are presented in this report, but due to its large size, separation from Fire Island, and close association with the mainland of Long Island, issues related to this portion of FIIS are not otherwise discussed in detail. A wide range of sources were reviewed to obtain information on natural resources in the park.

Of particular interest were georeferenced datasets that could be used to provide a spatial perspective on condition. Georeferenced datasets were assembled into a geographic information system (GIS) that was used to create the maps included in this report. In addition to georeferenced data, the authors relied heavily on a number of excellent synthesis reports commissioned by the National Park Service that provide reviews of park resources (Bokuniewicz et al. 1993; Klopfer et al. 2002; Hinga 2005; Conover et al. 2005) as well as major factors influencing habitat (Psuty et al. 2005; Nordstrom and Jackson 2005) and the potential impacts of water quality issues (Hinga 2005; Cooper 2007).

This report provides a basic description of FIIS, including the geomorphology of the island and basic processes governing the oceanography of surrounding waters, hydrology, and groundwaters. Habitats and associated natural communities are then described, and stressors and threats to these resources and their impacts identified and discussed. A summary of overall condition and trends in status is also presented.

Park Description

Setting

Fire Island National Seashore is primarily located on Fire Island, a barrier island in southeastern New York, approximately 80 km east of New York City and from 1.6 to 8 km off the southern shore of Long Island (Figure 1). The total marine and terrestrial area of the park is 7,832 ha, of which approximately 4,300 ha are submerged. The park is bordered by Robert Moses State Park to the west, Smith Point County Park and Moriches Inlet to the east, Great South Bay (GSB) to the north, and the Atlantic Ocean to the south. The park also encompasses the William Floyd Estate, a 2.5 km^2 property on the south shore of Long Island adjacent to the eastern end of Fire Island, twenty-five smaller federally owned islands, some additional islands owned by towns or Suffolk County, and seventeen privately owned communities, which existed prior to the establishment of the park in 1964 and continue to operate within the boundary of the National Seashore. The southern shore of FIIS is a continuous stretch of beach, and the park boundary extends 305 m (1,000 ft) beyond the beach into the Atlantic Ocean. The north shore of FIIS is a network of salt marshes, small beaches, bulkheaded private property, marinas, and related structures. The park boundary extends 1.2 km (4000 ft) north into GSB. Private communities are a dominate feature in the western half of FIIS. The Fire Island Wilderness Area, the only federally designated wilderness area in New York State, is a dominate feature in the eastern half of FIIS.

The geology of Fire Island is closely tied to the geology of Long Island. Fire Island is located south of Long Island's Ronkonkoma moraine, the terminal end of the Laurentian ice sheet. The glacier began its retreat 8,000-12,000 years ago, and residual material supplied the sand found on Fire Island. The sediments found on the south shore of Long Island and all of Fire Island were either deposited directly by the Laurentide glacial event or developed from glacial drift deposited offshore during a period of sea-level rise in the Holocene. In the latter case, the sediments are largely derived from reworking of Pleistocene sediments and now are dominated by quartz sands (Schwab et al. 2000).

Ancestral barrier islands along the south shore of Long Island may have been formed from the reworked Pleistocene sediments approximately 9,000 years ago as the rate of sea-level rise during deglaciation slowed. More recent slowing of sea-level rise approximately 4,000 years ago made conditions for barrier island formation even more favorable (Schwab et al. 2000). Continued sea-level rise forced landward migration of barrier islands; rates of migration were faster in the east where the offshore slope is steeper. As a consequence, the western lagoon (GSB) is larger than the eastern lagoons (Moriches and Shinnecock Bays), and the barrier island in the west tends to be wider than that in the east. At present the central area of the barrier islands, including FIIS, is 1,200 years old and represents the oldest portion of this barrier island system (Leatherman and Allen 1985).

FIIS was established on September 11, 1964 "for the purpose of conserving and preserving for the use of future generations relatively unspoiled and undeveloped beaches, dunes and other natural features" under Public Law 88-587. The seashore provides access and recreational and educational opportunities to visitors in this natural setting close to densely populated urban and suburban areas, consistent with the policies of NPS (http://www.nps.gov/fiis/parkmgmt/1977-

general-management-plan.htm). In addition to FIIS's natural resources and recreational value, it includes many cultural resources. The remnants of the old lighthouse, constructed in 1828, and its replacement, the largest lighthouse in the United States, constructed in 1856, as well as the shipwreck presumed to be the BESSY WHITE http://www.lejabeach.com/Leja/Endless/bwhite102505.html) represent the seafaring heritage of Long Island. Additionally, the William Floyd Estate includes the house and 248 ha of land donated by the Floyd family in 1976. The property is named for the Revolutionary War general and signer of the Declaration of Independence who was born and raised at the site. Artifacts on display and the culturally maintained historic landscape provide insight into 18th, 19th, and 20th century life in then-rural Long Island.

The natural resources of FIIS are abundant and in relatively pristine condition as compared to mainland Long Island. The lack of hard-surfaced roads in FIIS limits accessibility to recreation areas and private communities that are serviced mainly by ferry or private boat, thus shielding resources from excessive visitation. Several threatened or endangered plant and animal species are found within the park boundary.

Land Cover And Land Use

Land cover maps for Fire Island were generated from the Multi-Resolution Land Characteristics (MRLC) Consortium National Land Cover Dataset (NLCD) 2001 data (available online at http://www.mrlc.gov). FIIS land cover (including the William Floyd Estate) is shown in Figure 2. The most common land cover classifications are open water: 49.4 km^2; barren land (which would include sand dunes): 13.0 km^2; and emergent herbaceous wetlands: 8.8 km^2. Combined, these land types cover 64, 17, and 11% of the area of FIIS, respectively, making natural habitats the predominate landscape feature in FIIS.

History and Human Utilization

Fire Island's early history is primarily related to its use as a nautical outpost. In 1653 a whaling station was constructed on the western end. As whale spouts were spotted from lookout towers, whalers launched boats from the beach in pursuit. The first lighthouse on Fire Island was completed in 1826, but the 23 m tower was not effective. The original lighthouse was disassembled and used in the construction of a 51 m lighthouse, which opened in 1858 and served as an important navigational beacon for ships approaching New York Harbor.

The Island became a desirable recreational destination beginning in the 1920s. Small properties were developed, and by the 1950s several communities had formed. Concomitant with the establishment of these communities, local governments and residents debated the future of Fire Island. In 1938 a plan to construct a parkway the length of the island was submitted, but the project was put on hold due to the cost. An amended version of this development plan was released in 1962, but by then the communities on Fire Island as well as visitors were opposed to the parkway. On September 11, 1964 Fire Island National Seashore was established under the administration of NPS. The lighthouse was decommissioned in 1973, and the land was incorporated into FIIS in 1979. Private money to restore and maintain the lighthouse was raised, and it was recommissioned in 1986. At present it is fully operational and remains on nautical charts as a privately funded aid to nautical navigation.

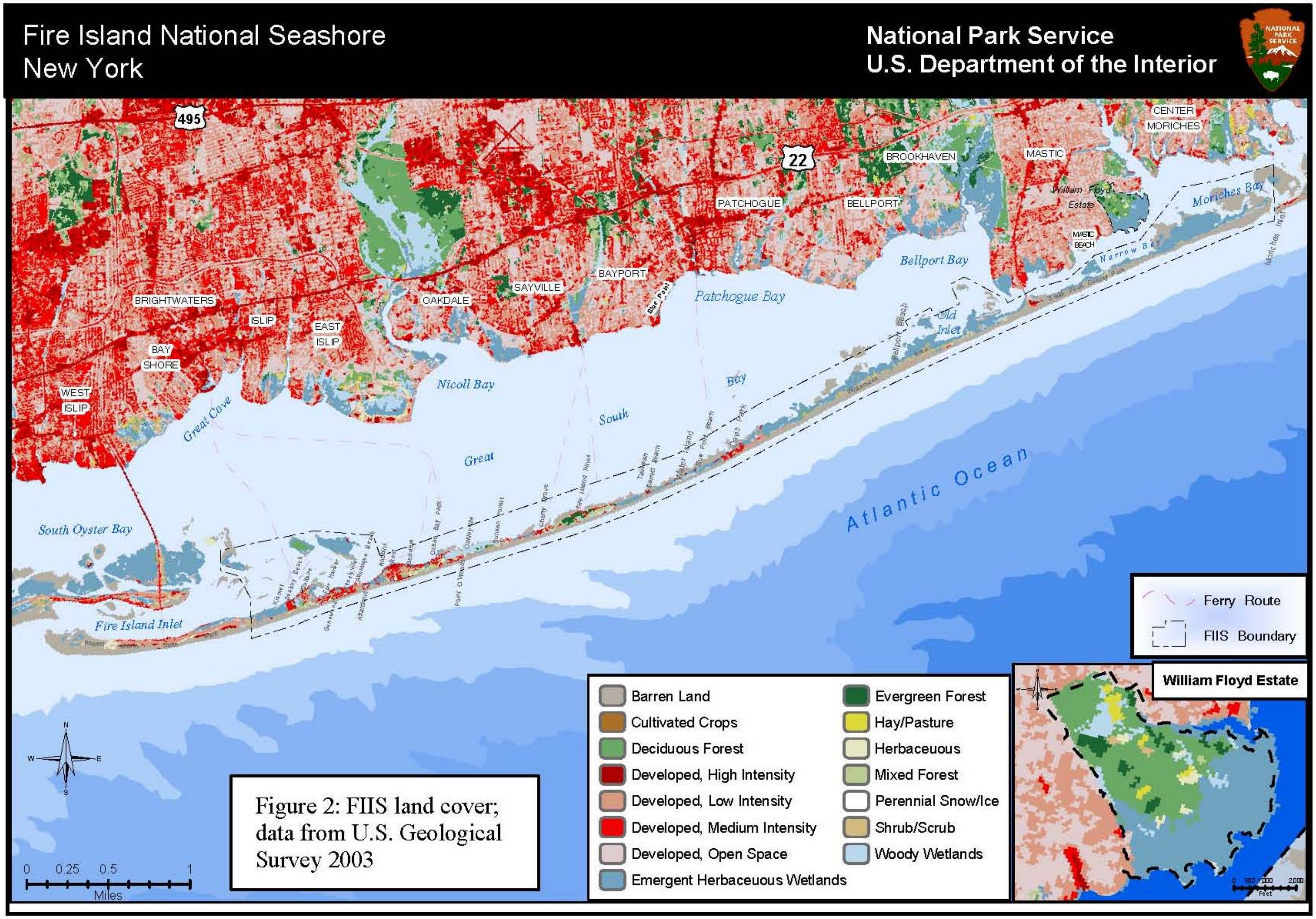


Figure 2: FIIS land cover; data from U.S. Geological Survey 2003

The National Park System is the largest landholder on Fire Island (NPS 1992). Of the 17 private communities, two are incorporated villages, Ocean Beach and Saltaire. Politically, the island is split between the towns of Islip and Brookhaven. According to the Long Island Power Authority (2006), there are 350 full-time residents on Fire Island occupying 138 households, most of which are concentrated in Ocean Beach (United States Census 2000). However, there are a total of 3,157 housing units, mostly occupied by a seasonal population during the summer tourist season. The number of people visiting Fire Island (including the 17 communities, Smith Point County Park, the waterways surrounding Fire Island, or a FIIS facility) on a peak season weekend day can be as high as 100,000 and about 2.2 million people are estimated to visit annually (http://www.nps.gov/fiis/parkmgmt/statistics.htm). Annual visitation to FIIS proper is compiled annually, and has risen over the past 30 years, peaking in 2004 with 975,000 people. Visitation in 2006 was down somewhat at 734,000. Human use is concentrated in the communities and along the south shore beaches and is not extensive in the wilderness area (Figures 1, 2).

Hydrologic Setting

Oceanography and Physical Processes

Fire Island, a 48-km-long barrier beach, is an integral part of the Long Island south shore lagoonal regime. Oceanographically, these systems are distinct from classic estuaries in that they lack major riverine sources of fresh water and their openings to the sea are restricted. Stretching from Fire Island Inlet to the west and Moriches Inlet to the east, Fire Island protects the western one-third of Moriches Bay and the eastern two-thirds of GSB. The boundaries of Fire Island are now artificially stabilized, but that has not always been the case. Moriches Inlet was created in the March 1931 nor'easter. It migrated westward more than a kilometer by 1947, at which time a jetty was constructed on the west side of the opening in order to stabilize it (Kassner and Black 1982). Moriches Inlet was closed from May 1951 to spring of 1954. At that time, Fire Island extended some 24 km further east to Shinnecock Inlet. Moriches Inlet was widened in 1958 after reopening in 1954. Fire Island Inlet, which apparently has been continuously open since the early 1700s (Kassner and Black 1983), was stabilized in 1941 (Yasso and Hartman 1976). Panuzio (1968) estimated that between 1825 and 1939 the inlet migrated to the west on the order of 65 m/year or nearly 7.4 km. While the inlets at the boundaries of Fire Island are now quasi-permanent, shore line change along the seaward coast is expected. Erosion and overwash associated with storms could form new breaches at any time. These are natural processes associated with all barrier islands.

The fluid geomorphology of Fire Island has a pronounced effect on the physical oceanographic conditions in its shallow lagoons and, as a consequence, their respective species compositions. The circulation and salinity in the lagoons are largely controlled by this same geomorphology, so alterations in geomorphology can influence other factors such as water quality.

The mean depth of GSB is only 1.3 m mean low water (MLW; Bokuniewicz and Schubel 1991); it reaches its greatest depth, about 4.0 m, off Fire Island Pines in the center of the bay (Schubel 1991). The mean depth of Moriches Bay is about 1.2 m MLW (Redfield 1952). The bathymetry of GSB is depicted in Figure 3.

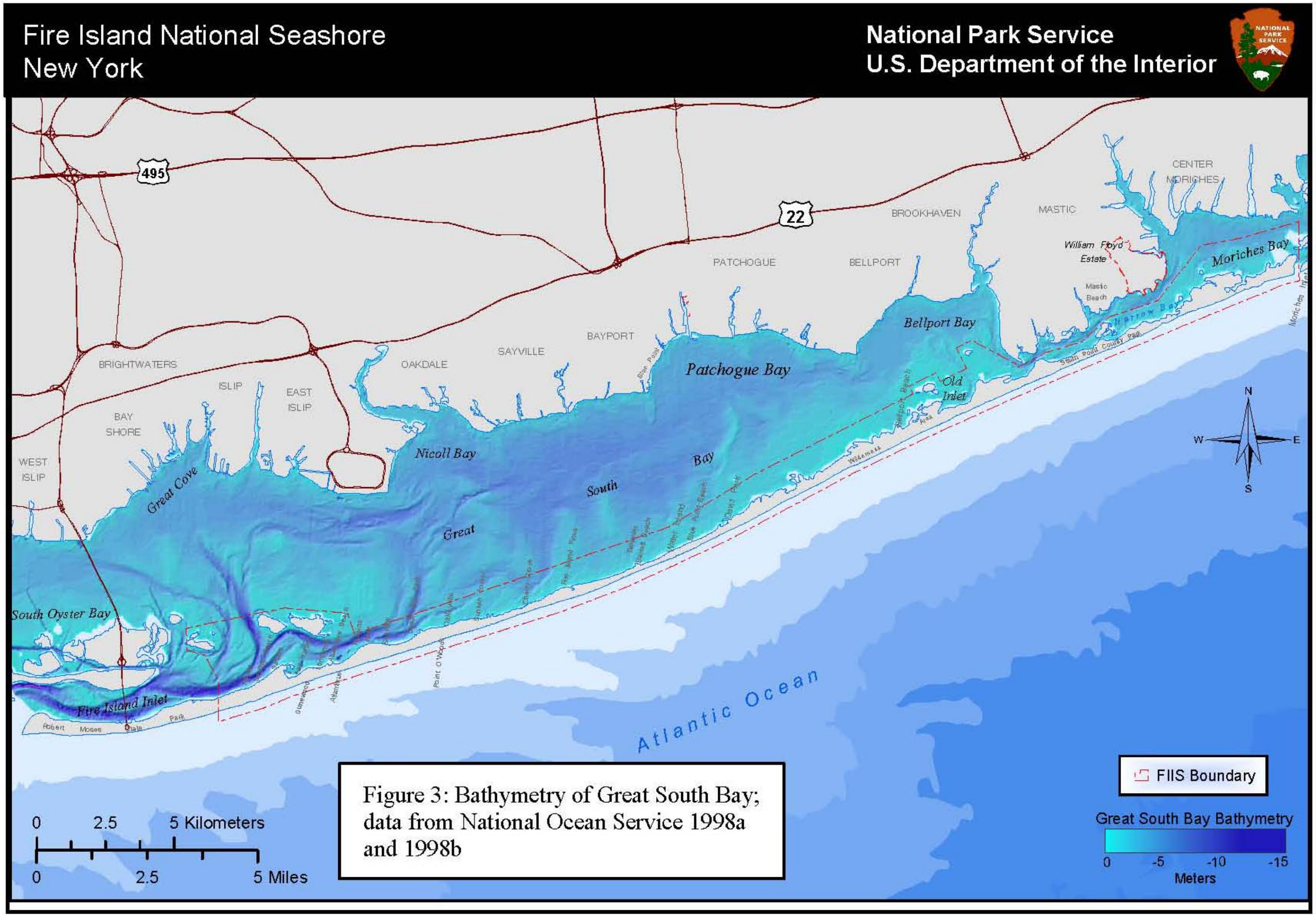


Figure 3: Bathymetry of Great South Bay; data from National Ocean Service 1998a and 1998b

The mean tidal range on the ocean side of Fire Island is about 1.07 m at Moriches Inlet and 1.25 m at Fire Island Inlet (Swanson 1976). Spring tidal ranges are on the order of 0.24 m and 0.27 m larger, respectively. High water arrives at Moriches Inlet about 0.1 hour earlier than Fire Island Inlet and low water arrives about 0.2 hour earlier at Moriches Inlet. Just inside Fire Island Inlet, the semidiurnal tidal range is about 0.61 m; at Smith Point, the range has been reduced to less than 0.4 m. The time of arrival of high water at Smith Point is greater than 2.5 hours after that at the Fire Island Inlet (NOAA 2008).

The range and time of tide are also considerably modified in Moriches Bay. The US Army Corps of Engineers (USACE) reported the tidal range throughout most of the bay to be about 0.76 m (USACE 2004). At the extreme eastern and western ends of Fire Island, the range decreases to around 0.61 m.

Great South Bay and Moriches Bay are subject to excessive storm surges. According to Nichols (1964), the storm surge associated with the 1938 hurricane reached 4.79 m above MLW at Harts Cove. The elevation of Fire Island relative to mean high water is 0.9 m at Old Inlet (an old washover area) and 7.9 m at the top of the dunes at Watch Hill (USACE 2006).

Tidal currents are sluggish in the bays due to the shallow water depth (Figure 4). Current velocities at the inlets can be about 1.03 m/s, but in the interior of GSB, velocities are quickly dampened to 0.15 m/s, with the eastern end being about 0.10 m/s. Moriches Bay has similar tidal currents. The tributaries on the north shore of the bays are little influenced by tidal currents (USACE 2004). However, the greatest source of freshwater to Moriches Bay is apparently the Forge River. R.L. Swanson and R. Wilson of Stony Brook University have estimated surface flow into the upper reaches of the Forge River to be about 650 l/s (personal communication). The exchange between Moriches Bay and GSB through Narrow Bay is to the east into Moriches Bay. When Moriches Inlet is closed, the net flow reverses and is greater (Nichols 1964).

In the winter the bays are thermally well mixed but haline-stratified. However, in summer, thermal and haline stratification are both quite strong, particularly considering the depths of the bays. Salinities in the tidal portion of Moriches Bay can vary between 19-30 psu and are greatly influenced by the influx of groundwater, rainfall, and wind stress. Salinities in GSB are similarly influenced (Figures 5a and 5b).

Wind stress external to and throughout the bays influences circulation and at times is more important than tidal circulation (Figure 6). In general winds over the bays are from the NW in winter and S-SW in summer. Wilson et al. (1991) found low frequency fluctuations of sea level along the outer coast and in GSB of about 0.76 m in winter and up to 0.46 m in summer. When winds blow alongshore and toward the east, as is often the case in winter, the sea level drops inside and outside the bays. Wilson et al. (1991) attribute this to Ekman transport, whereby water is advected 90° to the right of the wind. Thus, water pours from the bays through the inlets, lowering sea level. To a lesser extent, sea level fluctuations will also occur when low frequency wind stress transports water in one inlet and out another. This causes sea level variations along the axes of the bays.

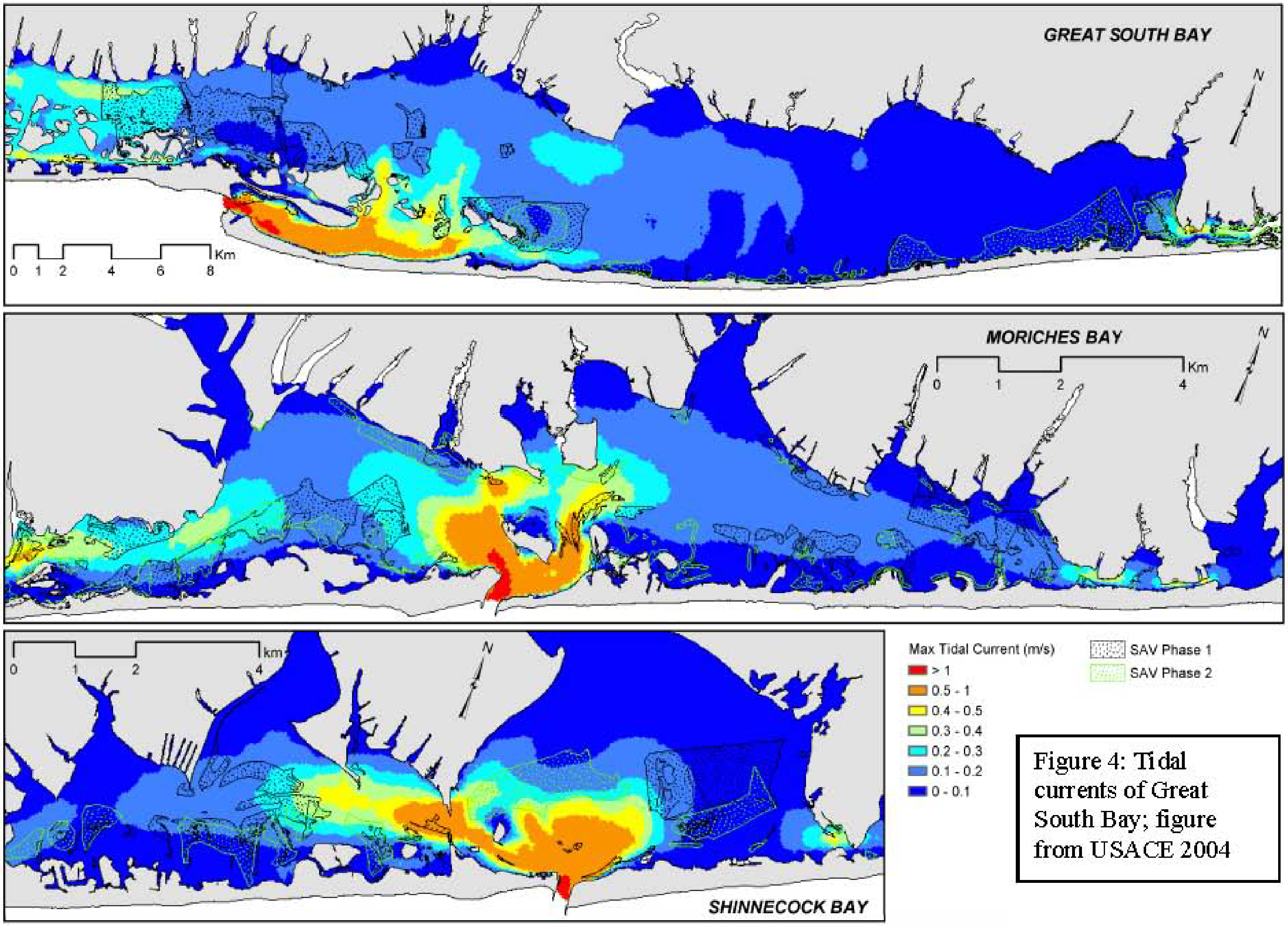


Figure 4: Tidal currents of Great South Bay; figure from USACE 2004

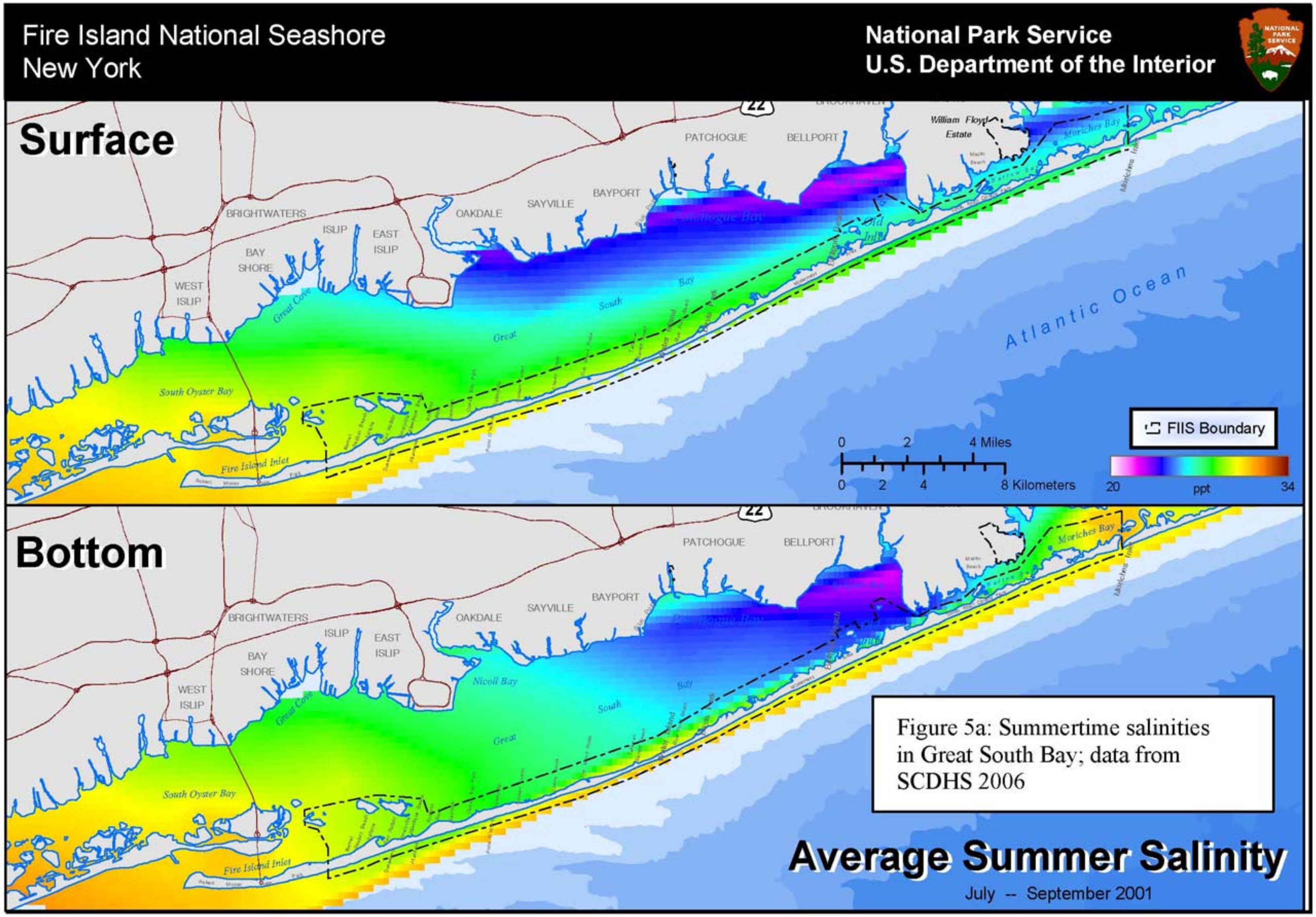


Figure 5a: Summertime salinities in Great South Bay; data from SCDHS 2006

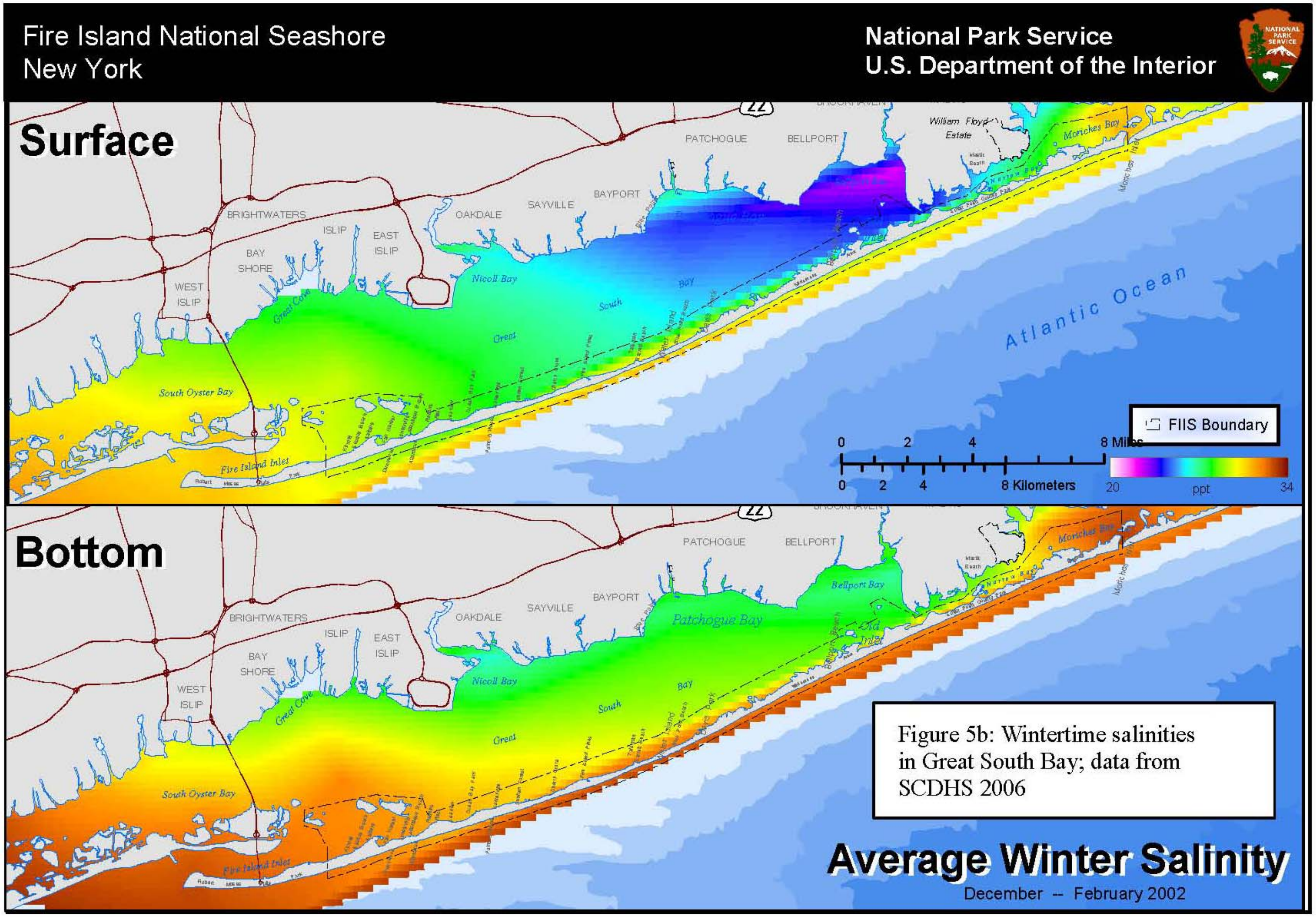


Figure 5b: Wintertime salinities in Great South Bay; data from SCDHS 2006

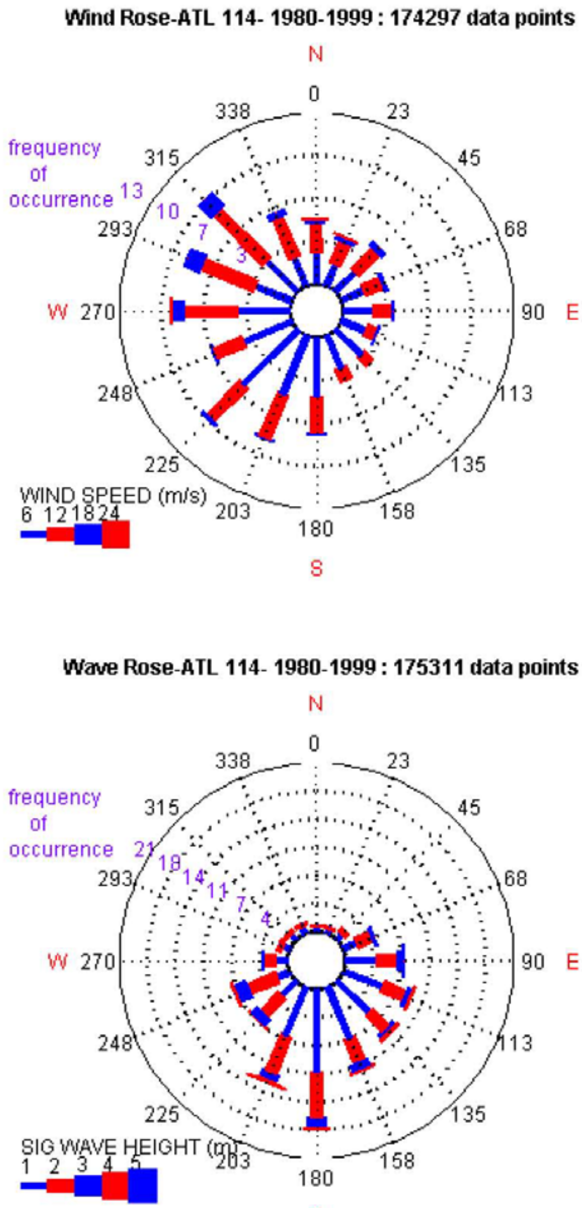


Figure **6**. Wind and wave roses for FIIS (data from USACE: http://frf.usace.army.mil/wis.html, site 114).

Location of inlets is the dominant feature in determining the salinity regimes in these bays. In the 1950s the Woods Hole Oceanographic Institution conducted a series of studies assessing the impacts of the Long Island duck farming industry on the water quality of GSB and Moriches Bay (Guillard et al. 1960). These studies spanned a period when Moriches Inlet was alternately opened, closed and reopened. Guillard et al. (1960) show that the salinities in Moriches Bay were on the order of 10 psu lower when the inlet was closed relative to when it was opened. They also show that the tide range at East Moriches gradually increased some 0.06 m after the inlet was reopened; when the inlet was widened in 1958, the tidal range increased another 0.15 m. Fire Island is subject to modification, erosion, and breaching due to waves and storm surges. In fact, there have been nine breaches recorded on the island between 1763 and 2004 (USACE 2004). The US Geological Survey (USGS) has classified the island as being very highly vulnerable to "significant waves" (Pendleton et al. 2004).

Storms are a major force modifying the landscape of barrier islands, supplying and redistributing sand as well as impacting upland vegetation and structures through wind and water damage. According to Pendleton et al. (2004), three major storms were particularly damaging to property on the south shore of Long Island. These were the 1938 hurricane, the March 1962 extra-tropical storm, and the December 1992 nor'Easter. The March 1962 storm resulted in the destruction of 35 homes on Fire Island alone (Wood 1976). Kassner and Black (1982) discuss many of the changes that occurred at Moriches Inlet as a consequence of storm events and the engineering attempts to improve and stabilize the inlet. It is clear that despite great improvements in the understanding of inlet and barrier island dynamics, the consequences of natural processes and engineered improvements are largely unpredictable.

Besides the dramatic impact of major storms on the Fire Island environment, it is generally shaped by the prevailing wind, waves, and currents of the area. Figure 6 indicates that the wind is out of the southwest (203˚-248˚) approximately 25% of the time. Fifty-six percent of the time the winds are out of the southwest to northwest quadrant (USACE 2004). The vector mean wind speed measured at Westhampton for January and February is typically out of the northwest at about 2.1 m/s. In March the mean vector wind is northwest at 2.3 m/s. From May through August, the mean vector wind is out of the southwest quadrant at 1.0-1.5 m/s. By October the wind has once again shifted to the northwest quadrant, varying between 1.0-2.1 m/s (Lettau et al. 1976).

It should be noted that while the winds are southerly only about 9% of the time (USACE 2004), it is during these events that Fire Island is most likely to have a washup of marine debris (Swanson and Zimmer 1990). The most serious of recent debris washups occurred in the summers of 1976 and 1988 when the winds were persistently out of the south to south-southwest for periods of about a month (Swanson and Zimmer 1990).

Significant waves (Figure 6) are primarily out of the east to south-southwest. Eighteen percent of the time they are from the south, and almost 50% of the time they are out of the east to south quadrant. Perhaps 8% of the time the significant wave height is greater than 2 m (Psuty et al. 2005).

Hydrology

The hydrology affecting many of the natural resources and ecosystems of FIIS is largely influenced by the surface and groundwater processes of Long Island. The surface water system of southern Long Island is comprised of a network of streams discharging into GSB. The streams discharge water as baseflow and stormflow. Baseflow is the discharge from shallow groundwater from the upper glacial aquifer (see discussion of groundwater, below) that is intercepted by the stream channel. Stormflow is the additional discharge caused by precipitation falling on the stream or redirected to the stream from storm water drains.

The effect of extensive development along the south shore of Long Island has been to decrease the baseflow and increase the storm water flow of this network of streams (Monti and Scorca 2003). Factors contributing to this change include: 1) increased groundwater withdrawal for public water supply decreasing baseflow; 2) increased use of municipal sewer systems, which diverts wastewater that would have been returned to the groundwater system via septic tanks, also decreasing baseflow; 3) construction of impervious surfaces (e.g., roads and parking lots) which reduce groundwater recharge and increase storm water runoff; and 4) construction of storm sewers routing storm runoff to streams (Monti and Scorca 2003). Under pre-development conditions, baseflow accounted for 95% of annual streamflow (Franke and McClymonds 1972). At present the percentage of stream discharge due to baseflow is inversely proportional to the amount of development. Annual baseflow as a percentage of total streamflow in highly urbanized Nassau County averaged from 14% in western Nassau County to 78% in eastern Nassau County and from 88% in western Suffolk County to 96% in eastern Suffolk County (Spinello and Simmons 1992).

There are almost no fresh surfacewater resources on Fire Island, and understandably, they have been poorly classified and have received almost no attention in previous surfacewater studies. There are no streams on the island. The only surface water on Fire Island is found in a network of shallow ponds that are likely coupled with the shallow groundwater system.

The groundwater system under Long Island is complex but has been extensively studied and modeled (Buxton and Shernoff 1999; Misut and Monti 1999; Monti and Scorca 2003). It consists of unconsolidated glacial, lacustrine, deltaic, and marine deposits of clay, silt, sand, and gravel that range in age from Late Cretaceous to Pleistocene. These deposits overlie a southward sloping basement complex of Precambrian and (or) Paleozoic-aged crystalline bedrock (Figure 7).

Although little is known about the groundwater system under Fire Island, the relative stratigraphy of the deposits and aquifers is inferred from Long Island. The 17 residential beach communities that in summer months greatly increase in population, along with the NPS's facilities at Watch Hill and Sailors Haven, may have a detrimental effect on groundwater quality. Wastewater from the numerous homes and businesses in the barrier island communities is discharged directly into the shallow groundwater system through use of private septic systems; wastewater from the NPS facilities also enters this system through a series of leach fields and cesspools.

The shallow part of this aquifer system is highly susceptible to degradation from nutrient and/or pathogen contamination, which can pose a threat to coastal habitats. Additionally, the public water supply for these barrier island communities, and all park facilities, is derived solely from wells that pump groundwater from the underlying aquifer system. Most water supply is withdrawn from the uppermost Late Cretaceous (Magothy) aquifer because freshwater in the overlying Pleistocene (upper glacial) aquifer is limited to an isolated, shallow lens. Historically, the shallow groundwater system was used to supply summer residences; however, this supply has largely been abandoned due to elevated levels of chloride, nitrate, and coliform bacteria (Leggette, Brashears and Graham, Inc. 1996).

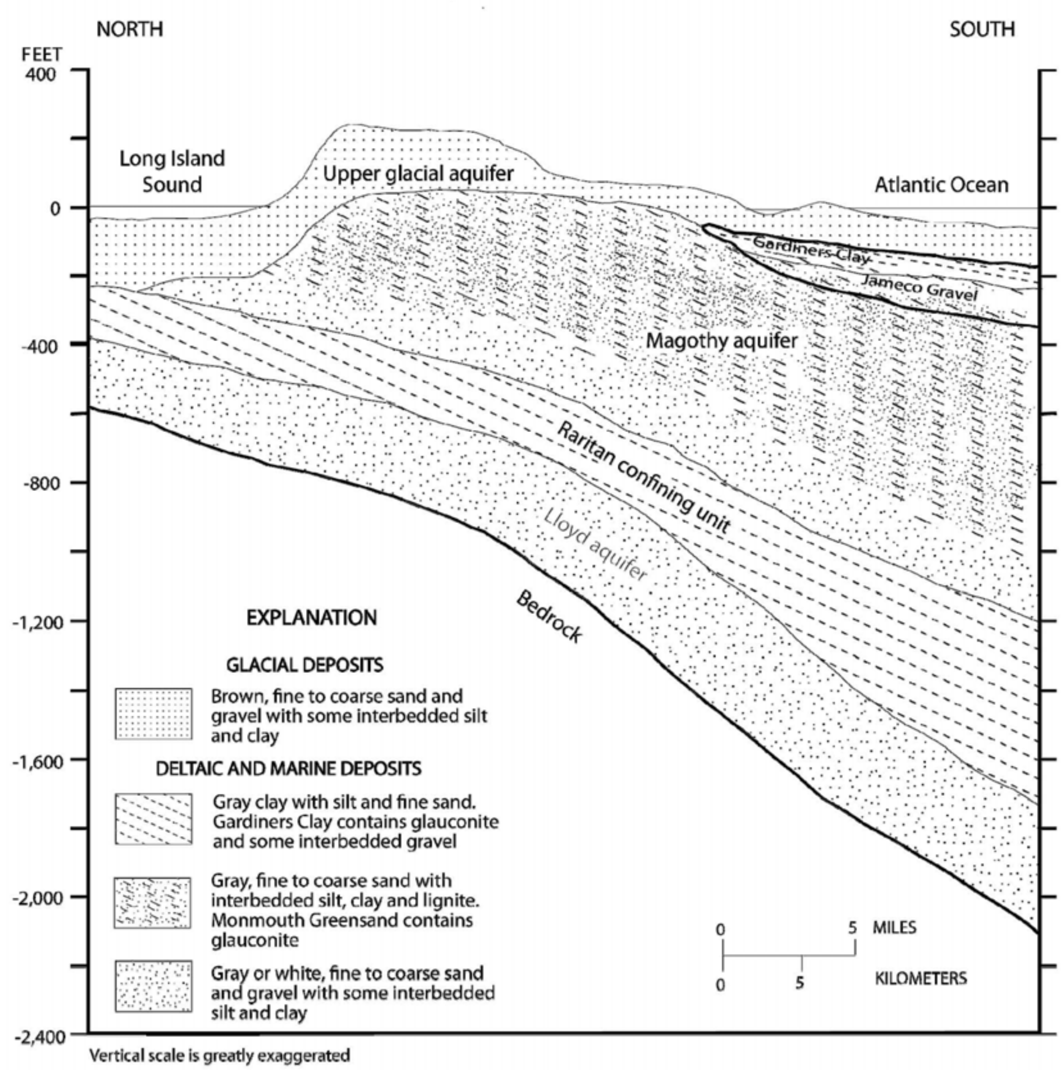


Figure modified from Nemickas et al., 1989

Figure **7**. Generalized hydrologic units of the Long Island subsurface.

Habitats And Associated Communities

Marine Habitats and Species

Marine Benthic

The 305 m wide oceanside bottom of FIIS is sandy and dynamic, characteristic of high-energy, surf zone beaches. Such areas tend to have low infaunal diversity, transient benthic macrofauna, and relatively low fish diversity. Common benthic fishes in this area include northern kingfish (*Menticirrhus saxatilis*), summer (*Paralichthys dentatus*) and windowpane flounder (*Scopthalmus aquosus*), striped searobin (*Prionotus evolans*), and skate (*Raja*) spp. (Schaefer 1967). In the early 1960s, northern puffer (*Spheroides maculatus*) was exceedingly common in the surf zone (Briggs 1965) but has since declined. Calico (*Ovalipes ocellatus*) and blue crabs (*Callinectes sapidus*) may be numerous during warmer months. Surf clams (*Spisula solidissima*) occur seaward from FIIS; Cerrato and Keith (1992) found a broad spectrum of age classes to as much as 22 years and high growth rates. Surveys of benthic invertebrates and pelagic fishes and invertebrates were also conducted as part of the USACE borrow area compilation database in support of the Fire Island to Montauk Storm Damage Reduction Reformulation Study FIMP (USACE 2004).

The bayside waters of FIIS are shallow with a mainly sandy bottom. Two distinguishable species assemblages are present: a high salinity ($\geq$ 28 psu), high flow fauna associated with the largely unvegetated inlets (Fire Island and Moriches) and a lower salinity fauna (Conover et al. 2005). Briggs (1975) characterized Fire Island Inlet's ichthyofauna over summer and autumn 1970 and 1971, finding 57 species with numerical domination by Atlantic silversides (*Menidia menidia*) and northern pipefish (*Syngnathus fucus*).

Conover et al. (2005) also divided the benthic bayside waters into two other categories: vegetated subtidal and non-vegetated subtidal. They noted that many animal species occur in both habitats, but their densities may differ. Briggs (1975) sampled two locations in Fire Island Inlet, one which was near its interior margin, opposite the Fire Island Lighthouse. This site had both vegetated (eelgrass - *Zostera marina*, sea lettuce - *Ulva lactuca*, and *Cladophora gracilis*) and unvegetated patches. From Briggs (1975) and Briggs and O'Connor (1971), fishes that appeared to prefer vegetated areas include northern pipefish, silver perch (*Bairdiella chrysoura*), pollock (*Pollachius virens*), winter flounder (*Pseudopleuronectes americanus*), Atlantic needlefish (*Strongylura marina*), fourspine stickleback (*Apeltes quadracus*), tautog (*Tautoga onitis*), mummichog (*Fundulus heteroclitus*), and Atlantic tomcod (*Microgadus tomcod*). Atlantic silversides and northern kingfish were more common over open sandy bottom. Seagrass beds also have higher abundances of decapods such as grass shrimp (*Palaeomonetes pugio*), sand shrimp (*Crangon septemspinosa*), and blue crab (Raposa and Oviatt 2000).

Eelgrass beds in particular are ecologically important habitat structuring features of mid-Atlantic coastal bays. In a New Jersey estuary, Sogard (1989) found that distance from eelgrass had a pronounced effect on the composition of the resultant community of fishes and decapod crustaceans, with significant differences in densities near and far from eelgrass beds. Raposa and Oviatt (2000) examined the relationship between nekton community and eelgrass beds at seven sites along the north shore of Fire Island. Significant positive correlations were found between nekton abundance and eelgrass biomass, although distance from shore also was an important determinant. Figure 8 shows a map of submerged aquatic vegetation (SAV) in GSB adapted from NOAA (2003). From this map it can be seen that rooted aquatic vegetation predominates in the bay side waters of FIIS. Specimens of the diamondback terrapin (*Malaclemys terrapin*) have been reported within FIIS boundaries and nest in the high marsh at FIIS (Russell Burke, Hofstra University, personal communication; Conover et al. 2005).

Marine Pelagic

Pelagic habitat along the ocean strand of FIIS is highly dynamic with nearshore currents and active breakers that result in considerable mixing of water. Persistent offshore winds may push surface waters away from shore, allowing cooler bottom waters to replace them; the opposite may occur for persistent onshore winds.

The pelagic habitat of GSB has been variable through time as a function of water quality. Water quality, indicated by salinity, light penetration, nutrient levels, plankton densities, and contaminant levels, is partially the product of such factors as point and non-point runoff from the bay's watershed to the north and *in situ* processing of nutrients by algae and the filter-feeders that regulate algae. Occasional plankton blooms have occurred, including harmful brown tides (Hinga 2005).

The federally protected FIIS waters of GSB and its ocean strand provide excellent bay and barrier beach fish habitat. These waters host a diverse ichthyofauna that shows pronounced seasonal changes. The nearshore ocean waters are home to particular gamefish species comfortable in this high energy environment, including striped bass (*Morone saxatilis*), weakfish (*Cynoscion regalis*), and bluefish (*Pomatomus saltatrix*). Other common, usually transient, migratory pelagic fishes include alosines such as hickory shad (*Alosa mediocris*), American shad (*Alosa sapidissima*), blueback herring (*Alosa aestivalis*) and alewife (*Alosa pseudoharengus*), smooth dogfish (*Mustelis canis*), menhaden (*Brevoortia tyrannus*), and striped mullet (*Mugil cephalus*) (Schaefer 1967). The bay waters generally show higher fish biodiversity. Primary recreational pelagic species include bluefish, weakfish, and striped bass, although some of these are marked by wide fluctuations in abundance. Bay anchovy (*Anchoa mitchilli*) is a dominant open water prey species (Monteleone 1992).

The annual abundance in FIIS waters of most of these species is determined by their coastwide abundance; such species have large, widespread populations of adults and subadults that "spill" into FIIS waters. Conover et al. (2005) stated: "The ecological value of FIIS waters to these species is probably a direct function of the proportional shoreline length that FINS (Fire Island National Seashore) represents in relation to the overall coastline." Other species reproduce in GSB (Monteleone 1992), and for such fishes, the value of FIIS habitat may greatly exceed its proportional contribution to the coastline. Winter flounder is one example. This species appears to have localized spawning throughout its range that may exist as discrete stocks (Phelan 1992) but that currently are treated as part of southern New England stock by the Atlantic States Marine Fisheries Commission (ASMFC 2004).

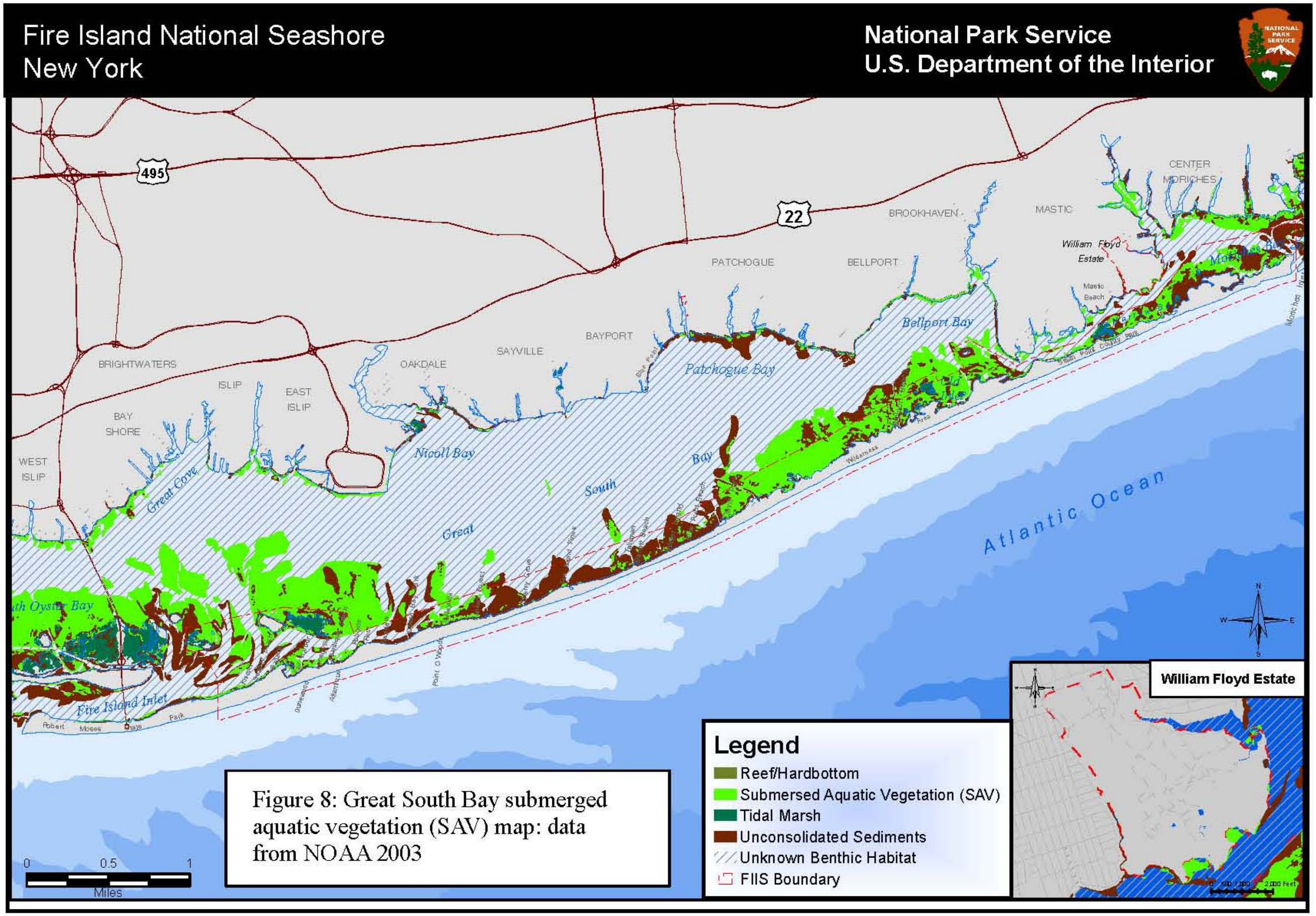


Figure 8: Great South Bay submerged aquatic vegetation (SAV) map: data from NOAA 2003

The productive bay waters are known for high concentrations of wintering waterfowl such as Brant (Branta bernicla), Canada geese (*Branta canadensis*), American black duck, (*Anas rubripes*), Bufflehead (*Bucephala albeola*), Long-tailed duck (*Clangula hyemalisand*), and red-breasted mergansers (*Mergus serrator*) that gather to feed and rest there (MaryLaura Lamont, National Park Service, personal communication). Adult striped bass and bluefish congregate in the deeper waters of the eastern bay around the Smith Point Bridge where forage species such as menhaden are plentiful (United States Fish and Wildlife Service 1997).

Nineteen species of marine mammals, whales, porpoises and dolphins, and seals have been recorded within the boundaries of FIIS. The harbor seal (*Phoca vitulina*) is a regular winter visitor at both Fire Island inlets. Three species of endangered whales have been reported in the waters offshore of Fire Island: fin whale (*Balaenoptera physalus*), humpback whale (*Megaptera novaeangliae*), and northern right whale (*Eubalaena glacialis*) (http://www.nps.gov/fiis/naturescience/mammals.htm).

Table 1 lists fish and macroinvertebrates commonly found in aquatic habitats around FIIS. It is based on expert opinion of material available in the literature as well as reports from the fishing community. Routine surveys of these resources need to be done to provide more quantitative information. Such a survey was recently conducted by Frisk and Munch at Stony Brook University during the spring, summer, and fall of 2007 (M. Frisk, Stony Brook University, personal communication).

Table 1. Fish and Macroinvertebrates commonly found in aquatic habitats around FIIS.

Species	Primary FIIS Location	Recreational and/or Commercial Value	Present Abundance
Bluefish	ocean & bay	high	high
Weakfish	ocean & bay	high	moderate
Striped bass	ocean & bay	high	high
Summer flounder	ocean & bay	high	high
Winter flounder	bay	high	low
American eel	bay	medium	low
Northern puffer	bay	medium	low
Northern kingfish	ocean & bay	medium	moderate
Northern pipefish	bay	low	moderate
Tautog	inlet	medium	moderate
Black sea bass	inlet	medium	moderate
Atlantic silversides	bay	low	moderate
Bay anchovy	bay	low	moderate
Mummichog	bay	medium	moderate
Striped killifish	bay	low	moderate
Blue crab	bay	high	moderate
Hard clam	bay	high	low
Surf clam	ocean	medium	high
Oyster	bay	high	low
Bay scallop	bay	high	low
Horseshoe crab	bay	medium	moderate

Table prepared by John Waldman based on expert opinion

Intertidal Habitats and Species

A comprehensive assessment of all vegetative communities at Fire Island National Seashore was conducted by Klopfer et al. (2002). As part of that study, a detailed map delineating the geographic distribution of 39 land cover classes, including 25 National Vegetation Classification System (NVCS – Grossman et al. 1998) associations (e.g., Northern Beachgrass Dune, Low Salt Marsh) and 14 non-NVCS types (e.g., pavement, ocean/bay), was produced. A summary of that map, displaying the distribution of 13 consolidated vegetation classes (or habitats), including 9 natural and 4 cultural classes, is shown in Figures 9a and 9b. Of the total mapped area (46 km^2), 44% (20 km^2) is open water, and the remaining 56% (26 km^2) consists of intertidal, upland, and palustrine habitats on Fire Island itself, the adjacent small islands, and the William Floyd Estate (Table 2). Only 17% percent (5 km^2) of those habitats are cultural (e.g., Residential or Commercial Property, Pavement). See Klopfer et al. (2002) for a detailed analysis of the original, association-level vegetation map. Data on current condition of Fire Island habitats are generally not available. NY Natural Heritage has qualitative data on condition for the following Fire Island communities that are considered "significant" from a statewide perspective based on their aerial extent relative to other similar resources within the state. These habitats include: Maritime Beach, Maritime Dunes, Maritime Holly Forest, High Salt Marsh, Maritime Freshwater Interdunal Swales, Maritime Pitch Pine Dune Woodland, and Salt Pannes.

Salt Marsh

Salt Marsh is the most abundant cover type mapped on Fire Island; at 670 ha, it encompasses 26% of the area (Table 2). The salt marshes are primarily located along the north shore in the GSB, forming discontinuous patches of "backbarrier fringe-marshes" (Oertel and Woo 1994). Approximately 17 km of the 48 km northern shoreline of Fire Island is salt marsh. The absolute length of the interface of the salt marshes with GSB is much longer than this linear distance due to the crenulated shape of the marshes. Salt marshes consist of beds of intertidal vegetation, such as cordgrass (*Spartina alterniflora*) and saltmeadow cordgrass (*Spartina patens*), that are flooded and drained by the rise and fall of the tide (Day et al. 1989). They are accretional environments, accumulating terrigenous and biogenic sediments in response to tidal flooding. Most salt marshes on Fire Island have formed in bay shoreline areas that were overwashed in the past or located on old flood tide deltas (Nordstrom and Jackson 2005; Psuty et al. 2005; Roman et al. 2007). The effect of historic overwashes was to raise the bayside sediment level into the intertidal zone, thus allowing for colonization by early successional marsh vegetation (Nodstrom and Jackson 2005; Roman et al. 2007). Most overwashes have historically occurred in the areas east of Watch Hill, and consequently, this is where most salt marshes are found (Figure 9c).

Salt marshes provide several beneficial functions. For example, they are the primary source of the nutrients and organic matter that form the foundation of the estuarine trophic food chain. Salt marsh substrate can remove and store accumulated pollutants, sediments, and nutrients. The mosaic of salt marsh islands and fringe marshes provides storm protection by buffering shorelines from waves. Salt marshes also provide habitat and food for a wide array of birds, fishes, and other animals (Niedowski 2000).

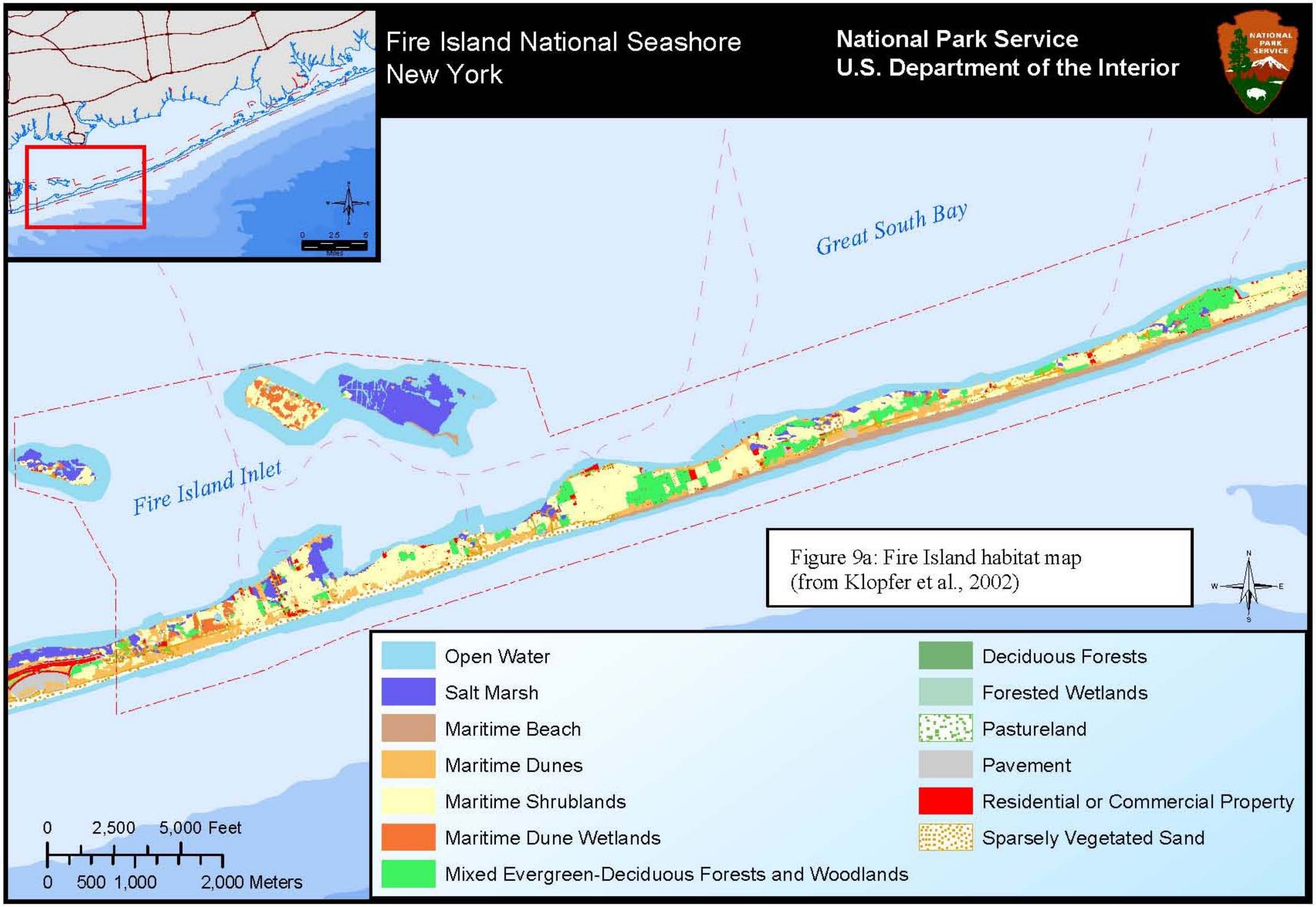


Figure 9a: Fire Island habitat map
(from Klopfer et al., 2002)

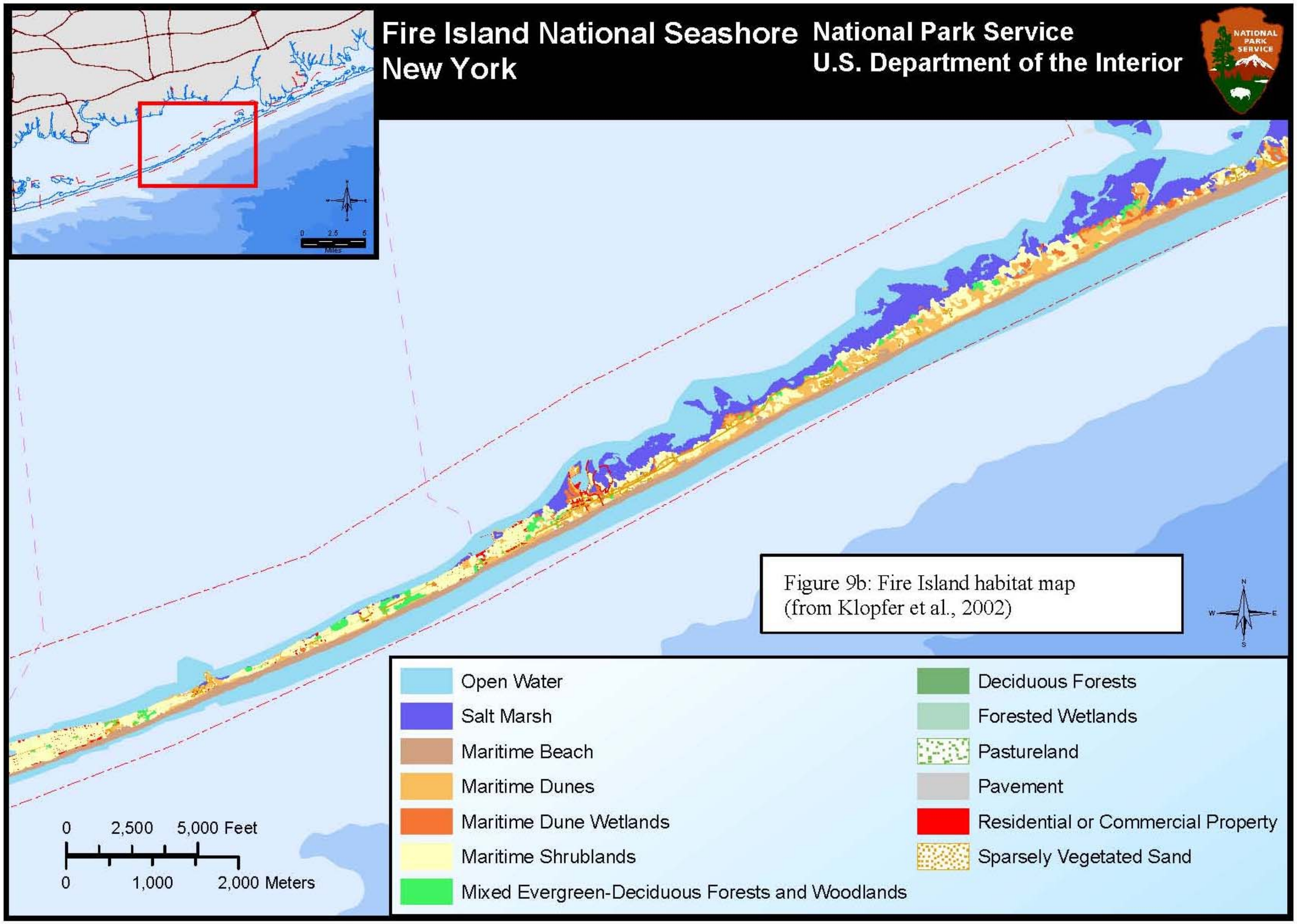


Figure 9b: Fire Island habitat map
(from Klopfer et al., 2002)

Table **2**. Percent cover of vegetated and cultural habitats at FIIS (from Klopfer et al., 2002).

Vegetation class	Component associations	Hectares	% Cover
Salt Marsh			
	Mosquito Ditch	17	1%
	Reedgrass Marsh	142	6%
	Low Salt Marsh	226	9%
	High Salt Marsh	200	8%
	Northern Salt Shrub	76	3%
	Brackish Meadow	6	0.2%
	Total	667	26%
Maritime Beach			
	Open Beach	321	17%
	Total	321	17%
Maritime Dunes			
	Maritime Vine Dune	3	0.1%
	Overwash Dune Grassland	4	0.2%
	Northern Sandplain Grassland	2	0.1%
	Beach Heather Dune	75	3%
	Interdune Beachgrass-Beach Heather Mosaic	39	2%
	Northern Beach Grass Dune	250	10%
	Total	373	15%
Maritime Dune Wetlands			
	Northern Interdunal Cranberry Swale	3	0.1%
	Brackish Interdunal Swale	4	0.2%
	Highbush Blueberry Shrub Swamp	43	1.7%
	Total	50	2%
Maritime Shrublands			
	Autumn Olive	6	0.2%
	Maritime Deciduous Scrub Forest	263	10%
	Northern Dune Shrubland	186	7%
	Total	455	18%
Mixed Evergreen-Deciduous Forests and Woodlands			
	Japanese Black Pine Forest	80	3%
	Pitch Pine Dune Woodland	15	1%
	Maritime Holly Forest	26	1%
	Pitch Pine-Oak Forest	18	1%
	Total	139	5%
Deciduous Forests			
	Maritime Post Oak Forest	<1	0.01%
	Coastal Oak-Heath Forest	97	4%
	Total	97	4%
Forested Wetlands			
	Acidic Red Maple Basin Swamp	6	0.2%
	Total	6	0.2%
Pastureland		19	1%
Pavement		72	3%
Residential or Commercial Property		141	6%
Sparsely Vegetated Sand		222	9%
Grand Total		2562	100%

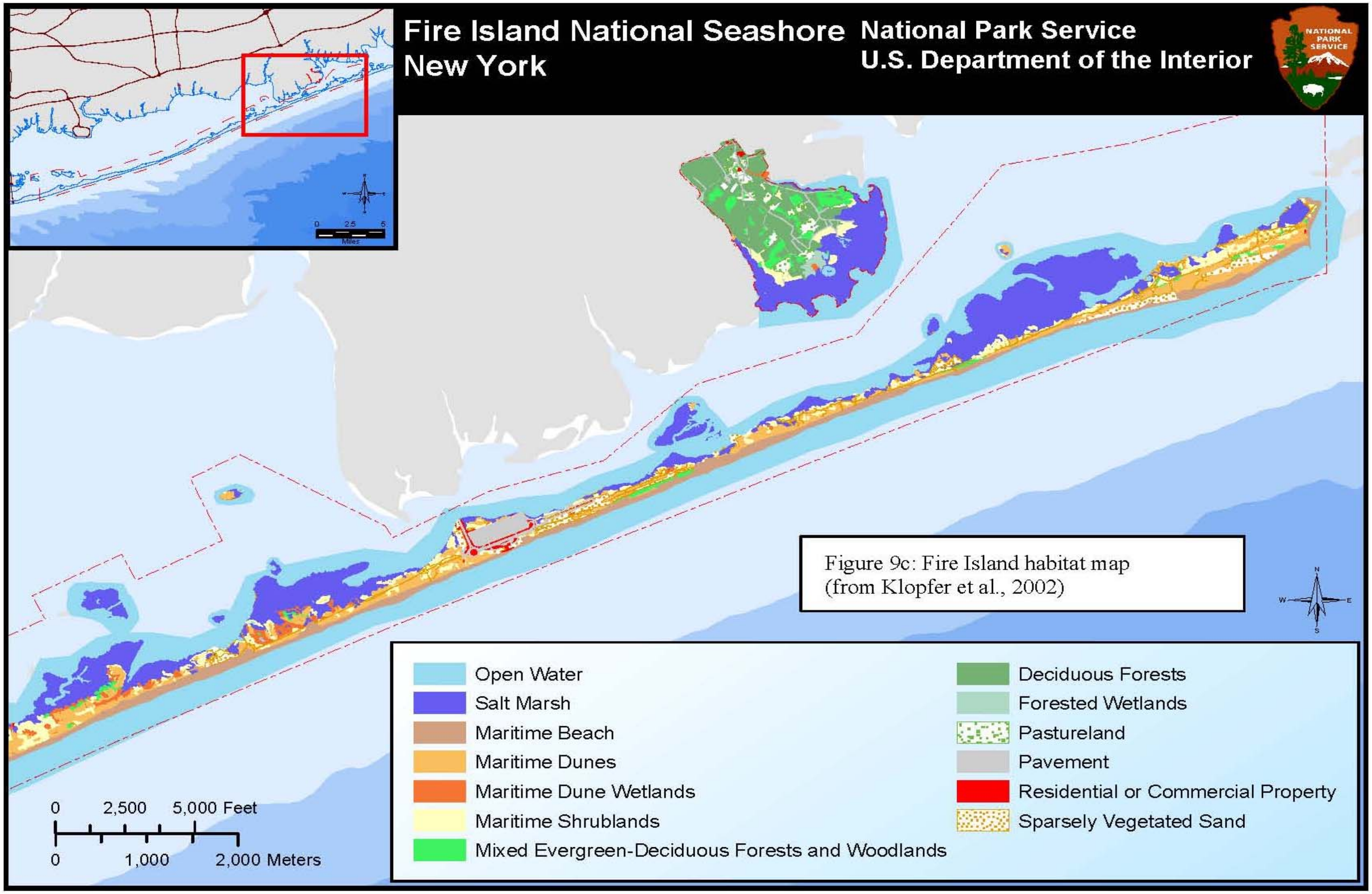


Figure 9c: Fire Island habitat map
(from Klopfer et al., 2002)

Characteristic Salt Marsh Vegetation: The salt marsh map unit contains the following associations, presented here from the lowest to highest elevation: 1) Low Salt Marsh dominated by cordgrass and occurring at the seaward border of the high marsh, along the edges of saltwater tidal creeks, and along mosquito ditches that drain the high salt marsh; 2) High Salt Marsh dominated by saltmeadow cordgrass or the dwarf form of cordgrass; large areas dominated by spikegrass (*Distichlis spicata*), black-grass (*Juncus gerardii*), and glassworts (*Salicornia* spp.) are also common; 3) Salt Pannes dominated by the dwarf form of cordgrass and glassworts in shallow depressions within the marsh; 4) Northern Salt Shrub dominated by groundsel-tree(*Baccharis halimifolia*) and/or saltmarsh-elder (*Iva frutescens*) at the upland border of the high salt marsh; 5) Brackish Meadow dominated by switch grass (*Panicum virgatum*) and saltmeadow cordgrass occurring at the upland border of the high salt marsh; 6) Oligohaline Tidal Marsh, occurring as a narrow band between high salt marsh and salt shrub vegetation, dominated by spikerush (*Eleocharis rostellata*) and twig-rush (*Cladium mariscoides*); 7) Brackish Tidal Marsh dominated by narrow-leaved cattail (*Typha angustifolia*); and 8) Reedgrass Marsh dominated by common reedgrass (*Phragmites australis*). Detailed descriptions of all vegetation associations are included in the Fire Island Vegetation Mapping Project final report (Klopfer et al. 2002), and a list of salt marsh plants at FIIS is presented in Table 3.

Table **3.** Salt marsh plant list for FIIS.

Plant Type	Scientific Name	Common Name
Shrubs	*Baccharis halimifolia*	Groundsel Tree
	Iva frutescens	Marsh Elder
Vines	*Toxicodendron radicans*	Poison Ivy
Herbs	*Atriplex patula*	Spear Orach
	Cakile edentula	American Searocket
	Calystegia sepium	Hedge False Bindweed
	Chenopodium album	Lambs-quarters
	Distichlis spicata	Spikegrass
	Hibiscus moscheutos	Rosemallow
	Juncus gerardi	Black-grass Rush
	Limonium carolinianum	Sea-lavender
	Phragmites australis	Common Reedgrass
	Pluchea odorata	Saltmarsh Fleabane
	Salicornia bigelovii	Dwarf Glasswort
	Salicornea depressa	Glasswort, Saltwort
	Sarcocornia pacifica	Chickenclaws, Glasswort, Saltwort
	Schoenoplectus americanus	Three-square Bulrush
	Solidago sempervirens	Seaside Goldenrod
	Spartina alterniflora	Saltwater Cordgrass
	Spartina patens	Saltmeadow Cordgrass
	Suaeda linearis	Sea-blite
	Symphyotrichum tenuifolium var. *tenuifolium*	Perennial Salt-marsh Aster
	Teucrium canadense var. *canadense*	Canada Germander

Data from: Art 1976, Klopfer 2002, Stalter et al. 1986, and NY Natural Heritage database

Characteristic Salt Marsh Fauna: There is very little published information on salt marsh fauna, specific to FIIS (Conover et al. 2005; Bokuniewicz et al. 1993). However, data from elsewhere and observational data at FIIS (MaryLaura Lamont, National Park Service, personal communication) indicate that the tidal marshes and mudflats provide feeding and migratory stopover habitat for thousands of migratory birds, such as dowitcher (*Limnodromus* spp.), plovers (*Pluvialis* spp., *Charadrius spp*), sanderling (*Calidris* spp.), red knots (*Calidris canutus*), dunlin (*Calidris alpina*), and sandpipers (*Calidris* spp.) (USFWS 1997). Birds that breed in or near Fire Island's salt marshes include American Black Duck (*Anas rubripes*), clapper rail (*Rallus longirostris*), and willet (*Catoptrophorus semipalmatus*) (Mitra and Putnam 1999; Niedowski 2000). Seaside sparrow (*Ammodramus maritimus*), sharp-tailed sparrow (*Ammodramus caudacutus*), and marsh wren (*Cistothorus palustris*) nest directly in the salt marsh. The marsh wren nests in the cattail-dominated brackish tidal marsh. Red-winged blackbirds (*Agelaius phoeniceus*) commonly nest in the taller shrubs along the upper salt marsh margin. Other birds often seen and heard in the salt marsh include barn and tree swallows (*Hirundo rustica, Tachycineta bicolor*), gray catbird (*Dumetella carolinensis*), common yellowthroat (*Geothlypis trichas*), eastern meadowlark (*Sturnella magna*), and yellow-rumped warbler (*Dendroica coronata*). In addition to those that nest in salt marshes, numerous other birds utilize this habitat as a food source (e.g., cordgrass, insects, invertebrates, small fishes, etc.). Birds that feed in salt marshes and mudflats include glossy ibis (*Plegadis facinellus*), great egret (*Ardea alba*), green heron (*Butorides striatus*), laughing gull (*Larus atricilla*), snowy egret (*Egretta thula*), and terns (*Sterna* spp.) (Niedowski 2000; Perry 1985).

Fishes that are known to utilize salt marshes on Long Island include alewife, Atlantic silversides, bluefish, menhaden, mullet, mummichog, sand lance (*Ammodytes americanus*), sea bass (*Centropristis striata*), sheepshead minnow (*Cyprinodon variegatus*), striped bass, striped killifish (*Fundulus majalis*), tautog, and winter flounder (Niedowski 2000). However, detailed information on the importance of FIIS marsh resources to these fish has yet to be adequately assessed (Bokuniewicz et al. 1993; Hinga 2005; Conover et al 2005).

Other characteristic animals of the high and low salt marsh in New York include salt marsh mosquitoes (*Aedes* spp.), greenhead flies (Tabanidae), salt marsh snail (*Melampus bidentatus*), fiddler crabs (*Uca pugilator* and *U. pugnax*), and ribbed mussel (*Geukensia demissa*; Edinger et al. 2002).

Rare, Threatened, and Endangered Species of Salt Marshes: The only documented occurrence of the State Endangered dark-green sedge (*Carex venusta*) in New York State is located at the upper margin of the salt marsh at the William Floyd Estate.

There are several rare bird species tracked by NY Natural Heritage that nest and forage in or near the salt marshes of FIIS, including common tern (*Sterna hirundo*), least tern (*Sterna antillarum*), roseate tern (*S. dougallii*), black skimmer (*Rynchops niger*), and seaside sparrow (Appendix A, Table A1, NY Natural Heritage Biotics Database 2007).

In addition, Fire Island provides habitat for migrating and wintering northern harrier (*Circus cyaneus*), which breed there, as well as short-eared owl (*Asio flammeus*) and snowy owl (*Nyctea scandiaca*). The short-eared owls and harriers are rare, with the harrier listed as threatened and the short-eared owl as endangered in New York State. These birds forage over the swales and salt marshes that fringe the northern shore (USFWS 1996). Lastly, the State Endangered eastern mud turtle (*Kinosternon subrubrum*) breeds in the fresh-to-brackish water portions of the coastal marsh complex (NY Natural Heritage Biotics Database 2007).

Maritime Beaches

There are 1.2 ha mapped acres of maritime beach at FIIS, which represents 17% of the total land cover of the island (Table 2). The bayside beaches, located along the northern shore of Fire Island and on the protected bay islands, occur much less frequently than the oceanside beaches that line the southern shore of the island (Figures 9a, b, and c).

Bayside Beaches: Bayside beaches are small, usually measuring only a few meters from the tide line to the dune, and have relatively steep planar foreshores fronted by a broad, flat low tide terrace. Throughout the tidal cycle and during storm events, two generalized mechanics of wave dissipation occur. When water levels are low, the low tide terrace dissipates wave energies during strong onshore winds. The surf zone may be wide at these times, but the energy is not concentrated. During high water events, waves usually break as plunging waves on the upper foreshore at higher water levels, concentrating energy over distances of only a few meters (Nordstrom and Jackson 1992). Nordstrom and Jackson (2005) recently completed a synthesis reviewing the physical processes determining bayside shoreline structure on FIIS. Waves represent the primary force influencing sand removal on the bayside beaches, although locally, wakes from boat traffic can also have an influence. The bayshore environment provide important habitat for a wide range of organisms.

Characteristic Bayside Beach Vegetation and Fauna: Dowhan and Rozsa (1989) list the following plants as either common or frequent along the wrack line of Fire Island's bayside beaches: black mustard (*Brassica nigra*), crested saltbush (*Atriplex cristata*), hairy smother-weed (*Bassia hirsuta*), lamb's-quarters (*Chenopodium album*), rough cockleburr (*Xanthium strumarium*), salsola (*Salsola kali*), sea-blite (*Sueda linearis*), spear orach (*Atriplex hastata*), and wild peppergrass (*Lepidium virginicum*).

Invertebrates that were collected from bayside beaches include beach fleas (*Talorchestia longicornis, Orchestia grillus*) and insects, such as *Lasius neoniger,* dipteran gnats, and shore flies of the family Ephydridae (USACE 2005).

Rare, Threatened, and Endangered Species of Bayside Beaches: Long Island colonial water birds appear to utilize bayside beaches as well as islands within bays for breeding. These are also important non-breeding habitats, presumably for foraging. There are several rare bird species tracked by NY Natural Heritage that nest and forage in or near the bayside beaches of FIIS, including Common Tern, Least Tern, Roseate Tern, Black Skimmer, and Seaside Sparrow (Erin White, New York Natural Heritage Program, personal communication).

Oceanside Beaches: The south shore of Fire Island consists of an uninterrupted stretch of beach typical of ocean-facing barrier island beaches. There are 320 ha of mapped beach on the oceanside of FIIS (Table 2) stretching for 41 km. An additional 10 km stretch (90 ha) of beach-like habitat in the western portion of the island was classified by Klopfer et al. (2002) as "sparsely vegetated sand." In combination there appears to be nearly 51 km of oceanside beach on the island (Figures 9a,b and c). Beach depth (distance from the tide line to the beginning of the dune) varies spatially and temporally across the island, ranging from less than 10 m wide in developed areas after storm events (USACE 1999) to 50 m wide near Sunken Forest (Art 1976). The landward margin of the beach begins at the toe of the dune, approximately 3-3.5 m above sea level, and slopes seaward to a crest that is approximately 2 m above sea level. This area, the crest of the beach berm, is about 25-50 m wide during quiescent conditions. Seaward is the face of the beach berm that slopes rapidly down toward the water, usually only a few meters depending on tide. Under storm or erosional conditions, sand is removed from the berm and transported offshore and alongshore. The berm can shrink or disappear, depending on the severity of the storm and erosion. Sand that is moved offshore is stored as part of a sand bar, which delivers sand back to the beach as the berm is rebuilt during the recovery period. This episodic erosion and rebuilding of the beach berm is part of the natural geomorphology of the beach environment. Large storm events can create sand bars far enough offshore that they do not contribute to the rebuilding of the berm, resulting in a net loss of sand and extensive erosion (Psuty et al. 2005).

The beach can be subdivided into the following two communities: 1) Marine intertidal gravel/sand beach, which is unvegetated, tidally influenced, and found at lower elevation; and 2) upper beach, which is located above mean high tide and is very sparsely vegetated.

The marine intertidal gravel/sand beach is washed by rough, high-energy waves and is composed of sand or gravel substrates that are well drained at low tide. These areas are subject to high fluctuations in salinity and moisture. This intertidal habitat generally supports a relatively low diversity resident community in New York; it is perhaps best characterized by its benthic invertebrate fauna, including polychaetes (*Spiophanes bombyx, Pygospio elegans, Clymenella torquata, Scoloplos fragilis,* and *Nephtys incisa*), and amphipods (*Protohaustorius deichmannae* and *Acanthohaustorius millsi*). Similarly, the marine intertidal gravel/sand beach provides feeding grounds for migrant shorebirds, such as sanderling and semipalmated plover (*Charadrius semipalmatus*), and breeding shorebirds, such as piping plover among other species (Edinger et al. 2002).

Characteristic Oceanside Beach Vegetation: The upper beach at Fire Island is very sparsely vegetated. The dominant plants include sea-rocket (*Cakile edentula ssp. edentula*), seabeach knotweed (*Polygonum glaucum*), seaside spurge (*Chamaesyce polygonifolia*), salsola, and beachgrass (*Ammophila breviligulata*) (Klopfer et al. 2002). A list of plants found on the oceanside maritime beaches at FIIS is contained in Table 4.

Characteristic Oceanside Beach Fauna: Migratory sanderlings and other small shorebirds, gulls, fish crow (*Corvis ossifragus*), and songbirds feed on the crustaceans on the beach. The fish crow and boat-tailed grackle (*Quiscalus major*) are characteristic birds of the upper beach zone. Other migratory and resident beach birds include Dunlin, Semipalmated Sandpipers among many others (Perry 1985). Abundant nearshore fish populations provide forage for thousands of northern gannets (*Morus bassanus*), all three species of scoters (*Melanitta* spp.), and common loons (*Gavia immer*) that migrate through this region or winter on Fire Island (MaryLaura Lamont, National Park Service, personal communication).

To our knowledge the most comprehensive analysis of invertebrates associated with oceanside beaches of Fire Island was conducted by Steinbeck (1999). She documented the oceanside invertebrate communities at Kismet, Sailor’s Haven, Talisman, Long Cove, Old Inlet, and Smith Point in a study that examined spatial and temporal trends as well as the effects of disturbance

Table **4**. Maritime beach plant list for Fire Island.

Plant Type	Scientific Name	Common Name
Herbs	*Amaranthus pumilus*	Seabeach Amaranth
	Ammophila breviligulata	American Beachgrass
	Atriplex cristata	Crested Saltbush
	Atriplex patula	Spear Orach
	Atriplex prostrata	Thinleaf Orach
	Bassia hirsuta	Hairy Smother-weed
	Brassica nigra	Black Mustard
	Cakile edentula	American Searocket
	Chamaesyce polygonifolia	Seaside Spurge
	Chenopodium album	Lambs-quarters
	Chenopodium pratericola	Narrowleaf Goosefoot
	Lepidium virginicum	Wild Peppergrass, Poor-man's Pepper
	Polygonum glaucum	Seabeach Knotweed
	Salsola kali	Russian Thistle, Common Saltwort
	Suaeda linearis	Sea-blite
	Xanthium strumarium	Rough Cockleburr

Data from: Art 1976, Klopfer 2002, Sirkin 1972, Stalter et al. 1986, and NY Natural Heritage databases

due to off-road vehicles (ORV). Insects dominated the fauna at most locations, although amphipods, worms, and spiders were also common. The wrack line was shown to be an extremely important habitat for this community. Notable animals of the beach include crustaceans, such as beach fleas and ghost crabs (*Ocypode quadrata*). The previously mentioned shorebirds forage for beach fleas and ghost crabs. Raccoons (*Procyon lotor*) commonly feed on ghost crabs at night (Perry 1985).

Rare, Threatened, and Endangered Species of Oceanside Beaches: Rare plants that occur above the wrack line up to the base of the primary dune of oceanside beaches include the Federally Threatened seabeach amaranth (*Amaranthus pumila*) and State Rare seabeach knotweed (Appendix A, Table A1, NY Natural Heritage Biotics Database 2007, Stalter et al. 1986). As of 2007, NY Natural Heritage has documented about 435 seabeach amaranth plants at six locations and over 400 seabeach knotweed plants at four locations within FIIS (NY Natural Heritage Biotics Database 2007).

With help from partners, NY Natural Heritage has documented an average of 28 pairs of the Federally Endangered piping plover nesting on the beaches of FIIS between 2005 and 2007 (not all sites are surveyed every year), producing an average of 31 fledglings (NYS DEC 2005-2007, NY Natural Heritage Biotics Database 2007). Nesting success depends largely on optimal nesting and foraging areas, consisting of enough wrack material, open vegetation, ephemeral pools, inlets, and bay tidal flats (USFWS 1996, Elias et al. 2000).
On Fire Island nesting areas include the beaches up to the base of the primary dune, and forage areas include wrack lines, open vegetation on the dunes proper, and bayside tidal flats. Predation, beachgoers, off-road vehicles, and other human activities can disturb the birds and

may contribute to low nesting success (USFWS 1996). Disturbances on Fire Island include a high red fox (*Vulpes vulpes*) population, human recreation, including beach combing and boating, ORVs (so far used only by the US National Park Service and Suffolk County Park police), deer, and predation by snakes, gulls, crows, feral cats, raccoons, and loose dogs (NY Natural Heritage Biotics Database 2007). Despite these disturbances, piping plover breeding activity has generally remained constant on Fire Island in recent years, with fledglings being primarily produced along the beach in the Wilderness Area (NYS DEC 2005-2007). Other rare species that utilize the beaches of Fire Island include common tern, least tern, roseate tern, and black skimmer (Appendix A, Table A1, NY Natural Heritage Biotics Database 2007, USFWS 1996).

FIIS recently released summary data from their Threatened and Endangered Species Monitoring Program for 2007 (Barrera et al. 2007). Although the number of nesting pairs was the highest it's been since 1993, the number of chicks fledged per pair in 2007 was the lowest it's been since 1997, with 25 nesting pairs producing only 18 fledged chicks. Abandonment was found to be the predominant cause of nest failure. More recent data from the 2008 survey indicates the number of nesting pairs in 2008 was significantly less than in 2007, with 15 as compared to 25 nests, respectively. Despite the decline in nesting pairs, FIIS fledged more chicks in 2008 compared to 2007. This in turn significantly increased the productivity from last year’s 0.7. Nest overwash and predation seemed to be the predominant causes of nest failure in 2008 rather than abandonment, as was observed in 2007. Other highlights of the 2008 survey include documentation of 38 seabeach amaranth plants and 118 seabeach knotweed (*Polygonum glaucum*) plants. Although the numbers of seabeach amaranth and seabeach knotweed were higher in 2008 than in 2007, both populations have been in decline since 2003 (MaryLaura Lamont, National Park Service, personal communication).

Upland And Palustrine Habitats and Species

The types of upland and palustrine vegetation and their observed spatial pattern on Fire Island, as on all barrier islands, are a direct result of dynamism. The forces of sand deposition, storm-driven overwash, salt spray, and surface water all play major roles in affecting vegetation distribution. More recently, disturbance from both humans and white-tailed deer (*Odocoileus virginianus*) have impacted vegetation communities on Fire Island (Klopfer et al. 2002).

Maritime Dune Communities

Characteristic Dune Vegetation: There are 370 ha of dunes mapped at FIIS, covering nearly 15% of the property (Table 2, Figures 9a,b and c). Dunes extend nearly the entire length of Fire Island, broken only by the developed residential areas. Primary dunes on Fire Island may range from about 1.8 to 7 m above mean sea level, whereas secondary dunes may range from about 3 to 9 m above mean sea level (Art 1976). The dune vegetation class contains the following associations: 1) Northern Beachgrass Dune dominated by beachgrass (*Ammophila breviligulata*), 2) Overwash Dune Grassland dominated by saltmeadow cordgrass, 3) Northern Beach Heather Dune dominated by woolly beach heather (*Hudsonia tomentosa*) and bearberry (*Arctostaphylos uva-ursi*), 4) North Atlantic Coastal Plain Vine Dune dominated by poison ivy (*Toxicodendron radicans*) and greenbrier (*Smilax* spp.), and 5) Northern Sandplain Grassland dominated by little bluestem (*Schizachyrium scoparium*). A mosaic type, Interdune Beachgrass-Beach Heather Dune, was also included in the consolidated dune map unit. Detailed descriptions of all vegetation associations are included in the Fire Island Vegetation Mapping Project final report (Klopfer et al. 2002). A list of plants found on the dunes at FIIS is contained in Table 5.

Characteristic Dune Fauna: Several gulls, shorebirds, and terns nest in the areas between beach and dune. Savannah sparrow (*Passerculus sandwichensis*) is one the few birds that both nests and feeds in the dunes of the mid-Atlantic coast. It consumes many insects as well as the seeds of beachgrass, which accounts for about one-third of its diet (Perry 1985). Despite the plentiful beachgrass on the dunes, Savannah sparrows do not currently breed on Fire Island (Mitra and Putnam 1999).

Mammals that forage and hunt in the dunes are generally nocturnal and not restricted to this habitat. The most abundant dune mammals include white-tailed deer, eastern cottontail rabbit (*Sylvilagus floridanus*), red fox, white-footed deer mouse (*Peromyscus leucopus*), meadow vole (*Microtus pennsylvanicus*), and raccoon (Perry 1985).

Rare, Threatened, and Endangered Species of Dunes: A rare plant that occurs in the drier swales of the dunes near the Fire Island lighthouse is the State Endangered rough rush-grass (*Sporobolus clandestinus*) (Appendix A, Table A1, NY Natural Heritage Biotics Database 2007).

Rare species that utilize the dunes at Fire Island for nesting include common tern, least tern, roseate tern, and black skimmer (Appendix A, Table A1, NY Natural Heritage Biotics Database 2007). Although they build their nests on the dunes and swales, these species primarily feed over the water.

Maritime Dune Wetlands

There are 50 ha of maritime dune wetlands mapped at FIIS, covering nearly 2% of the property (Table 2, Figures 9a, b and c). The maritime dune wetland vegetation class includes the following three vegetation associations (Edinger et al. 2002): 1) Maritime Freshwater Interdunal Swales (called Northern Interdunal Cranberry Swale in Klopfer et al. 2002), 2) Brackish Interdunal Swales, and 3) the Coastal Plain variant of Highbush Blueberry Bog Thicket (called Highbush Blueberry Shrub Swamp in Klopfer et al. 2002). The two swale communities are summarized below. Detailed descriptions of all vegetation associations are included in the Fire Island Vegetation Mapping Project final report (Klopfer et al. 2002).

Characteristic Maritime Freshwater Interdunal Swale Vegetation and Fauna: Maritime freshwater interdunal swales occur in low areas between dunes. These swales are formed either by blowouts in the dunes that lower the soil surface to groundwater level or by the seaward extension of dune fields. Soils are either sand or peaty sand. Water levels fluctuate seasonally and annually, reflecting changes in groundwater levels. The dominant species are sedges and herbs. Low shrubs are usually present, but they are never dominant. These wetlands may be quite small (less than 0.1 ha), and species diversity is usually low. The composition may be quite variable between different interdunal swales (Edinger et al. 2002).

Table **5**. Maritime dune plant list for Fire Island.

Plant Type	Scientific Name	Common Name
Shrubs	*Amelanchier canadensis*	Serviceberry
	Arctostaphylos uva-ursi	Bearberry
	Elaeagnus umbellata	Autumn Olive
	Hudsonia tomentosa	Beach-heather
	Ilex opaca	American Holly
	Juniperus virginiana	Eastern Red Cedar
	Lyonia mariana	Staggerbush
	Myrica pensylvanica	Bayberry
	Photinia melanocarpa	Black Chokeberry
	Pinus rigida	Eastern red Cedar
	Pinus thunbergiana	Japanese black pine
	Prunus maritima	Beach Plum
	Prunus serotina	Black Cherry
	Quercus stellata	Post Oak
	Quercus velutina	Black Oak
	Rhus copallinum	Winged Sumac
	Rosa carolina	Pasture Rose
	Rosa rugosa	Rugosa Rose
	Rosa virginiana	Virginia Rose
	Rubus flagellaris	Northern Dewberry
	Rubus hispidus	Bristly Dewberry
	Sassafras albidum	Sassafras
	Vaccinium angustifolium	Lowbush Blueberry
	Vaccinium corymbosum	Highbush Blueberry
	Viburnum dentatum	Arrowwood
Vines	*Lathyrus japonicus*	Beach Pea
	Parthenocissus quinquefolia	Virginia Creeper
	Smilax glauca	Sawbrier
	Smilax rotundifolia	Roundleaf Greenbrier, Common Greenbrier
	Toxicodendron radicans	Poison Ivy
Herbs	*Agrostis gigantea*	Black Bentgrass
	Ammophila breviligulata	American Beachgrass
	Antennaria plantaginifolia	Plantain-leaf Pussytoes
	Aralia nudicaulis	Wild Sarsaparilla
	Artemisia campestris ssp. *caudata*	Field Sagewort, Field Wormwood
	Artemesia stelleriana	Dusty Miller
	Atriplex patula	Spear Orach
	Cakile edentula	American Searocket
	Carex pensylvanica	Pennsylvania Sedge
	Carex silicea	Sea-beach Sedge

Table **5**. Maritime dune plant list for Fire Island (continued).

Plant Type	Scientific Name	Common Name
Herbs	*Chamaesyce polygonifolia*	Seaside Spurge
	Cirsium horridulum	Yellow Thistle
	Conyza canadensis	Canadian Horseweed
	Cyperus grayi	Gray's Flatsedge
	Cyperus polystachyos	Manyspike Flatsedge
	Cyperus rotundus	Purple Flatsedge
	Dichanthelium acuminatum	Panic Grass
	Dichanthelium sabulorum	Panic Grass
	Dichanthelium sphaerocarpon	Roundfruit Panic Grass
	Euthamia tenuifolia	Slender Flattop Goldenrod, Grass-leaved Goldenrod
	Gnaphalium obtusifolium	Fragrant Cudweed
	Hieracium venosum	Rattlesnake Hawkweed
	Hypochaeris radicata	Spotted Cat's-ear
	Juncus greenei	Greene's Rush
	Lactuca canadensis	Canada Lettuce
	Lathyrus japonicus	Beach Pea
	Lechea maritima	Beach Pinweed
	Lepidium sp.	Peppergrass
	Maianthemum stellatum	Starflower Solomon’s-seal
	Nuttallanthus canadensis	Blue Toadflax
	Oenothera oakesiana	Oakes' evening-primrose
	Panicum virgatum	Switchgrass
	Phytolacca americana	Common Pokeweed
	Pityopsis falcata	Sickle-leaf Golden-aster
	Polygonella articulata	Coastal Jointweed
	Pteridium aquilinum	Bracken Fern
	Rumex acetosa	Common Sorrel
	Rumex acetosella	Sheep Sorrel
	Schizachyrium scoparium	Little Bluestem
	Solidago odora	Fragrant Goldenrod
	Solidago sempervirens	Seaside Goldenrod
	Spartina patens	Saltmeadow Cordgrass
	Symphyotrichum pilosum var. *pilosum*	Hairy White Old Field Aster
	Teucrium canadensis	Canada Germander
	Trientalis borealis	Starflower

Data from: Art 1976, Klopfer et al. 2002, Sirkin 1972, Stalter et al. 1986, and NY Natural Heritage databases

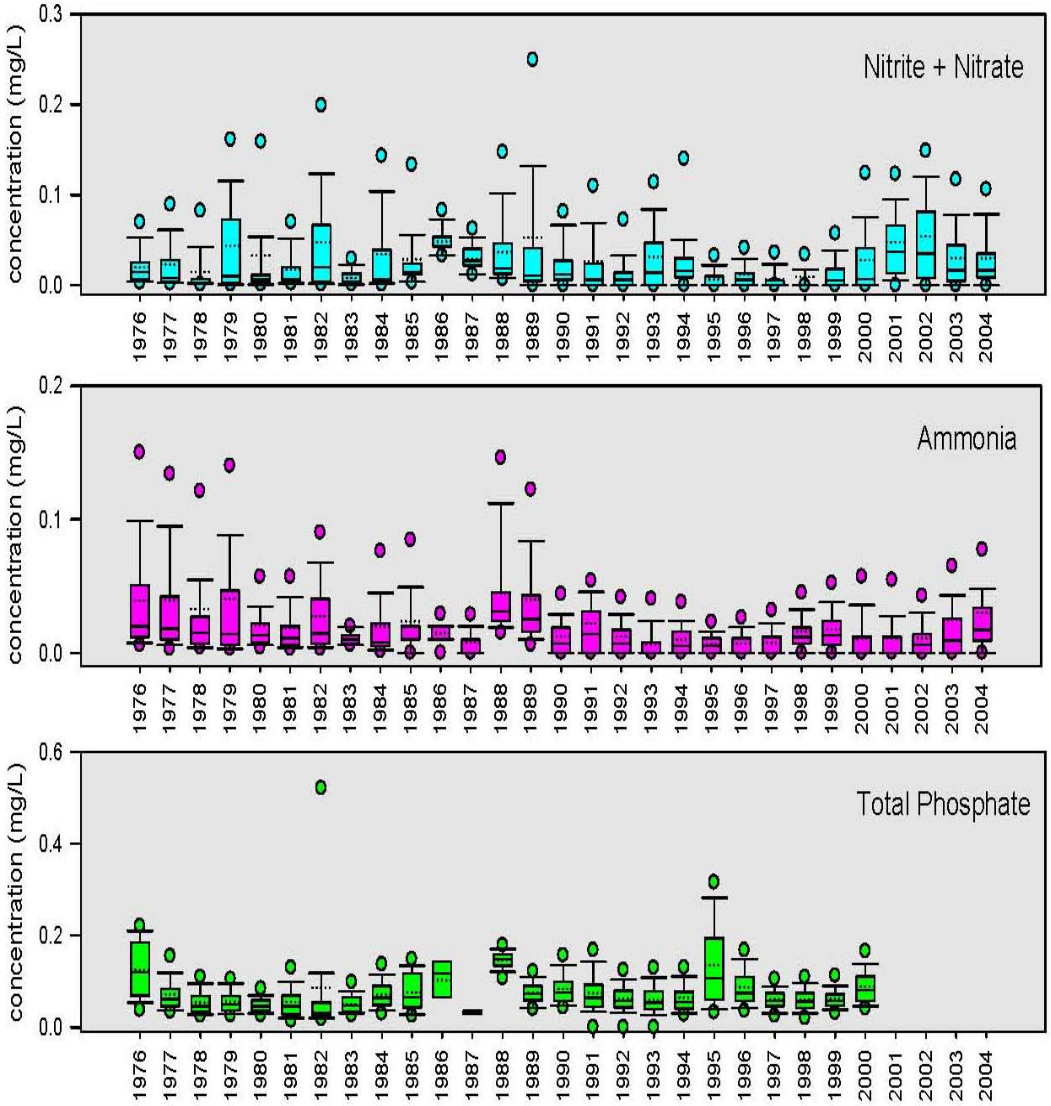


Figure **10**. Annual statistics for nutrients at all SCDHS stations (dashed line: mean; solid line: median; lower and upper boundaries of box: 25th and 74th percentile; lower and upper boundaries of whiskers: 10th and 90th percentile; circles: 5th and 95th percentile). Data from SCDHS 2006; for a detailed description of georeferenced data, see Benotti, 2008.

Characteristic species include twig-rush, flat sedges (*Cyperus* spp.), beakrush (*Rhynchospora capitellata*), marsh rush (*Juncus canadensis*), round-leaf sundew (*Drosera rotundifolia*), cranberry (*Vaccinium macrocarpon*), bladderwort (*Utricularia subulata*), slender yellow-eyed grass (*Xyris torta*), bayberry (*Myrica pensylvanica*), and highbush blueberry (*Vaccinium corymbosum*; Edinger et al. 2002). A list of plants found in maritime freshwater interdunal swales at FIIS is contained in Table 6.

Rare, Threatened, and Endangered Species of Maritime Freshwater Interdunal Swales: Rare plants that occur in the maritime freshwater interdunal swales include the State Endangered slender marsh-pink (*Sabatia campanulata*) and the State Threatened swamp sunflower (*Helianthus angustifolius*) (Appendix A, Table A1, NY Natural Heritage Biotics Database 2007). As of 2007, NY Natural Heritage has documented a single, small population of slender marsh-pink on Fire Island and a small population of swamp sunflower at four locations (NY Natural Heritage Biotics Database 2007).

Characteristic Brackish Interdunal Swale Vegetation and Fauna: Generally in New York, brackish interdunal swales are temporarily tidally flooded, temperate marshes located between dunes. They are dominated by salt tolerant grasses. Individual swales occur as small patches positioned between fore-, primary, and secondary dunes in a maritime dunes system, typically on barrier islands. Swales experience dynamic fluctuations in water levels and salinity. Water levels are highest after sporadic overwashes that occur when tides or waves overtop the berm, transporting water and suspended sand through the foredune into low-lying areas within the dune system. Overwashes usually occur during extreme spring tides or major storms. Flood frequency can vary from several times per year to as little as once every 25 years. At this time, groundwater levels rise, vegetation may float, and water pools into temporary ponds. During the driest times, ponds evaporate, surface sands are no longer saturated, salt concentrates and enters the groundwater, and salt deposits form on the surface. Salinity is typically mixohaline, with water being derived from a mix of saline ocean overwash and the freshwater groundwater lens. However, it can vary greatly at certain times of the year from oligohaline (0 PSU) to supersaline (70 PSU) in response to the salinity of the groundwater and accumulation of salt during evaporation (Edinger et al. 2002). Specific studies of this habitat within FIIS are needed.

The dominant flora are mostly grasses, sedges and rushes including saltmeadow cordgrass, dwarf spikerush (*Eleocharis parvula*), three-square (*Schoenoplectus pungens*), flatsedge (*Cyperus polystachyos*), and jointed rush (*Juncus articulatus*). The abundance of any one dominant can vary widely year to year in response to salinity fluctuations. Other characteristic flora include halophytes such as salt-meadow grass (*Diplachne maritima*), seaside bulrush (*Scirpus maritimus*), toad-rush (*Juncus ambiguus*), sedge-rush (*Juncus scirpoides*), mock bishop's-weed (*Ptilimnium capillaceum*), golden dock (*Rumex maritimus*), saltmarsh aster (*Aster subulatus*), red pigweed (*Chenopodium rubrum*), saltmarsh fleabane (*Pluchea odorata*), rosemallow (*Hibiscus moscheutos*), knotweed (*Polygonum ramosissimum*), and saltmarsh-elder (Edinger et al. 2002). A list of plants found in brackish interdunal swales at FIIS is contained in Table 7. As described in Edinger et al. (2002), the nomenclature for this list generally follows the PLANTS 3.5 Database developed by the Natural Resource Conservation Service in cooperation with the Biota of North America Program, but for the purposes of this review, some common names listed in

Table **6**. Maritime freshwater interdunal swale plant list for Fire Island.

Plant Type	Scientific Name	Common Name
Shrubs	*Clethra alnifolia*	Sweet Pepperbush
	Gaylussacia baccata	Black Huckleberry
	Myrica pensylvanica	Bayberry
	Photinia melanocarpa	Black Chokeberry
	Rhododendron viscosum	Swamp Azalea
	Vaccinium corymbosum	Highbush Blueberry
	Vaccinium macrocarpon	Large Cranberry
Vines	*Smilax rotundifolia*	Roundleaf Greenbrier, Common Greenbrier
	Toxicodendron radicans	Poison Ivy
Herbs	*Carex atlantica ssp. capillacea*	Howe Sedge, Prickly Bog Sedge
	Cladium mariscoides	Twig Rush
	Drosera intermedia	Spoon-leaved Sundew
	Drosera rotundifolia	Roundleaf Sundew
	Eleocharis flavescens var. *olivacea*	Yellow Spikerush Green Spikerush
	Eleocharis tenuis	Slender Spikerush
	Fimbristylis sp.	Fimbry
	Hypericum boreale	Northern St. John's-wort
	Hypericum canadense	Canadian St. John's-wort
	Juncus canadensis	Canada Rush
	Juncus dichotomus	Forked Rush
	Juncus dudley	Dudley's Rush
	Juncus scirpoides	Needlepod Rush
	Lycopodiella appressa	Southern Bog Clubmoss
	Lycopodiella inundata	Northern Bog Clubmoss, Marsh Clubmoss
	Oenothera perennis	Small Sundrops
	Osmunda cinnamomea	Cinnamon Fern
	Panicum virgatum	Switchgrass
	Pogonia ophioglossoides	Rose Pogonia
	Polygala cruciata	Crossleaf Milkwort
	Rhynchospora alba	White Beakrush
	Rhynchospora capitellata	Brownish Beakrush
	Schizachyrium scoparium	Little Bluestem
	Schoenoplectus pungens	Three-square Bulrush
	Sporobolus clandestinus	Rough Rush-grass
	Triadenum virginicum	Marsh St. John's Wort
	Typha angustifolia	Narrow-leaved Cattail
	Utricularia subulata	Zigzag Bladderwort
	Xyris torta	Twisted Yellow-eyed-grass
Non-Vascular	*Sphagnum cuspidatum*	Peat Moss
	Sphagnum compactum	Peat Moss
	Sphagnum rubellum	Peat Moss

Data from: Klopfer 2002 and NY Natural Heritage databases

Table **7**. Brackish interdunal swale plant list for Fire Island.

Plant Type	Scientific Name	Common Name
Shrubs	*Baccharis halimifolia*	Groundsel Tree
Vines	*Toxicodendron radicans*	Poison Ivy
Herbs	*Argentina anserina*	Silverweed Cinquefoil
	Bolboschoenus fluviatilis	River Bulrush
	Bolboschoenus robustus	Saltmarsh Bulrush
	Cyperus polystachyos	Manyspike Flatsedge
	Dichanthelium acuminatum	Panic Grass
	Distichlis spicata	Spikegrass
	Eleocharis acicularis	Needle Spikerush
	Eleocharis parvula	Dwarf Spikerush, Small Spike-rush
	Iris prismatica	Slender Blue Flag
	Oenothera perennis	Small Sundrops
	Phragmites australis	Reedgrass
	Pluchea odorata	Saltmarsh Fleabane
	Schoenoplectus americanus	Three-square Bulrush
	Schoenoplectus pungens	Three-square Bulrush
	Spartina patens	Saltmeadow Cordgrass
	Teucrium canadense	Canada Germander
	Typha sp.	Cattail

Data from: Klopfer 2002 and NY Natural Heritage databases

the PLANTS database were changed to reflect the common names typically used by ecologists and resource managers in this region.

Soils in this area are deep sands that often become anaerobic but lack peat accumulation. The surface is often rusty-colored from a coating of algae. Community variants include semi-permanent pools, long-lived wet swales with perennial graminoids, and newly formed, sparsely vegetated damp swales with early successional annual forbs. Occurrences of this community are sometimes ephemeral, representing the early stages of salt marsh or coastal salt pond formation or rapidly transforming into reed grass marshes (Edinger et al. 2002).

Brackish interdunal swales are known for their importance to wildlife. Characteristic fauna include piping plovers, American oystercatchers, yellowlegs (*Tringa melanolueca* and *T. flavipes*), and Canada geese (who use the community as a foraging ground), abundant salt marsh mosquitoes, fiddler crabs (*Uca* spp.), odonates, and other insects. Eastern mud turtles reportedly use this habitat (USACE 1995, 1999).

Maritime Shrublands

Characteristic Maritime Shrubland Vegetation: There are nearly 5 km^2 mapped of maritime shrublands at FIIS, covering 18% of the area (Table 2). Maritime shrublands often form a patchy mosaic with maritime dunes and maritime forests; they may form on or behind primary dunes, within the upland portion of interdunal swales, on the foredune and top of secondary dunes, and interspersed within the various maritime forests (Figures 9a, b and c). The maritime shrubland vegetation class contains the following associations: 1) Northern Dune Shrubland (<2 m) dominated by bayberry and beach plum (*Prunus maritima*); 2) Maritime Deciduous Scrub Forest, a tall shrubland (>2 m) dominated by a mix of Canada serviceberry (*Amelanchier canadensis*), highbush blueberry, and bayberry; and 3) Autumn Olive (*Eleagnus umbellata*) dominated shrublands. Woolly beach heather and bearberry dominated shrublands and poison ivy dominated vinelands (each <2 m) on maritime dunes are addressed under the Maritime Dunes section above. Detailed descriptions of all vegetation associations are included in the Fire Island Vegetation Mapping Project final report (Klopfer et al. 2002) and a list of maritime shrubland plants can be found in Table 8.

Characteristic Maritime Shrubland Fauna: Many of the above-listed plants provide food for a wide array of birds and mammals on Fire Island. The song sparrow (*Melospiza melodia*) prefers the dense shrub thickets of the back dune and swales. The gray catbird is particularly dependent on the dense shrub thicket for cover. Other characteristic birds of the maritime shrubland include brown thrasher (*Toxostoma rufum*), mourning dove (*Zenaida macroura*), northern cardinal (*Cardinalis cardinalis*), northern mockingbird (*Mimus polyglottos*), redwing blackbird (*Agelaius phoeniceus*), rufous-sided towhee (*Pipilo erythrophthalmus*), White-throated sparrow (*Zonotrichia albicollis*), yellow-rumped warbler, and yellow warbler (*Dendroica petechia*) (Perry 1985). However, detailed information on the importance of maritime shrubland resources to these birds has yet to be adequately assessed at FIIS.

A number of mammals can be found in maritime shrublands, and throughout all of the upland and freshwater wetland communities on Fire Island, including eastern cottontail rabbit, little brown bat (*Myotis lucifugus*), short-tailed shrew (*Blarina brevicauda*), masked shrew (*Sorex cinereus*), meadow vole, muskrat (*Ondatra zibethicus*), Norway rat (*Rattus norvegicus*), raccoon, red fox, weasel (*Mustela* spp.), white-footed deer mouse, and white-tailed deer (http://www.nps.gov/fiis/naturescience/mammals.htm).

Maritime shrubland reptiles that occur on Fire Island include eastern box turtle (*Terrapene carolina*) and northern black racer (*Coluber constrictor constrictor*) (Perry 1985).

Maritime Forests and Woodlands

Mixed Evergreen-Deciduous Forests and Woodlands: Mixed evergreen-deciduous forests and woodlands cover just over 140 ha (5%) of FIIS (Table 2, Figures 9a, b and c). The following associations are included in the vegetation class: 1) Maritime Holly Forest; 2) Maritime Pitch Pine Dune Woodland; 3) Pitch Pine-Oak Forest (which is quite similar to Coastal Oak-Heath Forest, discussed in the "Characteristic Coastal Oak-Health Forest Vegetation" section, but with more

Table **8**. Maritime shrubland plant list for Fire Island.

Plant Type	Scientific Name	Common Name
Shrubs	*Amelanchier canadensis*	Serviceberry
	Arctostaphylos uva-ursi	Bearberry
	Ilex opaca	American Holly
	Juniperus virginiana	Eastern Red Cedar
	Lyonia mariana	Stagger-bush
	Myrica pensylvanica	Bayberry
	Photinia melanocarpa	Black Chokeberry
	Pinus rigida	Pitch Pine
	Prunus maritma	Beach Plumb
	Prunus serotina	Black Cherry
	Rhus copallinum	Winged Sumac
	Rosa rugosa	Rugosa Rose
	Rosa virginiana	Virginia Rose
	Rubus flagellaris	Northern Dewberry
	Rubus hispidus	Bristly Dewberry
	Vaccinium corymbosum	Highbush Blueberry
	Viburnum recognitum	Arrowwood
Vines	*Parthenocissus quinquefolia*	Virginia Creeper
	Smilax glauca	Sawbrier
	Smilax rotundifolia	Roundleaf Greenbrier, Common Greenbrier
	Toxicodendron radicans	Poison Ivy
Herbs	*Ammophila breviligulata*	American Beachgrass
	Antennaria plantaginifolia	Plantain-leaf Pussytoes
	Carex silicea	Sea-beach Sedge
	Cyperus grayi	Gray's Flatsedge
	Euthamia tenuifolia	Slender Flattop Goldenrod, Grass-leaved Goldenrod
	Gnaphalium obtusifolium	Fragrant Cudweed
	Juncus greenei	Greene's Rush
	Lechea maritima	Beach Pinweed
	Nuttallanthus canadensis	Blue Toadflax
	Dichanthelium sabulorum	Panic Grass
	Dichanthelium sphaerocarpon	Roundfruit Panic Grass
	Panicum virgatum	Switchgrass
	Polygonella articulata	Coastal Jointweed
	Rumex acetosella	Sheep Sorrel
	Schizachyrium scoparium	Little Bluestem
	Teucrium canadensis	Canada Germander

Data from Art 1976, Klopfer 2002, Stalter et al. 1986, and NY Natural Heritage databases

abundant pitch pine, *Pinus rigida*); and 4) Japanese Black Pine Forest. Detailed descriptions of all vegetation associations are included in the Fire Island Vegetation Mapping Project final report (Klopfer et al. 2002).

Characteristic Maritime Holly Forest Vegetation at Sunken Forest: The Sunken Forest on Fire Island (Figures 9a, b and c) was the focus of several research efforts in the 1970s, starting with a study of Maple Bog (Sirkin 1972) and followed by a thorough study of the maritime holly forest and its surrounding environs by Henry W. Art (1976). Art (1976) used an aerial photograph to produce a vegetation map of the Sunken Forest area. The Sunken Forest is the northernmost holly-dominated maritime forest on the Atlantic barrier island chain. This community type is considered globally rare and very State rare (G2, S1) by The Nature Conservancy (USFWS 1996).

The maritime holly forest of Fire Island is dominated by American holly (*Ilex opaca*) trees of up to 300 years in age with an average diameter at breast height (dbh) of 24 cm. Frequent associates in the tree canopy include Canada serviceberry and sassafras (*Sassafras albidum*). Other associated trees include blackgum (*Nyssa sylvatica*), black cherry (*Prunus serotina*), pitch pine, and black oak (*Quercus velutina*). The shrub layer is poorly developed and most frequently includes saplings of species in the tree layer, usually American holly, blackgum, black cherry, and Canada serviceberry. Although not frequent, bayberry, highbush blueberry, black huckleberry (*Gaylussacia baccata*) and inkberry (*Ilex glabra*) may be present. The herbaceous layer is also poorly developed and is characterized by Pennsylvania sedge (*Carex pensylvanica*), with pink ladyslipper (*Cypripedium acaule*) as an occasional associate. Vines and lianas are typical of this association, most notably greenbrier (*Smilax rotundifolia*), Virginia creeper (*Parthenocissus quinquefolia*), and catbrier (*Smilax glauca*; Klopfer et al. 2002).

Historical studies of this association at Fire Island have revealed a substantial change in the composition of the shrub and herb layers since 1967, when black huckleberry and highbush blueberry were regular associates of the shrub layer, and sarsaparilla (*Aralia nudicaulis*), Canada mayflower (*Maianthemum canadense*), starry false Solomon's-seal (*Maianthemum stellatum*), bracken fern (*Pteridium aquilinum*), and starflower (*Trientalis borealis*) were frequent associates of the herbaceous layer. These changes are attributable to heavy deer browse as a result of the increase in the deer population in recent decades (Art 1987, 1992). A list of plants found in maritime holly forest at FIIS is contained in Table 9.

Characteristic Maritime Holly Forest Fauna: Birds are the primary consumers and dispersers of American holly berries along with deer, squirrels, and other small mammals. Over a dozen species of birds are known to eat holly berries (Stransky et al. 1976, Van Dersal 1938). The mourning dove (*Zenaida macroura*) is an example of one of Fire Island's common birds that consumes holly berries, whereas the northern bobwhite (*Colinus virginianus*) is an uncommon Fire Island bird that also consumes holly berries. According to NPS observers, American robins (*Turdus migratorius*) consume the most holly berries (MaryLaura Lamont, National Park Service, personal communication). The yellow-bellied sapsucker (*Sphyrapicus varius*) is a notable migratory bird that forages in the maritime holly forest (http://www.nps.gov/archive/fiis/SFTour-3.htm). Resident birds of Sunken Forest include American redstart (*Setophaga ruticilla*), American robin, black-capped chickadee (*Parus atricapillus*), brown thrasher (*Toxostoma rufum*), carolina wren (*Thryothorus ludovicianus*), fish crow, gray catbird, northern mockingbird (*Mimus polyglottos*), and rufous-sided towhee (*Pipilo erythrophthalmus*) (Perry 1985; http://www.nps.gov/archive/fiis/SFTour-5.htm).

Table **9**. Maritime holly forest plant list for Fire Island.

Plant Type	Scientific Name	Common Name
Trees	*Amelanchier canadensis*	Serviceberry
	Ilex opaca	American Holly
	Juniperus virginiana	Eastern Red cedar
	Nyssa sylvatica	Blackgum
	Pinus rigida	Pitch Pine
	Prunus serotina	Black Cherry
	Quercus alba	White Oak
	Quercus coccinea	Scarlet Oak
	Quercus stellata	Post Oak
	Quercus velutina	Black Oak
	Sassafras albidum	Sassafras
Shrubs	*Amelanchier canadensis*	Serviceberry
	Aronia arbutifolia	Red chokeberry
	Baccharis halimifolia	
	Gaylussacia baccata	Black Huckleberry
	Ilex glabra	Inkberry
	Ilex opaca	American Holly
	Myrica pensylvanica	Bayberry
	Nyssa sylvatica	Blackgum
	Prunus serotina	Black Cherry
	Rhododendron viscosum	Swamp Azalea
	Rhus copallina	Winged Sumac
	Ribes cynobati	Currant
	Rosa rugosa	Rugosa Rose
	Rubus sp.	Blackberry
	Sassafras albidum	Sassafras
	Toxicodendron vernix	Poison Sumac
	Vaccinium corymbosum	Highbush blueberry
	Vaccinium macrocarpon	Cranberry
	Viburnum dentatum	Arrowwood
Vines	*Calystegia sepia*	
	Lonicera japonica	Japanese Honeysuckle
	Parthenocissus quinquefolia	Virginia Creeper
	Smilax glauca	Sawbrier
	Smilax rotundifolia	Roundleaf Greenbrier, Common Greenbrier
	Toxicodendron radicans	Poison ivy
	Vitis spp.	Wild grape
Herbs	*Aralia nudicaulis*	Wild Sarsaparilla
	Carex pensylvanica	Pennsylvania Sedge
	Cypripedium acaule	Pink Ladyslipper
	Gaultheria procumbens	Wintergreen
	Maianthemum canadense	Canada Mayflower
	Maianthemum stellatum	Starflower Solomon's-seal
	Osmunda cinnamomea	Cinnamon Fern
	Phragmites australis	Reedgrass
	Pluchea purpurascens	Saltmarsh Fleabane
	Pteridium aquilinum	Bracken Fern
	Solidago sempervirens	Seaside Goldenrod
	Teucrium canadense	Canada Germander
	Thelypteris palustris	Marsh Fern
	Triadenum virginicum	Marsh St. John's-Wort
	Trientalis borealis	Starflower
	Xanthium echinatum	Rough Cockleburr

Data from: Art 1976, Klopfer 2002, Sirkin 1972, Stalter et al. 1986, and NY Natural Heritage databases.

The Sunken Forest provides habitat for several mammals, including eastern cottontail rabbit, eastern gray squirrel (*Sciurus carolinensis*), long-tailed weasel (*Mustela frenata*), red fox, and white-tailed deer. Reptiles such as box turtle (*Terrapene carolina*) and northern black racer

(*Coluber constrictor constrictor*) are also found here (http://www.nps.gov/archive/fiis/SFTour-9.htm).

Characteristic Maritime Pitch Pine Dune Woodland Vegetation: On Fire Island this maritime woodland occurs on sand dunes adjacent to shrubland or salt marsh (Figures 9a,b and c). The canopy is composed solely of pitch pine that is 5-10 m tall. The shrub layer is sparse with bayberry most common and black huckleberry present in lesser amounts. Vines are a prominent component, especially greenbrier. Short shrubs are of sparse cover and include dewberry (*Rubus flagellaris*), black chokeberry (*Photinia melanocarpa*), and winged sumac (*Rhus copallina*). Beach heather may not always occur within this vegetation on Fire Island. The herbaceous layer is sparse with switch grass and little bluestem commonly occurring. Portions of Fire Island support a variant of this community in which *Pinus rigida* is stunted, reaching only 2 m in height (Klopfer et al. 2002). Dowhan and Rozsa (1989) list the following additional species as common to occasional within pine woods or in open sandy areas of pine woods: sedge (*Carex artitecta*), pine barren sandwort (*Minuartia caroliniana*), wintergreen (*Gaultheria procumbens*), sheep laurel (*Kalmia angustifolia*), and starflower.

Deciduous Forests: Deciduous forests cover 1 km^2 (4%) of FIIS and are restricted to the William Floyd Estate (Figures 9a,b and c). The following associations are included in the map unit: 1) Coastal Oak-Heath Forest and 2) Maritime Post Oak Forest. Detailed descriptions of all vegetation associations are included in the Fire Island Vegetation Mapping Project final report (Klopfer et al. 2002).

Characteristic Coastal Oak-Heath Forest Vegetation: This deciduous forest occurs on well-drained sandy loam over sand and gravel outwash deposits on flat terrain, mainly at the William Floyd Estate (Figures 9a,b and c). Its composition is quite variable among stands, particularly moving from north to south. Generally, the canopy is dominated by black and white oak (*Quercus velutina, Q. alba*). Mockernut hickory (*Carya tomentosa*) and scarlet oak (*Q. coccinea*) are common canopy or subcanopy associates. The shrub layer contains oak species present in the canopy with sassafras, highbush blueberry, and/or arrowwood (*Viburnum dentatum*). Black huckleberry (*Gaylussacia baccata*) is often present in the short shrub layer with considerable cover. Vines, where present, tend to be abundant, especially greenbrier. The herbaceous layer is sparse to absent.

Characteristic Maritime Post Oak Forest Vegetation: This maritime oak forest forms a narrow belt on sandy deposits of the William Floyd Estate along Moriches Bay (Figures 9a,b and c). The tree canopy is co-dominated by mockernut hickory and black oak, but post oak (*Quercus stellata*), reaching 254 years old, is particularly characteristic. The shrub layer is fairly diverse with tall shrubs being dominated by sassafras and short shrubs dominated by bayberry. Greenbrier is a common vine with greater than 25% cover. The herbaceous layer is sparse and characterized by Pennsylvania sedge.

Forested Wetland Habitats and Species

Characteristic Red Maple-Blackgum Swamp Vegetation: Forested Wetlands make up 0.06 km^2 (0.23%) of the area of FIIS (Table 2, Figures 9a, b, and c). The vegetation class represents one association: Red Maple-Blackgum Swamp. It is found on the William Floyd Estate adjacent to small creeks in poorly drained basins with silt loam substrates or adjacent to tidal creeks. It also occurs on Fire Island in wet interdunal swales. Detailed descriptions of all vegetation associations are included in the Fire Island Vegetation Mapping Project final report (Klopfer et al. 2002).

In this swamp blackgum is the canopy dominant with red maple (*Acer rubrum*) often present. The shrub layer commonly has highbush blueberry with swamp azalea (*Rhododendron viscosum*) and sweet pepperbush (*Clethra alnifolia*). Vine cover is common, especially greenbrier. The herbaceous layer is variable although not diverse. Individual species are often locally dominant, especially cinnamon fern (*Osmunda cinnamomea*), marshpepper smartweed (*Persicaria hydropiper*), Virginia bugleweed (*Lycopus virginicus*), swamp dock (*Rumex verticillatus*), marsh St. John's-wort (*Triadenum virginicum*), and fringed sedge (*Carex crinita*). Hummock and hollow microtopography are common. Peat mosses (*Sphagnum* spp.) are dominant where present (Klopfer et al. 2002).

Threats To Natural Resources And Effects Observed

There are many potential threats to the natural resources of FIIS. These can be categorized into five main types: a) pollution, b) habitat alteration, c) human overuse, d) invasive and problematic native species, and e) global climate change. In this report each is discussed separately, although human overuse is clearly linked to all other stessor categories. Within each category, sub-categories of specific existing or potential threats as well as indicators of degraded condition have been identified. The status of each FIIS resource evaluated (marine benthic and pelagic, intertidal beach and salt marsh, upland dune, forest and freshwater marsh, and groundwater) has then been assessed with respect to specific stressors with each categorized as being an existing, potential, or not a problem (EP, PP, or NP, and color coded to emphasize the risk as red, yellow, or green, respectively). These rankings are summarized in Table 10, which outlines specific threats within each category of stressor, indicators of condition, and the references or information resources by which status was assessed.

Pollution

A pollutant is a substance present in an amount that adversely alters the physical, chemical, or biological properties of the environment. It can also be a substance in a concentration that exceeds standards or guidelines (http://iaspub.epa.gov/trs/trs_proc_qry.keyword). Nutrients, dissolved oxygen (DO), and biological and chemical contaminants are generally monitored in ground or surface water samples, in sediments, and in resident biota to assess the potential degree of pollution. Due to the potential for tropic transfer of contaminants to consumers of aquatic organisms, water quality data can also be used to assess pollutant risk to avian or terrestrial consumers. In the following sections, available water quality data are discussed and potential threats to biota and future problem areas identified.

Available Data on Water Quality

There is a long record of water quality monitoring data on GSB. The Suffolk County Department of Health Services (SCDHS) has been monitoring the water quality and coastal conditions in GSB since 1976 (SCDHS 2006). This data set includes measurements of fecal coliform, temperature, pH, DO, salinity, and dissolved nutrients. In addition to these general water quality parameters, chemical contaminant data in sediment and biota as well as sediment toxicity data are available at very limited locations within GSB from samples collected as part of the National Oceanic and Atmospheric Administration's (NOAA's) National Status and Trends survey (NOAA 2006; http://www.nos.noaa.gov/dataexplorer/data_topics/welcome.html#monitoring) and the Environmental Protection Agency's (EPA's) Environmental Monitoring and Assessment Program (EMAP) collected in 1990-1993. Interpretation of water quality data is based on these data sets, summaries prepared for two science synthesis papers written for the National Park Service (Bokuniewicz et al. 1993; Hinga 2005), and a recent report on chemical contamination and recommended monitoring plans for FIIS prepared by Cooper (2007).

Table 10. Summary of threats to FIIS natural resources.

EP=Existing Problem, PP=Potential Problem, NP=Not a Problem. Empty cells indicate that either the threat does not apply to that resource or that no data are available.

Stressor/Threat main category	Threat/Stressor sub-category	Indicator	Marine benthic	Marine pelagic	Intertidal beach	Intertidal salt marsh	Upland dunes	Upland forest	Upland freshwater marshes	Ground-water	References and Information Sources
POLLUTION: point and non-point source from existing and new development	Organic pollutants/ nutrient loading (fertilizers + wastewater)	Excessive plankton growth, high Chl a	pp	pp		PP					SCDHS
	Organic pollutants/ nutrient loading (fertilizers + wastewater)	Decreased DO	PP	PP		PP					EPA, NOAA
	Organic pollutants/ nutrient loading (septic tanks)	Groundwater enrichment		PP		PP			PP	EP	USGS
	Organic pollutants (pathogens)	Exceeding water quality standards	EP	EP							SCDHS
	Inorganic pollutants	Exceeding water quality standards, elevated levels in sediments/biota	PP	PP							EPA, NOAA
	Pesticides	Decline of non-target species	PP	PP		PP					SCDHS
HABITAT ALTERATION: dredging, ditching, filling, and other development	Ditching salt marshes	Decreased area of low salt marsh vegetation; increase in high marsh, tidal creek, or Phragmites cover				EP					Klopfer et al, 2002
	Open marsh water management	Decreased area of salt marsh vegetation; increase in artificial pools and ditches within salt marsh				PP					SCDPW DVC 2007
	Shoreline stabilization (bulkheads, revetments, riprap)	Bay-side erosion				EP					Nordstrom & Jackson 2005
	Shoreline stabilization (bulkheads, revetments, riprap)	Downshore sediment deficit; extent of armored shoreline			EP	EP	EP				Nordstrom & Jackson 2005
	Beach replenishment & potential disruption of beach-nesting species (plover, turtles, horseshoe crab) & rare plant populations	Length of beach replenished, volume of sand transported/stockpiled, number of storm breaches filled			PP	PP	PP				Kratzmann & Hapke 2008

Table **10**. Summary of threats to FIIS natural resources (continued).

Stressor/Threat main category	Threat/Stressor sub-category	Indicator	Marine benthic	Marine pelagic	Intertidal beach	Intertidal salt marsh	Upland dunes	Upland forest	Upland freshwater marshes	Ground-water	References and Information Sources
HUMAN OVERUSE: recreation, resource depletion	Human overuse (over-fishing)	Decline in species abundance	NP	NP							Waldman, Pers. com.
	Human overuse (over-fishing: hard clams)	Damaged SAV, decline in clam abundance, increased turbidity	EP								Conover et al, 2005, Hinga 2005
	Human overuse (speed boating/personal watercraft)	Boating use statistics, scraping of SAV and mudflats by boats in shallow water	PP	PP							NPS
	Human overuse (visitation: trampling, off-trail hiking)	Footpaths breaching dunes, vegetation trampling			EP		EP	PP			Art 1976
	Human overuse (visitation: driving on dunes and beach)	Tire tracks on beach; sand roads on dunes and in swales			EP		PP				Anders and Leatherman 1987
	Human overuse	Trash on beach			PP						
	Excessive ground-water withdrawal	Increased salt water intrusion, lower water table, freshwater wetland loss							PP	PP	Schubert 2007
INVASIVE SPECIES and PROBLEM NATIVE SPECIES	Existing invasive species	Species presence, expanding distribution			EP	EP		PP	PP		Klopfer et al. 2002,
	New invasive species invasions (via various dispersal vectors)	Species presence, expanding distribution	PP	EH	PP	PP	PP	PP	PP		Villalba et al. 2007
	Deer overpopulation	Decreased woody species regeneration, obvious browse line, change in herb composition				EP	EP	EP			Forrester et al. 2007
GLOBAL CLIMATE CHANGE	Sea level rise	Salt marsh loss, increased flooding				EP	PP			PP	Roman et al 2007
	Increased average air and water temperatures	Altered species composition	PP	PP	PP	PP	PP	PP	PP		
	Increased storm severity and frequency	Habitat and property damage	PP		PP	PP	PP	PP			

Nutrient Loading and Phytoplankton Biomass

Nutrient loading, or cultural eutrophication, can have numerous potential negative side effects as summarized in Nixon (1995) and Hinga et al. (1991, 1995). Nutrients are quickly utilized by phytoplankton, leading to elevated chlorophyll a (Chl a) levels. Hinga (2005) compared the dissolved inorganic nitrogen (DIN) and Chl concentrated in GSB to other estuarine systems. Of the 16 urban estuaries compared, GSB had the third lowest DIN concentrations but ranked fourth in Chl a levels, indicating it is among the more eutrophied estuaries in the U.S.

Nutrient concentrations for all SCDHS stations in GSB, Moriches Bay, and Shinnecock Bay are summarized in Figure 10. Average nutrient concentrations (nitrite plus nitrate, ammonia, and total phosphate) have declined slightly and generally remained low over the period of record (1976-present), although the upper 95^{th} percentile for nitrite plus nitrate and ammonia concentrations has been much lower in the most recent decade. In other words, the frequency of isolated high concentrations has decreased in recent years, possibly due to a decrease in crop and duck farms along the south shore of Long Island. Despite the overall trend for improvement, concentrations of ammonia and nitrate/nitrate since 2000 appear to be increasing, and a more detailed analysis of this and more recent measurements should be conducted to determine if this is a statistically significant trend.

The major source of nutrients to GSB is anthropogenic activity on Long Island. Nitrogen and phosphorous can enter GSB and the other lagoonal systems via subsurface groundwater discharge or as surface water stream flow. Sources of these nutrients include, but are not limited to, septic tank and wastewater discharge, agricultural or residential fertilizer application, and atmospheric deposition. Clark (2000) found that groundwater DIN concentrations in southern Long Island near GSB had decreased tenfold from 1983 to 1999, and that the amount of nitrogen in river input to the bay had also decreased. Monti and Scorca (2003) compiled historic ground- and surface-water nitrogen concentrations as well as historic ground- and surface-water discharges and calculated historic nitrogen loading to the South Shore Estuary Reserve (SSER; all the south shore lagoons, including GSB) for 1952-1997. The total nitrogen (N) load entering the SSER decreased in the last three decades, from approximately 1,000,000 kg total N per year around 1972 to <800,000 kg N per year since 1991 (Monti and Scorca, 2003). Figures 11 and 12 summarize these findings.

Largely based on suggestions from the Monti and Scorca (2003) report, the USGS in 2004, in cooperation with the NPS, established a 3-year program consisting of: 1) groundwater data collection that included water-level measurement and water quality analysis, 2) development of a three-dimensional model of the shallow aquifer system and adjacent marine surface waters to identify groundwater flow patterns and rates, and 3) calculation of nitrogen loads in simulated groundwater discharges from this system to the back-barrier estuaries and the ocean. Initial results illustrate that the overall total nitrogen (TN) load from Fire Island to marine surface waters, nearly all of which discharges to GSB, amounts to 18,900 kg/yr or about 5% of the load from Long Island (Christopher Schubert, USGS-NY, written communication).

Based on the available data, nutrient levels in GSB do not seem to present a current threat to resources in FIIS except in Moriches Bay, where hypereutrophication is causing hypoxic

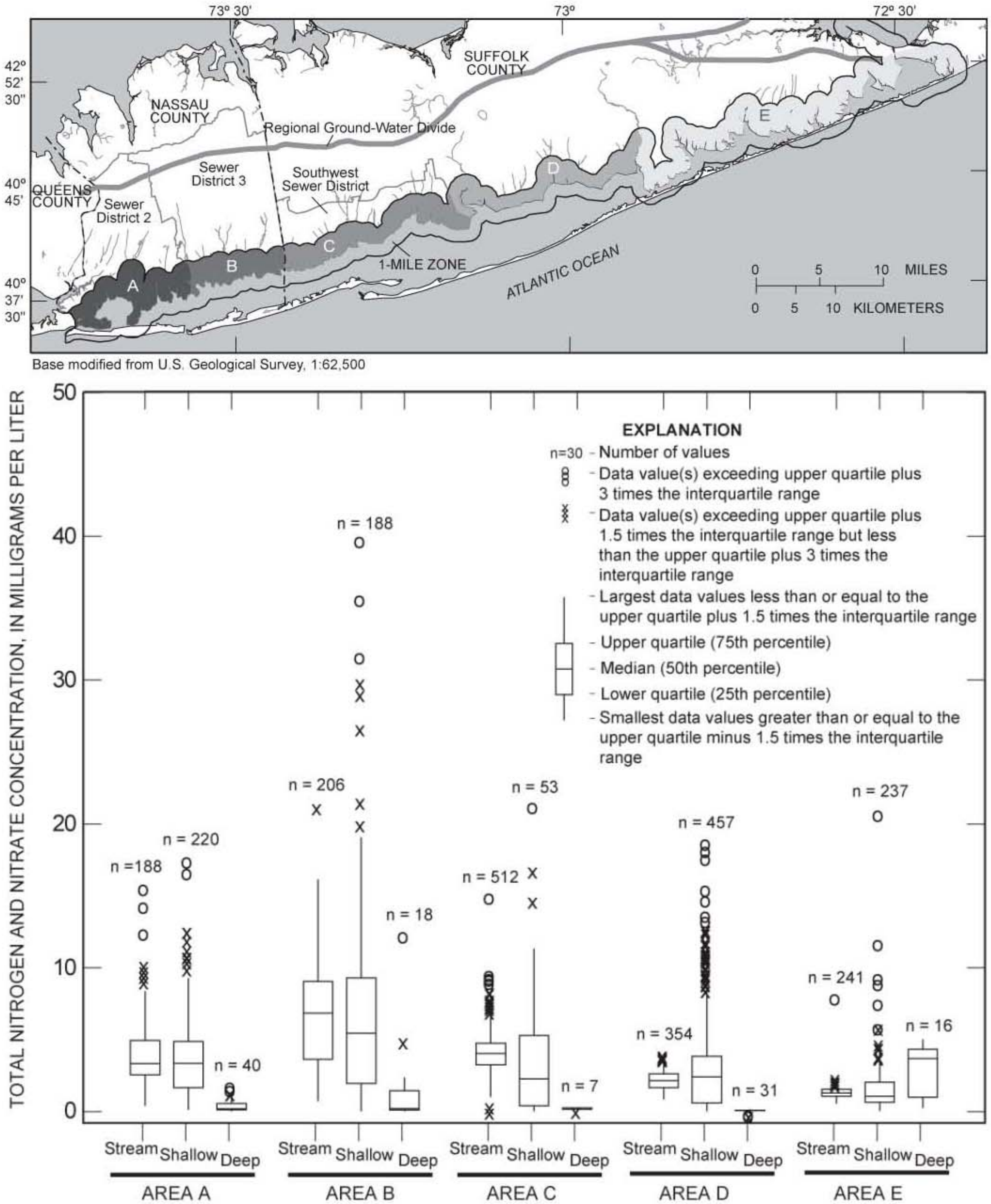
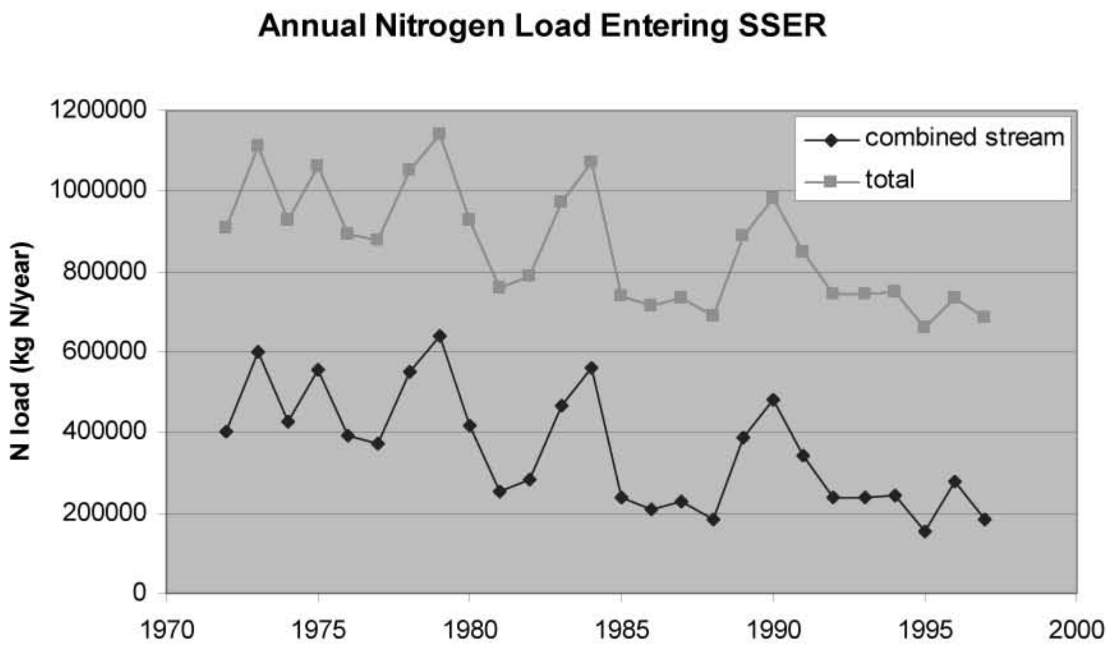


Figure from Monti and Scorca, 2003

Figure **11**. Map of South Shore Estuary Reserve and nitrogen discharge zones and box-plot of nitrogen concentration in surface, shallow ground-, and deep ground-water.



Data from Monti and Scorca, 2003

Figure **12**. Total nitrogen load to the South Shore Estuary Reserve.

conditions to develop (see discussion below). In addition, based on the Schubert (2007) data, Fire Island itself does not seem to be a significant source of DIN to GSB as compared to Long Island's mainland. Nevertheless, the apparent increase in nitrogen levels in surface waters since 2000 indicates that nutrient enrichment remains a potential problem to the resources of FIIS and GSB in general.

Dissolved Oxygen

Nutrients lead to the growth of plants that are eventually decomposed. Bacteria and other decomposers draw down oxygen concentrations as they metabolize the plant material. This process usually happens either spatially (deeper in the water column) or temporally (later in the season) removed from plant growth and is not offset by the production of oxygen during photosynthesis. Thus, closely related to nutrient inputs and eutrophication is the potential for decline in dissolved oxygen (DO) concentrations to hypoxic (DO <3-4 mg/L) or anoxic (DO unmeasurable) conditions. The presence of hypoxic or anoxic conditions is detrimental to aquatic life and therefore would represent a threat to submerged aquatic resources in GSB and FIIS.

The SCDHS dataset contains over 5,000 DO measurements between 1976 and 2004 (Figure 13). Concentrations below 3 mg/L were not reported, and only 42 samples are in the hypoxic range (< 4 mg/L). All these low measurements were made in 1976 or 2003 and were not isolated to any particular area within GSB. Despite the very low occurrence of hypoxic conditions, the recent (2003) decline in some water quality measurements deserves further attention. Additionally, if

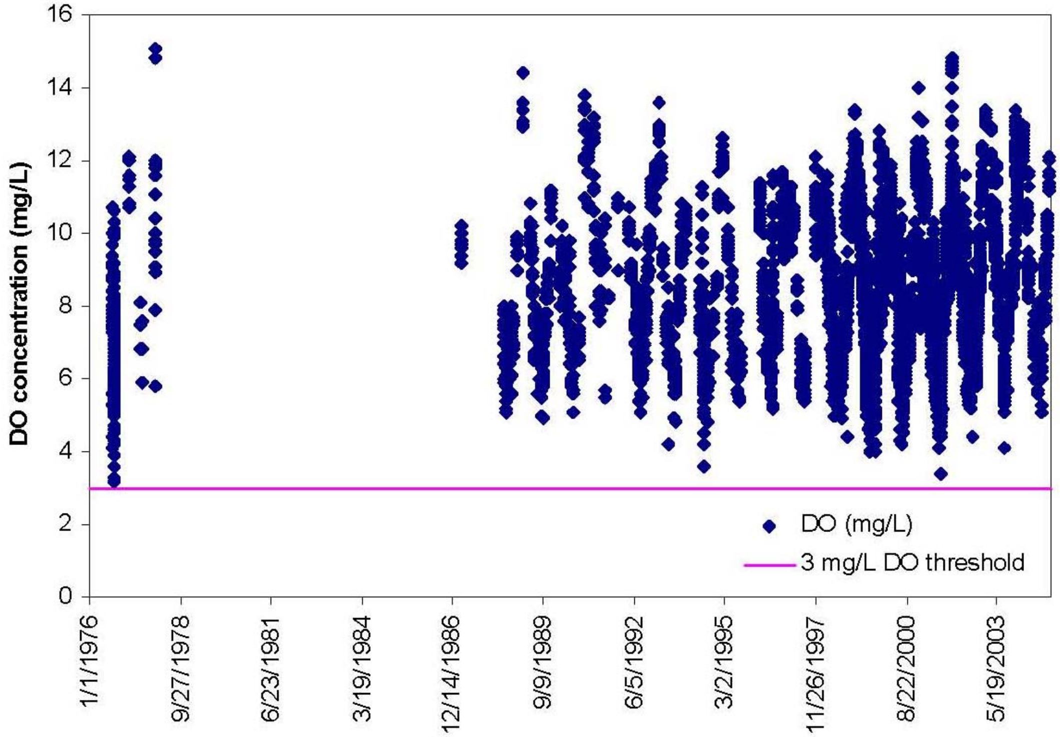


Figure **13**. All measured dissolved oxygen concentrations (5487 measurements) at 24 sites throughout Great South Bay and Hempstead Harbor between 1976 and 2004. Note that there were no measured DO concentrations below the 3 mg/L threshold, which defines suboxic conditions. Data from SCDHS 2006; for a detailed description of georeferenced data, see Benotti, 2008.

the recent trend of increasing nutrient concentrations continues, increased algal growth may lead to a decrease in DO concentrations.

Hinga (2005) evaluated an eight-year dataset (1996–2003) of DO values in central GSB. Neither surface nor bottom water DO fell below 5 mg/L and generally oscillated between 6 mg/L and 12 mg/L. There is a clear seasonal pattern with peak DO in the winter and lower DO in summertime, as would be expected. Color maps of DO concentrations constructed by SCDHS for summer (July-September 2001) and winter (December 2001-February 2002) illustrate this pattern (Figures 14a and 14b). These conditions are often attributed to strong stratification and bacterial production in the summer and additional wind and breakdown in stratification in the winter. However, Hinga suggests that the variability is due to the differential solubility of oxygen in colder and warmer water because values are all within 10% of saturation values. Although GSB does not have any widespread dissolved oxygen problems, local hypoxic conditions could exist in areas near river mouths, particularly on the north side of GSB, due to cultural nutrient enrichment.

The Forge River on the north shore of Moriches Bay is hypereutrophic in summer. Recent studies have shown that DO concentrations are often anoxic in bottom waters and vary from

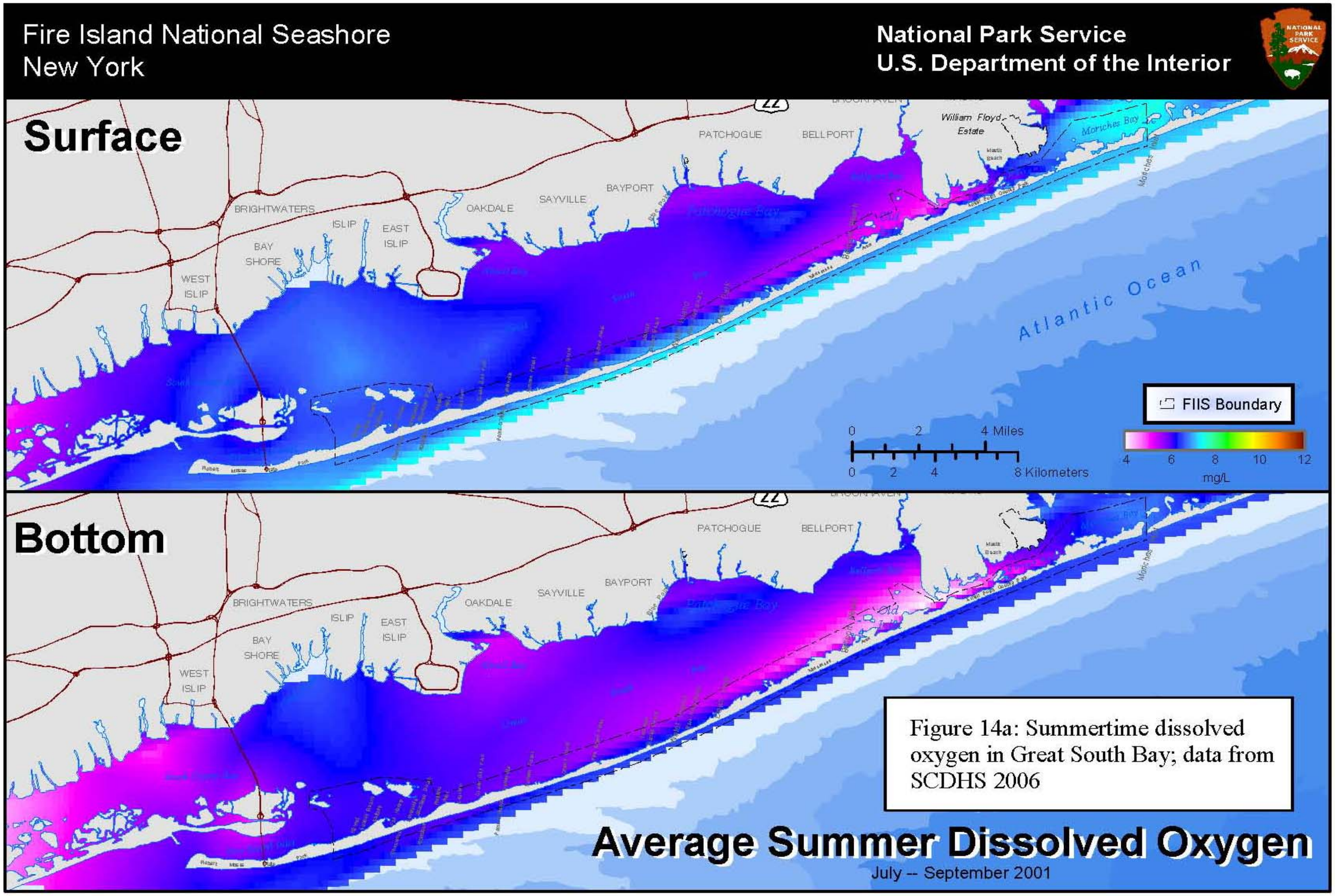


Figure 14a: Summertime dissolved oxygen in Great South Bay; data from SCDHS 2006

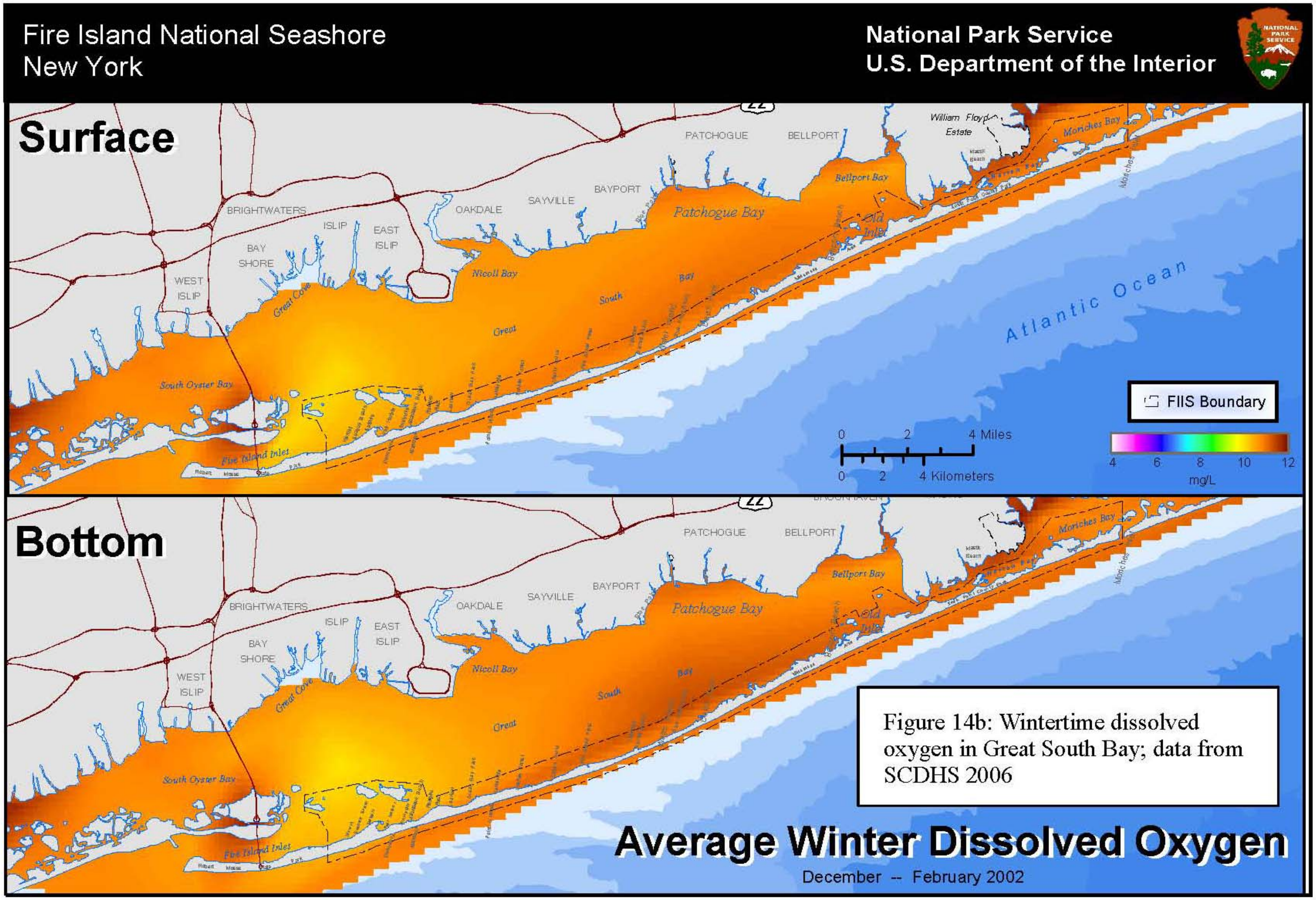


Figure 14b: Wintertime dissolved oxygen in Great South Bay; data from SCDHS 2006

being hypoxic at night to being supersaturated (150%) during the day (R.L. Swanson, Stony Brook University, personal communication). It is likely, but undocumented, that these conditions exist in other tributaries bordering the north side of Moriches and GSB.

Bacterial Contamination

Bacterial contamination in surface waters is generally estimated by either total coliform or fecal coliform standards (http://www.dec.ny.gov/regs/4590.html). In order for saltwater to remain open for shellfishing (classified as SA), the median most probable number (MPN) of total coliforms from at least five analyses cannot exceed 70. Less stringent standards must be met for primary and secondary recreational contact (classified as SB). For total coliforms, monthly median values and 20% of the samples analyzed cannot exceed 2,400 and 5,000 per 100 mls, respectively. For fecal coliforms, the monthly geometric mean cannot exceed 200 per 100 mls.

The beaches on the ocean side of Fire Island have been monitored for fecal coliform by both the U.S. EPA and Suffolk County since the 1970s and, except in rare cases, the water quality on the south side of Fire Island is excellent.

GSB has higher coliform counts than the southern ocean beaches of Fire Island. Plotted in Figure 15 are all 4835 Suffolk County records from 1976-2005. The vast majority of the stations sampled are within GSB, although the sampling grid does extend into Hempsted Bay on the west, and there is one oceanside monitoring station near the west end of Fire Island. A map showing the exact sampling locations can be found in Benotti (2008). Less than 10% of fecal coliform measurements had more than 200 CFU per 100 mls, the SB water quality standard for bathing, and most of these higher measurements occurred before 1980, but there are a number of measurements exceeding the standard after 2000.

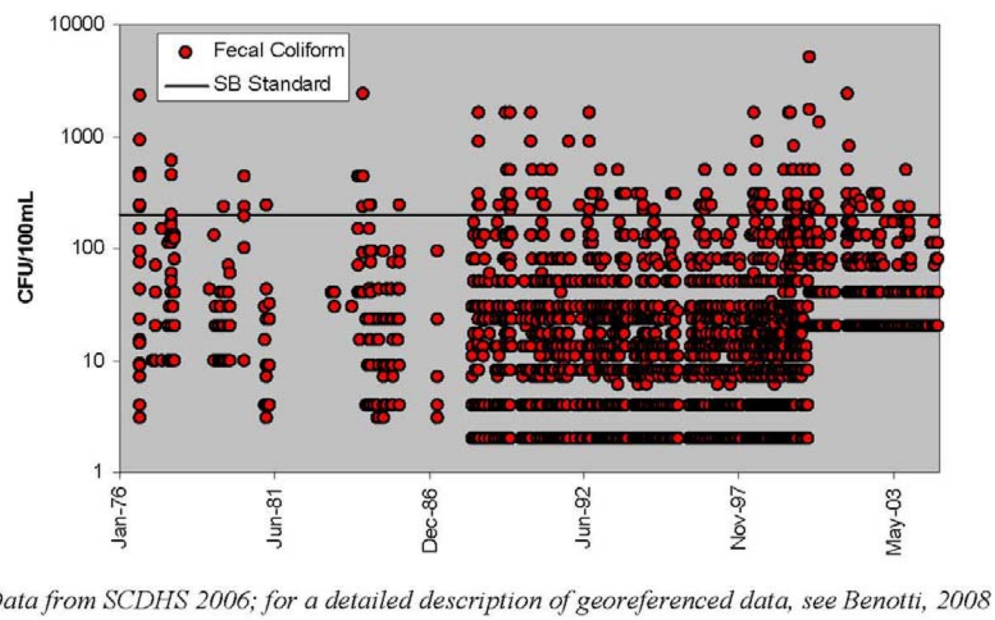


Figure **15**. All fecal coliform data from SCDHS between 1976 and 2004.

Figure 16 shows the location and number of times fecal coliform levels have exceeded the SB standard. It can be seen that the quality of the waters adjacent to Long Island is more extensively and frequently degraded than those associated with FIIS. However, high levels of total coliforms near both the western and eastern edges of FIIS are cause for concern.

Chemical Contaminants

Overview of Data Sources: There are many potential sources of chemical contaminants to GSB and the waters of FIIS. These include surface water runoff and groundwater inputs from Long Island, inputs from sewage treatment plants, fuel spills and leakage from marinas, ferries, private boats and personal watercraft, pesticide application, and atmospheric deposition.

Data on chemical contamination in the vicinity of FIIS have been reviewed most recently by Hinga (2005) and Cooper (2007). There are no comprehensive long-term monitoring programs for non-nutrient chemical contaminants in GSB. Limited data exist for concentrations of standard priority pollutants (metals and organic contaminants) from EPA's EMAP at two sites in GSB, one near Patchogue (VA90-023 collected in 1990) and one in Moriches Bay (VA92-532 collected in 1992) (http://www.epa.gov/emap). More recently, sediment chemical contaminant data have been collected as part of EPA's National Coastal Assessment Program (NCAP) from 2000-2006 (although data are currently available only for 2000 and 2001 for only two sites within GSB (http://www.epa.gov/emap/nca/html/regions/northeast.html). Sediment toxicity data and limited data on contaminant levels in fishes are also available at the sites sampled by the EPA as part of these assessments. The longest and most complete data set is from Mussel Watch, a part of NOAA's Status and Trends Program where contaminants in these filter feeding organisms were measured from 1989-2004 (NOAA 2006). This monitoring program remains ongoing, and an assessment of recent trends including data from 2005 has just been released (Kimbrough et al. 2008). Clark (2000) also conducted seasonal analyses of four metals, silver (Ag), lead (Pb), copper (Cu), and chromium (Cr), in water samples for 8-10 stations in GSB in 1998 and 1999.

Contaminant Levels in the Water Column: Mussel Watch monitored levels of contaminants in blue mussels (*Mytilus edulis*) as an indicator of water column contaminant concentrations, relying on the ability of these organisms to filter large quantities of water to make them good integrators of ambient conditions. Mussels were not actually sampled within the waters of FIIS; however, four Mussel Watch sites are located in close proximity to FIIS: one at Tuthill Point (MBTH) on the north side of Moriches Bay, one just to the west of FIIS near Robert Moses State Park at the Fire Island Inlet (LIFI), one at a site further west near Jones Inlet (LIJI), and a site further east in Gardiners Bay (LIGB: NOAA 2006).

Mussels were sampled generally every other year from 1989 to 2004 and analyzed for 24 polycyclic aromatic hydrocarbons (PAHs), 18 polychlorinated biphenyl (PCB) congeners, alkyl tin compounds, dichloro-diphenyl-trichloroethane (DDT) and its breakdown products, dichlorodiphenyldichloroethylene (DDE) and dichloro-diphenyldichloroethane (DDD), 16 other chlorinated pesticides, and 14 metals. Data for a number of the more common environmental contaminants at the Moriches Bay (MBTH) and Fire Island Inlet (LIFI), the sites closest to FIIS, are shown in Figure 17. Levels of the chlorinated pesticides no longer used, total DDTs and total

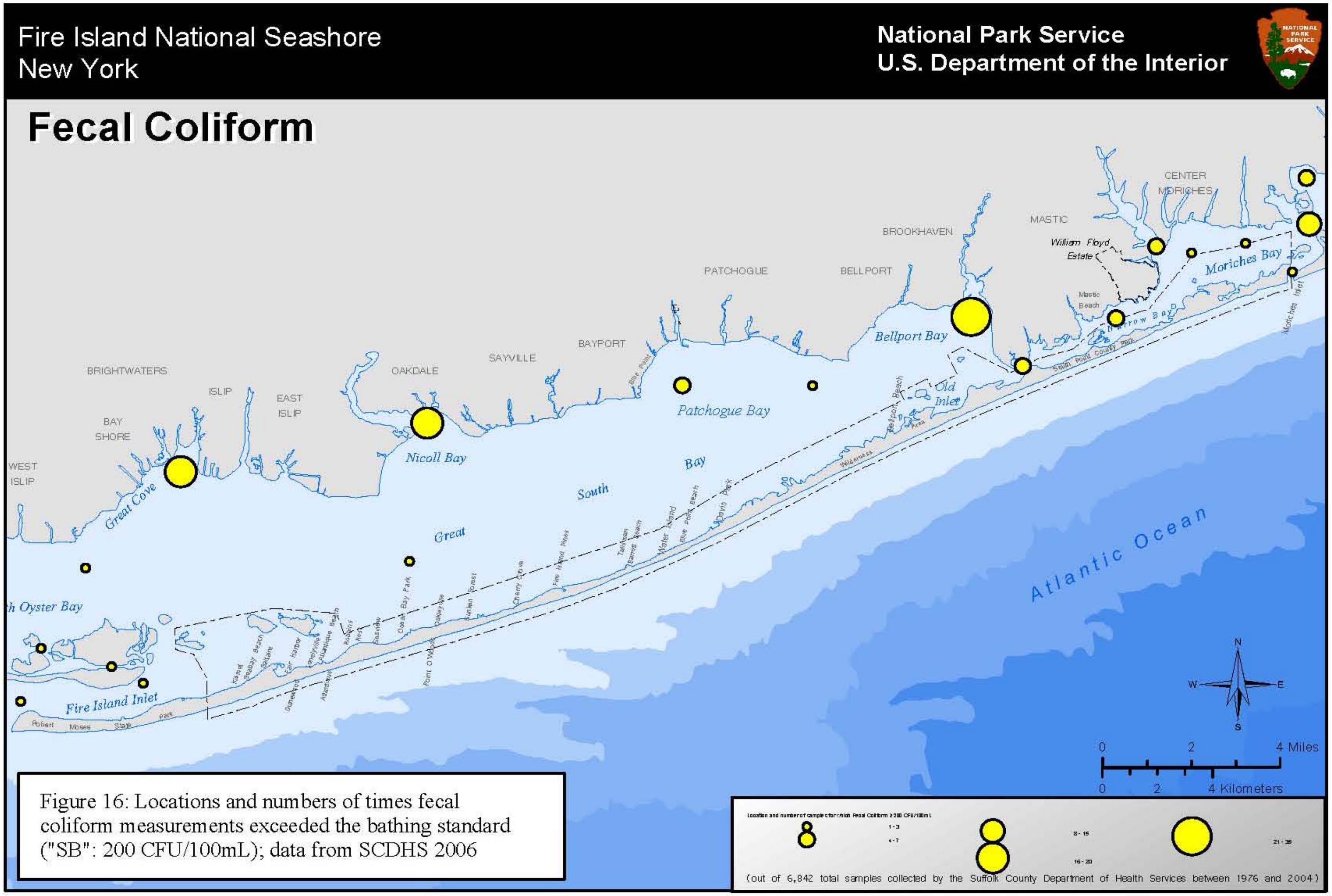


Figure 16: Locations and numbers of times fecal coliform measurements exceeded the bathing standard ("SB": 200 CFU/100mL); data from SCDHS 2006

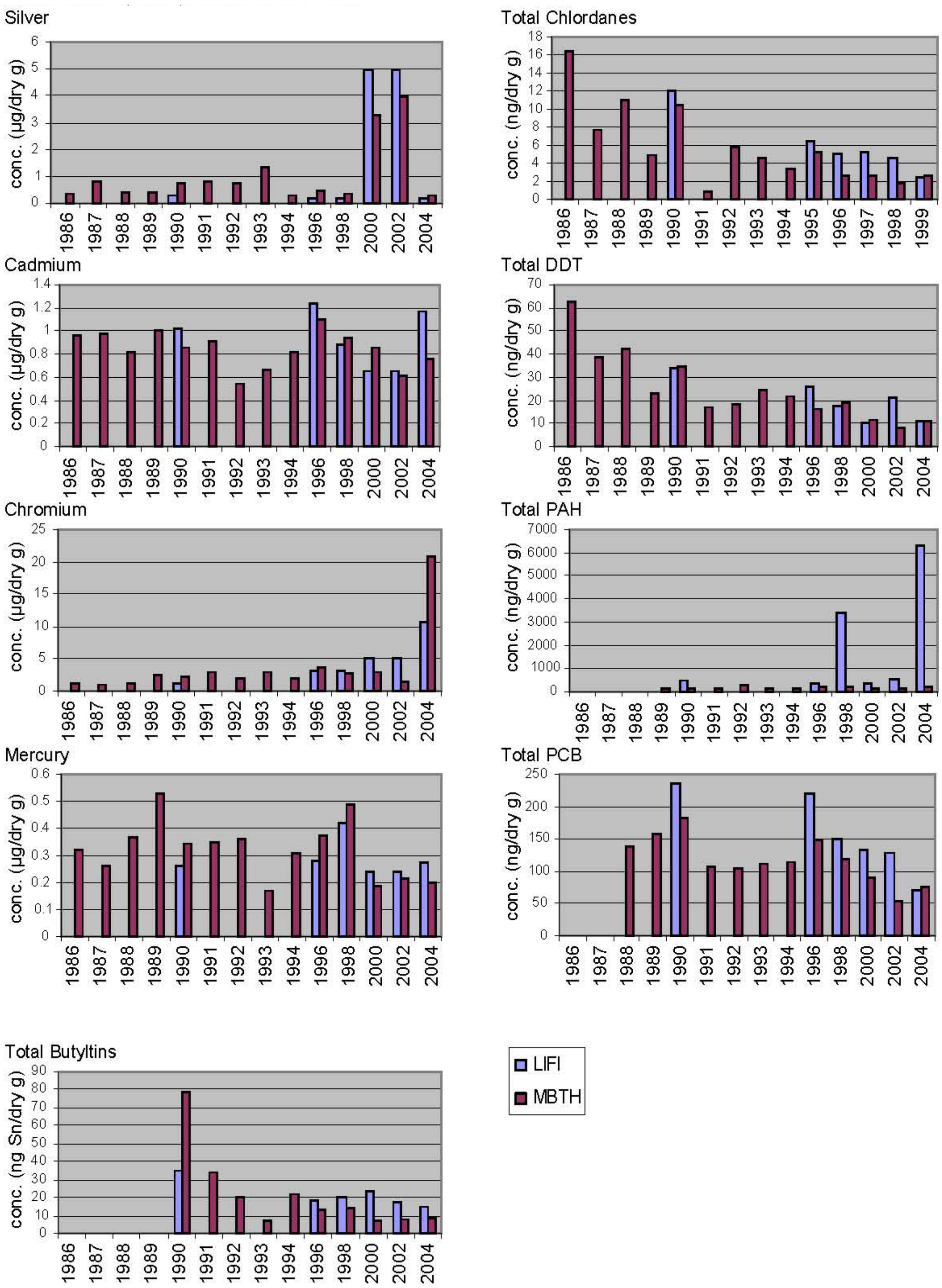


Figure **17**. Temporal trends in total PAHs. PCBs, DDTs, Chlordanes, Butyl tins, Hg, Ag, Cd, and Cr (NOAA, 2006. Status and Trends Moriches Bay (MBTH) and Fire Island Inlet (LIFI) sites 1986 to 2004).

chlordanes, decreased steadily beginning in the late 1980s. Butyl tins, measured only since 1990, also decreased after they were banned. PCBs generally decreased over the same period, although several elevated levels were reported at LIJI. The recently released assessment of 20 years of Mussel Watch data, including that collected between 2004 and 2005, provides long-term trend analysis on a regional and national scale (Kimbrough et al. 2008). Similar to the rest of the country, there was either no trend or a decreasing statistical trend in concentrations of most organic and inorganic contaminants at these sites. The only exceptions were nickel (Ni) and tin (Sn) concentrations at Moriches Bay where concentrations were shown to be increasing consistently over time on a national basis as well. Also noteworthy, concentrations of PAHs at the Fire Island Inlet site measured in 2004-2005 were ranked as being high on both a regional and national scale, the only contaminants, either organic or inorganic, measured that achieved this status. However, this spike in concentration likely represented a transitory source and is not necessarily representative of the general condition.

The Mussel Watch data are consistent with actual measurements of dissolved Ag, Pb, Cu, and Cr taken by Clark in 1998 and 1999 (Clark 2000). Even the maximum concentrations observed were below the lowest values from the NOAA Screening Quick Reference Tables (SQuiRT) that provide guidelines for gauging potential harm to living resources (Buchman 1999). Interestingly, Clark (2000) noted that the highest values of Cd and Cu were found near rivers on the north shore of GSB entering from southern Long Island, whereas the highest concentrations of Ag and Pb came from the Fire Island Inlet, suggesting an offshore source of sewage impacted waters. There are two sewage outfalls discharging to the ocean some 10+ km to the west of Fire Island Inlet. Silver, likely introduced as a byproduct of developing photographs, has been used as a sewage tracer in the past (Sañudo-Wilhelmy and Flegal 1992). However, with digital cameras capturing an increasing percentage of the photography market in the last decade, it is unlikely that silver will continue to serve as a useful and ubiquitous wastewater tracer of future inputs.

Sediment Contaminant Levels: The EPA EMAP (2007) program had two stations in GSB that monitored sediment metal and chemical contaminations, one near Patchogue (VA90-023) and another in Moriches Bay (VA92-532). Data for the Patchogue site were discussed in Hinga (2005). This station was near the mouth of a Long Island stream (Swan River) and so probably represents an upper limit for sediment contamination in the majority of GSB. Data from this site are reproduced in Table 11, along with the lowest threshold values in NOAAs SQuiRT tables (Buchman, 1999) and the hazard quotient calculated according to Cooper (2007). It can be seen that only a handful of metals [Cu, Pb, Hg, tin (Sb), and possibly Ag (detection limit is too high to say for sure)] exceed the lowest threshold levels. Even these have HQ of less than 2. Concentrations of organic contaminants never even approached the lowest threshold levels.

In 2000 and 2001, two more sites in GSB were sampled as part of EPA's National Coastal Assessment (EPA EMAP 2007). Murray (2004) reviewed the data on Hg accumulation in four popular sport fish and shellfish species (summer flounder, winter flounder, scup, and blue crab) from GSB locations and concluded that due to low levels of accumulation, there was no need for a human health consumption advisory for Hg. A broader suite of the 2000 and 2001 NCA data were reviewed by Cooper (2007). Sediment toxicity tests with the amphipod *Ampelisca abdita* indicated no toxicity, even though the concentrations of Hg, methyl-naphthalene, and

Table **11**. Sediment contaminant concentrations and hazard quotients for EMAP data collected at site VA90-023, near Patchogue in Great South Bay.

Element or chemical	Measured value	Lowest screening value	Units	HQ
Antimony	0.4	9.3	ug/g	0.0
Arsenic	5.4	7.24	ug/g	0.7
Cadmium	0.5	0.676	ug/g	0.7
Chromium	29.9	52.3	ug/g	0.6
Copper	20.6	18.7	ug/g	1.1
Lead	45.3	30.24	ug/g	1.5
Mercury	0.16	0.13	ug/g	1.2
Nickel	12.3	15.9	ug/g	0.8
Selenium	0.38	1	ug/g	0.4
Silver	<1	0.73	ug/g	
Tin	6.02	3.4	ug/g	1.8
Zinc	104	124	ug/g	0.8
Acenaphthene	1.14	6.7	ng/g	0.2
Acenaphthlylene	1.14	5.9	ng/g	0.2
Anthracene	1.14	47	ng/g	0.0
Fluorene	2.27	19	ng/g	0.1
Naphthalene	9.08	35	ng/g	0.3
Phenanthrene	20.4	87	ng/g	0.2
Low Molecular Weight PAHs	17	312	ng/g	0.1
Benz(a)anthracene	25	75	ng/g	0.3
Benzo(a)pyrene	1.14	89	ng/g	0.0
Benzo(b+k)fluoranthene	52.2	1800	ng/g	0.0
Benzo(e)pyrene	22.7	89	ng/g	0.3
Chrysene	26.1	107	ng/g	0.2
Fluoranthene	44.3	600	ng/g	0.1
Pyrene	43.1	665	ng/g	0.1
High Molecular Weight PAHs	243	1700	ng/g	0.1
Total PAHs	260	4022	ng/g	0.1

Table based on EMAP data presented in Hinga 2005. Hazard quotient calculated according to Cooper (2007)

naphthalene in sediments had HQ >1. Analyses of winter flounder and blue crab from GSB revealed detectable levels of Ag, Cr, As, Cd, Hg, Sb, Zinc (Zn), petroleum, PAHs, DDD, DDE, and a couple of PCB congeners. Calculations of potential toxicity to birds consuming these prey failed to yield HQ >1 for any analyte detected in the vertebrate or invertebrate prey species.

Risk Associated with Contaminant Levels in FIIS: Cooper (2007) applied a hazard quotient (HQ) approach to determining the potential risk for adverse effects in biota exposed to these levels of contaminants. Briefly, the HQ is the concentration of the contaminant either measured or predicted in the sediment divided by some criterion threshold for potential toxicity. In his review Cooper used the Threshold Effects Level (TEL) or the Effects Range Low (ERL) and calculated the sediment concentrations using bioaccumulation factors measured where sediment and mussel tissue analyses were conducted at the same site (LIJI). Benchmarks were obtained using NOAA's SQuiRT tables (Buchman 1999). In this analysis an HQ >1 raises cause for concern as toxic thresholds could be exceeded. Based on these calculations in 2004, Ag had the highest HQ

(11-15), whereas all other metals had HQs below 1, except for previous years where Cr, Pb, Hg, and nickel had HQs ranging from 1.05 to 1.08. Similar calculations for organic contaminants indicated HQs exceeding 1 for Dieldrin (HQ = 4.75), total DDT (HQ = 1.4), low molecular weight PAHs (HQ = 2.72), and naphthalene (HQ = 2.62).

Contaminant Sources: The patterns observed in sediment and biota contaminants from the area indicate that there are local sources of anthropogenic contaminants to the FIIS system. These most likely result from boat traffic and from groundwater leaching of contaminants from domestic sewage, sewage treatment plants (STP), and hazardous waste sites along the south shore of Long Island (Cooper 2007). Two STPs have discharges that could influence water quality in GSB: the Ocean Beach STP, which is located on Fire Island and discharges directly into GSB, and the Patchogue Village STP, which discharges into the Patchogue River, which empties into GSB. Additional permitted point source discharges that could impact GSB include The East Islip Marine, the Watergate Garden Apartments on the Patchogue River, and the Jurgielewicz Duck Farm on West Mill Pond (Cooper 2007). Areas of sediment deposition where fine-grained materials build up will be those most likely to contain contaminants. Because most of GSB contains sandy sediments, contaminant build-up is not likely to be a pervasive problem.

Boat traffic remains a potential source of hydrocarbons to the waters of FIIS. Due to limited road access, many visitors to the seashore arrive by ferry or private boat, and the park manages marinas at Sailors Haven and Watch Hill. Jet skis, or personal watercraft (PWCs), represent another source of hydrocarbon inputs. Use of PWCs is extremely restricted within park waters, and as older, more polluting two cycle engines are replaced with four cycle engines, the potential future impact of PWCs is limited.

Use of pesticides to control mosquito populations remains a contentious issue in the public arena. Persistent chlorinated pesticides such as DDT and chlordane are no longer used in the U.S., but there is concern about the more potent but less persistent modern pesticides used to control mosquito populations. Mosquito control within Suffolk County currently relies on biological (BT) and chemical (methoprene) larvacides to minimize emergence of adult mosquitoes, followed by application of pyrethroid adulticides if West Nile virus is detected or adult populations are reported at nuisance levels (D. Ninivaggi, Suffolk County Department of Health, personal communication). Suffolk County Vector Control has limited authorization to apply larvacide and adulticides within the communities in FIIS. On Federal lands NPS only allows larvacide and adulticide application when a significant disease threat has been verified (M. Bilecki, National Park Service, personal communication). Suffolk County and the NPS are working together to develop a mosquito management plan for all the lands within the boundary of FIIS.

Pesticides are not to our knowledge analyzed as part of any current monitoring programs in GSB or FIIS. However, pesticide occurrence and persistence in surface waters and sediments after spray events has been tracked by the USGS and independent investigators as part of Suffolk County’s environmental impact assessment for their Vector Control Program and for previous studies of the potential link between pesticide application and lobster mortality in Long Island Sound (Abbene et al. 2005; Cashin Associates 2005a, b; Zulkosky et al. 2006). Other than the synergist piperonyl butoxide (PBO), levels of these pesticides are only detectible at levels from ug/L (for methoprene) down to low ng/L concentrations for the pyrethroids 30 minutes immediately after spraying and decay rapidly within several hours after application. Methoprene was found to persist for longer periods in salt marsh sediments but did not build up, despite almost weekly application in some areas. Toxicity studies were conducted on marsh organisms caged within the spray sites and on native organisms exposed to water collected from the spray sites or to concentrations of pure pesticides in the laboratory. Results indicated that application of these pesticides as practiced by Suffolk County would not have acute effects on non-target aquatic organisms (Cashin Associates 2005a, b). Further work on potential long-term effects of pesticide use in Suffolk County is now under consideration.

Overall Threat of Chemical Contaminants in FIIS: Levels of contaminants found in water column samples, sediment samples, and in local biota in GSB are not elevated with respect to values reported in other urbanized estuaries, particularly those in the Northeast region. In the most recent National Coastal Condition Report issued by EPA (EPA 2007), although the GSB has nutrient and Chl a, concentrations that rank it as highly eutrophic, sediments from this area do not contain contaminants at levels exceeding toxic thresholds, are not toxic in standardized tests, nor does the benthic community structure indicate degraded conditions. This is in stark contrast to many sites in Long Island Sound, Jamaica Bay, New York Harbor, and the upper Chesapeake Bay.

The biggest threat for hydrocarbon contamination would be from a major oil spill occurring within GSB resulting from a boating accident or undetected operational problem associated with fuel transfer or storage at bayside facilities. If a spill of significant proportion occurred, oiling of marsh areas, water fowl, and contamination of shellfish beds could occur.

Habitat Alteration

Unlike mainland Long Island, FIIS has not been subject to major human-made habitat alterations. Primary anthropogenic habitat changes at FIIS have been ditching for mosquito control (SCDPW DVC 2007), home building, and shoreline hardening. Declines of eelgrass beds as habitat are important ecologically, but the relative contributions of human and natural causes for these declines remain unknown. Replenishment of eroded beaches has the potential to disrupt nesting animals, such as horseshoe crabs (*Limulus polyphemus*) and piping plover, and smother rare plants.

Eelgrass Beds

At the present time, eelgrass beds are concentrated in the shallow waters along the back side of Fire Island, especially at the eastern end. They are north and east of East and West Fire Islands and north of Captree and Cedar Island in the western portion of FIIS (USFWS 1997). This appears to be due to greater light penetration (~1.8 m) as compared to the north side of the bay where eelgrass is more scarce and where light attenuates faster (~0.5 m; Carpenter et al. 1991). An estimate of the distribution of SAV in GSB, including eelgrass, appears in Figure 8.

However, eelgrass abundance once was far greater. Historical accounts (Pickerell 2007) state that "it became necessary for the ferries to have to reverse their engines two or three times during a crossing to clear their wheels of grass and weeds." Between 1930 and 1933, wasting disease caused the near elimination of eelgrass throughout its range with survival occurring only in low salinity refugia. By the mid-1960s, eelgrass in GSB had recovered sufficiently that boaters again found it a nuisance. An aerial survey from 1981 indicated that eelgrass covered about a third of the bay bottom (Carpenter et al. 1991). More recent reviews concur that eelgrass occurrence in GSB was probably much greater in the past, yet point out that few historical data exist to quantitatively evaluate system-wide occurrence (Bokuniewicz et al. 1993; Hinga 2005).

Brown tide remains a threat to eelgrass, as the blooms block sufficient light from reaching the beds (McElroy 1996) with the consequence of lower leaf densities (Cosper et al. 1987). There also appear to be regional differences within GSB in the biomass per unit area (Hinga 2005). These observations suggest that the amount and distribution of eelgrass in GSB has varied widely, and that disease and algae blooms are threats. Other potential threats include dredging, sedimentation, heavy boat traffic, and anything that either reduces light penetration or that uproots these plants.

As most of the remaining eelgrass in GSB resides in or near the northern boundaries of FIIS (NOAA 2003), and due to the importance of eelgrass as habitat for important resource species in GSB (Raposa and Oviatt 2000), it is extremely important to understand factors limiting its growth and threatening its persistence in GSB. Population dynamics should be closely monitored.

Shoreline Hardening

Inlet Dynamics: The stabilized extremities of Fire Island have a pronounced effect on accretion and erosion along the island. Psuty et al. (2005) subdivide the island into three geomorphological zones: a 22 km Eastern Zone (Moriches Inlet to Watch Hill), a 20 km Central Zone (Watch Hill to Sailors Haven), and a 38 km Western Zone (Sailors Haven to Fire Island Inlet).

According to Allen et al. (2002), the stretch of beach immediately to the west of Moriches Inlet was a region of erosion between 1933, after the inlet was formed, and 1979. More recently, Psuty et al. (2005) state that the ebb tide delta at the inlet has stabilized after years of growth so that material is now bypassing the inlet moving west. However, the Eastern Zone overall is experiencing erosion.

The Central Zone is a region of accretion (Allen et al. 2002) fed from offshore and by the erosion to the east (Psuty et al. 2005). The offshore supply may be helping to reduce the rate of erosion in the Eastern Zone. The Western Zone also experienced erosion over the period 1933-1979, except for the area from Fire Island Inlet to about 4 km to the east (Allen et al., 2002). The area of accretion is a consequence of the hardening structures placed at the inlet, which are trapping the westward material transport. In addition to the alongshore changes in accretion and erosion, there appears to be a general landward displacement of the island as well. The island-wide displacement over the period 1933-1998 is about 0.34 m/year (Allen et al. 2002).

Inlets also affect the bayshore by influencing tidal range, storm surge, and serving as a source of sediments derived from oceanside beaches (Nordstrom and Jackson 2005). The irregular shoreline on some areas of the bayside is due to previous inlets. Management actions aimed at limiting inlet formation or longevity may lead to reduced sediment supply to bayside shoreline.

Oceanside Shoreline Hardening: Most of the oceanside shoreline of FIIS is free of hardening structures with the exception of the two groins in Ocean Beach. The construction of groins is an outdated means to stabilize beach erosion. While it effectively traps sand in areas adjacent to the groin, it prevents the longshore migration of sand, thereby starving beaches of sand and hastening erosion of beaches down-current. It is not clear to what extent the two groins at Ocean Beach are trapping sand, thereby starving beaches to the west, though it is important to note that they have fallen into disrepair, and some current passes through the crumbling structures.

More important to the oceanside beaches of FIIS are the groins constructed to the east, such as the structures at Westhampton. These groins and other hardened shorelines are likely trapping sand and starving the oceanside beaches of FIIS. It is not clear to what extent groins to the east are having an adverse effect on FIIS beaches. Therefore, it is the recommendation that a more comprehensive study of oceanside beach erosion be implemented and the degree to which the natural process of sand migration has been interrupted determined.

Bayside Shoreline Hardening: Nordstrom and Jackson (2005) reviewed physical processes affecting bayside shoreline, pointing out the significance effects of shoreline hardening on erosion. Bulkheads and breakwaters have been installed to curb erosion around marinas, park facilities, and private waterfront properties. Although they protect the armored areas, bulkheads and other shoreline armoring practices have the effect of diverting wave energy alongshore, resulting in concentrated wave energy at the unprotected margins of the armored area, often resulting in extensive erosion. Figure 18 shows a photo depicting erosion of a bayside beach area immediately adjacent to an armored shoreline. Figure 19 illustrates the extent of armored shoreline along the north shore of Fire Island as well as the amount of natural shoreline that is considered threatened by being located within 68 meters of an armored shoreline (Raineault 2006 a, b). Data from Raineault's study was compiled to create Table 12, which shows both the extent of armored and threatened shoreline along the north shore of Fire Island in terms of both km and as a percentage of total shoreline.

The extensive armoring of Fire Island’s bayside shoreline may also pose problems for some of the natural processes of the barrier island. As the island migrates landward to keep up with natural sea-level rise, sediment needs to be supplied from the ocean side by overwash and inlet formation. Maintaining the height of oceanside dunes reduces the frequency of these events, effectively limiting sediment replenishment of the bayshore (Leatherman and Allen 1985). Bulkheads can exacerbate this phenomenon by limiting erosion of upland deposits (Nordstrom and Jackson 2005).

Salt Marsh Ditching

Habitat alteration of the salt marshes, primarily in the form of historical grid ditching for mosquito control, has had lasting effects. In general grid ditching involves placing parallel ditches about 60 m apart with right angle cross ditches in order to drain standing water. Grid ditching changes the natural tidal regime and alters the vegetation distribution of the marsh (Niedowski 2000). Several studies have shown a decreased use of ditched marshes by birds (Clarke et al. 1985; Howe et al. 1978; Nixon 1982). Based on an examination of air photos, USGS 7.5 minute topographic maps, and the FIIS vegetation map (Klopfer et al. 2002), it

Photo: Mark J. Benotti, June 2006

Figure **18**. Photo of bayside erosion adjacent to armored shoreline on Fire Island.

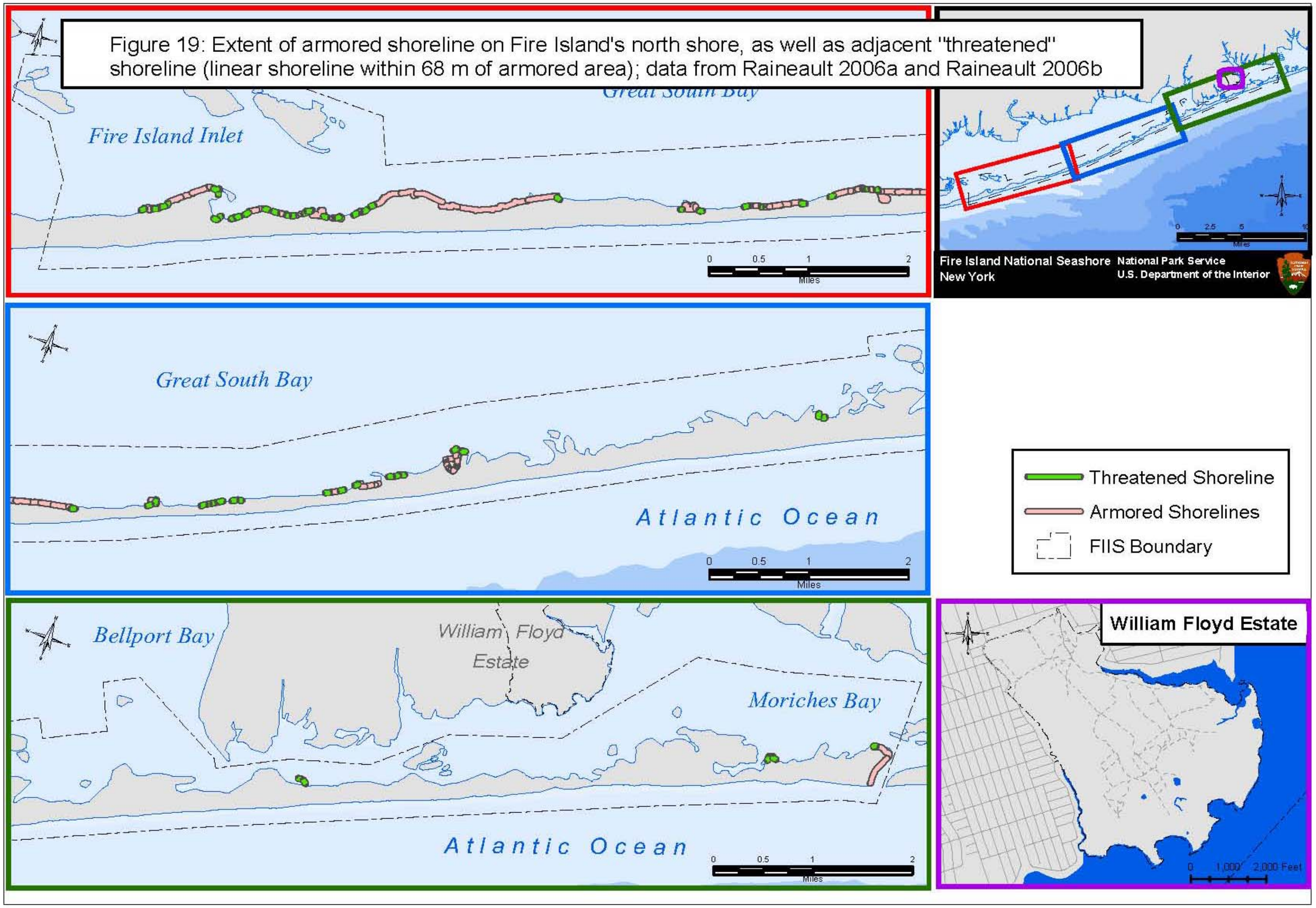


Figure 19: Extent of armored shoreline on Fire Island's north shore, as well as adjacent "threatened" shoreline (linear shoreline within 68 m of armored area); data from Raineault 2006a and Raineault 2006b

Table **12**. Linear distance of armored shoreline on north shore of Fire Island.

	distance (km)	percent of whole
Total length of Bayside shoreline	92.8	100
Armored North Shore	15.8	17
Threatened shoreline (68m influence)	4.1	5

Data from Raineault 2006a and Raineault 2006b.

appears that nearly all of the backbarrier fringe-marshes on Fire Island and the mid-lagoon marshes in Great South Bay have been grid ditched. The FIIS vegetation map includes 251 polygons of Mosquito Ditch totaling 17 ha (Klopfer et al. 2002). The practice of Open Marsh Water Management (OMWM) has been proposed as a method to restore grid-ditched marshes while simultaneously controlling mosquitoes without the use of chemicals (SCDPW DVC 2007).

Human Overuse

Population growth along the south shore of Long Island and within the residential communities of FIIS, increased visitation within FIIS and county beaches surrounding FIIS, and boat and PWC use in GSB all present potential problems to park resources. Human activities ultimately are the source of most chemical contaminants, pathogens and nutrient pollution, increased boat traffic, and shoreline modifications, which are discussed specifically above. In addition human activities can also have more direct effects through overharvesting natural resources, including fish, shellfish, and groundwater, as well as through contamination of groundwater with excess nutrients. These factors are discussed below.

Fishing Pressure

Finfish: There is considerable fishing activity within and near FIIS waters between early spring and late autumn. “Party” or “head” boats, charter boats, and private vessels routinely fish FIIS bay waters, many departing from nearby Captree State Park. There is also some seasonal surf fishing on the ocean side of FIIS and some sport fishing vessels may drift near the surf zone under calm conditions. There are no data available at this time on the effect of legal recreational fishing to the resources of FIIS. However, almost all targeted species are migratory. Their abundance is not reliant on recruitment emanating from the park itself, and it is our best professional judgment that recreational fishing does not pose a serious threat to FIIS resources. One possible exception is recreational fishing for the winter flounder populations, which display limited on/off shore seasonal migration and have been in a long term decline in GSB and elsewhere in coastal waters of the Northeast. Winter flounder are managed under restrictive guidelines developed by the state in conjunction with the Atlantic States Marine Fisheries Commission (ASMFC 2004).

Commercial fishing for finfish is prohibited within the park. Limited commercial fin fisheries do exist within GSB, primarily for bait, including menhaden, eels (*Anguilla rostrata*), and silversides (Conover et al. 2005). It is possible that some of this activity is occasionally conducted within the FIIS boundaries. The absence of hard data on questions of recreational and commercial fishing in FIIS and proximal waters suggests that a survey is warranted.

Shellfish: Historically, GSB supported major commercial and recreational shellfisheries; however, most of these are greatly reduced in scope. The most important commercial fisheries harvested hard clams, oysters (*Crassostrea virginica*), and bay scallops (*Argopecten irradians*) in the past.

Hard clam abundances appear to be naturally variable both temporally and geographically. In 1947 hard clam landings from GSB exceeded 5 million kg, declining to less than 1 million kg in 1954. During the 1960s, their numbers rose because of a series of excellent sets (Conover et al. 2005). In 2003 commercial hard clam landings from the bay were about 40,000 kg, almost one hundred times lower than the peak landings reported in 1976. Density estimates have ranged as high as 19 per m^2 in certain areas but are closer to 2 per m^2 in low abundance regions (Hinga 2005). Restoration of the hard clam fishery is a major goal of resource agencies. The restoration program, announced in 2004, includes The Nature Conservancy, which has acquired 5,200 ha of bay bottom, together with a coalition of agencies, municipalities, and other institutions under the umbrella of the Bluepoints Bottomlands Council.

Presently, both oyster and bay scallop landings from GSB are negligible. Other shellfish with significant harvests today or in the past include blue crab, horseshoe crab, blue mussel, and softshell clam (*Mya arenaria*); other shellfish species with likely limited or no harvesting also occur there. Surf clam occurs on the ocean side of FIIS, but harvesting there is illegal. Additionally, its nearshore waters are too shallow for commercial dredging (Conover et al. 2005).

There are no data available for the proportions of shellfish harvests in GSB that derive from FIIS waters. Shellfisheries conducted within GSB are managed primarily by the three towns bordering the bay: Babylon, Islip, and Brookhaven. The towns issue annual commercial shellfishing permits to town residents. Babylon and Islip also issue non-commercial (recreational/personal) shellfishing permits. In 2003 the towns issued fewer than 100 commercial permits, many of which may not have been used (Conover et al. 2005). Commercial shellfish harvesters within GSB must also possess a state shellfish diggers permit issued by the NYS Department of Environmental Conservation.

Permit survey data reported in SSER (1999) suggest that the south shore bays, including GSB, produce more blue crabs than any other New York State area, an estimated 74 % of landings in 1997. Blue crabs are commercially harvested by pots during the warm months and by dredges in winter. Recreational harvesting by collapsible traps, hand lines, and dip nets also takes place, but the level of recreational crabbing activity within FIIS is unknown. Incidental capture of diamondback terrapins in traps set for blue crabs could be a threat to these turtles if the animals drown before the traps are tended (Conover et al. 2005).

Groundwater Withdrawal and Contamination

Fire Island's groundwater is an important yet relatively understudied resource compared to the groundwater on Long Island. Activities like pumping for potable use, discharge of septic tanks/cesspools, and land application of fertilizers and pesticides have the potential for depleting groundwater quantity or quality.

Pumping Water for Public Supply: Groundwater is withdrawn across Fire Island for potable use. Virtually all of the potable water supply is withdrawn from the Magothy aquifer (Figure 7) because freshwater in the overlying upper glacial aquifer is limited to an isolated, shallow lens where withdrawal has been abandoned due to elevated levels of chloride, nitrate, and coliform bacteria (Leggette, Brashears and Graham, Inc. 1996). Fire Island was served by ten public water-supply systems in 2005, ranging from public supply wells operated by the Suffolk County Water Authority (SCWA) to localized water suppliers run by the communities or Robert Moses State Park. Summarized in Table 13 are monthly groundwater withdrawal data compiled as part of an ongoing study to better constrain the Fire Island groundwater system (Schubert 2007). Pumpage is low in the winter months (49,000 kl in December 2005) but soars in summer months (340,000 kl in August 2005). A total of 1,800,000 kl of groundwater was withdrawn for Fire Island's subsurface in 2005.

Fire Island groundwater withdrawal rates are currently sustainable and have not caused a noticeable depression in groundwater levels over the recent period of record (Figure 20). The relative absence of paved surfaces and high recharge rate (Christopher Schubert, USGS, personal communication) coupled with the return of most of the water to the subsurface via septic tanks and cesspools suggest that the quantity of groundwater is not threatened by potable water use.

Wastewater Discharge to Groundwater: Although groundwater quantity does not appear to be threatened by human activities on Fire Island, water quality may be. For Long Island, approximately 85% of pumped groundwater is returned to the groundwater system: 70% via septage and 15% via leaky distribution systems (Franke and McClymonds 1972). Thus, it is estimated that 240,000 kl of wastewater was returned to Fire Island's groundwater in August of 2005, whereas only 34,000 kl was returned in December of that year. Wastewater contains pathogens, organic compounds, nutrients, and other materials that can have a deleterious effect on water quality. The USGS recently installed monitoring wells across Fire Island to better characterize seasonal shallow groundwater quality, as it may be impacted by the large numbers of visitors to the island. Figures 21 and 22 show locations of installed wells and groundwater total nitrogen concentrations measured on three dates in 2005 and 2006. Concentrations increase in the summer months due to extensive recreational use, though there is insufficient information to draw conclusions across the entire boundary of FIIS. Submarine groundwater discharge could potentially threaten shallow bay habitats within park boundaries, and septic discharge is threatening surficial groundwater quality. In 2008 nitrate was not detected in any of the three drinking water supply areas on Fire Island; all deep wells from the Magothy aquifer (SCWA, 2008).

Destruction from Human Movement Activities

Physical disruption of habitat by humans or domesticated pets is another threat to some of Fire Island's natural resources. Driving on the beach and littering likely are the most important potential threats to the beach communities, but their environmental impact and scope at FIIS are undocumented. Steinbeck (1999) found ORV traffic significantly altered ocean beach communities by disrupting wrack, a key resource and refuge for this community. Human or

Table 13. Groundwater withdrawal rates on Fire Island (Christopher Schubert, USGS, written communication).

	Withdrawal (thousands of liters)												
Company/District Name	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Ocean Bay Park Water District	1,090	1,374	485	2,279	5,951	10,156	14,260	15,713	10,546	5,152	2,903	3,047	72,956
Ocean Beach Park Water District	15,842	12,401	13,964	17,489	28,939	20,555	40,368	40,250	29,640	14,903	14,604	12,178	261,133
Saltaire Water District	2,430	3,876	3,486	3,025	11,197	19,404	14,650	24,586	19,537	1,726	5,137	3,225	112,279
Seaview Water District	0	0	0	8,589	19,094	24,064	35,931	28,315	15,452	0	0	0	131,445
Robret Moses State Park	7,976	4,384	7,385	9,062	10,951	19,726	22,837	29,413	13,976	6,250	5,716	3,335	141,010
SCWA: Davis Park Zone	19,400	8,252	4,690	6,878	14,912	14,866	17,655	14,813	9,720	7,974	3,264	2,736	125,161
SCWA: Fair Harbor-Summer Club Zone	7,192	3,659	12,754	8,988	21,067	32,560	41,635	49,746	36,822	25,175	11,392	7,303	258,291
SCWA: Kismet Zone	340	267	417	4,985	6,314	8,547	14,148	16,018	9,382	6,481	1,919	322	69,141
SCWA: Point O'Woods-Fire Isl. Pines Zone	14,557	16,490	17,050	34,124	53,790	81,284	107,653	117,427	91,674	48,594	27,398	16,555	626,595
Total	68,826	50,703	60,232	95,418	172,215	231,163	309,136	336,281	236,748	116,255	72,332	48,702	1,798,011

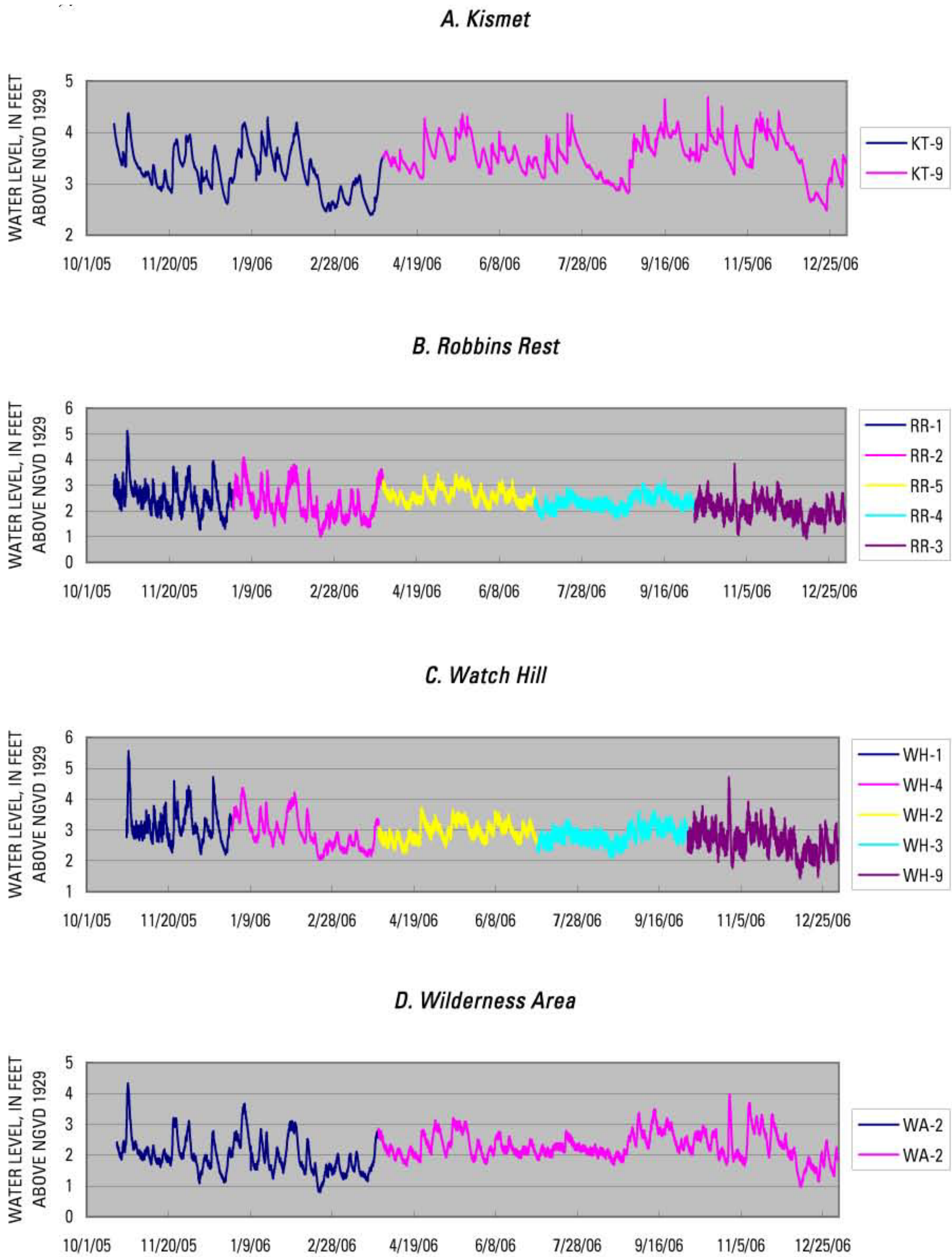


Figure **20**. Continuous groundwater level records during October 2005 to April 2007 at selected wells on Fire Island, Suffolk County, NY (NGVD 29, National Geodetic Vertical Datum of 1929); data from Schubert 2007.

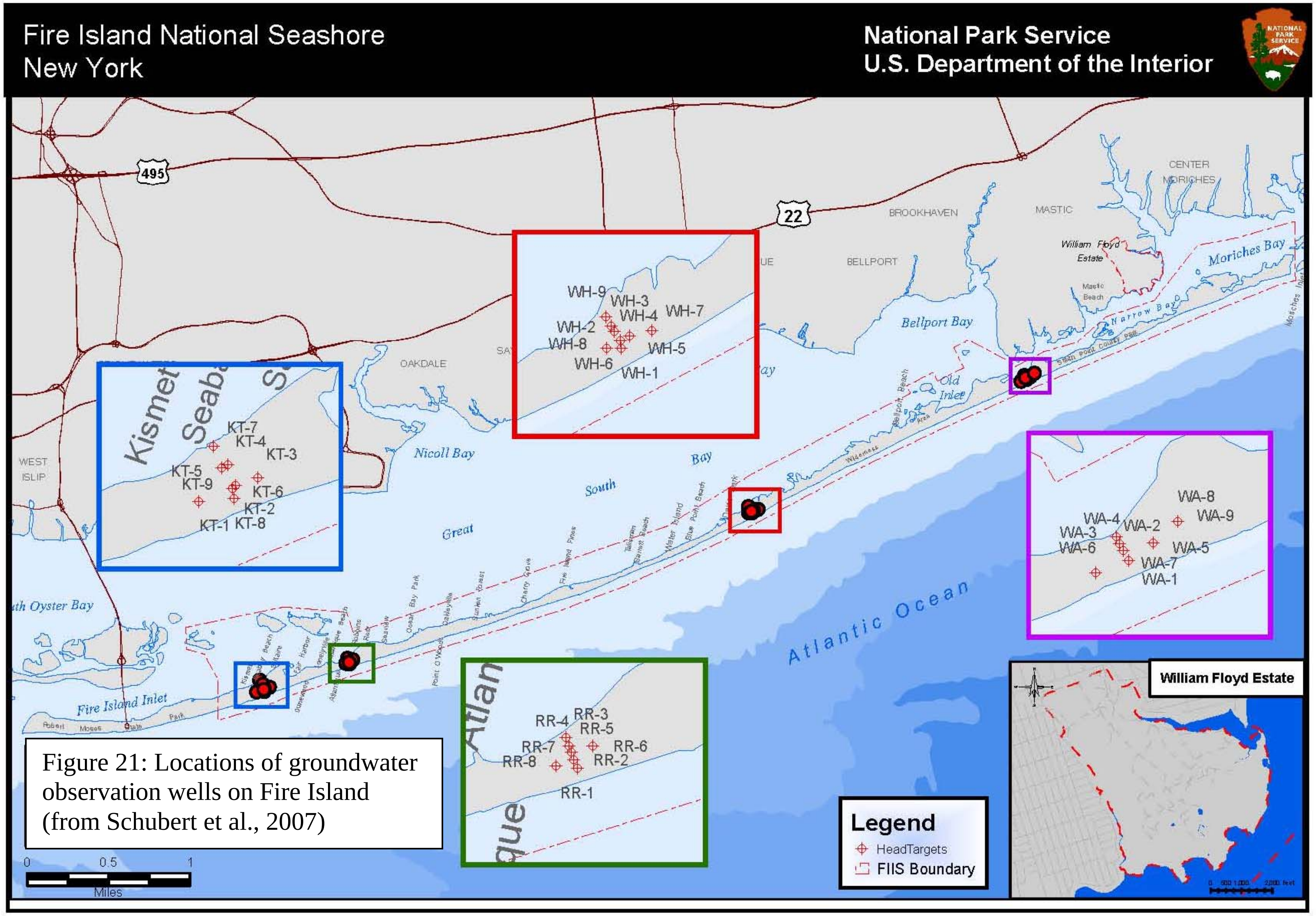


Figure 21: Locations of groundwater observation wells on Fire Island (from Schubert et al., 2007)

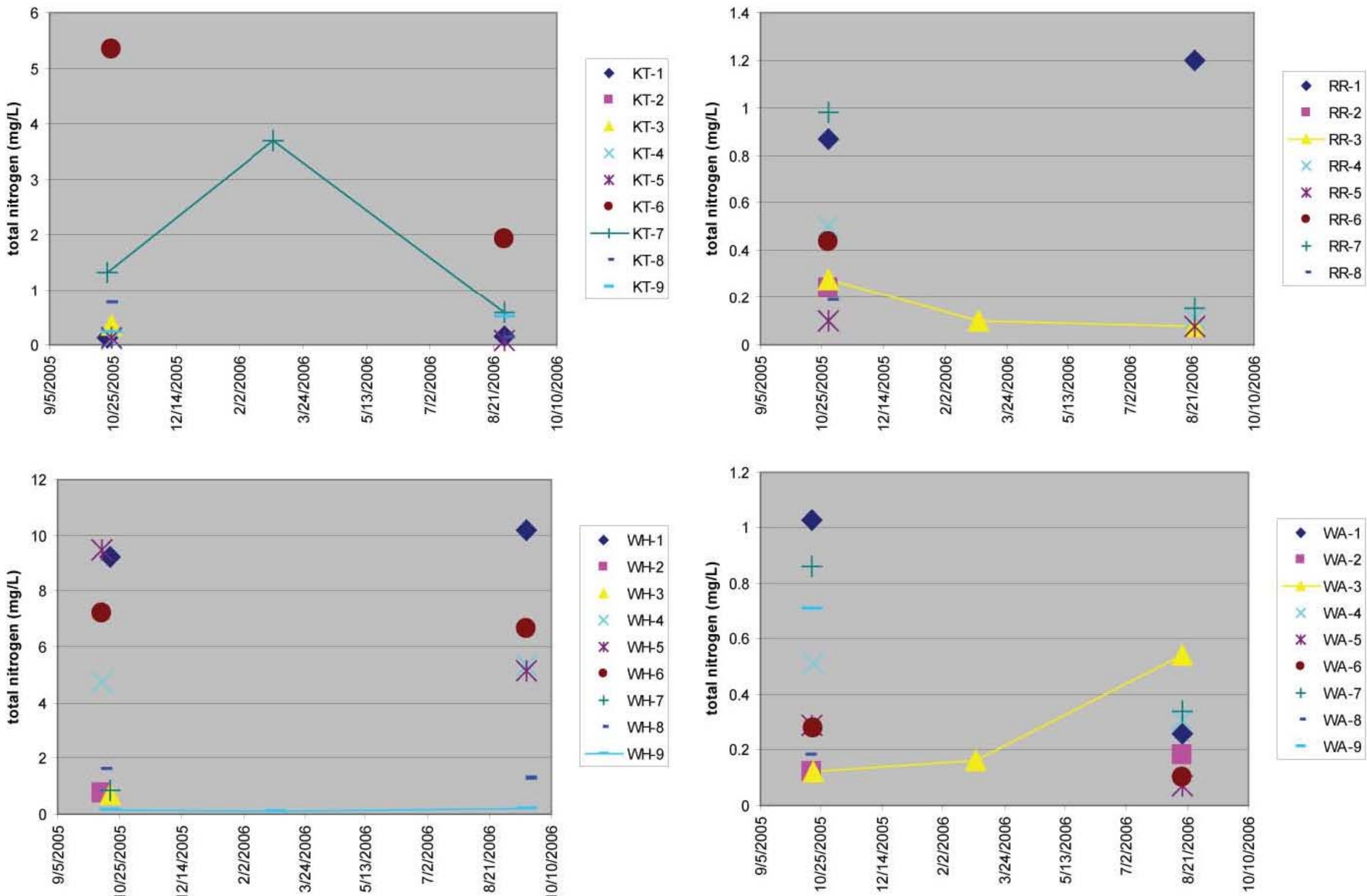


Figure **22**. Total nitrogen concentrations monitored in 2005 and 2006; data from Schubert 2007.

domestic animal trampling of dunes can kill vegetation, thereby increasing the possibility of erosion and blowouts and inhibiting dune restoration efforts. As a result, the NPS has taken preventative measures such as prohibiting walking on the dunes, physically barricading the most sensitive areas, and planting native, maritime dune flora that discourages trampling (i.e., poison ivy—not only do these species keep people away from fear of allergic reaction, but their root system provides substrate for dune growth; Michael Bilecki, NPS, personal communication). Domestic animals that accompany humans to Fire Island must be kept on leashes in NPS areas. It is not known if any quantifiable measurement of dune trampling has been made, although it is likely that current efforts to curb trampling are sufficient, as the areas most visited (e.g., the beaches adjacent to Fire Island communities) are some of the most patrolled by park personnel and lifeguards. The extent of trampling in the more remote areas of Fire Island (e.g., The Wilderness Area) is likely to be minimal due to limited visitation.

Off-road vehicles pose another serious threat to beach and dune communities. A study on Fire Island demonstrated that even minimal (once per week) traffic by ORVs on coastal foredunes led to significant reduction in dune grass and changed the dune profile in a manner likely to increase erosion (Anders and Leatherman 1987). Sea beach amaranth and piping plovers both utilize beach faces; therefore, driving on beaches and dunes is likely to threaten these and other rare, threatened, and endangered species.

Invasive Species and Problematic Native Species

Brown Tide

Blooms of *Aureococcus anophagefferens*, the picoplankton known as "brown tide," have been recurring in Great South Bay since 1985. Blooms tend to be associated with embayments that experience episodes of high organic nutrients, long water residence times, and high algal biomass resulting in reduced light penetration (Gobler et al. 2005). Once started, blooms can spread to cover wide areas. As early as 1987, it was clear that brown tide could decimate shellfish populations, such as bay scallops (Bricelj et al. 1987), mussels (Tracey 1988), and clams (Tracey 1988; Gainey and Shumway 1991; Bricelj et al. 2001), in addition to causing shading that negatively influenced eelgrass beds. The toxicity of brown tide to shellfish seems to be physical rather than chemical and involves reduction of gill function on contact (Gainey and Shumway 1991).

Documented impacts of brown tide in GSB are primarily associated with diminished growth and survival of the northern quahog, *Mercenaria mercenaria*. Studies have indicated that brown tide can cause mortality in juvenile clams (Greenfield and Lonsdale 2002), can reduce clam phytoplankton absorption rates (Greenfield et al. 2004), and can slow clam growth (Weiss et al. 2007) even at sub-bloom concentrations, although, as discussed above, blooms of brown tide are likely to negatively impact SAVs.

Brown tide had not bloomed extensively in Long Island waters since 2002 (Gobler et al. 2005), but bloomed again during the summer of 2008 (Finlayson, 2008). It is likely that recurrent blooms will continue to pose a threat to aquatic resources on the bay side of FIIS.

Non-indigenous Fishes and Invertebrates

Great South Bay is home to a number of non-indigenous marine species. Some, such as green crab (*Carcinus maenas*), colonized regional waters centuries ago, making it nearly impossible to discern any ecological disruptions they caused. Others colonized east coast waters much more recently, such as the Asian shore crab (*Hemigrapsus sanguineus*) in 1988. Studies have shown that they out-compete native northeastern mud crabs and green crab (Gerard et al. 1999; Jensen et al. 2002). A likely new invader is the Chinese mitten crab (*Eriocheir sinensis*), which is catadromous and could utilize the meso- and oligohaline tributary waters on the north side of Great South Bay. The first adult specimens of this species were seen in the Hudson and other east coast estuaries in 2007, and young individuals were seen in greater abundance in the Hudson and elsewhere in 2008. Mitten crabs may cause habitat damage by burrowing into marsh banks.

A new threat to bathers and people who fish in FIIS bay waters is the colonization of Atlantic coast waters by the Indo-Pacific lionfish (*Pterois volitans*) (Whitfield et al. 2002), a species with venomous spines. Juveniles of this species have become abundant enough in Long Island's south shore bays for aquarists to target them for collection. Although it is unlikely to have serious ecological consequences, it is possible that naïve or careless fish collectors, anglers, and swimmers will receive painful stings.

Invasive and Non-native Upland Vegetation

The National Park Service recently completed an inventory of invasive plants in portions of FIIS, specifically the Otis Pike Wilderness Area in the eastern portion of Fire Island and the William Floyd Estate on the mainland of Long Island (Villalba et al. 2007). Unfortunately, due to limited time and sources, only fields and main trails of the William Floyd Estate were assessed, and occurrence of the common reedgrass (*Phragmites australis*) was not quantified because it was so abundant. *Phragmites* remains a pervasive threat in brackish interdunal swales and the salt marsh ecosystem, especially in the upper fringes of the high salt marsh, the salt shrub band, and brackish habitats (Art 1976; Dowhan and Rozsa 1989; Klopfer et al. 2002; Stalter 1979; Stalter et al. 1986; Whitfield et al. 2002). This aggressive species changes the hydrology of the marsh surface and is generally thought to provide poor habitat and food resources for aquatic fish and invertebrates, and thus some migratory birds. Villalba also notes the Japanese Black Pine (*Pinus thunbergiana*) was the most abundant invasive plant in the Wilderness Area, and that autumn olive (*Eleagnus umbellata*) and common mullein (*Verbascum thapsus*), species usually associated with disturbed areas, were also abundant (Villalba et al. 2007).

A detailed invasive exotic plant inventory was conducted at FIIS during the summer of 2002 (Schwager 2002). Thirteen areas within FIIS were surveyed for 15 invasive plants. The most abundant species encountered were autumn olive, nodding thistle (*Carduus nutans*), and spotted knapweed (*Centaurea maculosa*). Fire Island's poor sandy soils and salt spray may prevent the introduction and spread of some invasive species that are a problem on Long Island, such as Japanese barberry (*Berberis thunbergii*), purple loosestrife (*Lythrum salicaria*), and mile-a-minute vine (*Polygonatum perfoliatum*). Hiking trails, bike paths, and roads provide dispersal corridors throughout FIIS, and most of the invasive species surveyed were found along these routes. Species that are currently present at low levels but may spread quickly include Oriental bittersweet (*Celastrus orbiculatus*) and Japanese honeysuckle (*Lonicera japonica*).

Deer

White-tailed deer populations have grown dramatically on FIIS since the early 1980s, and their impact has been documented in several research studies (e.g., Forrester and Leopold 2005; Forrester et al. 2006; Forrester et al. 2007; Underwood 2005). Special attention was paid to the impact of excessive deer browse on the globally rare maritime holly forest at Sunken Forest (Forrester and Leopold 2005; Forrester et al. 2006; Forrester et al. 2007). Within the maritime holly forest, trees become established in canopy gaps created by wind storms that topple large trees. The current high level of deer browse at Sunken Forest is impeding the regeneration of the vegetation in this forest (Forrester et al. 2007). By studying the soil seed bank, Forrester and Leopold (2005) concluded that if the white-tailed deer browsing on saplings was reduced or removed, then the characteristic overstory species would rebound to levels seen before the deer population increase. Comparison of the vegetation in and out of deer exclosures over three decades indicates that the potential natural recovery within the maritime holly forest could occur if deer herbivory were limited (Forrester et al. 2006).

Global Climate Change

Sea-Level Rise

Roman et al. (2007) recently completed a 52 month study evaluating marsh surface elevations with respect to sea level rise at three salt marsh locations on Fire Island: Great Gun Meadows, Hospital Point, and Watch Hill. All three sites were not keeping pace with even conservative estimates of sea level rise. These data suggest that existing marsh will be converted to mud flats with the marsh migrating upland when possible. The extensive armoring of the bayside of Fire Island will restrict this migration, resulting in eventual marsh loss.

Relative Mean Sea Level (RMSL) has risen at about 2.8 mm/year over the past century at The Battery in New York City. At Sandy Hook, New Jersey, RMSL has increased about 3.4 mm/year. The greater rate of RMSL at Sandy Hook is due to compaction of the unstable sediments of the barrier beach system. RMSL at Fire Island is probably similar to that at Sandy Hook. According to Pendleton et al. (2004), RMSL may rise another 480 mm by 2100. Psuty et al. (2005) state that there is not a sufficient sediment supply to the island given the projected rise in sea level, and thus the island is potentially vulnerable to extensive erosion. Of course, this projection is somewhat uncertain because RMSL rise may contribute to accelerated erosion of other features, such as coastal bluffs located to the east of Fire Island, that could help maintain the barrier island in some configuration. If the sediment supply is insufficient to maintain the barrier island system, Fire Island may cease to exist without extensive armoring or beach nourishment. The extensive wetlands behind the barrier islands could also be lost due to flooding and/or the loss of physical protection from the island.

The susceptibility of FIIS to the effects of sea-level rise was investigated as part of a USGS study determining the island's coastal vulnerability index (CVI; Pendelton et al. 2004). The CVI was determined based on six variables that influence coastal evolution: geomorphology, shoreline change rate, coastal slope, relative sea-level change, mean significant wave height, and mean tidal range. Vulnerabilities were determined for each factor as well as a total CVI combining all factors for the shoreline, which was broken up into 36 discrete cells along its east-west axis (Figure 23). The eastern

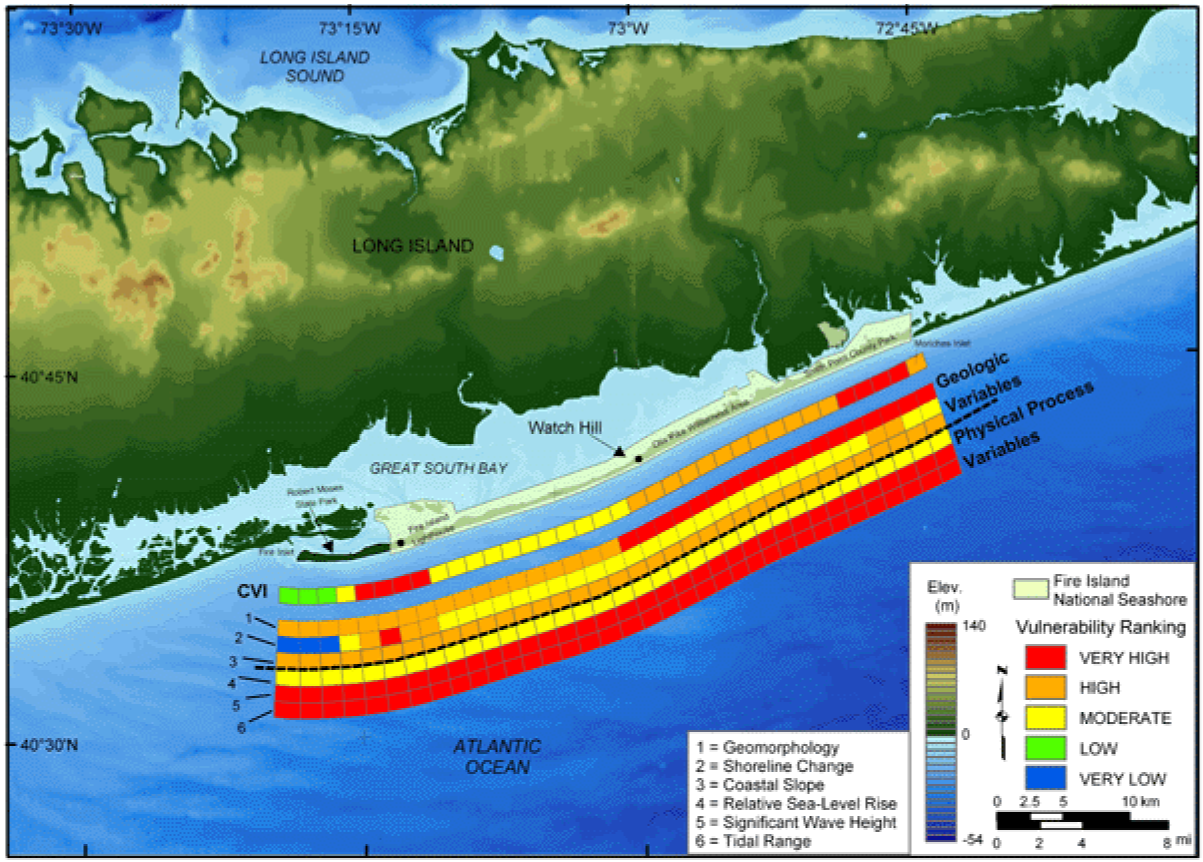


Figure **23**. USGS CVI and vulnerability map (data from Pendleton et al. 2004).

half of FIIS had a CVI of either "high" or "very high" with the eastern end being most vulnerable. The western half of FIIS, with the exception of the area just to the west of the lighthouse, has a CVI of either "low" or 'moderate."

Eutrophication

Sea-level rise, in addition to causing potential physical alterations to Fire Island, may also contribute to increasing pollution of GSB and Moriches Bay. As the water table rises, cesspools and septic systems will be compromised, along with storm water mitigation systems, exacerbating nutrient addition problems discussed above in the "Nutrient Loading and Phytoplankton Biomass" section. This and other potential failures of infrastructure linked to climate change should be considered in long range planning.

Assessment Of Natural Resource Condition Within FIIS By Habitat

The following section summarizes the condition of the significant habitats and associated living resources within FIIS. This information is presented in tabular format in Table 14. It should be noted that assessment of condition is based on best professional judgment following review of available published data. For each resource, specific indicators of condition are listed, assessment of current condition given, and the source of data on each indicator provided. A resource was designated as being in "good" condition if available data or trends in data suggest good or acceptable condition. A resource was listed as being in "poor" condition if trend data or other information suggested clear concern. The resource was designated as being "at risk" if information on current condition or threats indicate that condition is likely to deteriorate. Finally, if insufficient quantitative data were available with which to discern condition, the current condition was listed as "unknown." In making these designations, it should be pointed out that condition in the wilderness area on the eastern edge of FIIS is generally better than condition in the areas of Fire Island inhabited by people. Furthermore, it should be pointed out that although habitats and resources along the northern boundary of GSB may be in poor condition, the extent to which factors affecting these areas and resources impact resources within the boundary of FIIS is often difficult to discern.

Marine

Oceanside

There are little data on the species composition and abundances making up the oceanside resources within FIIS, so the status of these resources is unknown. Due to weaker connectivity to human populations outside FIIS and a high degree of mobility of organisms found in this habitat, these resources are less subject to local threats. Water quality, at least as measured by fecal coliforms, is good, rarely exceeding state standards (SCDH). Long term data on chemical contaminants at the Fire Island Inlet collected by NOAA indicates decreasing trends in some contaminants, but recent spikes in others or no trends, suggesting that oceanside resources, at least near the inlet, could be at risk for chemical contamination.

Bayside

Due to the semi-enclosed nature of GSB, the status of marine habitats and species that rely on this area is potentially threatened by changing environmental conditions and alterations in species composition The status of shellfish, particularly hard clams, within GSB is severely depressed (Conover et al. 2005; Hinga 2005). These species represent an important cultural and economic resource to the area, and through their filtering ability represent a key ecological resource whose presence can mitigate the potential effects of harmful algal blooms, such as brown tide. Periodic HAB remain a problem. Given its importance as habitat for a wide variety of organisms, the status and condition of SAV remain an area of concern. Significant declines in the population of winter flounder that spawn within GSB is also a concern, as this species has discrete stocks with limited geographic range (Conover et al. 2005). Finally, in GSB and other coastal areas, colonization by invasive species remains an important potential threat (Gerard et al. 1999; Whitfield et al. 2002).

Table **14**. Current conditions and trends of, and threats to, FIIS natural resources.

Classification based on best professional judgment following review of available data, condition for each indicator was assigned as follows:

Good condition – Trend data or other information suggests good or acceptable condition for the specific measure.

Poor condition -- Trend data, threats information, or other information for the specific measure suggests concern, perhaps indicating poor condition.

At Risk condition – Trend data or other information suggests good condition for the specific measure, but there is some information on condition or threats that may tend toward a condition of concern.

Unknown condition – Insufficient data to assign a condition category.

Resource	Indicator	Current Condition	Condition Notes and Data Source
MARINE			
Oceanside	Species composition and abundance	Unknown	• limited data available
	Water Quality (fecal coliform	Good	• monitoring since 1970s with rare exceedence of state standards (SCDH)
	Water column contaminants (at FI Inlet)	At Risk	• Decreasing trend of chlorinated pesticides, DDT, total chlordanes, and butyl tins, metals no trend (mercury, cadmium) or increasing for chromium, and silver. High PAHs at Fire Island Inlet (Source: Fig. 17, NOAA 2006)
Bayside	Species composition/abundance	Poor	• declining winter flounder recruitment (Conover et al. 2005) • shellfish declines (oyster, hard clam, bay scallop) (Conover et al. 2005, Hinga 2005) • increases in non-native species, e.g., Japanese Shore Crab, Indo-Pacific Lionfish (Gerard et al 1999, Whitfield et al. 2002) • Brown Tide, Harmful Algal Blooms occurrences (Greenfield and Lonsdale 2002, Conover et al. 2005, McElroy 1996)
	SAV (within FIIS boundary)	At Risk	• SAV beds common along FIIS shoreline (Fig. 8) • long-term trends in distribution declining (Pickerel 2007, Bokuniewicz et al. 1993)
	Water column contaminants	At Risk	• Decreasing trend of chlorinated pesticides, DDT, total chlordanes, and butyl tins (Fig 17, NOAA 2006), although elevated levels of Ni and Sn at Moriches indicate local sources
	Sediment contaminants	Good	• Hazard Quotients indicate concern only for some metals and organics (Source: Cooper 2007 and Table 11). • acceptable sediment toxicity tests, exceedences of toxic thresholds limited, community does not suggest degraded conditions (EPA 2007)
	Water column nutrients	At Risk	• Decreasing trend in nutrient loading, 1952-97 (Fig. 12, Monti and Scora 2003) • Nutrient and chlorophyll a levels ranked as eutrophic in comparison to region (EPA 2007)
	Dissolved Oxygen	At Risk	• Localized hypoxic condition, but no widespread hypoxia (Hinga 2005, Fig. 13 and 14)
	Fecal Coliform	Good	• No trend 1976-2003 with less than 10% of measurement exceeding bathing standard (Fig. 15); Exceedences focused on mainland shore of Bay (Fig 16) declining trend from 1976 to present, but increase in N level since 2000 (Fig. 10, SCDHS)

Table **14**. Current conditions and trends of, and threats to, FIIS natural resources.

Resource	Indicator	Current Condition	Condition Notes and Data Source
INTERTIDAL			
Salt Marsh	Species composition/ abundance	Good	• Among best examples of salt marsh in NY State (NY Natural Heritage Biotics Database 2007) • Supports diversity of community types, including NY state reference standards for salt shrub, high salt marsh, and salt panne (MacDonald and Edinger 2000) • Supports rare species (e.g., salt marsh sharptailed sparrow)
	Geomorphological processes	At Risk	• Extensive ditching, altered landscape pattern and hydrology (Klopfer et al. 2002) • Marsh elevation not keeping pace with sea-level rise in recent past (Roman et al. 2007) • Shoreline structures on western portion impede natural processes (Fig 19, Rainault 2006, Nordstrom and Jackson 2005)
Beach	Species composition/abundance	Good	• Rare bird species and forage habitat (NY Heritage) • Piping Plover forage sites (Elias et al. 2001) • Largest extent of ocean beach in NY state (NY Natural Heritage Biotics Database 2007) • Supports rare plants and animals (seabeach amaranth, seabeach knotweed, Piping Plover), yet rare plant abundance is declining (Barrera et al. 2007)
	Shoreline processes	Poor	• Although natural processes prevail in wilderness area and condition there is good, shoreline structures on western portion impede natural processes (Fig 19, Rainault 2006, Nordstrom and Jackson 2005) • Beach nourishment and beach scraping in developed portion of island is littering adjacent areas (Psuty et al. 2005) • High vulnerability to sea-level rise impacts on eastern portion of Fire Island (Fig 23, Pendleton et al. 2004)
UPLAND			
Maritime Dunes	Species composition, abundance, extent	Good	• Largest extent within NY state (NY Natural Heritage Biotics Database 2007) • Supports rare plants and animals (NY Natural Heritage Biotics Database 2007)
	Geomorphological processes	At Risk	• Natural processes prevail in wilderness area and dunes are in good condition, but man-made structures altering dune migration in settled portions (Psuty et al. 2005)
Maritime Forests/ Woodlands	Species composition, abundance, extent	At Risk	• Sunken Forest premier example of Holly Forest, among oldest in the world (Art 1976, Edinger et al. 2008) • Deer browsing is a concern (Forrester et al. 2006, 2007
Maritime Dune Wetlands	Species composition, abundance, extent	At Risk	• Phragmites invasion is a concern • Over 2-ha of interdunal swale classified as state significance (NY Natural Heritage Biotics Database 2007)
Maritime Shrublands	Species composition, abundance, extent	At Risk	• Likely most extensive in NY State and exemplary example (NY Natural Heritage Biotics Database 2007) • Invasive species (Villalba et al. 2007, Schwager 2002)

There are relatively little data on water column and sediment contaminants (NOAA 2006; EPA 2007). Levels of chlorinated pesticides appear to be decreasing, but at Moriches elevated levels of some metals indicate local sources of contamination, suggesting risk. Available data on sediment contaminants and toxicity tests indicate that condition of this resource is generally good. Although water column nutrients have generally been decreasing, nutrient and chlorophyl a levels rank GSB as being eutrophic in comparison to the region (EPA 2007). Hypoxia appears to be a problem only in localized areas.

Intertidal

Salt Marsh

The salt marshes of FIIS are considered to be in good condition. This can be inferred by their designation as reference wetlands by the NY Natural Heritage Program. While there may be larger and higher quality salt marshes elsewhere, it is clear that the FIIS salt marshes are among the best examples in New York (NY Natural Heritage Biotics Database 2007). Three natural communities (Salt Shrub, High Salt Marsh, and Salt Panne) within the salt marsh habitat were selected as reference wetlands in a study conducted by NY Natural Heritage (MacDonald and Edinger 2000). In this study reference wetlands were equivalent to “reference standard wetlands” defined as: “a group of wetlands that represents the range of variation of the same class and that maintains functions at characteristic levels for that class under unaltered or least altered conditions” (Brinson 1998). A qualitative comparison of barrier island salt marshes along the Atlantic Coast would allow a more accurate comparison (e.g., compare size, condition, and landscape context) of the FIIS with marsh systems in other areas.

Fire Island Wilderness Area was chosen as a Salt Shrub reference wetland for its landscape context and intact storm overwash features. Linear patches of salt shrub form in a dynamic pattern along the landward margins of salt marsh. The salt shrub at the Fire Island site is the least impacted along south shore by barrier spit stabilization and invasion by common reedgrass. Vegetation is diverse and was the most variable found on any south shore setting (MacDonald and Edinger 2000).

Fire Island National Seashore was chosen as a High Salt Marsh reference wetland because of its excellent landscape setting and its intact storm overwash features and undisturbed barrier beach. This location was the highest ranked backbarrier fringe-marsh (Oertel and Woo 1994) found on the south shore of Long Island. Disturbance has been minimal, and the marsh shows many areas of storm overwash and recent formation on relict inlet deltas. Vegetation is the most diverse of the backbarrier fringe-marshes sampled. There is sufficient freshwater input at Old Inlet to produce a low quality sea level fen. This site has vegetation characteristic of the south shore where high salt marsh is dominated by the cordgrass, spikegrass, and saltmeadow cordgrass (MacDonald and Edinger 2000).

Fire Island Wilderness Area represents the best landscape setting for Salt Panne development on the south shore. Intact overwash and relict inlet features form high marsh surfaces for panne formation. Ditching influences ninety-five percent of the marsh surface, but ditches are widely spaced at about 40–60 meters apart. Pannes are positioned on sinuous 200-400 meters wide patches of high marsh. Vegetation composition reflects the adjacent marsh and is dominated by the dwarf form of cordgrass, spikegrass, and saltmeadow cordgrass. Panne vegetation at this location contains appreciably higher salt marsh species than other locations and lower soil pore water salinity (23

PSU) than most locations surveyed. Disturbance is frequent in pannes influenced by bayside storms as well as stochastic Atlantic-side overwashes. Pannes show signs of formation by storm wrack deposition and scour. At some locations, active dunes are currently covering pannes (MacDonald and Edinger 2000).

Although the existing marshes serve as reference wetlands, there are important threats experienced by this resource due to geomorphological processes. Salt marsh ditching and open marsh water management is an existing problem altering the hydrography of the marsh systems. Wetland area lost due to bayside erosion should also not be ignored. The combined impact of these processes put salt marshes at risk for degradation.

A recent study conducted on the Fire Island Wilderness Area marshes suggests that elevation increases of the marsh are not keeping pace with the rate of sea-level rise (Roman et al. 2007). If this trend were to continue for the long-term, the marshes could become wetter, areas of high marsh *Spartina patens* may convert to the more flood-tolerant *Spartina alterniflora*, and open water habitat may increase. Marsh conversions of this type have been noted elsewhere on Long Island (e.g., Hartig et al. 2002).

Beach

Oceanside Beaches: Covering about 405 ha, the maritime beach on the south shore of Fire Island is the largest example in the state currently documented by NY Natural Heritage (NY Natural Heritage Biotics Database 2007). Beaches within the wilderness area in the eastern portion of FIIS are undisturbed, and although the beaches along the more developed, western portion of FIIS appear to be in good shape, recent studies have quantified that the effects of beach replenishment and scraping projects in developed areas significantly influence the beach in others areas and tends to enhance erosion (Kratzmann and Hapke 2008). The maritime beach extends 52 km along the south shore of Fire Island from Democrat Point east to Moriches Inlet with an 11 km stretch within the Otis Pike Fire Island High Dune Wilderness (NY Natural Heritage Biotics Database 2007). Recreation on the ocean-side beaches is the primary factor drawing the multitudes of park visitors each year. In addition to the recreational value of the ocean-side beaches, these beaches provide habitat that supports rare and endangered species, such as the federally threatened seabeach amaranth, the state rare seabeach knotweed, the federally endangered Piping Plover, and Common Tern, Least Tern, Roseate Tern, and Black Skimmer (NY Natural Heritage Biotics Database 2007).

Bayside Beaches: The bayside beaches are significant for their role as nursery and nesting habitat for a wide variety of estuarine organisms and as habitat for migratory water birds.

Bayside beaches in the undeveloped wilderness portion of FIIS are in good condition, but beaches throughout the western portion of the Seashore where shoreline stabilization structures have been built are in poor condition due to the impact of these structures on natural sediment transport processes (Nordstrom and Jackson 2005).

Upland

Maritime Dunes

Klopfer et al. (2002) mapped 270 ha of maritime dunes on Fire Island, making them among the largest documented dune environments in New York State (but occurrence information for this example has not been entered into the NY Natural Heritage Biotic Database). Jones Beach is currently the largest maritime dune occurrence (360 ha) in the state with the second largest (200 ha) at Robert Moses State Park at the east end of Fire Island (NY Natural Heritage Biotic Database 2007).

In the wilderness natural processes prevail, and dunes are in good condition, but in settled portions of Fire Island, man-made structures are altering dune migration (Psuty et al. 2005), putting this resource at risk.

Maritime Forests

The rarest vegetation association at FIIS is the maritime holly forest at Sunken Forest. It is the oldest of only two known occurrences in the world. The other, larger example coincidentally grows on NPS land on Sandy Hook at Gateway National Recreation Area (Edinger et al. 2008). Sunken Forest is considered an excellent example of maritime holly forest by NY Natural Heritage (NY Natural Heritage Biotics Database 2007). Although the maritime holly forest at Sunken Forest is much smaller in size (26 ha) than the example at Sandy Hook, NJ (108 ha), it is apparently a more mature forest (Art 1976), and the surrounding landscape has fewer anthropogenic disturbances (Klopfer et al. 2002, Edinger et al. 2008). The ages of the dominant holly trees are generally 100-150 years with at least one tree reaching 164 years old (Art 1976). The Sandy Hook occurrence is bisected by a regularly used paved park road, which serves as a corridor for invasive plants but lacks significant deer browse, whereas Sunken Forest has a less intrusive boardwalk and possesses a high incidence of deer browse. Because of its limited size and importance, the potential impact of deer browse puts the holly forest at risk.

Maritime Freshwater Marshes

One significant occurrence of a 2.02 ha maritime freshwater interdunal swale is documented at FIIS (NY Natural Heritage Biotics Database 2007). There may be an additional 1.2 ha of this community at FIIS given that Klopfer et al. (2002) mapped just over 3.2 ha of this vegetation association. Klopfer et al. (2002) mapped slightly over 4.0 ha of brackish interdunal swale at FIIS. If this was determined to be one occurrence in good condition (i.e., not excessively invaded by common reedgrass), then it would likely be considered significant from a statewide perspective by NY Natural Heritage. Currently, there are three occurrences of brackish interdunal swale in the state (NY Natural Heritage Biotics Database 2007): Jones Beach Island East (3.6 ha), Jones Beach Island West (7.3 ha), and Walking Dunes (7.3 ha).

Conclusions

Summary

Fire Island's proximity to New York City and highly urbanized areas of the northeast United States appear to make it particularly vulnerable to natural resource degradation. Despite being situated in one of the most densely populated areas of the nation, natural resource conditions in FIIS remain relatively healthy. Nevertheless, the fragile nature of this ecosystem and its vulnerability to human-made and natural stressors require careful management of resources and monitoring of existing and potential threats and stressors.

Major threats to FIIS resources include: pollution, habitat alteration, human overuse, invasive species and problematic native species, and global climate change. These threats are summarized in Table 10. The condition of each of the main habitats within FIIS has been assessed with respect to specific threats under these general categories and their status summarized in Table 14. Both tables identify the indicators used to evaluate impact and the primarily data sources used in our assessment. As Table 10 shows, almost all resources within FIIS are potentially threatened. This is largely because of their proximity to urban centers, the vulnerability of resource habitats to physical disruption from storms and wave action, and the presence of problem native or invasive species. Despite these obvious threats, as indicated in Table 14, only a limited number of the resources associated with FIIS are currently in poor condition. These findings argue for continued, and in some cases expanded, monitoring of the park's resources.

The primary existing threats endangering FIIS resources concern: habitat alteration of salt marshes and shoreline; human overuse impacting shellfish, SAV, and endangered species, such as the seabeach amaranth and piping plovers; invasive species and problematic native species, such as brown tide blooms, impacting shellfish and SAV; *Phragmites* out-competing native salt marsh plants; and deer populations threatening woody species regeneration. Although levels of nutrients in GSB waters have been stable or decreasing, organic nutrients are listed as an existing threat due to cultural eutrophication that has led to high levels of productivity and likely contributes to brown tide blooms. In addition to existing threats, many of these stressors pose a potential threat to many of the park's natural resources and habitats.

Excessive erosion on both the bay and ocean side of Fire Island is probably the most serious immediate threat facing homeowners and businesses on Fire Island. On the bay side, erosion adjacent to sensitive habitats, such as the submerged forest, could threaten these areas of critical importance. Armoring of bayside shoreline for both private and public development has already caused significant loss of adjacent unarmored shoreline. A plan to address and balance competing use must be formulated.

Erosion on the ocean side is driven largely by storms. Whatever actions are eventually adopted from the FIMP (US ACE 2005), the inevitability of sea-level rise and the likely impact of increasing storm intensity due to climate change will need to be considered for long-range planning at FIIS. In addition to direct physical damage and loss of habitat due to rising sea level, secondary effects leading to further water quality degradation are also likely. One of the geologic features of a barrier island is to protect interior land masses from ocean currents and storms. In that sense, natural erosion and sand migration is to be expected on the ocean side of FIIS. However, it is unclear what the extent of additional erosion due to climate change and sea-level rise will be. The future management plan of FIIS must strike a balance between the natural migration of a barrier island, rising sea-level and increased rates of erosion, and the needs of property owners and businesses within FIIS boundaries. In many ways, this is the single most difficult management challenge facing FIIS and requires a better understanding of the rates of natural erosion and increased rates of erosion attributed to climate change and sea-level rise.

Nutrient enrichment of the waters of GSB and Moriches Bay remains a potential problem. Long Island is the primary source of nutrient loading to GSB. The major threats to FIIS resources are degradation of bayside waters and the subsequent potential impacts on pelagic and benthic resources. Although nutrient concentrations generally have remained stable or decreased despite growing populations on the south shore of Long Island, the ability of the GSB ecosystem to process nutrient inputs could be exceeded at any time. In areas of high population density and restricted circulation, such as Moriches Bay, nutrient loading is already a problem.

Increased incidence of brown tide has been linked to groundwater inputs of nutrients. This picoplankton has negative impacts on shellfish populations and eelgrass beds even when it does not reach bloom concentrations. The potential for other HABs to take hold in GSB and Moriches Bay is also an issue. Re-establishment of shellfish communities in GSB, if successful, would help mitigate the effects of HABs, including brown tide. Promoting the recovery of SAV will also provide essential habitat to both fish and shellfish species. A better understanding of the population dynamics of resident aquatic species within GSB and FIIS, particularly those that are already in threatened or poor condition, such as clams, winter flounder, and SAV, would help gauge potential negative impacts and allow managers to verify the success of restoration efforts.

Along with nutrient contamination comes bacterial contamination due to run-off and wastewater inputs. Coliform data indicate that this is an existing problem at many sites along the northern shores of GSB and Moriches Bay, including sites at the eastern end of FIIS. Given the high visitation experienced by FIIS and the potential human health impacts, bacterial contamination remains an important issue. The intensity of human activity on Fire Island is also a threat to groundwater resources where nutrient loading from septage and land application of fertilizer as well as depletion from pumping for potable use are potential problems.

Although bacterial contamination is already an existing problem in a few areas, there is a general paucity of data on non-nutrient chemical contaminants. Surface runoff, sewage and septage inputs, and chronic petroleum inputs and spills associated with watercraft and their fuel remain potential problems, largely of unknown magnitude.

Essential or important upland habitats within FIIS also need to be protected. The regular monitoring of invasive plants on FIIS will detect new introductions and alert resource managers to the spread of known patches of already established invasive plants (Schwager 2002). Early detection and prompt management will likely be the most efficient ways to deal with invasive plants at FIIS. Continued attention needs to be focused on limiting human and domestic pet impacts on rare, threatened, and endangered species requiring dune habitat such as the piping plover and seabeach amaranth.

FIIS represents a unique property where heavily visited seaside recreation and wilderness areas exist in close proximity to a major urban center. Many of its resources are in excellent shape, but close monitoring of resource condition, potential threats, and an action plan designed to minimize threats will be important to sustain the park, particularly in light of global climate change and sea level rise.

Data Needs and Recommendations

There are a number of critical data needs outlined in this report. Many have already been identified in the Northeast Coastal and Barrier Island Network Vital Signs Monitoring Plan (Stevens et al. 2005). As can be seen in Table 13, we currently have insufficient data to allow assessment of condition or trends in condition for some FIIS resources, and many others are at risk. Acquisition of monitoring data recently begun as part of the Vital Signs Monitoring Plan should begin to address these data gaps. In 2007 nutrient enrichment, seagrass extent and condition, water quality, shoreline position, and salt marsh extent were measured within FIIS. Measurement of salt marsh vegetation, nekton, and elevation are scheduled to begin in 2009 with continued biannual sampling of all indices planned. Coastal beach and dune topography measurements will also be conducted in 2009-2010. Estuarine nitrogen loading and vegetation/habitat change monitoring is also scheduled to be done in 2010 and repeated at 5 to 10 year intervals. (Sara Stevens, National Park Service, personal communication). The Vital Signs Monitoring Plan, if implemented as planned, will eventually provide a long range data set for assessing trends within FIIS. Research and monitoring activities already underway as part of related management/conservation activities being conducted by the New York State Department of Environmental Conservation (NYSDEC), the New York State Department of State (NYSDOS), Suffolk County Department of Health Environmental Conservation Division, and the Long Island office of The Nature Conservancy should also be followed and available data included in future management plans for FIIS. Of particular note is the Great South Bay Restoration Research effort being currently funded by NYSDOS. This effort is collecting data to develop an ecosystem-based model that can be used to manage key resources of GSB (Robert Cerrato, Stony Brook University, personal communication). Once available, this model should be extremely helpful in the management of the aquatic resources of FIIS.

We believe the following monitoring activities deserve priority status.

- The retreat of bayside shoreline should be monitored closely, and management actions to mitigate the effects of existing and proposed bulkheads should be considered.

- A detailed analysis of recent nutrient monitoring data is warranted to determine if ambient nutrient concentrations are increasing. Seasonal monitoring of nutrients and DO in coastal embayments surrounding GSB would identify problem areas requiring remediation, hopefully before nutrient loading in these areas has a negative impact on GSB and FIIS. Similarly, only limited monitoring of groundwater nutrient levels has been conducted recently. It is recommended that a more extensive monitoring effort be implemented to determine the spatial extent and depth of nitrogen contamination, both within the groundwater system and within shallow bay habitats. These measurements should be continued with particular emphasis on monitoring during time periods of maximal drawdown during the summer. Monitoring of fecal and total coliforms or other suitable markers of sewage bacterial contamination should be expanded in GSB and Moriches Bay, particularly in the waters near FIIS, to ensure that this potential risk to human health is adequately assessed and support management plans enacted to reduce impacts.

- There are almost no data on levels of non-nutrient contaminants in GSB and Moriches Bay in general and FIIS in particular. Analysis of contaminants in indigenous filter feeding organisms, such as that underway in NOAA's Mussel Watch program, at several year intervals at some sites within or near FIIS waters would be a way to address this issue. Such a program would provide a measure of bioavailable contaminants within the waters of the park.

- FIIS should consider conducting an assessment of shellfish populations within its bayside boundary to better assess this resource. Restricting harvest of these populations might help regenerate shellfish populations baywide and provide a form of biological control on brown tide. Efforts to restore shellfish and eelgrass communities in GSB being conducted by The Nature Conservancy and the NYDOS should be closely followed. Data generated from these efforts should be considered in future management plans.

- FIIS deer population levels should be monitored along with herbaceous regeneration and the recruitment of tree canopy seedlings, especially within the maritime holly forest. FIIS should consider reducing or controlling deer populations via appropriate and acceptable methods in areas where overbrowsing is most severe.

- FIIS should continue to monitor the introduction and spread of invasive plants into the various habitats on Fire Island. In particular, the spread of *Phragmites* into the upper fringes of salt marshes and brackish habitats should be closely monitored. Management plans should include actions that would help eradicate or prevent the spread of this species.

- FIIS should monitor visitor recreational use of the natural habitats, especially beaches, dunes, and maritime forests. Off trail trampling of vegetation may increase erosion, spread invasive species, and disturb ground-nesting birds. This threat can be minimized via adequate trail signage and appropriate placed string fencing.

Filling in the data gaps and making resources available for continued monitoring of important resources at appropriate temporal scales will help ensure proper management of the natural resources of FIIS.

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