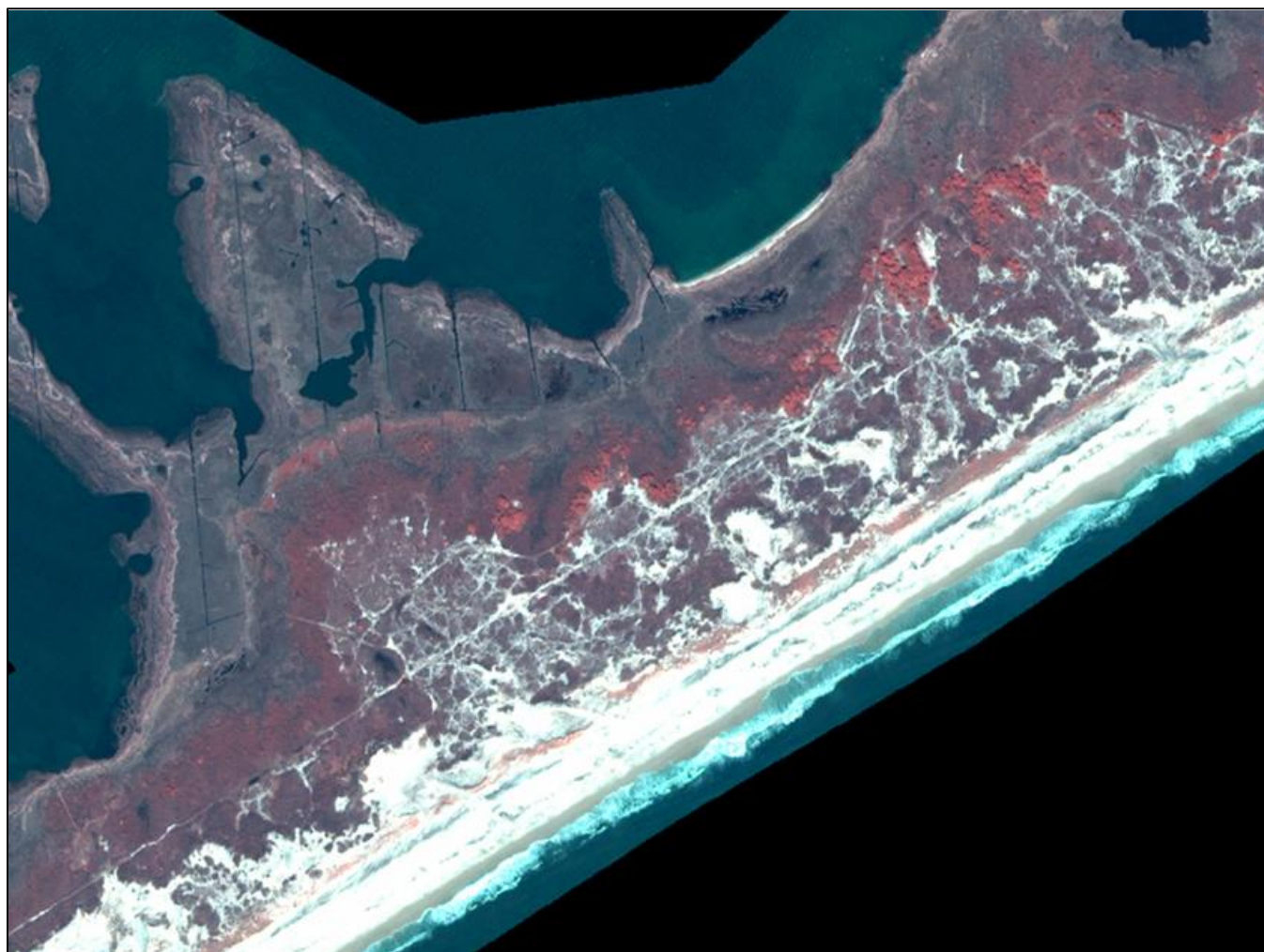




Remote Sensing of Terrestrial and Submerged Aquatic Vegetation at Fire Island National Seashore

Long-term Resource Management and Monitoring

Natural Resource Technical Report NPS/NCBN/NRTR—2013/742



ON THE COVER

An example of pseudo color QuickBird-2 satellite imagery covering a section of the Fire Island National Seashore. The image was acquired April 8, 2004 and is displayed in Bands 4,3,2 in RGB combination.

Photograph courtesy of Y. Q. Wang

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Fort Collins, Colorado

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Executive Summary

Fire Island National Seashore (FIIS) is located on Fire Island, a member of the Long Island barrier island system in the State of New York. As a barrier island, the vegetation communities and spatial patterns on Fire Island are highly dynamic, resulting from interactions with driving forces such as sand deposition, storm-driven over wash, salt spray, surface water, as well as human disturbances. Therefore, mapping the vegetation on FIIS is an important task for the Northeast Coastal and Barrier Network (NCBN) of the National Park Service (NPS) Inventory and Monitoring (I&M) Program.

In 1994, the United States Geological Survey (USGS) began the Vegetation Mapping Program in cooperation with the NPS. A vegetation mapping project at FIIS was initiated in June of 1999 and completed by the contracted agencies in 2002 (Klopfer *et al.*, 2002). That project followed the standards and general procedures of other NPS Vegetation Mapping Program projects, in which vegetation classification and mapping were accomplished via manual delineation using 1997 aerial photography. The classification used five broadly defined vegetation groups: salt marshes, dune grasslands, dune shrublands, interdunal swales, and forests/shrublands. These types were further classified into 27 different associations representative of a typical middle and upper Atlantic barrier island system. In all, a total of 39 classes of land cover were mapped on Fire Island and the park's associated William Floyd Estate. (This data product will subsequently be referred to as the Phase I map.)

The Phase I mapping project also identified several potential points for improvement. One of the suggestions was that since the barrier island is constantly changing, updates to the map product should be completed on a regular basis as to ensure changes are rapidly assessed. In addition, we noted that two further efforts were needed to enhance the results of the completed vegetation mapping project, or Phase I map, at the Fire Island National Seashore.

First, there was a need to explore new data sources and approaches that could more efficiently update vegetation maps. The recent development of high-resolution satellite remote sensing data offers one possible solution. For example, QuickBird-2 satellite data possess 0.61-meter spatial resolution for the panchromatic band and 2.5-meter spatial resolution for the multispectral bands ranging from the visible to the near infrared spectrum. These high spatial resolution satellite data can meet the requirements of NPS vegetation mapping efforts and facilitate long-term monitoring.

Second, a missing component from the Phase I map of FIIS was information about submerged aquatic vegetation (SAV). Seagrass communities are among the richest and most productive coastal systems. SAV habitats protect and improve water quality, provide shoreline stabilization, and are important for an array of fish, birds, and other wildlife. Natural and human impacts on these vital resources from population growth, pollution, physical damage, and other activities can disrupt the growth of seagrass communities and have devastating effects on their health and vitality. Inventory and monitoring efforts are required to determine the dynamics of seagrass ecosystems and devise better management and restoration for these rich resources. Therefore, an effort to extract information about SAV along FIIS became necessary.

The primary goal of this project was to explore efficient uses of remote sensing data sources and technical approaches to map both terrestrial and submerged aquatic vegetation at FIIS. The project aimed to develop a long-term coastal resource management and monitoring protocol using the latest developments in remote sensing data and technology.

We started the project by compiling the existing vegetation data from the previous mapping project (Klopper *et al.*, 2002). We compiled all GIS and image data into ArcGIS and ERDAS Imagine format. We employed this existing data as ancillary information for image classification and vegetation mapping.

We next ordered QuickBird-2 satellite remote sensing data covering the FIIS mapping area. Due to the 52 kilometers (32 miles) east-west expanse of FIIS, it required multiple data acquisition tasks to obtain the necessary QuickBird-2 imagery to cover the entire mapping area. The final dataset included QuickBird-2 satellite images that were acquired on April 8th, April 16th, May 4th, and May 6th of 2004.

We rectified the QuickBird-2 image data geometrically using true-color orthophotos of the same study area provided to us by the Coastal Service Center of the National Oceanic and Atmospheric Administration (NOAA). The reported accuracy of the NOAA orthophotography was 5.5 meters. We selected between 10 and 20 control points for each scene of Quickbird-2 images and registered the images to an accuracy of 0.5 pixels (1.25 meters), determined from the root mean square error by ERDAS Imagine software. This yielded a combined spatial accuracy of 6.75 meters between our registration and the reported accuracy of the base image.

We followed the classification scheme and field guide developed by the Phase I mapping project so that the results from the two projects would be consistent and comparable. In order to focus on vegetation mapping, we grouped urban related categories defined by the Phase I map into a single impervious surface category and kept all vegetation categories unchanged. Our final map included a total of 30 classes.

We conducted fieldwork and ground truthing in October 2003 and in May and August of 2004. We employed both a Trimble® Geo Explorer 3 GPS and a Kodak® Field Imaging System (KFIS) to document ground verification locations for the vegetation and other land cover types. The KFIS consisted of a 12 channel Garmin® GPS III unit that was connected to a Kodak® 265 digital camera. Each KFIS photograph included latitude/longitude coordinates and the general compass direction that the photographer was facing at the time of photography. We recorded 780 georeferenced digital photographs for terrestrial vegetation sites and 400 georeferenced digital photographs for observed patches of SAV beds (water surface). We also used underwater digital videography to document SAV habitats and bottom conditions. We collected 7 hours of underwater video that covered 206 30-m transects of SAV beds. We organized the ground reference data within the GIS to establish a virtual field reference database (VFRDB). The VFRDB provided not only the geographic coordinates for each ground referencing location, but also all landscape information observed at the time of field reconnaissance. Georeferenced photographs and underwater video transects effectively identified the locations and characteristics of terrestrial vegetation and SAV habitats, respectively, and played a critical role in subsequent digital image classification and vegetation mapping.

In order to eliminate the confusion caused by the spectral signals from both ocean and bay waters, we masked out water areas as much as possible during the classification process for terrestrial vegetation and land cover types. We adopted an unsupervised, stratified classification approach for mapping vegetation types. The stratified classification employed the Phase I map data as the control to mask out the area of each identified vegetation type as a subset of images. We then ran unsupervised classifications on each subset of images. This ensured that classifications were focused on the vegetation types and other land cover categories identified by the Phase I map. Pixels with spectral features that matched the Phase I map identification were labeled with the same categories as the control data. Pixels with spectral features significantly different from the Phase I map categories were relabeled to the corresponding categories. The advantage of this protocol is that mapping products are consistent with the existing NPS vegetation mapping efforts, allowing for updating of the vegetation map and for change analysis. It is also a simple protocol for future mapping replication.

For SAV classification, we adapted a classification scheme used by the New York Department of State's (NYDOS) Division of Coastal Resources. Our classification included subcategories of High Density Seagrass (HDS), >25% seagrass cover; Low Density Seagrass (LDS), < 25%; and unvegetated bottom or Sand (SND), < 5%. Similar to terrestrial vegetation mapping, we masked out the land area so that the classification could focus on SAV beds.

As the albedo of deep water is similar to that of a dense SAV bed, areas of deep water can be a considerable source of error in classifying and mapping SAV habitats. In general SAV does not exist any deeper than 2 meters in the Great South Bay. To reduce the influence of bathymetry on the overall classification result, we generated a bathymetric model to mask out all areas deeper than 2.5 meters below mean low water in the study area using bathymetric data from the NOAA National Geophysical Data System (GEODAS). We employed about 32,289 points from 19 surveys to generate the depth mask. We converted the point data into a 5 meter grid using an inverse distance weighting (IDW) algorithm. Because of the age of the data, it did not include some of the newly dredged channels. For these areas we generated a depth mask using the 2002 true color aerial photographs as a guide.

Upon finishing the classifications, we randomly selected 1500 pixels, 50 from each category, for the accuracy assessment of the terrestrial vegetation map. The overall accuracy was 82.07% with an overall Kappa statistics of 0.81.

The unsupervised classification for SAV mapping identified 2,246 hectares of seagrass habitat within the FIIS park boundary. Of that area, 69% (1,544 hectares) was classified as high density seagrass and 31% was classified as low density seagrass.

The under-water video transects provided critical data in SAV habitat mapping and monitoring. The documented field photos also provided vital records of the landscape at the time of the study and can be used for monitoring and comparison in vegetation mapping in the future.

Routine monitoring of vegetation, both terrestrial and SAV, is a critical component of protecting the habitats of FIIS and other similar setting of the National Parks (Wang et al., 2007). The data sources used and the protocol developed in this project demonstrate that high spatial resolution satellite remote sensing imagery can provide sufficient spatial and spectral data for extraction of

vegetation types for the FIIS study site. With support from existing vegetation GIS data and ground referencing data, the stratified classification is capable of extracting information to meet the goals of updating vegetation maps and for change analysis. We recommend similar practices continue to be employed to create a time series of vegetation maps in order to facilitate the long-term vegetation monitoring.

Acknowledgments

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Introduction

General Background

The vegetation communities and spatial patterns at Fire Island National Seashore (FIIS) are dynamic, shaped by the impacts from forces such as sand deposition, storm-driven over wash, salt spray, and surface water. Mapping the vegetation communities and tracking their changes are among the important tasks that challenge resource managers. Remote sensing has been identified as one of the primary data sources to conduct change analysis and monitoring (Coppin and Baure, 1996; Hansen *et al.*, 2002; Griffith *et al.*, 2003; Rogan *et al.*, 2002; Turner *et al.*, 2003; Wilson and Sader, 2002; Wang *et al.*, 2003). A previous vegetation mapping effort at FIIS was accomplished as part of the National Park Service Vegetation Mapping Project (Klopfer, *et al.* 2002). The vegetation types were visually interpreted and manually delineated from a set of 1997 color infrared and true color 1:1,200 scale aerial photos. The hardcopy aerial photos were digitally scanned at 600 dpi and georeferenced for heads-up digitizing. The classification system included 5 broadly defined vegetation groups including salt marsh, dune grassland, dune shrubland, interdunal swale, and forest/shrubland, which were further separated into 39 subcategories. The minimum mapping unit was 0.25 hectares. The project provided important baseline information for FIIS, and we refer to this completed, vector GIS format, vegetation map as the Phase I map.

The Northeast Coastal and Barrier Network (NCBN) of the National Park Service (NPS) Inventory and Monitoring (I&M) Program identified two further efforts to enhance the Phase I map. Firstly, updating of the vegetation mapping product on a regular basis is crucial to ensure monitoring of the dynamic changes of the vegetation communities on this barrier island. Therefore it was determined that exploration of new data sources and approaches that could efficiently update the vegetation map was necessary. Recent development of high spatial resolution satellite remote sensing images could meet these goals. For example, QuickBird-2 satellite data possess 0.61-meter spatial resolution for the panchromatic band and 2.5-meter spatial resolution for the multispectral bands from the visible to the near infrared range of the spectrum. The capability of repeated data acquisition by satellites could facilitate the practice of regular mapping of dynamic vegetation communities.

Secondly, the NCBN determined that an important missing component from the Phase I map was information about submerged aquatic vegetation (SAV), such as seagrass species and bed locations. Seagrass communities are among the richest and most productive coastal systems. They protect and improve water quality, provide shoreline stabilization, and are important habitats for an array of fish, birds, and other wildlife. Natural and human impacts on these vital resources from population growth, pollution, physical damage and other activities can disrupt the growth of seagrass communities and have devastating effects on their health and vitality. Inventory and monitoring are required to determine the dynamics of seagrass ecosystems and to devise better management and restoration practices for these rich resources. Therefore, an effort to extract information about SAV along FIIS becomes necessary.

Mapping of seagrass is inherently difficult as most species are subtidal. Traditionally, mapping of seagrass has been accomplished using a combination of aerial photographs and in-situ sampling by divers using SCUBA. Some studies have utilized satellite imagery such as Landsat and SPOT data to map seagrass coverage (Armstrong 1993; Dobson *et al.* 1995, Ferguson and

Korfmacher 1997; Mumby et al. 1997; Green et al. 2000, Moore et al. 2000; Lanthrop et al. 2006). Satellite imagery offers certain advantages over aerial photography, including larger individual scenes with spectral uniformity, increased reimage availability, and affordable pricing. The digital nature of satellite data makes computer aided image classifications for vegetation mapping possible. This type of classification can be done quickly, reduces labor costs, and limits bias from visual interpretation and manual delineation.

To evaluate the possibility of involving high spatial resolution satellite remote sensing data in coastal resources inventory and monitoring, the objectives of this study were to:

1. map terrestrial vegetation and SAV within the FIIS boundary using QuickBird-2 satellite remote sensing data;
2. compare and validate agreement between satellite derived vegetation maps and the delineation result from conventional aerial photo interpretation so that repeated monitoring of vegetation change using satellite remote sensing can be achieved; and
3. develop working protocols for using high spatial resolution satellite remote sensing data for terrestrial and SAV habitat mapping that are transferable among NPS projects.

Study Area

Location and Regional Setting

Fire Island National Seashore is a member of the Long Island barrier island system and it is located in Suffolk County in the State of New York. The earliest inhabitants of Fire Island were likely the Secatogue Native American tribe, who used the island for hunting. The first records of European habitation date back to the late 17th century. Fire Island has a colorful history as a haven for pirates, whalers, fisherman, and slave runners. Fire Island became a resort island after 1855. Several resort communities, still in existence, began appearing in the early 1900's. Currently, the Seashore contains 17 private communities scattered throughout the Western portion of the area.

In the mid 1950's, the U.S. Congress commissioned the NPS to study seashore and lakeshore areas for possible inclusion in the National Park system. As a result FIIS was officially designated in 1964. Fire Island extends about 52 kilometers (32 miles) from Fire Island Inlet to Moriches Inlet. FIIS is bounded on the West by Robert Moses State Park and on the East by Smith Point County Park. The 2.6-square kilometer (640-acre) William Floyd Estate, the home of New York's Continental Congress delegate and signatory of the Declaration of Independence, became part of FIIS in 1976. This parcel is located in Mastic, NY on Long Island (Figure 1). The administrative boundary of FIIS extends 305 meters (1,000 feet) into the Atlantic Ocean to the south, and 1,219 meters (4,000 feet) north into the Great South Bay and includes West and East Fire Island, Sexton Island, Ridge Island, John Boyle Island, Hospital Island, and Pattersquash Island. In 1980, approximately 16 square kilometers (1,300 acres) stretching about 11 kilometers (7 miles) from Watch Hill to Smith Point County Park were designated as the Otis Pike High Dune Wilderness, which is the only federally designated wilderness area in the state of New York. In this project, all terrestrial properties of FIIS and the buffered water bodies along the FIIS shoreline in the Great South Bay were targeted mapping areas. The terrestrial component matched the same mapping areas the Phase I map.

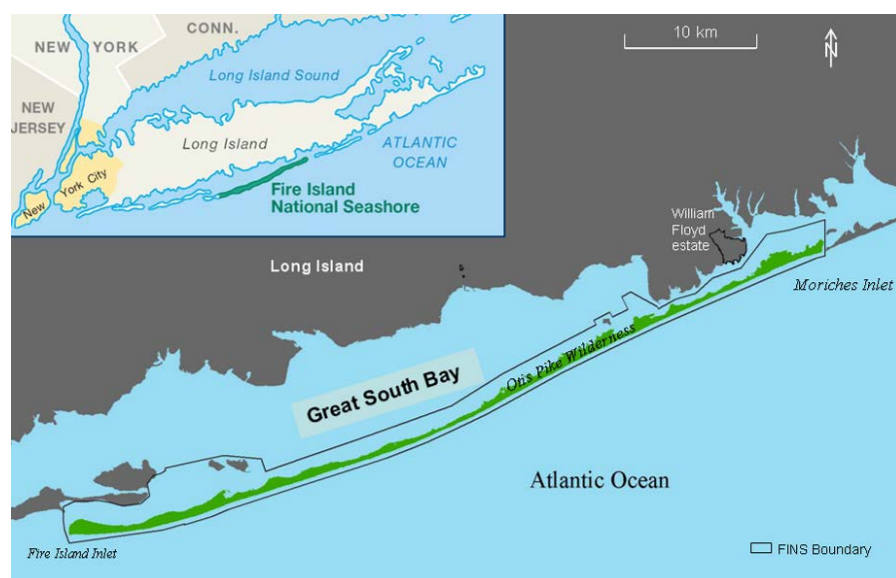


Figure 1. The Fire Island National Seashore and the study area.

Park Attributes Related to the Vegetation Mapping Project

The vegetation communities and their spatial patterns on Fire Island are a direct result of dynamic natural processes such as breaching, overwash, and long shore sediment transport. The morphology of Fire Island is typical of a barrier island. Several morphological zones can be readily identified along the gradient, and different edaphic conditions and vegetation patterns often follow these zones. The primary vegetation gradient extends from the Atlantic Ocean towards the Great South Bay (Figure 2).

Immediately adjacent to open ocean is non-vegetated sand extending to the base of the primary dune. Sparse herbaceous plants can be found at the base of the primary dune and the dune face exposed to the ocean. Grass vegetation typically increases in cover from the crest of the primary dune and into the inter-dune or swale area. These swales are often a mosaic of shrub and grass types. Different types of grass, dwarf-shrub, woody shrub, vine, and tree communities begin to appear in the swales. Occasionally depressions are present with near-surface water available to the vegetation. Shrubs tend to increase in density towards the secondary dune and the Bay salt marshes, although many areas of Fire Island do not have a well-defined secondary dune. When a well-formed secondary dune is present, larger trees often replace shrubs. Trees can be over 10 meters in height. Most of the Bay-side of the island is salt marsh which gradually tapers into the shallows of the Great South Bay (Klopfer et al., 2002). These patterns are observable on QuickBird satellite imagery as confirmed by field photos (Figure 2). This pattern of vegetation provided helpful guidance in assisting with image interpretation as well as digital image classification as each zone is readily definable and vegetation communities are predictable.

Submerged Aquatic Habitat Associated with Fire Island National Seashore

The Atlantic side of Fire Island is a classic example of exposed barrier beach habitat. The high energetic, steep drop off, and low organic sediment are not suited to SAV growth so there is very little rooted vegetation on this side of the island. Our mapping efforts focused on the bay side of the Island. Great South Bay is a shallow and quiet embayment protected from the incoming surf and high energy by the system of the barrier island. The average depth of the bay is approximately 1 meter at mean low water. Aside from dredged channels the naturally deep areas (> 2 meters mean low water) of the Bay can be found by the inlets caused by tidal scour and along the northern side of the Bay. The southern side of Great South Bay, associated with the Park, is primarily made up of large areas of shallow, flat, and sandy bottom. Two major species of seagrass found within the FIIS boundary are widgeon grass (*Ruppia maritima*) and eelgrass (*Zostera marina*). The majority of the seagrass that grows within Great South Bay is located along the East and West sides of Fire Island close to the two inlets. This is most likely an effect of flushing from the breachways increasing the water clarity around the inlets and allowing more lights to reach the plants.

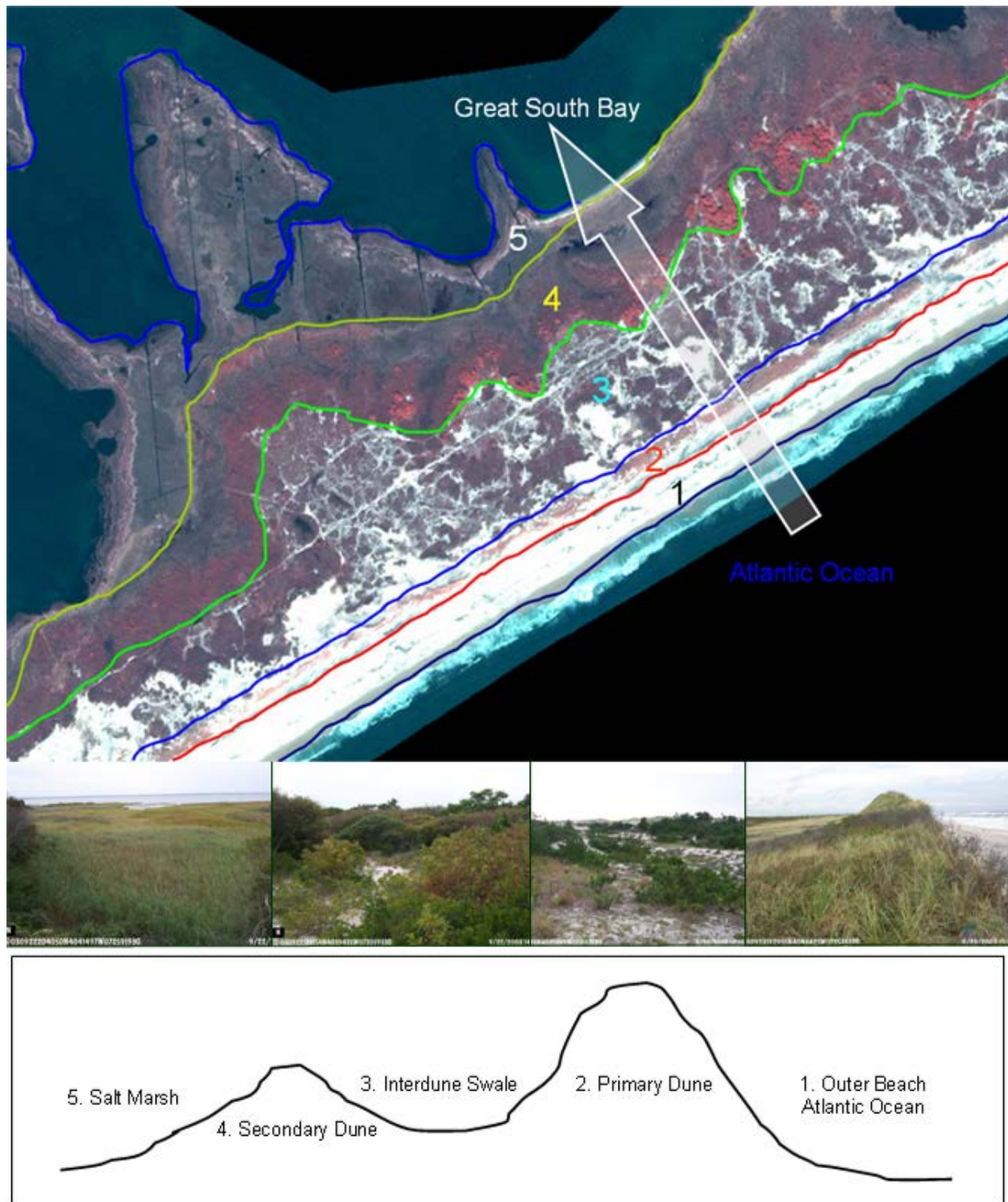


Figure 2. Cross-section of Fire Island extending from the Atlantic Ocean (right) to the Great South Bay (left). The vegetation zones are delineated over Quickbird-2 imagery with example field photos.

Methods

Acquisition of QuickBird-2 Satellite Remote Sensing Data

We ordered high spatial resolution Quickbird-2 satellite imagery data to be collected between April and May 2004. The imagery data consisted of separate image scenes covering the entire study area (Figure 3). The QuickBird-2 data possess 2.5-meter spatial resolution for the multispectral bands that cover the visible light and near infrared portion of the electromagnetic spectrum, and a panchromatic band with 0.6-meter spatial resolution. Due to water clarity issues we ordered a follow-up scene in May 2005; this scene was used solely for assistance in SAV mapping. The above time window for image acquisitions was chosen to increase the chances of optimal data collection for mapping SAV habitats. SAV in the Great South Bay begins to increase dramatically in biomass during the early spring and peaks in mid to late June. However the period of peak biomass in June also occurs when plankton blooms make the water clarity the poorest. For this reason we selected the timing of image acquisition for SAV mapping to be from early to late spring when plant biomass is rising along with water clarity. This time window also met the needs for mapping terrestrial vegetation types on FIIS.

Initial Image Processing

We conducted all image processing using ERDAS Imagine software version 8.7 (Leica Geosystems, 2003). We registered each scene of QuickBird images independently via image-to-image geometric rectification using the 2002 true color aerial orthophotograph as the reference base. We selected from 10 to 20 ground control points to tie each QuickBird-2 image scene to the reference true-color digital image. We registered each scene to an accuracy of 0.5 pixels (or 1.25 meters), which was determined from the root mean square error. This would yield a combined accuracy of 6.75 meters between our registration and the reported accuracy of the base image. Finally, we mosaicked the georectified scenes into a single, seamless QuickBird dataset for the entire FIIS (Figure 4). To reduce the spectral effects of water surface on terrestrial vegetation, and vice versa, we clipped the registered image using areas of interest (AOI). Examples of the clipped QuickBird-2 images in true color and pseudo color combinations are illustrated in Figures 5 and 6.

Spatial Resolution and Minimum Map Unit Consideration

Spatial resolution is one of the main considerations when choosing which type of imagery to be used for a mapping project. The Phase I project adopted 0.25 hectares as the minimum mapping unit, an area that corresponds to about 400 pixels at 2.5 meters spatial resolution. Therefore, the spatial resolution of the multispectral bands of QuickBird data is sufficient for vegetation mapping and comparison with the Phase I map. (The associated 0.6-m panchromatic QuickBird data were not utilized for this project.)

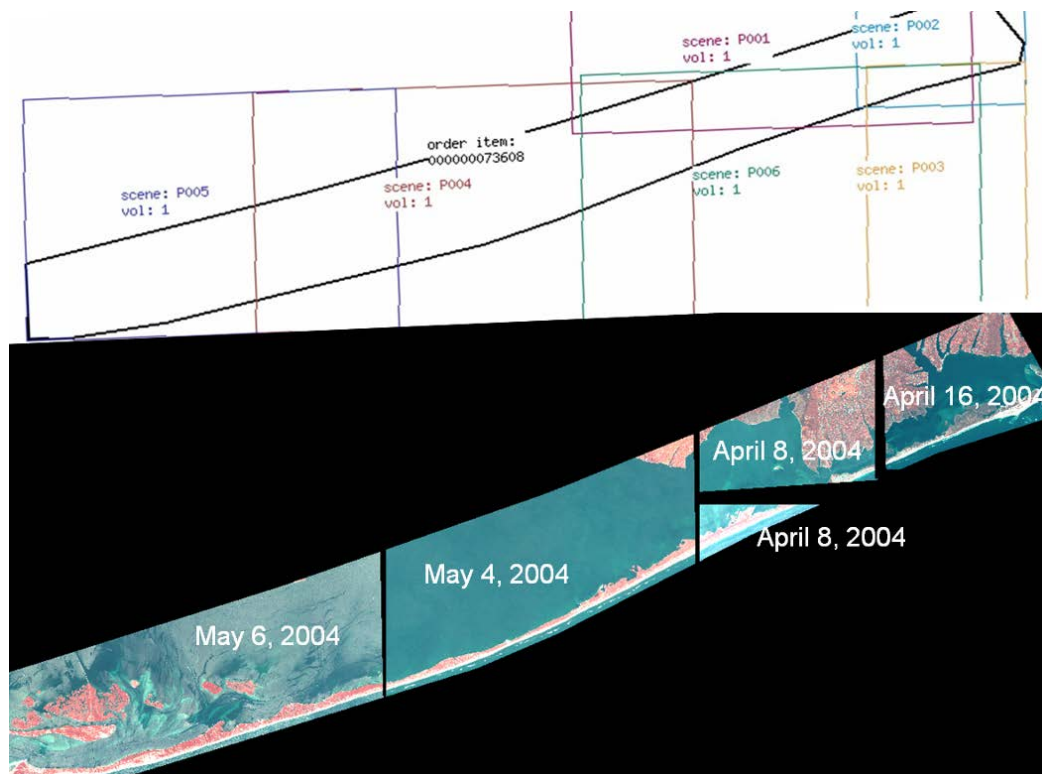


Figure 3. Time frame of Quickbird-2 imagery scene acquisition. The images are displayed in pseudo color with bands 4, 3, 2 in RGB.

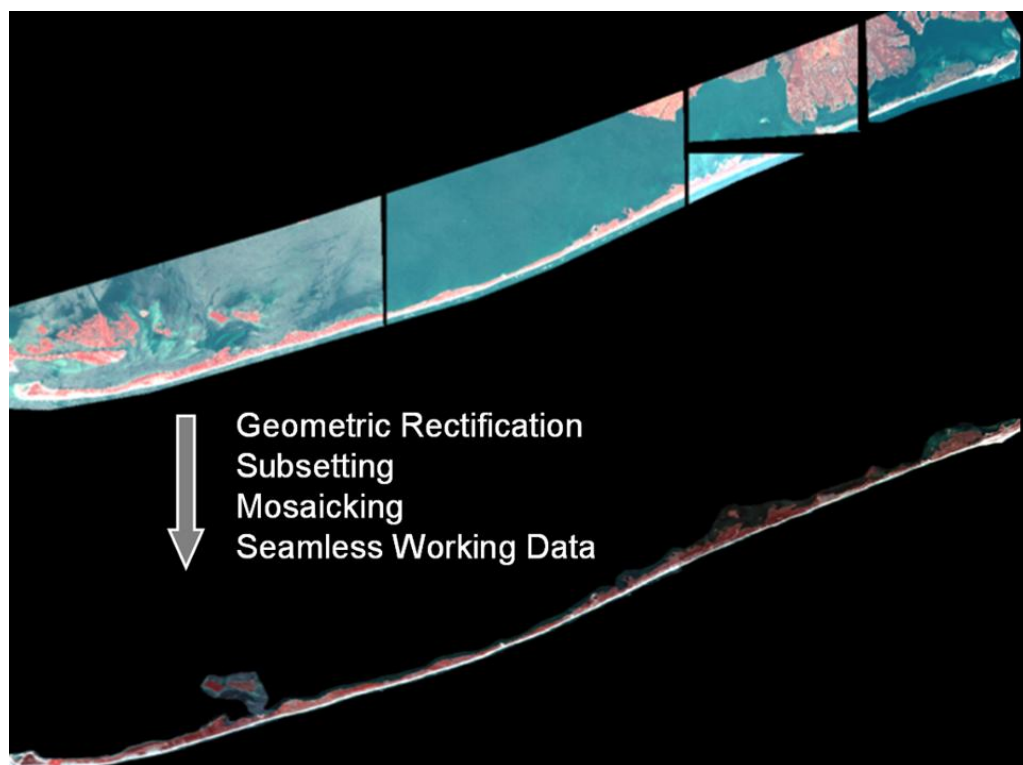


Figure 4. The final mosaicked Quickbird-2 satellite image covering the entire FIIS study area.



Figure 5. Example of final, clipped QuickBird-2 images in true color combinations - Watch Hill area of Fire Island National Seashore. (Image displayed as bands 3, 2, 1 in RGB)



Figure 6. Example of final, clipped QuickBird-2 images in pseudo color combinations - Watch Hill area of Fire Island National Seashore. (Image displayed as bands 4, 2, 1 in RGB)

Supporting Geospatial Data

We obtained a set of true color digital orthophotos acquired by the New York Department of State and the NOAA Coastal Services Center in 2002 in order to provide precise and accurate reference data for rectification of QuickBird images and other rasterized GIS data. The reported accuracy of the orthophotograph was 5.5 meters. We mosaicked the orthophotos to create a complete cover of FIIS (Figure 7a).

Since the albedo of deep water in visible color is similar to that of dense eelgrass beds, areas of deep water can be a considerable source of error in digital image classification of eelgrass habitats. Bathymetry is highly correlated with seagrass distributions. The depth range in which seagrass grows is variable and dependent on the local physical and environmental characteristics, as well as the light limitations of the plant. In general SAV beds do not exist in any location that is deeper than 2 meters (6 feet) below mean low water in the Great South Bay. For this reason we decided to create a depth mask that would eliminate all image pixels that occur in water deeper than 2 meters. We used about 19,000 sounding points from the surveys collected by the NOAA National Geophysical Data System (GEODAS) to generate the bathymetric data as the depth mask (Figure 7b). We converted the point data into a 5 meter grid using an inverse distance weighted (IDW) algorithm. Because of the age of the data, it did not include some newly dredged channels. For those areas we generated a depth mask using the 2002 true color aerial photographs as the guide. The straight edge and dark color that are indicative of dredged channels made these areas discernible in the aerial photographs (Figure 7c). With the depth data we masked out all areas known to be too deep for eelgrass or widgeon grass growth in the Great South Bay.

At the beginning of the project we conducted a thorough review of the existing data products from previous vegetation mapping projects. The Phase I project was the most relevant and the first detailed vegetation mapping effort on Fire Island and the associated William Floyd Estate (though offshore SAV were not included). The Phase I map was based on a detailed classification system developed in conjunction with the mapping project (Sneddon and Lundgren 2001). These comprehensive and ecologically detailed studies have created a thorough base on which we were able to build using satellite based image classification and mapping.

Very few studies have investigated SAV cover in the Great South Bay. Early studies include projects conducted by the Marine Science Research Center in 1978 (Greene et al 1978) and in 1980 (Jones and Schubel 1980). The Army Corp of Engineers conducted a survey in 1997 (USACOE, 2004). More recently the New York Department of State and the NOAA Coastal Services Center conducted SAV habitat mapping in 2002; this project used 1:1,200 color orthophotography to map SAV habitat by visual interpretation and manual delineation. The produced data included categories of continuous and discontinuous rooted vegetation in vector format GIS polygons. Maps of the Great South Bay from this recent project constitute the SAV reference data used for the present project.

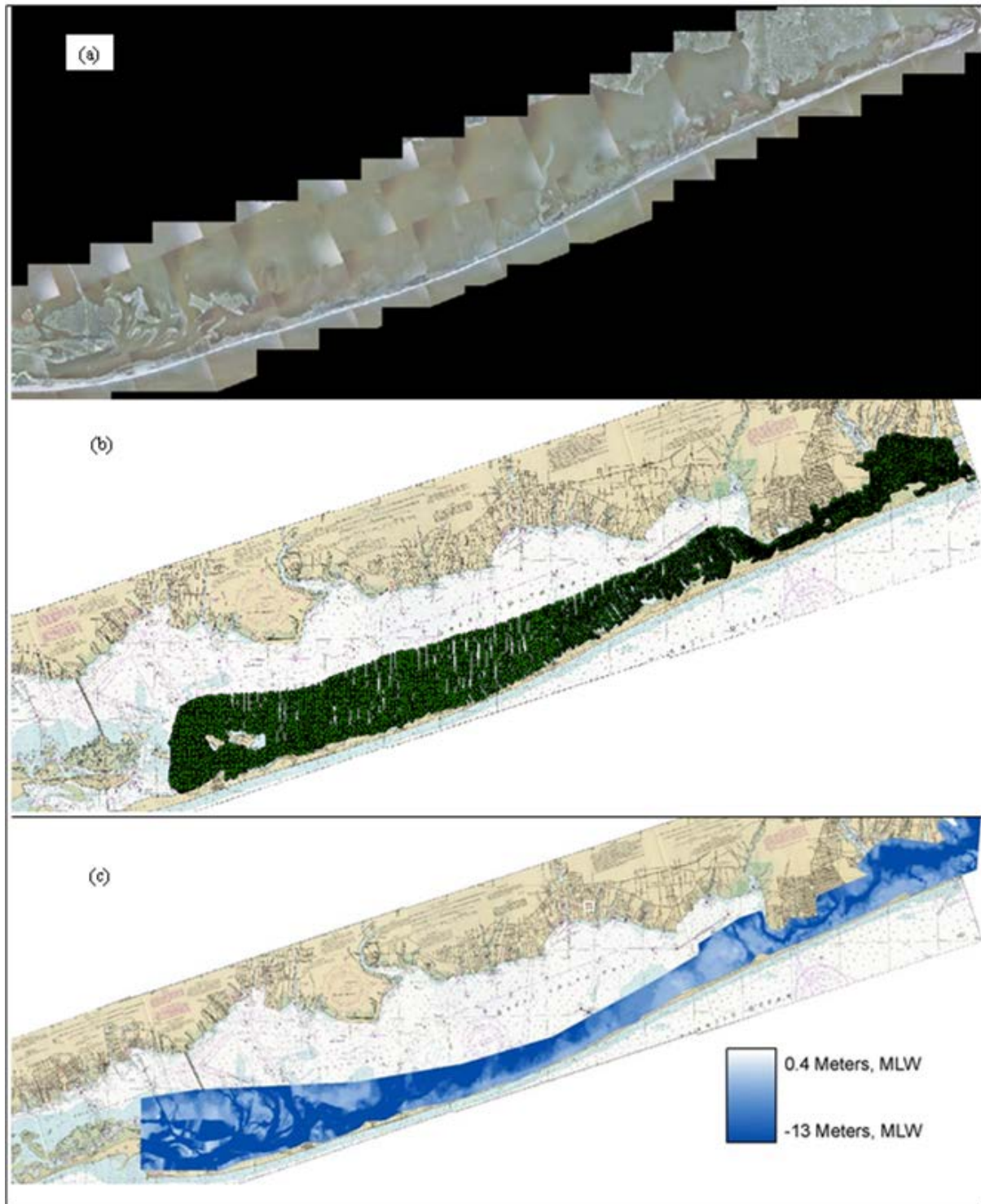


Figure 7. Supporting geospatial data: (a) a mosaic of two 2002 true color digital orthophotos; (b) sounding points for developing the bathymetry data; and (c) dredged channels and deep water areas visible on aerial photos.

Classification Scheme

Classification Scheme for Terrestrial Vegetation Mapping

The vegetation classification scheme used for this study was modified from the Phase I mapping project, which included 39 classes. Detailed description of the classes can be found in Sneddon and Lundgren (2001). For this study we grouped and renamed categories associated with urban land cover types into a single category of impervious surface cover. We kept the terrestrial vegetation types in the Phase I classification scheme unchanged. Table 1 summarizes the classification current scheme and compares it with the land cover and vegetation categories of the Phase I map. Vegetation category descriptions employed by both the Phase I map project (Klopfer et al., 2002) and this study are as follows:

Forests

Maritime Holly Forest (code 6376)

This type is characteristically green on the color photographs (where deciduous species do not have leaves). This type has a definite forest signature, with height apparent in stereoscopic view and large tree-like canopies. It occurs just behind the backdune. Can be distinguished from younger shrublands by visible tree canopies, tall vegetation and dominance of green color signifying the dominant evergreen holly.

Old Field Red-Cedar Forest (code 6024)

This type appeared with a dark green signature and was found on William Floyd Estate. Individual trees are smaller-crowned and scattered in with hardwoods. Distinct shadows are visible through the canopy.

Maritime Post Oak Forest (code 6373)

This type was limited to the edge of waterways on the Floyd Estate. Only one stand was identified through ground survey. This stand appears very similar to the other oak-dominated types found on the property.

Coastal Oak-Heath Forest (code 6375)

This type covers a large portion of the William Floyd Estate. It appears on the photography as a tall, forested area with a tan or brown color stippled with shadows from tree trunks oriented all in the same direction. Individual green *Pinus rigida* is often present but not in high enough proportion to classify as coniferous forest.

Acidic Red Maple Basin Swamp Forest (code 6156)

This forest type is found on both the Floyd Estate and Fire Island. It appears as a light grayish tree canopy over very dark understory (i.e., wet). These types are usually near water or other wetland types.

Pitch pine - Oak Forest (code 6381)

This type is very similar to *Quercus coccinea* - *Quercus velutina*/*Sassafras albidum*/*Vaccinium palladium* Forest in color and texture except that the coniferous *Pinus rigida* is more dominant.

Japanese Black Pine Forest (code 6012)

Pinus thunbergii is found in many isolated patches on Fire Island. It is often used to stabilize the fore dune – especially on the eastern end of the island and around human communities. This type appears very similar to the Pitch Pine Dune Woodland but the density is usually higher and the canopy more continuous.

Woodland

Pitch Pine Dune Woodland (code 6117)

The type is found throughout Fire Island behind the primary dune. Green to dark-green interspersed with brown to tan coloring. Polygons appear splotchy due to varying canopy heights within one polygon (signifying open canopy of *Pinus rigida* with shrubs/herbaceous layer below). Bright patches of sand are often seen within the polygon.

Shrubland

Maritime Vine Dune (code 3886)

This type is difficult to identify from photos as the *Toxidendron radicans* is often found growing over shrubs. It is perhaps best described as what it is not, for it does not appear like *Myrica pennsylvanica* usually found around it. This type does appear as a brown color highly interspersed with open sand when occurring in larger polygons.

Northern Salt Shrub (code 6063)

This type is often found between the more obvious, taller shrub types on and around the backdune. It is always near wetlands. *Baccharis halimifolia* has a uniform gray color lighter than the surrounding wetter areas and very fine speckling can be seen. Individual plants are impossible to discern.

Maritime Deciduous Scrub Forest (code 6145)

This vegetation type is found on the bay side, often behind a large primary dune on wider parts of the island. It appears as a mix of brown, gray, and green with variable-sized discernable crowns in most cases.

Northern Dune Shrubland (code 6295)

This type is very common and dominates the interdune areas on Fire Island. It varies in height between 0 and 1 meter. It is often interspersed with lighter-colored signatures of *Ammophila breviguilata* and *Hudsonia tomentosa*. This type has a dark brownish-red color and is typically uniform in texture throughout the polygon. Little sand shows through.

Highbush Blueberry Shrub Forest (code 6371)

This is a wet shrub type found on both Fire Island and the William Floyd Estate. It is a brown color finely dissected with dark lines, which is the water showing through the canopy. It is seen in noticeable depressions or swales throughout the interdune area.

Dwarf-shrubland

Northern Interdunal Cranberry Swale (code 6141)

This association is found in the interdune zone as small, pond-like bodies of shallow water. They appear dark, like open water, but do have a partially submerged layer of *Vaccinium*

macrocarpon. These small polygons are found mostly in the Otis Pike Wilderness Area of Fire Island.

Beach Heather Dune (code 6143)

This type is widespread on Fire Island and is found from Fire Island Inlet to the Moriches Inlet predominantly, although not exclusively, in the interdune zone. The color is a very dark green with equal amounts of bright sand showing through. It is often intermingled with *Ammophila brevigulata* which has a light tan color. Because of this mixing, this type is also found in complex with the Northern Beach Grass Dune association.

Overwash Dune Grassland (code 4097)

This type is difficult to identify from photography alone, although it occurs on recent overwash areas (breach) near the foredune. These overwashes may be identified. The vegetation is typically more sparse and therefore “washed out” on the photography.

Reedgrass Marsh (code 4187)

This widespread type is found in and around most wetland areas on both the Floyd Estate and Fire Island. It has variable color and texture on the photographs ranging from a very “soft” light brown/tan to a dark, “dirty”-looking brown at the high ends of the salt marshes. There is often a readily identifiable band of horizontal debris associated with the bay-side of these polygons which can aid in identifying the taller *Phragmites australis* stands.

Low Salt Marsh (code 4192)

One of the two common salt marsh types found on both the William Floyd Estate and Fire Island. This type is associated with more regularly flooded parts of the marsh. The color of this type is usually a medium to dark gray adjacent to water bodies, mosquito ditches, and salt pannes. The *Spartina patens* types are found in close proximity but tend to be lighter and more tan in color.

High Salt Marsh (code 6006)

This association dominates the salt marshes of Fire Island and the Floyd Estate. It is found in close proximity to *Spartina alterniflora* on the less frequently flooded portions of the salt marsh. This type has a uniform tan color and is often bisected by mosquito ditches (which dry the areas further).

Northern Sandplain Grassland (code 6067)

This type was rare and apparently limited to the wider parts of the Otis Pike Wilderness Area. The codominance of *Myrica pensylvanica* in this type makes it difficult, if not impossible, to separate from the Northern Dune Shrubland type.

Cultivated Pasture (code 6517)

These types are found on the William Floyd Estate where past land use practice has left openings in the forest. These types were seeded and used for managing game for hunting. It is easily classified from the photography as very lawn-like tan and green areas. Individual fields differ in species composition due primarily to management (i.e., mowing, seeding, etc.). Older, less disturbed areas are reverting to Successional Meadow.

Brackish Meadow (code 6150)

This type is found uncommonly near the highest portions of the salt marsh on the bay side of Fire Island. It typically occurs in small polygons or in thin bands on the edge of the Northern Salt Shrub type. It has a distinctive rusty-red color and appears wet (i.e., dark surface water is sometimes visible).

Northern Beach Grass Dune (code 6274)

This type is perhaps the most prevalent on Fire Island. It is found on the ocean side of the interdune area from the crest through the high salt marsh. This association appears as a uniform tan when cover is high, but can have streaks of bright sand showing through. It is often found in small polygons interspersed with the Beach Heather Dune type (where it is classified as a mosaic) and with Northern Dune Shrubland polygons.

Brackish Interdunal Swale (code 6342)

This type is found behind primary and secondary dunes where saline surface water is found. When these wetlands are not dominated by *Phragmites australis* they appear dark and closely match open water. The vegetation is emergent and is difficult to identify specifically from the photography.

Classification Scheme for Submerged Aquatic Vegetation Mapping

For the classification scheme for SAV mapping, we defined three categories: high density seagrass (HDS), low density seagrass (LDS), and unvegetated or sand bottom (SND). HDS refers to the areas where seagrass cover of the bottom is greater than 25 percent. LDS refers to the areas where seagrass cover of the bottom is less than 25 percent but greater than 5 percent. SND refers to the areas where seagrass coverage is less than 5 percent.

We determined coverage using a technique similar to that used by Moore et al. (2000). We used a gridded pattern to assess the total coverage within an image scene and assigned major categories of 0-25, 25-50, 50-75 and 75-100 percent for each scene. We grouped scenes with 25-100 percent seagrass coverage as HDS, 5-25% seagrass coverage as LDS, and less than 5% seagrass coverage as SND. It was impossible for us to accurately map differences between eelgrass (*Zostera marina* L.) and widgeon grass (*Ruppia maritima*), as these are not spectrally separable with QuickBird-2 imagery. For the purpose of this study, we therefore grouped both species as SAV. We did not consider un-rooted macro algae species in this project.

Field Reference

Field Reference for Terrestrial Vegetation Mapping

To support the mapping efforts, we conducted fieldwork in September and October 2003 and May 2004 to characterize both terrestrial vegetation and SAV. Resource managers at FIIS provided guidance for the fieldwork. We used global positioning system (GPS) technology, including a Trimble ProXR GPS unit, to record locations of field transects and points of interest. We recorded general landscape characteristics and associated information using a data dictionary uploaded to the ProXR. We also examined vegetation types on the Phase I vegetation map as the reference.

We recorded georeferenced site photos along transects and at points of interests using a Kodak DC265 Field Imaging System (FIS). The FIS consists of a 12-channel Garmin GPS III unit

connected to a digital camera. The photographs were tagged with both geographic locations (UTM coordinates) and general compass bearings (Figures 8 and 9). When associated with QuickBird-2 satellite image, the GPS photos helped identify the locations and characteristics of vegetation types as well as the landscape settings of the sites. These field photos can also serve as benchmark references for long term monitoring of vegetation change in the future.

Field Reference for Submerged Aquatic Vegetation

We created a video database as a field reference of benthic habitats. SAV videography data were collected in September and October 2003, and again in May 2004. Between the time of field data collection and satellite imagery data acquisition, there were no significant storm events in Great South Bay that might have resulted in substantial changes in the presence or extent of SAV beds, thus ensuring that the field data remained an appropriate reference.

We attached an underwater video camera to a sled (Figure 10) and towed the sled behind a vessel. The position, heading, and speed of the vessel were output from a GPS receiver located on the vessel and overlaid on the live video image. To increase the spatial accuracy of the coordinates, we placed the Trimble ProXR GPS receiver in a kayak and positioned it directly over the sled (Figure 11). We used a VCR/TV combo on the towing vessel to record SAV conditions and geographic coordinates on video files (Figure 12). We related the recorded video files to the coordinates captured on the towed GPS unit through time stamp. We also conducted direct observations on top of the water surface and recorded conditions in observed seagrass patches when applicable (Figure 13).

We digitized video of underwater transects from analog data using Adobe Video Premier Software. Based on the speed of the towing vessel, we were able to calculate the amount of video equaling 30-meter transects. For example, at a speed of 1 knot, approximately 1 minute of video covers 30 meters of bottom traveled. We used the start and end coordinates of each segment to create a linear feature coverage in ESRI Arc/Info GIS format. We linked the digital video file corresponding to each line segment to the file in a GIS database.

We viewed each 30-meter video and observed the percentage of SAV within each transect. We used a gridded, 0.25-meter PVC frame to estimate the percentage cover of SAV (Figure 14). We estimated the percentage by dividing the number of seconds in which seagrass was observed in the camera field of view by the total seconds in each clip. This yielded a percent cover of seagrass over each 30-meter long by 0.25-meter wide transect. We also noted the dominant seagrass species in each video transect. We then overlaid the line coverage on top of the satellite images (Figure 15) to aid our classification and accuracy assessment.

During fieldwork we collected roughly 780 georeferenced terrestrial field photos, 400 field photos of water-surface SAV patches, and 7 hours of underwater video capturing 206 30-m transects for SAV beds (Figures 16 and 17). The fieldwork and observations provided essential independent reference data for identifying vegetation types to be mapped.

Table 1. A comparison of classification schemes for the terrestrial vegetation in FIIS.

Current Class Description	Code	Phase I Map Class Description	Code
Water	1	Inland Water	42
		Mosquito Ditch	595
		Ocean / Bay	40
Impervious Surface Cover	2	Commercial Property	53
		Residence / Building	51
		Paved Road	591
		Pavement / Parking Areas	590
		Boardwalk / Dock	593
		Rock Piles / Jetties	596
Open Beach/Sand Road	3	Sand Road / Path	597
		Open Beach	59
Lawn/Cut Grass	4	Lawn / Cut Grass	79
		Cultivated Pasture	6517
Sparsely Vegetated Sand	5	Sparsely Vegetated Sand	594
Autumn Olive	6	Autumn Olive	713
Maritime Holly Forest	7	Maritime Holly Forest	6376
Old Field Red-Cedar Forest	8	Old Field Red-Cedar Forest	6024
Maritime Post Oak Forest	9	Maritime Post Oak Forest	6373
Coastal Oak-Heath Forest	10	Coastal Oak-Heath Forest	6375
Japanese Black Pine Forest	11	Japanese Black Pine Forest	6012
Pitch Pine Oak Forest	12	Pitch pine-Oak Forest	6381
Pitch Pine Dune Woodland	13	Pitch Pine Dune Woodland	6117
Northern Dune Shrubland	14	Northern Dune Shrubland	6295
Maritime Deciduous Scrub Forest	15	Maritime Deciduous Scrub Forest	6145
Acidic Red Maple Basin Swamp Forest	16	Acidic Red Maple Basin Swamp Forest	6156
Maritime Vine Dune	17	Maritime Vine Dune	3886
Highbush Blueberry Shrub Forest	18	Highbush Blueberry Shrub Forest	6371
Northern Salt Shrub	19	Northern Salt Shrub	6063
Beach Heather Dune	20	Beach Heather Dune	6143
Northern Interdunal Cranberry Swale	21	Northern Interdunal Cranberry Swale	6141
Northern Beach Grass Dune	22	Northern Beach Grass Dune	6274
Overwash Dune Grassland	23	Overwash Dune Grassland	4097
Brackish Interdunal Swale	24	Brackish Interdunal Swale	6342
Brackish Meadow	25	Brackish Meadow	6150
Reedgrass Marsh	26	Reedgrass Marsh	4187
Low Salt Marsh	27	Low Salt Marsh	4192
High Salt Marsh	28	High Salt Marsh	6006
Northern Sandplain Grassland	29	Northern Sandplain Grassland	6067
Interdune Beachgrass-Beach Heather Mosaic	30	Interdune Beachgrass-Beach Heather Mosaic	6243



Figure 8. Example of GPS field photo of an interdune swale containing locational information (geographic coordinates and cardinal direction) and the time of photography.



Figure 9. Example of GPS field photo of Maritime Holly Forest containing locational information (geographic coordinates and cardinal direction) and the time of photography.



Figure 10. Underwater video camera attached to a sled and towed behind a vessel.



Figure 11. Trimble ProXR GPS receiver mounted on a kayak positioned directly over the camera sled.



Figure 12. VCR/TV combo aboard the towing vessel recording SAV conditions and geographic coordinates on video files.

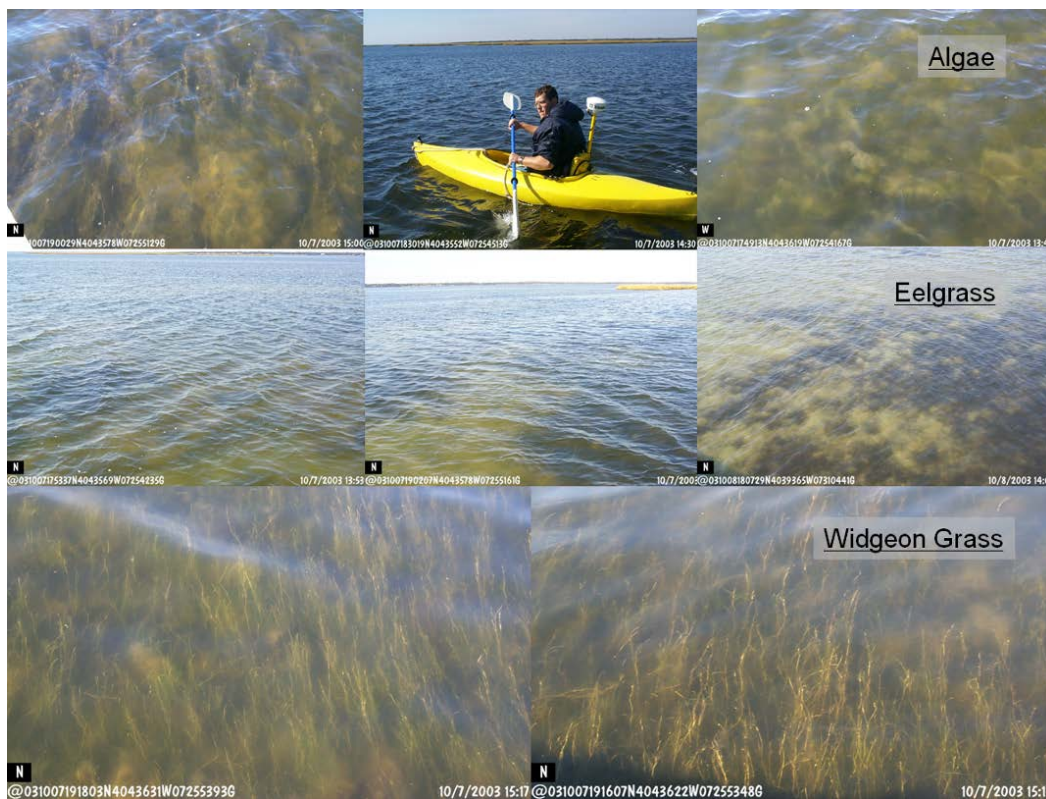


Figure 13. Surface observations for identifying seagrass patches, densities, and species.



Figure 14. Gridded, 0.25m PVC frame used to estimate percentage cover of SAV.

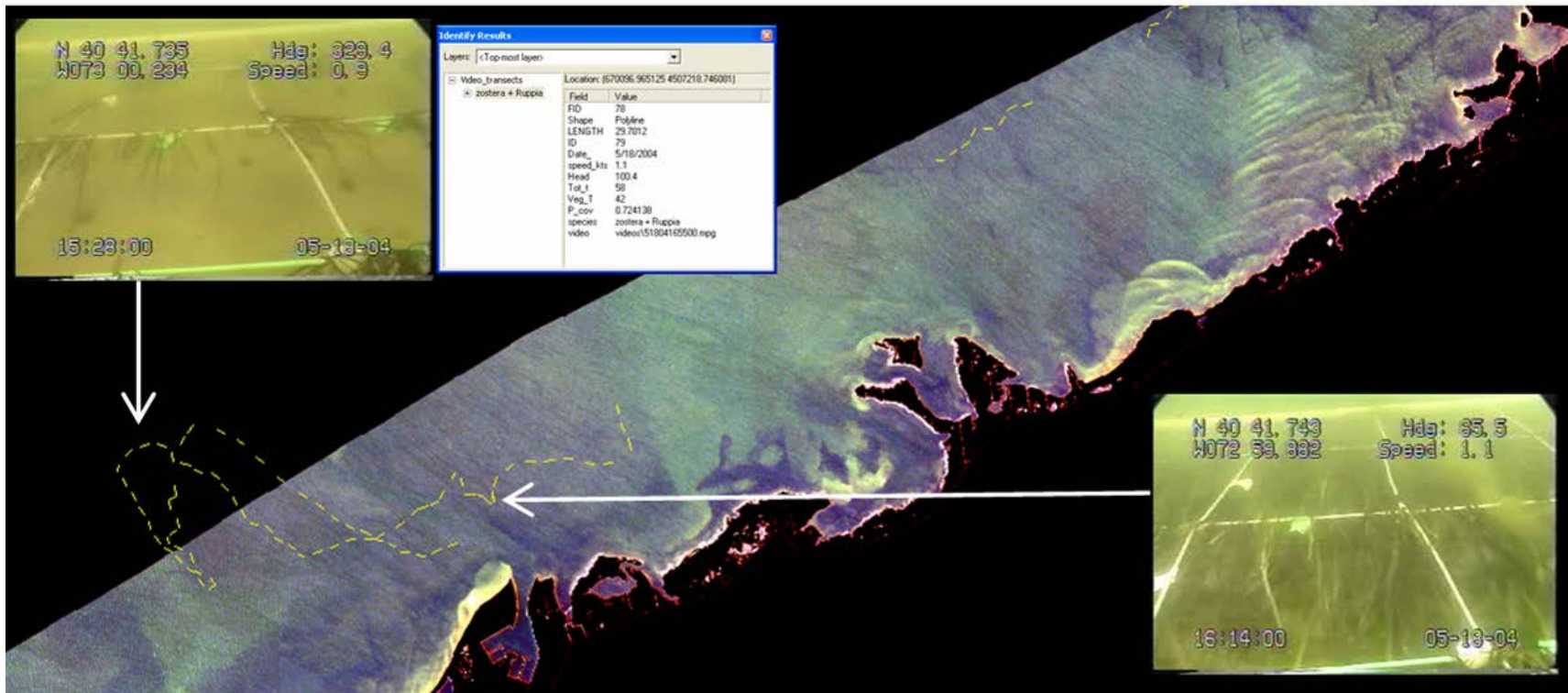


Figure 15. Digital video files corresponding to each 30-meter line segment. Percent SAV observed within each transect was estimated by dividing the number of seconds in which seagrass was observed in the camera field of view by the total seconds in each clip.

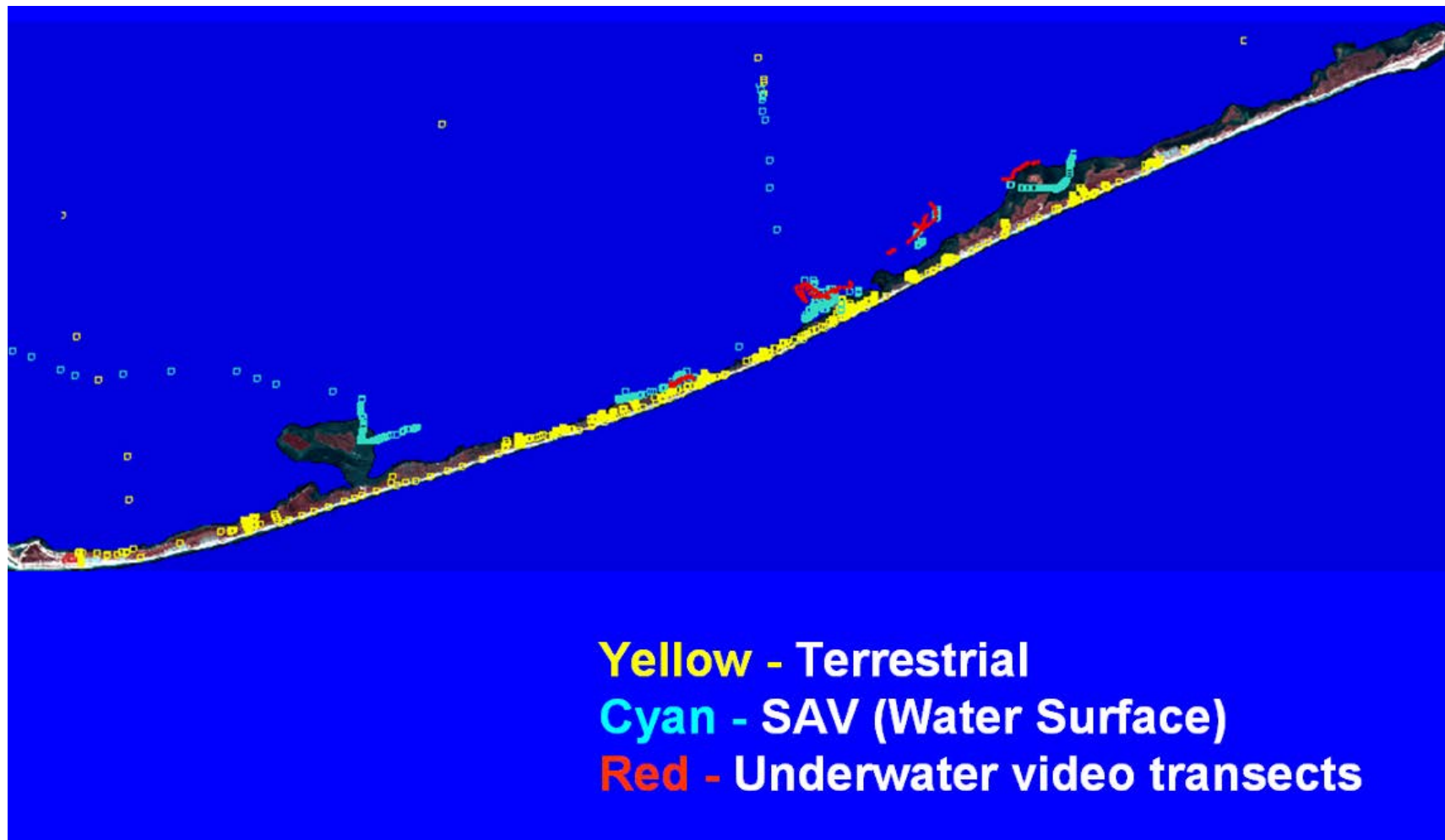


Figure 16. Locations of field verifications sites for both terrestrial vegetation and SAV at FIIS. Sites in William Floyd Estate not shown.

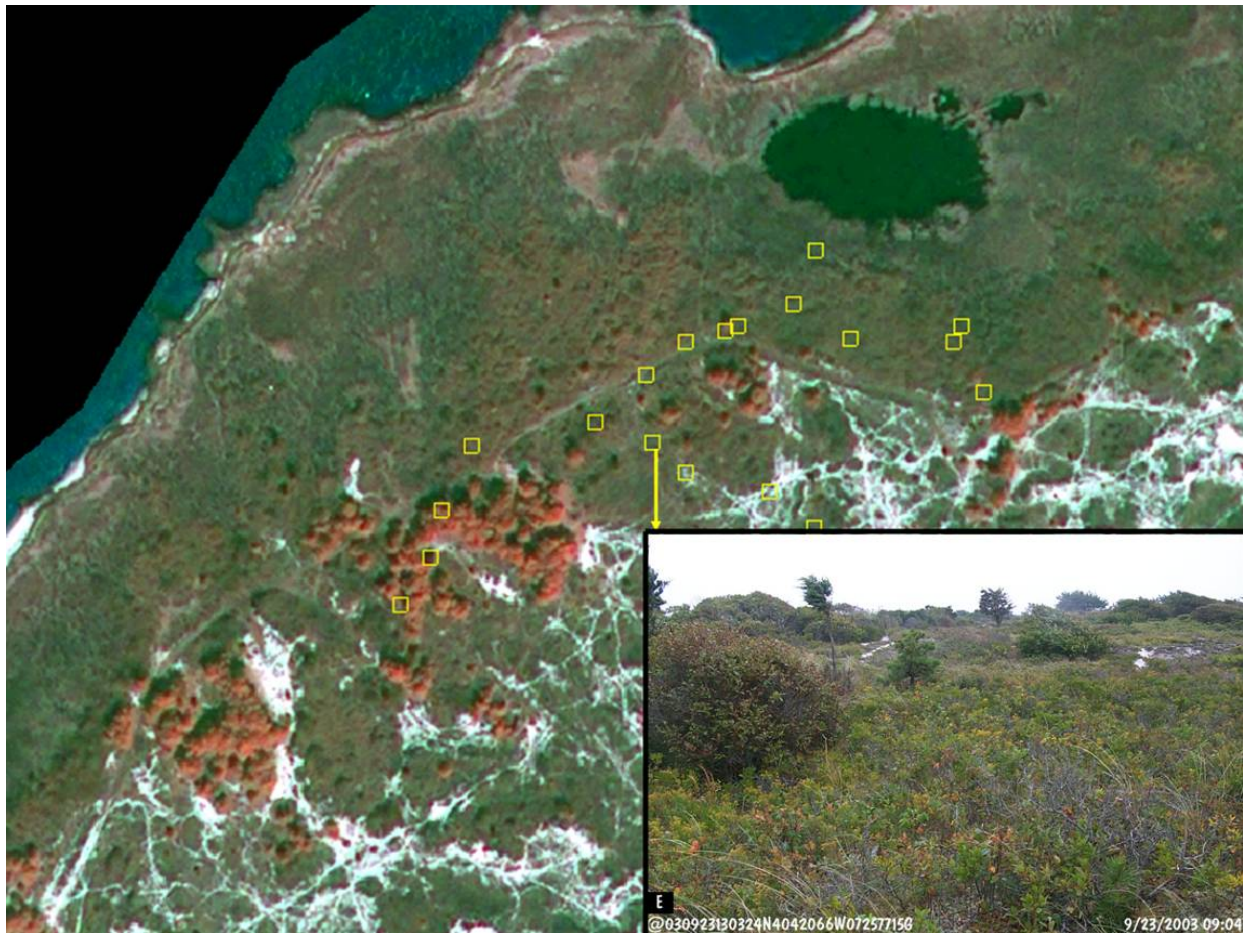


Figure 17. Example of a GPS field photo corresponding to a ground reference location on a QuickBird-2 image. The field photo is imprinted with GPS-obtained UTM coordinates, compass bearing, and a date/time stamp.

Digital Image Classification

Image Classification for Terrestrial Vegetation Mapping

We used a stratified digital image classification technique to extract terrestrial vegetation types from the QuickBird imagery data. This protocol required the support from an existing vegetation map in GIS format, which defined approximate boundaries of vegetation types from previous delineations on aerial photos. For this purpose, we referenced the vegetation communities identified by the Phase I map. The stratified classification helped reduce errors caused by the similar spectral features among some common terrestrial vegetation types on FIIS. The protocol procedures were as follows:

- We first rasterized the vector-format vegetation data from the Phase I map. The resampled pixel size matched the 2.5-meter resolution of Quickbird-2 satellite multispectral imagery data.
- We rectified the rasterized Phase I GIS vegetation map by image-to-image geometric rectification with georegistered Quickbird-2 imagery as the base. Cells of rasterized Phase I vegetation map were aligned with the pixels in the Quickbird-2 imagery.

- Using the “mask” function of the ERDAS Imagine software system, we developed masks for each vegetation type and land cover category defined in the rasterized Phase I vegetation map in order to extract pixels from the Quickbird-2 images that fell into those masked areas. This masking process separated the QuickBird-2 imagery data into subset segment images for further classifications.
- We then employed the ISODATA algorithm in unsupervised classifications for the subset images. We classified each image scene into 10 spectral clusters (classes), setting the convergence threshold at 0.95 and the maximum number of iterations at 20. The classifications performed on each subset image reached the convergence threshold before the maximum number of iterations was reached.
- We then labeled the resultant 10 spectral clusters according to the vegetation types of each of the subset segment image identified during the masking process. As the dominant category of the spectral clusters in each subset image should be the vegetation type defined in the original Phase I map, we labeled the pixels that possessed significant spectral differences into other categories based on our interpretation of collected field reference data, georeferenced photographs, and the 2002 aerial orthophotography. We repeated this procedure until all of the masked subset images were classified and labeled.
- We visually assessed agreement between the Phase I GIS vegetation map and the classification result.
- We mosaicked all of the subset images to create the final vegetation map.
- We met with resource managers at FIIS to present and discuss the preliminary classification results. We addressed problem areas identified by the resource managers, and finalized the classification before conducting a formal accuracy assessment.

Figure 18 illustrates an example of the rasterized Phase I vegetation map for a section of the Otis Pike Wilderness Area of FIIS. Using the salt marsh area identified in the Phase I map as the control, we masked out the corresponding pixels from the QuickBird-2 data (Figure 18). As can be clearly seen in this subset segment image, the spectral features for some of the pixels did not match the spectral features of the salt marsh categories. The dark red pixels, for example, represent a typical spectral response of coniferous trees (pitch pine dune woodland in this case), rather than salt marsh. Those pixel areas were either misinterpreted in the original delineation of salt marsh in the Phase I mapping, or may represent a change of vegetation pattern between the two imaging dates. After the unsupervised classification we reclassified those clusters of dark red pixels into the pitch pine dune woodland category. We labeled the pixels in the rest of the clusters that agreed with the Phase I map as salt marsh categories. Figure 19 illustrates the final vegetation map for this section.

The above example illustrates the process by which we updated the vegetation mapping in the Phase I map using fine spatial resolution multispectral QuickBird-2 remote sensing data. This protocol has the following advantages: it kept the classification system consistent with the previous vegetation mapping efforts, met the goal of updating the original Phase I vegetation map, and provided a means for change analysis and monitoring. Because the digital image classification used was pixel based, we were able to extract more detailed features within a delineated polygon for a given vegetation type in the Phase I map. In this process, the Phase I

map played an important role as the control data layer. Combining the two data sources resulted in comprehensive information on vegetation communities. It also demonstrated the necessity for repeated vegetation mapping for change analysis and monitoring.

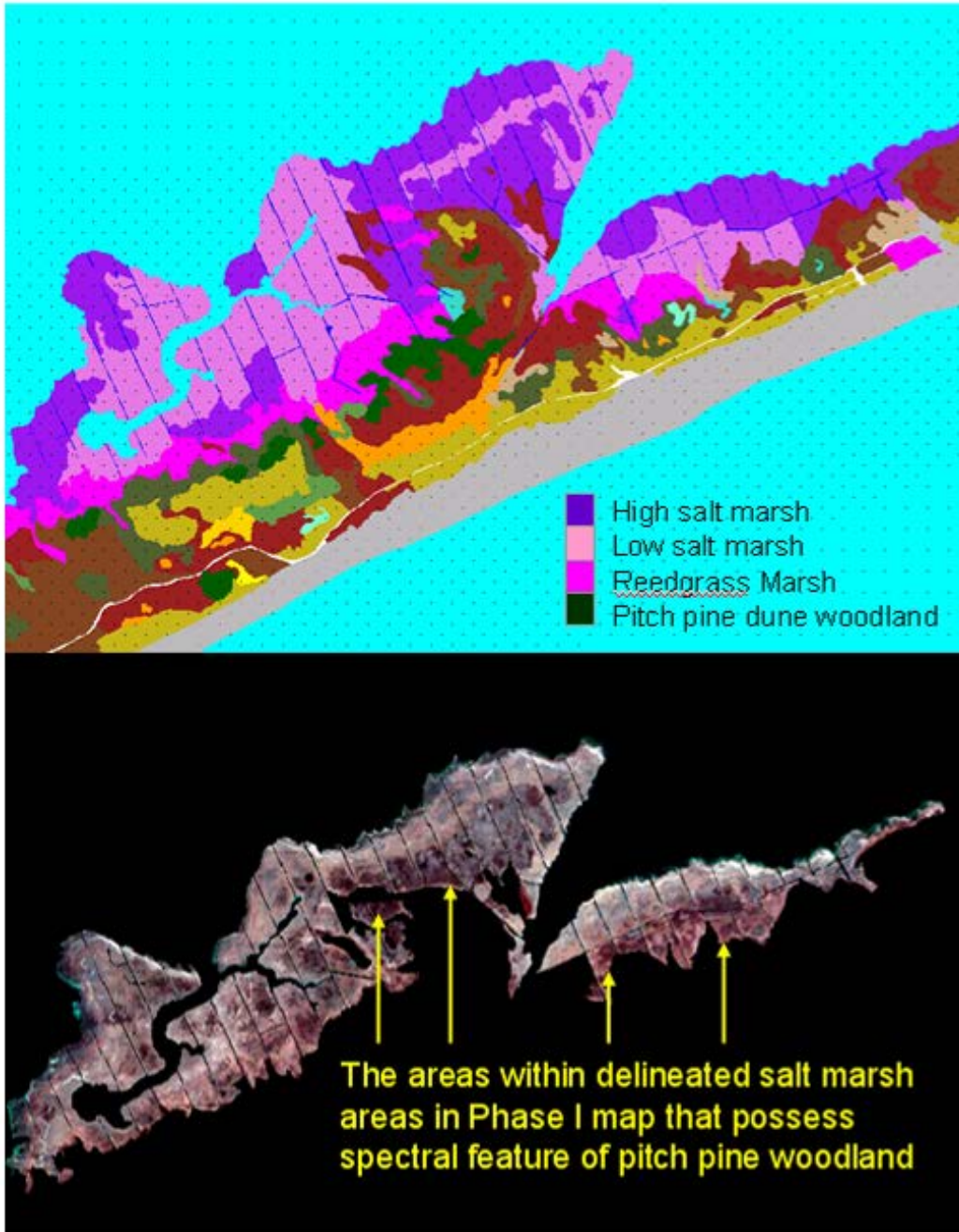


Figure 18. An example of the rasterized Phase I vegetation map for a section of the Otis Pike Wilderness Area of FIIS (top). Using the salt marsh area identified in the Phase I map as the control, we masked out the pixels from the QuickBird-2 image as the candidates for the category of salt marsh (bottom). The dark red-colored pixels displayed the typical spectral response of coniferous trees (in this case pitch pine dune woodland), rather than the salt marsh.

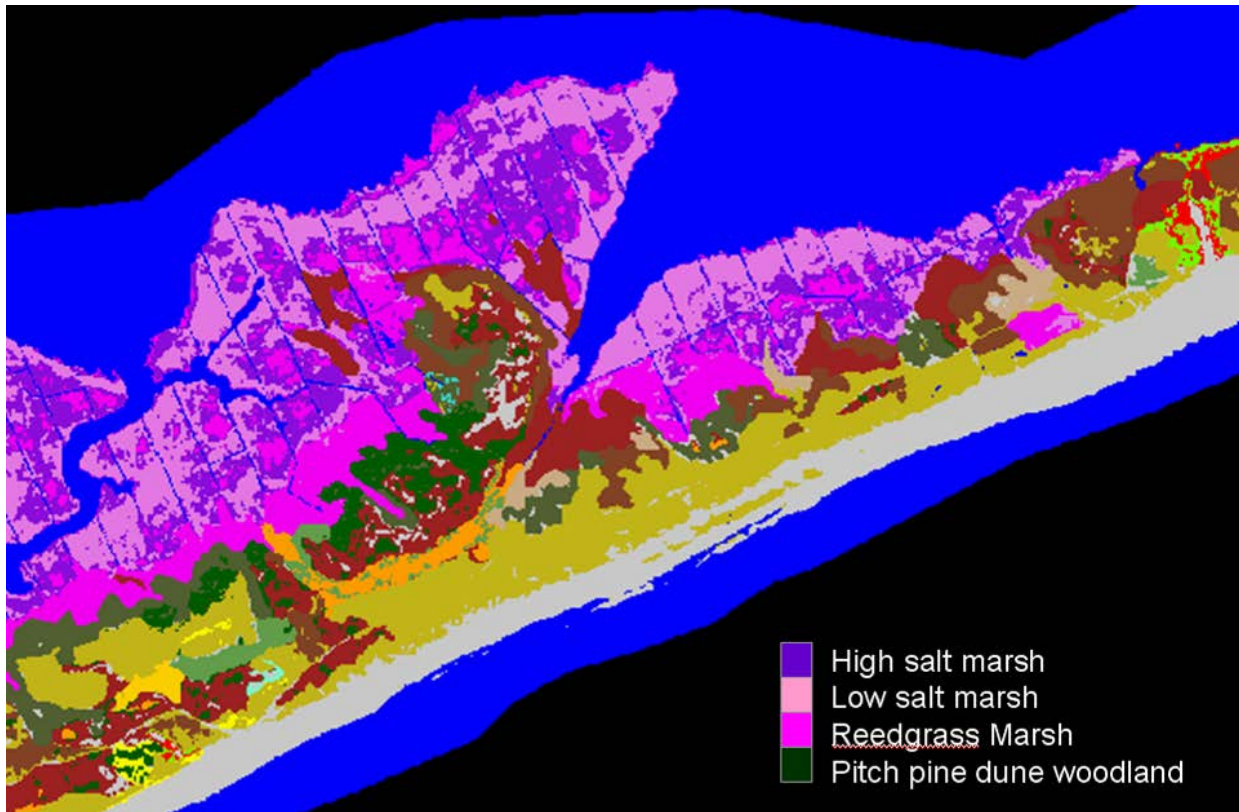


Figure 19. A section of the final vegetation map resulting from stratified classification. Spatial details and updates of the vegetation categories based on the Phase I vegetation map were derived from the finer spatial resolution QuickBird-2 data.

Image Classification for Submerged Aquatic Vegetation Mapping

For mapping of SAV areas, we eliminated the inland pixels from the QuickBird-2 imagery so that the classification could be focused on bay-side waters. We first created the land-mask Area of Interest (AOI) by conducting a two-class unsupervised classification using only the near infrared band of the QuickBird-2 imagery data. Due to the absorption characters of the water column on near infrared portion of the electromagnet radiation, this technique accurately separated the water areas from the land areas of FIIS (Figure 20).

We interpolated the NOAA bathymetric sounding data (Figure 21) to create a mask data layer for eliminating the deep water areas where SAV would be unlikely to exist. We manually delineated deep water areas that were not included in the bathymetric sounding data, such as deep channels in the bay, in order to remove those areas from the image data (Figure 22).

We then used the resulting data to mask out pixels of land and deep water areas in the bay from individual QuickBird-2 images so that the classification focused on SAV-related water areas only. Individual images were also kept separate in recognition of differences in image acquisition conditions, such as weather and water depth or clarity (Figure 23).



Figure 20. A section of the land-mask AOI created by a two-class unsupervised classification using only the near infrared band of the QuickBird-2 imagery data.

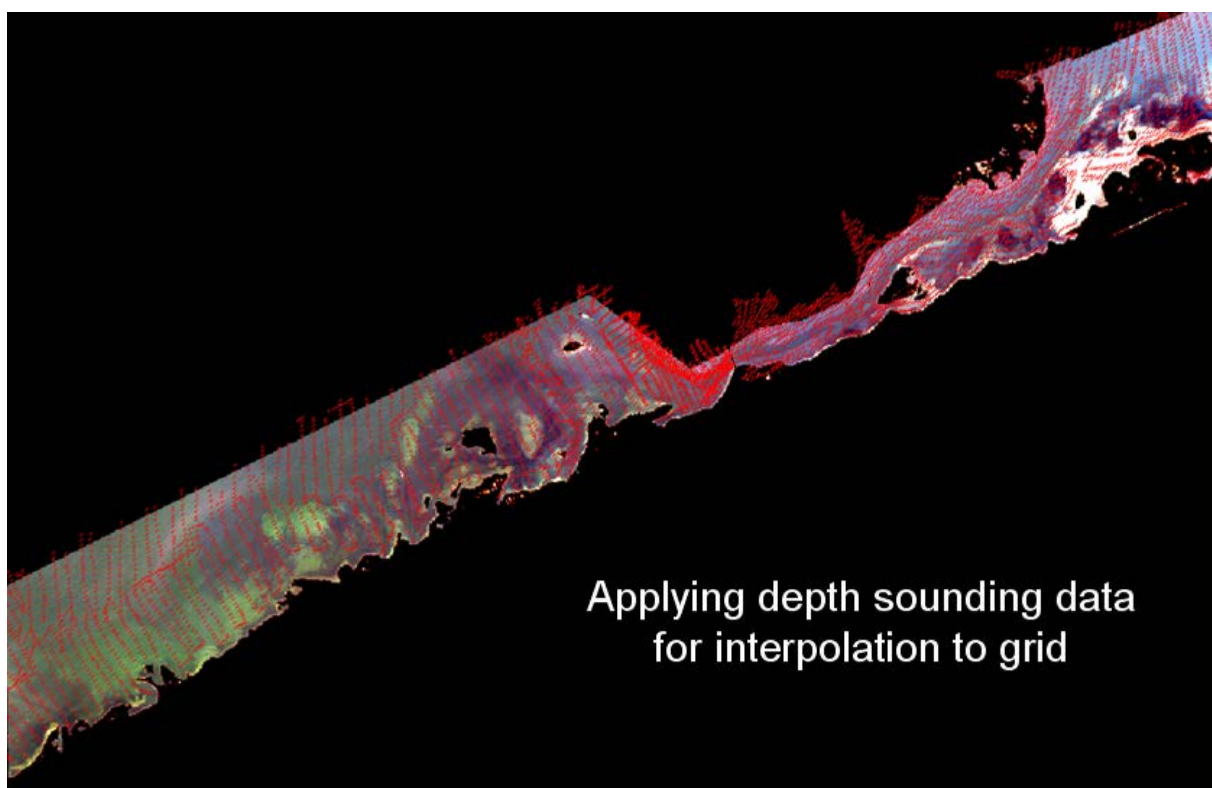


Figure 21. An example of NOAA bathymetric sounding data used to interpolate a raster surface and create a mask data layer for eliminating the deep water areas where SAV would be unlikely to exist.

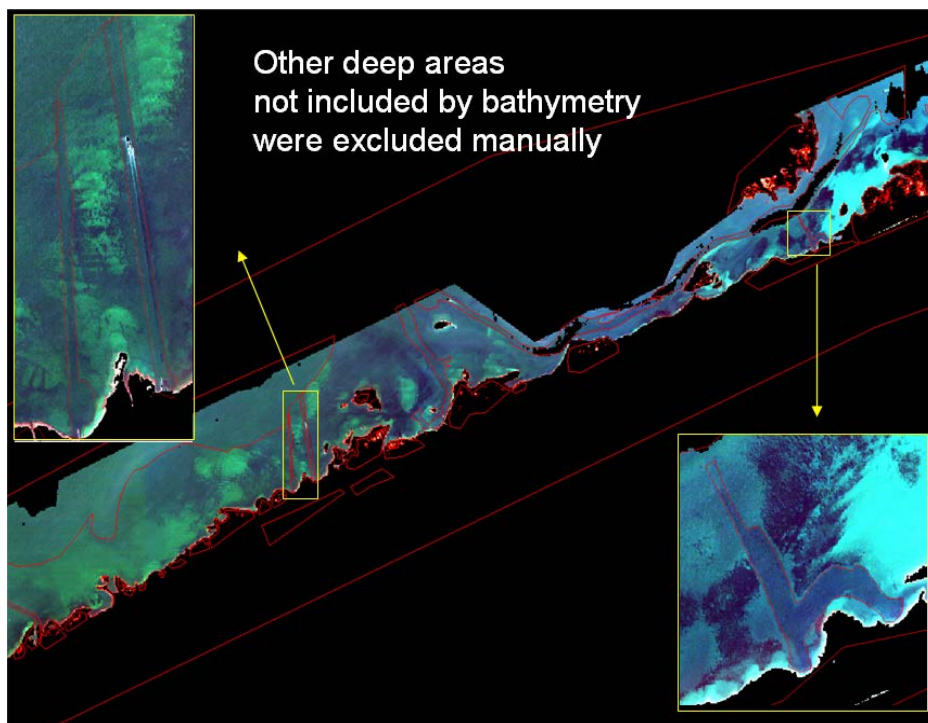


Figure 22. An example of deep water areas (such as deep channels) that were not included in the bathymetric sounding data. These areas were instead manually delineated in order to remove them from the image data.

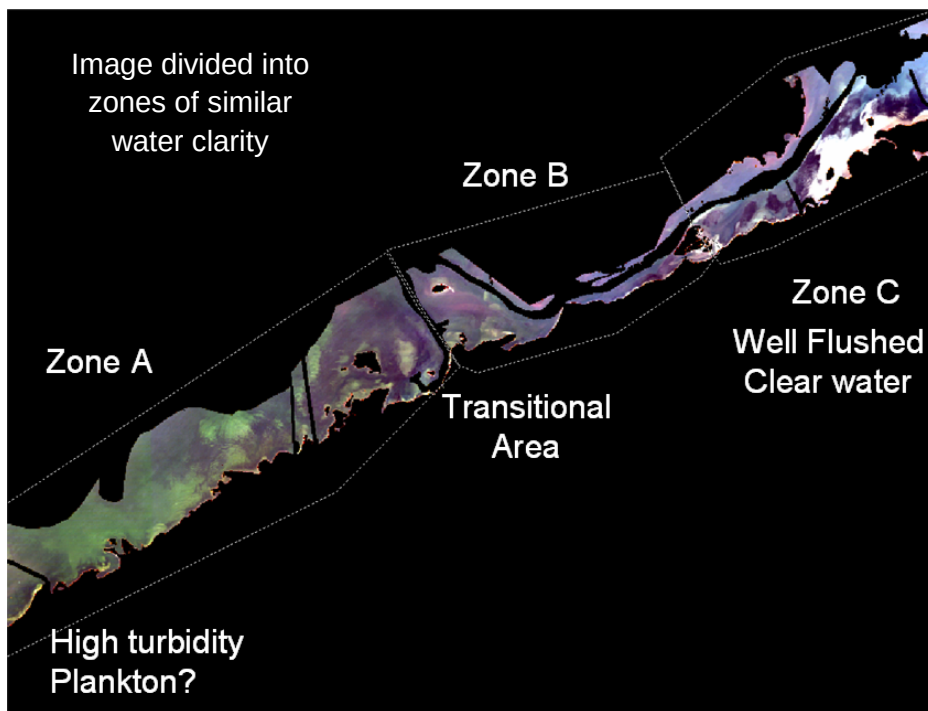


Figure 23. An example of QuickBird-2 imagery with land and deep water areas in the bay masked out in order to focus on SAV-related water areas only. Images with different acquisition conditions are delineated into zones.

This processing of individual images was done to compensate for subtle effects of environmental differences at the time of image acquisition, including changes in surface condition caused by high winds or areas of varying fetch. High winds can cause surface waves that affect the spectral responses of the subsurface signatures. A second difference in acquisition conditions is water depth due to different tidal heights. As the QuickBird satellite images were acquired on different dates, the water depth varied from scene to scene causing changes in spectral signatures. The clarity of varying water columns affected the albedo of seagrass signatures. The classification of images from individual scenes reduced the errors caused by such environmental differences associated with the time of image acquisition.

As the SAV habitats are so dynamic and we did not have a reliable reference data as a guide, we simply employed the ISODATA algorithm in unsupervised classifications for mapping this habitat. We classified each image scene into 20 spectral clusters with a convergence threshold of 0.95 and a maximum number of iterations of 20. The classifications performed on each subset image reached the convergence threshold before the maximum number of iterations was reached. We then classified the resultant 20 clusters into three categories of high-density seagrass (HDS), low-density seagrass (LDS), and unvegetated bottom or sand (SND).

We employed several ancillary data sets in the process of labeling areas of SAV. These references included 2002 SAV mapping data generated by the New York Department of State and the NOAA Coastal Services Center, which used 1:1,200 color orthophotography for visual interpretation and manual delineation for two categories of continuous and discontinuous rooted vegetation in vector format GIS polygons (Figure 24). We also used our field georeferenced photographs and the 2002 aerial orthophotography to aid in our interpretations. During this process, we met with resource managers at FIIS to present and discuss the preliminary classification results, and we addressed problem areas that were identified. Finally we created the vegetation map by mosaicking together the results from the stratified classification of terrestrial vegetation and the unsupervised classification for SAV.

NY DOS and NOAA SAV mapping (1:12,000)

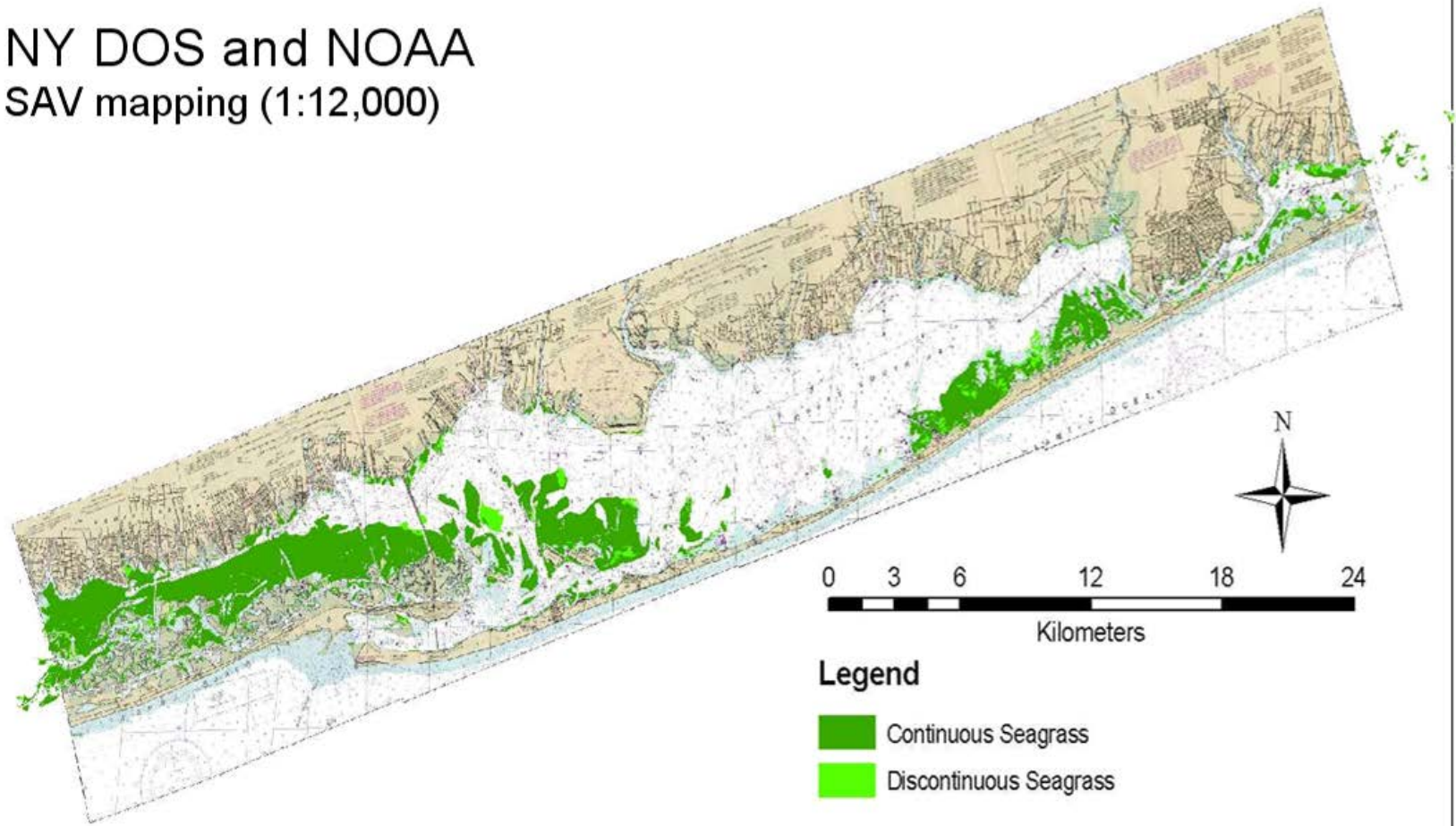


Figure 24. The 2002 NYDOS / NOAA SAV data provided reference information concerning the presence and absence of seagrass habitats in Great South Bay, NY.

Results

Terrestrial Vegetation Mapping

Terrestrial Vegetation Classification

Given that we used a stratified classification with the Phase I map data as the control, the resulting map could be considered an update of the Phase I map with an enhanced level of detail. The original descriptions of the vegetation communities in the Phase I map are applicable to this project, as well.

Because both the Phase I map and the current map utilize the same classification, we were able to compare spatial distributions statistics of the vegetation types at FIIS. Figure 25 shows a close up example of the final vegetation map for the Otis Pike Wilderness Area. Figure 26 shows a comparison between the terrestrial vegetation classification from QuickBird-2 imagery data and the Phase I vegetation map data for the Williams Floyd Estate of FIIS. Table 2 summarizes the final classification and the total area of each terrestrial vegetation type at FIIS (including the William Floyd Estate).

[Because of their small size, the vegetation types of Old Field Red-Cedar Forest and Maritime Post Oak Forest were eliminated from the current vegetation map, and they were subsequently not used in accuracy assessment. This does not necessarily mean that these vegetation types do not exist at FIIS, but rather they need to be identified by land managers who are familiar with their locations.]

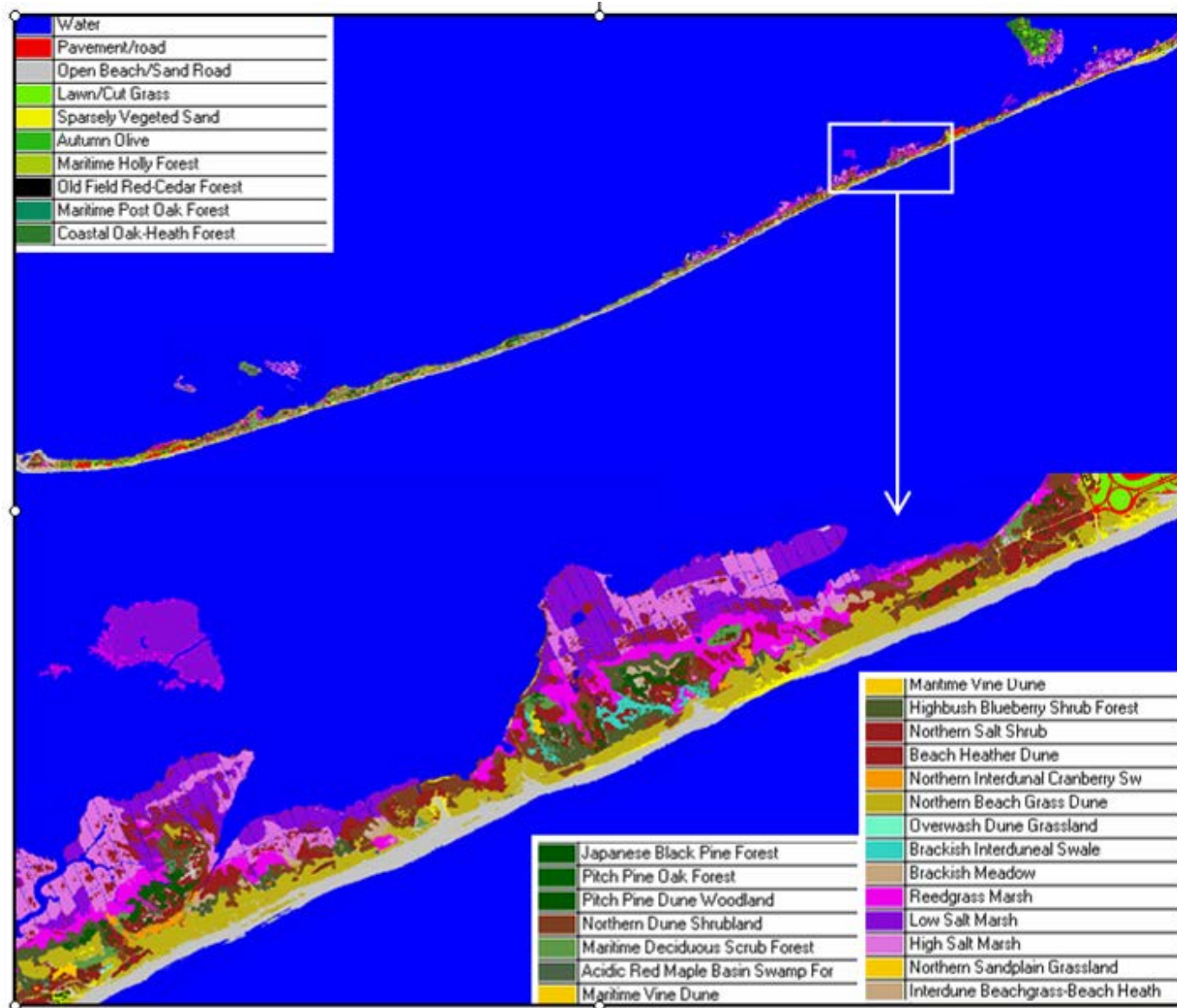


Figure 25. An example of terrestrial vegetation classification at the Otis Pike Wilderness Area of FIIS.

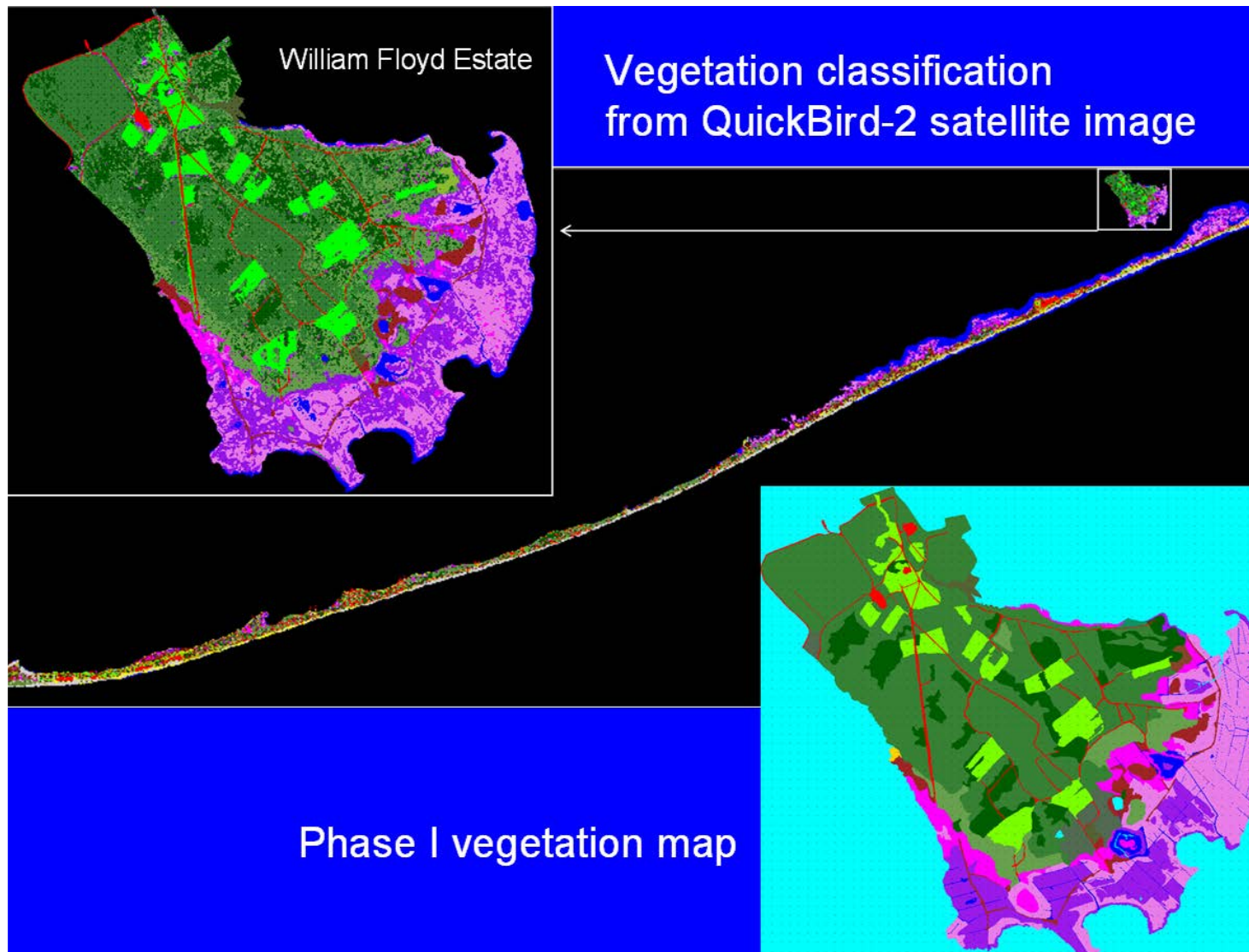


Figure 26. A comparison of the terrestrial vegetation classification from QuickBird-2 imagery data and the Phase I vegetation map data for the Williams Floyd Estate of FIIS.

Table 2. Results of the final classification and total area of each terrestrial vegetation type at FIIS (including the William Floyd Estate).

Vegetation Type	Area (ha.)
Autumn Olive	4.0
Maritime Holly Forest	25.0
Coastal Oak-Heath Forest	55.0
Japanese Black Pine Forest	86.0
Pitch Pine Oak Forest	34.0
Pitch Pine Dune Woodland	17.0
Northern Dune Shrubland	169.0
Maritime Deciduous Scrub Forest	278.0
Acidic Red Maple Basin Swamp Forest	0.4
Maritime Vine Dune	3.0
Highbush Blueberry Shrub Forest	39.0
Northern Salt Shrub	99.0
Beach Heather Dune	62.0
Northern Interdunal Cranberry Swale	2.3
Northern Beach Grass Dune	208.0
Overwash Dune Grassland	2.5
Brackish Interdunal Swale	2.5
Brackish Meadow	4.7
Reedgrass Marsh	119.0
Low Salt Marsh	224.0
High Salt Marsh	188.0
Northern Sandplain Grassland	1.1
Interdune Beachgrass-Beach Heather Mosaic	37.0
Lawn/Cut Grass	88.0
Sparsely Vegetated Sand	84.0

Accuracy Assessment

It is important to note that there are always errors in land cover maps derived from the classification of remote sensing data. Accuracy assessment is the process of quantitatively determining the accuracy of a land cover dataset in terms of thematic classification in order to determine whether the product meets the requirements of the intended application.

Accuracy assessment is the general term used for comparing the land cover classification results to geospatial data that are assumed to be true. The assumed-true data are derived from ground referencing data or other reliable data sources. It is not practical to ground reference or otherwise test every pixel of a classified image. Therefore, a subset of reference pixels is usually used. Reference pixels are points on the classified image for which actual data are known. These reference pixels are usually randomly selected. By allowing the reference pixels to be selected at random spatial locations, the possibility of bias is lessened or eliminated (Congalton 1991).

We used the ERDAS Imagine accuracy assessment functions to conduct the accuracy analysis. We employed the “equalized random” sampling method, which randomly drew an equal number of sampling pixels from each land cover type derived from the classification. The process creates an accuracy assessment CellArray, or Error Matrix, for each data file to compare the classified image with reference data. The CellArray is a square array of numbers laid out in rows and columns that express the number of sample units assigned to a particular category relative to the actual category as verified in the field. The columns normally represent the reference data, while the rows indicate the classification generated from the remotely sensed data.

There are two types of accuracies reported: the producer’s and user’s accuracy. Producer’s accuracy is a reference-based accuracy that is computed by looking at the predictions produced for a class and determining the percentage of correct predictions. User’s accuracy is a map-based accuracy that is computed by looking at the reference data for a class and determining the percentage of correct predictions for these samples.

The Kappa coefficient expresses the proportionate reduction in error generated by a classification process, compared with the error of a completely random classification. For example, a Kappa value of .82 would imply that the classification process was avoiding 82 percent of the errors that a completely random classification would generate (Congalton 1991).

In this project, we used a total of 1,500 randomly selected pixel locations, 50 from each category, to compare with the Phase I vegetation map and our own ground verification data for accuracy assessment. We examined the agreement between the classification result and the visual interpretation for each of the reference pixel locations. The overall accuracy was ~ 82%, with an overall Kappa statistic of 0.81 (Table 3). The confusion matrix describes the errors among categories (Table 4). The results reveal that the most significant sources of error came from the categories of Coastal Oak-Heath Forest and Pitch Pine Oak. Spectral similarities between the two categories contributed to misclassifications. Another major source of error was confusion between the categories of Northern Beach Grass Dune and Sparsely Vegetated Sand. These two categories were simply too dynamic and shared common features, such as exposed sand, that caused the confusion.

Table 3. Accuracy assessment of terrestrial vegetation classification of FIIS.

Class	Reference Totals	Class Totals	Number Correct	Accuracy		Kappa
				Producers	Users	
Water	60	50	49	81.67%	98.00%	0.9791
Pavement/Road	54	50	45	83.33%	90.00%	0.896
Open Beach/Sand	41	50	34	82.93 %	68.00%	0.6703
Lawn/Cut Grass	42	50	38	90.48%	76.00%	0.7526
Sparse Veg.	48	50	34	70.83%	68.00%	0.6686
Autumn Olive	46	50	45	97.83%	90.00%	0.8966
Maritime Holly Forest	46	50	45	97.83%	90.00%	0.8966
Old Field Red Cedar Forest	0	0	0	--	--	0
Maritime Post Oak Forest	0	0	0	--	--	0
Coastal Oak-Heath Forest	83	50	48	57.83%	96.00%	0.9575
Japanese Black Pine Forest	53	50	45	84.91%	90.00%	0.8961
Pitch Pine Oak Forest	17	50	15	88.24%	30.00%	0.2914
Pitch Pine Dune Woodland	41	50	38	92.68%	76.00%	0.7528
Northern Dune Shrubland	57	50	44	77.19%	88.00%	0.8749
Maritime Deciduous Scrub Forest	72	50	39	54.17%	78.00%	0.7681
Acidic Red Maple Basin Swamp	35	50	34	97.14%	68.00%	0.6718
Maritime Vine Dune	46	50	44	95.65%	88.00%	0.8759
Highbush Blueberry Shrub Forest	53	50	40	75.47%	80.00%	0.7921
Northern Salt Shrub	42	50	34	80.95%	68.00%	0.6701
Beach Heather Dune	59	50	43	72.88%	86.00%	0.8538
Northern Interdunal Cran. Swale	44	50	44	100.00%	88.00%	0.8761
Northern Beach Grass Dune	75	50	42	56.00%	84.00%	0.8309
Overwash Dune Grassland	50	50	49	98.00%	98.00%	0.9793
Brackish Interdunal Swale	44	50	41	93.18%	82.00%	0.8142
Brackish Meadow	38	50	38	100.00%	76.00%	0.7533
Reedgrass Marsh	63	50	47	74.60%	94.00%	0.9372
Low Salt Marsh	47	50	42	89.36%	84.00%	0.8344
High Salt Marsh	54	50	44	81.48%	88.00%	0.8752
Northern Sandplain Grassland	47	50	47	100.00%	94.00%	0.9379
Interdune Beachgrass-Heath	43	50	41	95.35%	82.00%	0.8143
Overall Classification Accuracy = 82.07%						
Overall Kappa Statistics = 0.8141						

Table 4. Confusion matrix for classification of terrestrial vegetation of FIIS.

Classified Data		Reference Data																																
		Water	Pavement/road	Open Beach/Sand	Lawn/Cut Grass	Sparse Veg	Autumn Olive	Maritime Holly	Old Field Red-Cedar maple	Maritime Post Oak Forest	Coastal Oak-Heath forest	Japanese Black Pine	Pitch Pine Oak	Pitch Pine Dune	Northern Dune Shrub	Maritime Deciduous Forest	Acidic Red Maple Basin Swamp	Maritime Vine Dune	Highbush Blueberry Shrub Forest	Northern Salt Shrub	Beach Heather Dune	Northern Interdunal Cran. Swale	Northern Beach Grass Dune	Overwash Dune Grassland	Brackish Interdunal Swale	Brackish Meadow	Reedgrass Marsh	Low Salt Marsh	High Salt Marsh	Northern Sandplain Grassland	Interdune Beachgrass-heath	Row Totals		
		49	45	34	38	1						1				1								1								50		
		1				3										3							5									2	50	
				1	2										1								13					1					50	
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Submerged Aquatic Vegetation Mapping

The unsupervised classification of SAV identified seagrass habitats within the park boundaries. Among SAV area identified, about 69% (1,544 ha) was classified as high-density seagrass (HDS) beds and 31% was classified as low-density seagrass beds (LDS). In comparison to the 2002 aerial seagrass survey that reported a total of 1,468 hectares of seagrass habitat, the result of this study should be more precise in SAV area coverage and spatial distributions because we used high spatial resolution raster format data instead of a rather generalized manual delineation of polygons.

Classification results show that the majority of the SAV habitats are located along the east and west sections of Fire Island. This is consistent with the results from both the NYDOS/NOAA 2002 mapping project data and the 1997 Army Corp of Engineers survey (USACOE, 2004). An example of our SAV map (Figure 27) shows a section of submerged habitat along the western portion of the Otis Pike Wilderness area. A close-up example illustrates more details of SAV mapping in this section (Figure 28). The pixel-based classification extracted more precisely the spatial distributions of the SAV habitats in the categories that were defined.

We conducted an accuracy assessment for SAV mapping using a similar procedure as that for the terrestrial vegetation types. Figure 29 illustrates the randomly selected sampling locations. The overall classification accuracy was about 75%. The producer and user accuracy for the HDS category were 80% and 72%, respectively. The producer and user accuracy for the LDS category were 77% and 66%, respectively (Table 5). It was difficult to discriminate between LDS and non-vegetated areas for some sites (Table 6).

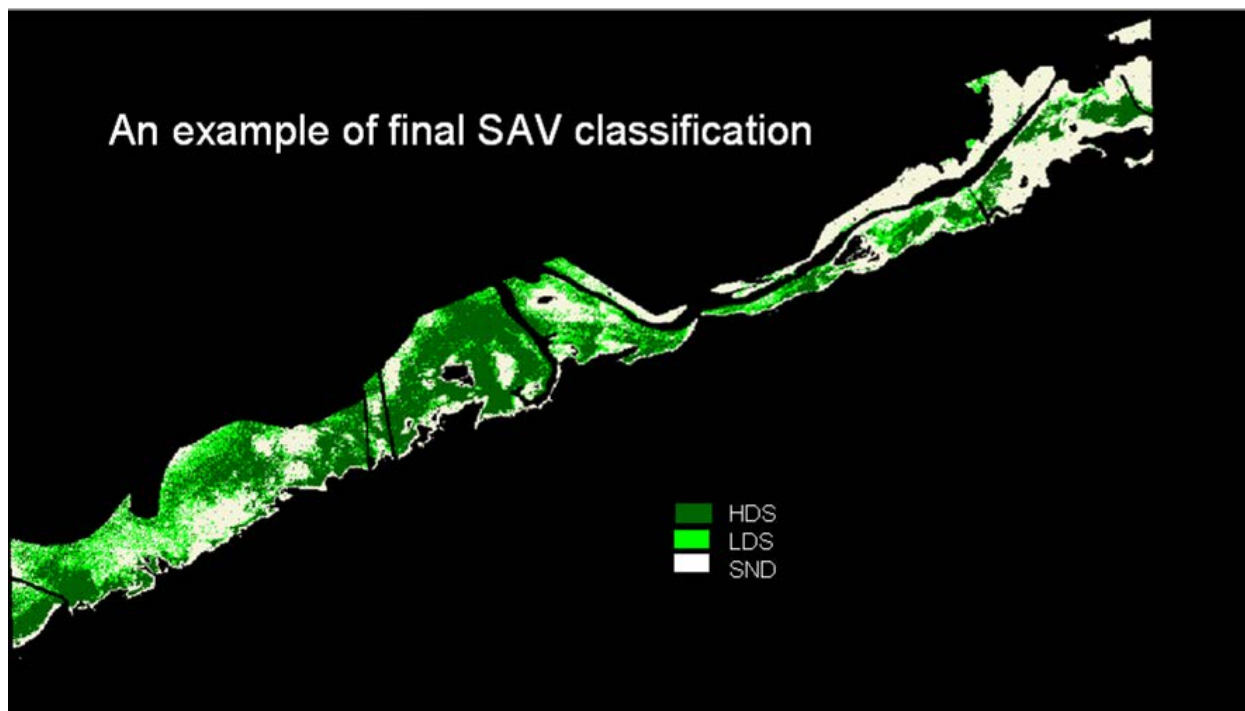


Figure 27. A portion of the SAV map showing a section of submerged habitat along the western portion of the Otis Pike Wilderness area.

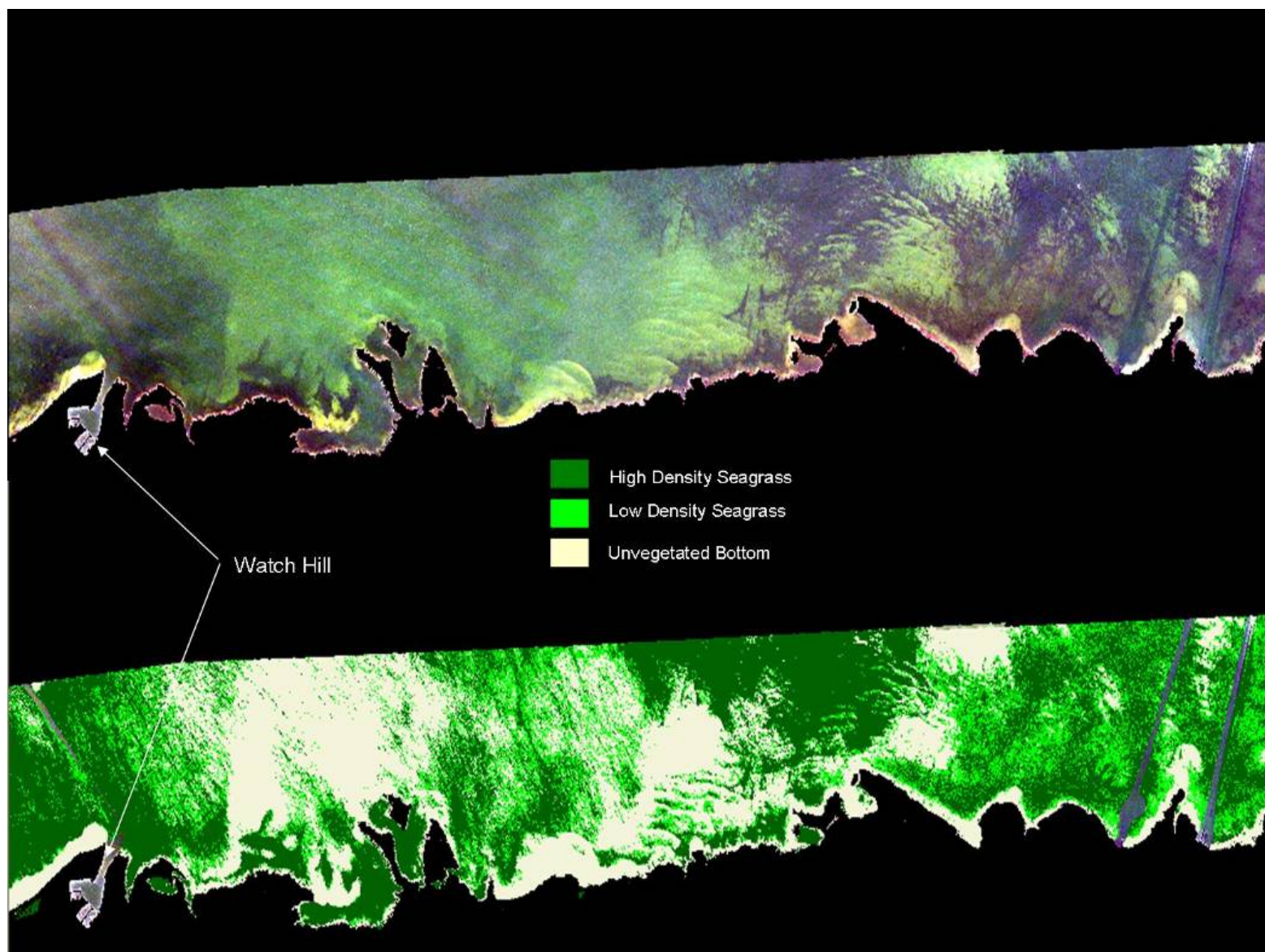


Figure 28. A close-up example illustrating more details of the SAV map (below) in comparison with the original QuickBird-2 imagery data (above).

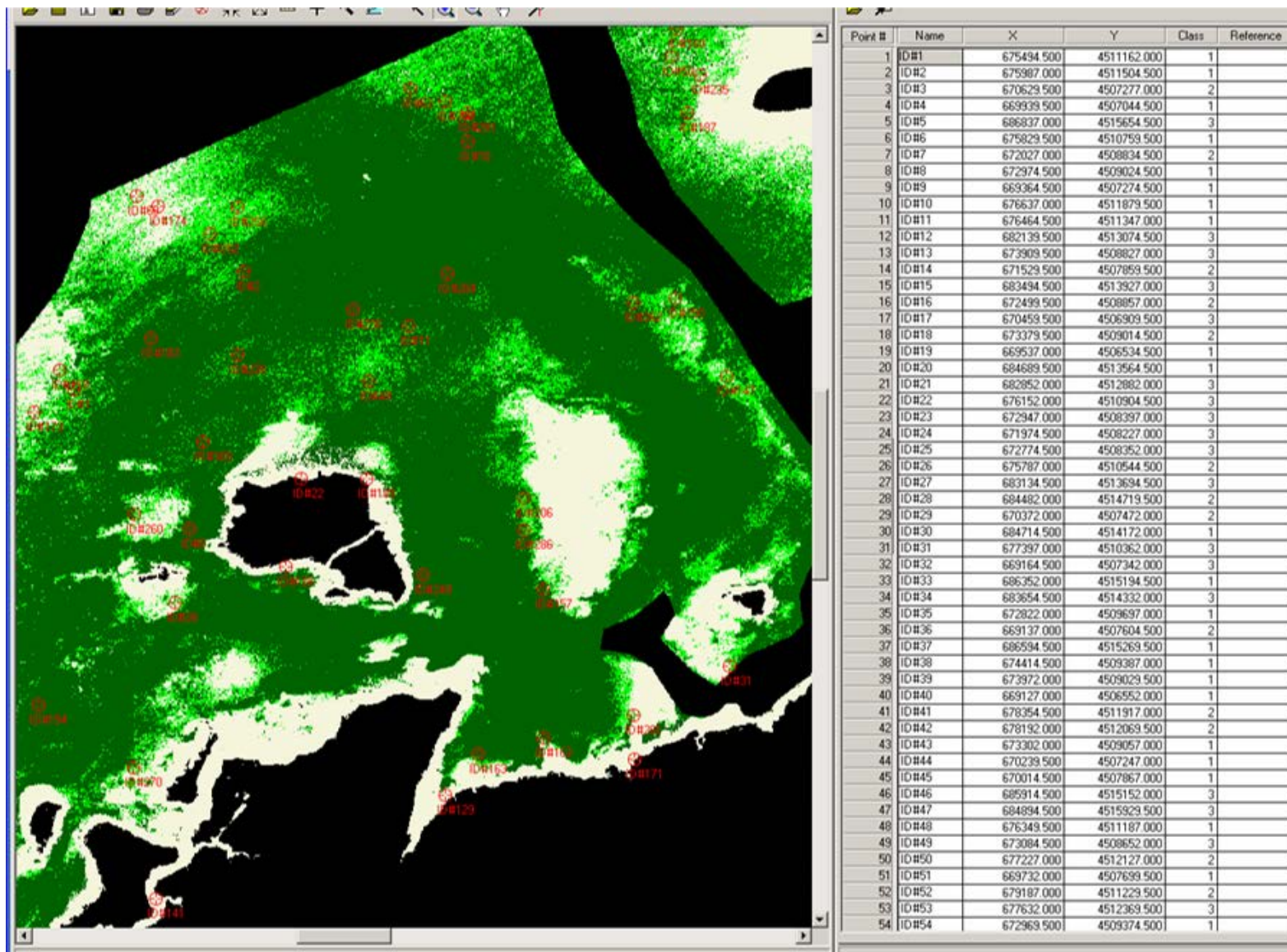


Figure 29. An example of randomly selected sampling locations used for accuracy assessment.

Table 5. Accuracy Assessment for SAV Classification.

Class	Reference Totals	Classified Totals	Number Correct	Accuracy		Kappa
				Producers	Users	
HDS	45	50	36	80.0%	72%	0.6
LDS	43	50	33	76.7%	66%	0.52
SND	62	50	43	69.4%	86%	0.76

Overall Classification Accuracy = 74.7 %
 Overall Kappa Statistic = 0.62

Table 6. Error Matrix for SAV Classification.

		<u>Reference</u>			Row
		HDS	LDS	SND	
<u>Classified</u>	HDS	36	5	9	50
	LDS	7	33	10	50
	SND	2	5	43	50
Column		45	43	62	150

We compared our SAV mapping using high spatial resolution QuickBird-2 imagery data with the NYDOS/NOAA image interpretation (Figures 30, 31). Our pixel-based classification extracted the SAV by defined spectral clusters rather than by subjectively determined polygon boundaries. Therefore more precise spatial locations were recorded and classified. However, the fine pixel size also generated so called “salt-and-pepper” effect, referring to isolated individual pixels scattered throughout the map that may not be meaningful indications of SAV habitat. These isolated pixels could either be eliminated through a filtering process in GIS or kept for future comparison and monitoring.

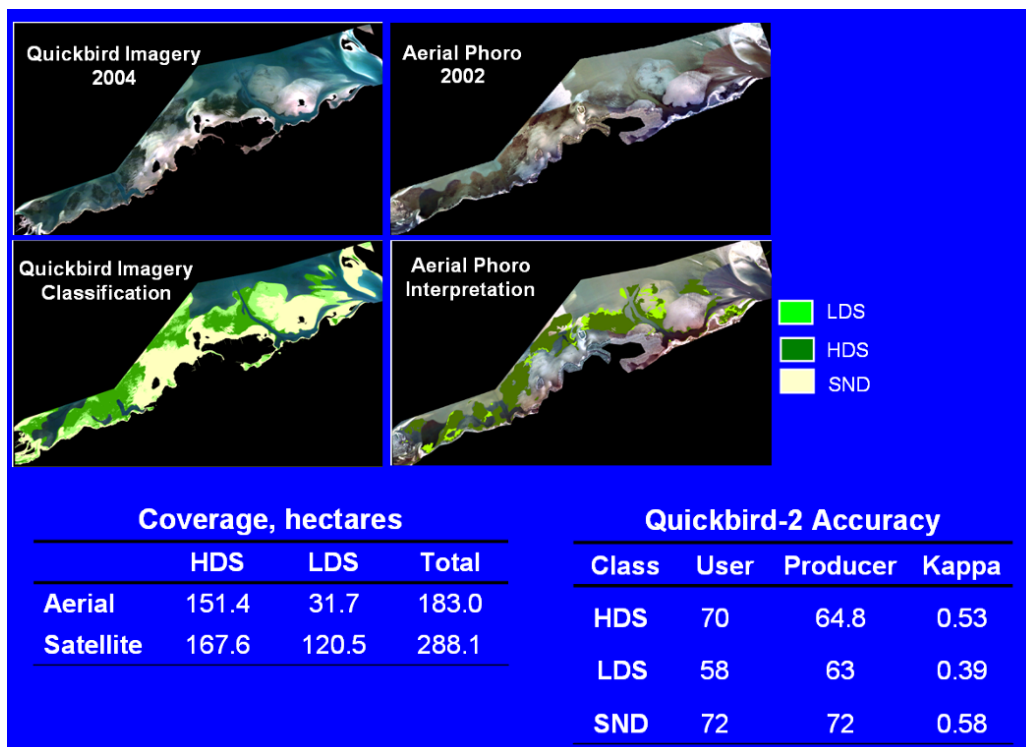


Figure 30. An example comparison (a) between our SAV mapping using high spatial resolution QuickBird-2 imagery data and the NYDOS/NOAA image interpretation.

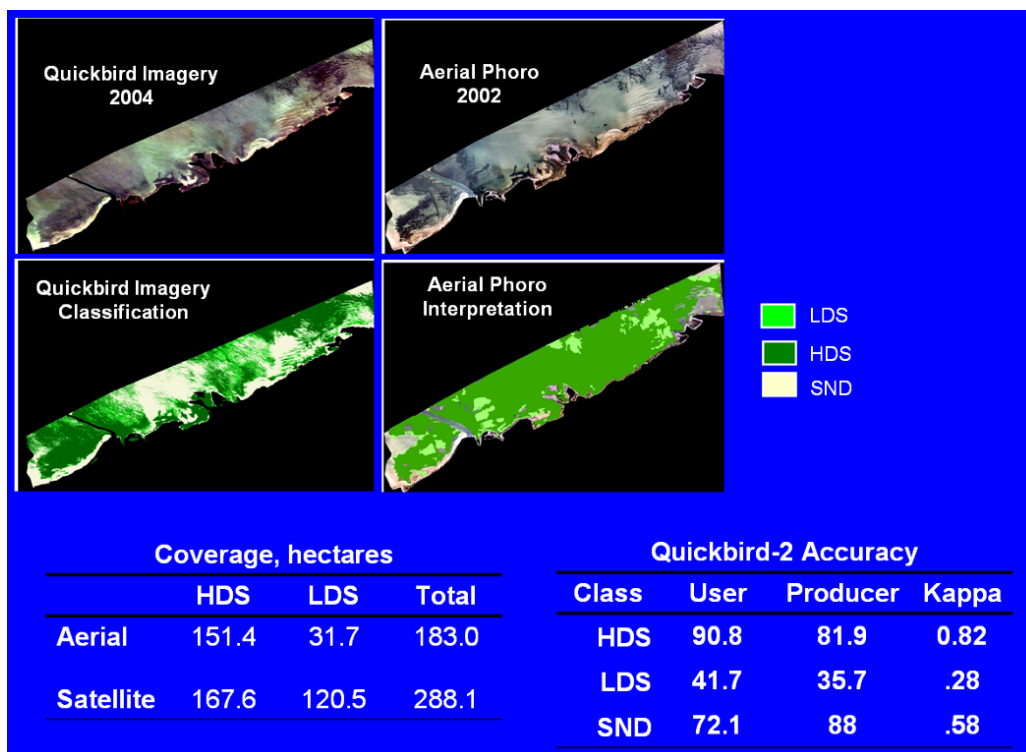


Figure 31. An example comparison (b) between our SAV mapping using high spatial resolution QuickBird-2 imagery data and the NYDOS/NOAA image interpretation.

Discussion

As stated in the Phase I vegetation mapping project report (Klopfer et al., 2002), “*The barrier island ecosystem is dynamic. Changes in dune topography, water availability, and salinity drive the community structure of the island. Periodic disturbances further change the vegetation communities. This dynamism, so integral to the function of the barrier island ecosystem, is often at odds with social and economic goals of the surrounding human communities. All of these factors contribute to the diversity and complexity of the vegetation found on Fire Island.*”

As the barrier island is constantly changing, updating of vegetation data products on a regular basis presents a challenging but necessary task for the Northeast Coastal and Barrier Network of the NPS I&M Program. This study engaged high spatial resolution satellite remote sensing data and intensive field sampling to update the existing Phase I terrestrial vegetation map and to establish baseline data for SAV mapping. This project produced new pixel-based map data that should be valuable as a reference for future mapping efforts in this National Seashore.

The Mapping Protocol

The Phase I vegetation map in GIS format played an important role as the control data layer. A combination of this existing spatial data and QuickBird-2 satellite remote sensing data helped achieve more comprehensive information on vegetation communities. Using stratified and unsupervised classification procedures, we subset the Quickbird-2 images and classified the pixels based on the control data. In this way we were able to identify areas where pixels had changed classification, as well as those where pixels remained in the same category as in the Phase I vegetation map.

Because this protocol maintains a consistent classification scheme with previous vegetation mapping efforts, it is able to meet goal of updating existing maps and can be utilized for change analysis and monitoring. Also, because digital image classifications were pixel-based, more detailed spectral features could be extracted within each delineated polygon from the Phase I dataset.

We feel that this is a practical protocol for future mapping replications. However, the protocol does require at least one existing vegetation map in GIS format to guide the classification process. Therefore, this may not be an appropriate tool for mapping areas for which no such vegetation data exists or for which such data does not meet the required level of detail for both assigning thematic information and determining spatial distributions.

The Mapping Results

Through classification of QuickBird-2 satellite images, we were able to identify areas that exhibited changes in vegetation type since the time of aerial photo acquisition of the Phase I project. Since the Phase I project was based on 1997 aerial photos and our classification used 2004 QuickBird-2 images, our results reflected changes in terrestrial vegetation on FIIS over seven years. These data are valuable for future comparative studies, as well as for inventory and monitoring activities.

The result of SAV mapping provides the most up-to-date, high-spatial-resolution information for FIIS. This study demonstrates that high spatial resolution remote sensing data can be used to

extract SAV information effectively. Masking procedures were necessary in order to separate the land areas from water habitats. The pixel-based classification generated products representing the detailed spatial distribution of SAV habitats at the time of image acquisition, in contrast to subjectively determined manual delineations of polygons. Underwater videography provided a critical reference to assure the quality of image classification for SAV mapping. However, we had limited success in differentiating between high-density and low-density seagrass habitats, as well as in discerning areas of differing species. More study is needed to understand the spectral differences among key SAV species so that this level of SAV mapping can be achieved.

To this end, we did attempt to use hyperspectral remote sensing data acquired by the Hyperion sensor on board the EO-1 satellite data to differentiate areas of differing SAV species and thus improve the SAV mapping. The Hyperion sensor possesses a 30-meter spatial resolution with 220 spectral bands ranging from the visible to infrared portion of the spectrum in 10-nm intervals. We hoped that this nearly continuous spectral coverage would reveal signature information for different SAV species that could not be obtained by multispectral sensor data. However we were unable to obtain enough data to cover the study area for meaningful testing due to factors such as the limited swath of the sensor and cloud cover at the time of image acquisition. We still hope that an airborne hyperspectral sensor system – such as the AVIRIS, which possesses a similar spectral capacity as the Hyperion sensor – may provide the critical data needed to reveal spectral differences among common seagrass species in the Great South Bay, but further testing will be necessary.

Satellite Remote Sensing Data

The multispectral, 2.5-meter resolution QuickBird-2 satellite remote sensing data are considered sufficient for updating vegetation maps produced by interpretation of aerial photo data products. Other satellite remote sensing data that have similar spectral coverage and spatial resolutions can also be applied to such mapping efforts. For example, IKONOS data possess a 4-meter spatial resolution in multispectral bands and have the same spectral coverage as the QuickBird-2 data.

Although high spatial resolution satellite imagery data have advantages in mapping spatial details, they also possess limitations. When utilizing aerial photography, project planners may work with a vendor to schedule flights so that the best time for data acquisition can be achieved. Timing of acquisition of satellite imagery data is mostly out of the control of end. This is particularly true for SAV mapping. In this project, for example, despite requesting a time window from April 1 to June 30, it was still difficult to obtain optimal data within those three months due to cloud cover. The problem is further exacerbated by the fact that seagrass mapping requires water clarity to be such that water radiation transfer is maximized. The result is that standards of data acquisition for submerged mapping projects can often not be met by satellite data providers. For example, the NOAA CCAP protocol requires that aerial photograph collection for SAV habitat delineation should be conducted within 2 hours of mean low water, with cloud cover of less than 10%, with a wind speed of 10 mph or less, and with a sun declination angle between 10 and 30 degrees. These conditions are very difficult to meet in satellite data acquisition. Luckily, seagrass habitat is often found in quiet embayments behind protective barrier beaches and in small lagoons that usually have smaller tidal amplitudes, thus increasing the chances of obtaining useable satellite imagery.

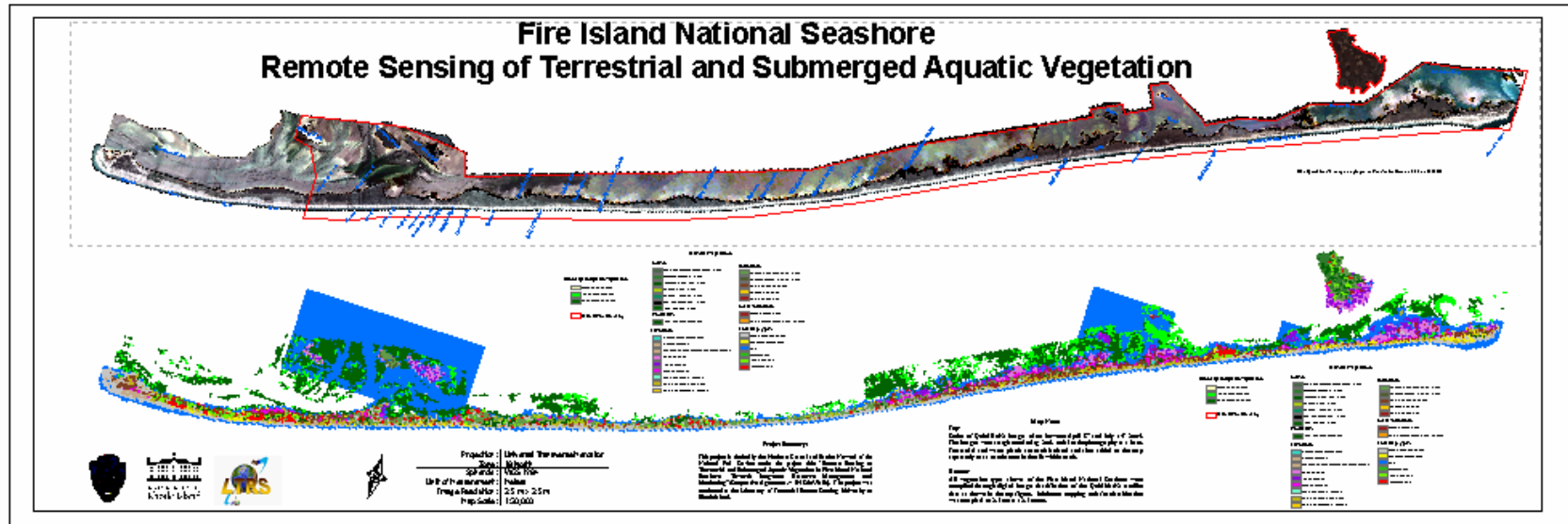
Another consideration of satellite data acquisition is orbit orientation. Most imaging satellites are in Sun-synchronous orbit, which means that they track from north to south. With each pass the satellite has a limited imaging capability in the east-west orientation. To cover a study area that is predominantly oriented in the east-west direction, such as FIIS, data acquisition must occur over multiple days. QuickBird-2 data, for example, can image a swath at nadir with a maximum width of 16.5 km. Differences in weather, tides, water column properties, and submerged plant conditions result in having to classify the various images separately.

Nevertheless, this study demonstrates that high spatial resolution satellite remote sensing data provide a promising data source for mapping both terrestrial vegetation and SAV in FIIS (Wang et al., 2007).

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Appendix B: Metadata for Terrestrial Vegetation Map

Identification_Information:

Citation:

Citation_Information:

Originator: YQ Wang

Originator: Mike Traber

Publication_Date: Unpublished Material

Publication_Time: Unknown

Title: fiisvegetationfinal.img

Geospatial_Data_Presentation_Form: remote-sensing image

Description:

Abstract:

Classification of Terrestrial Vegetation from Quickbird-2 Satellite imagery for the Fire Island National Seashore. An unsupervised classification was performed to classify the terrestrial habitats only within the Fire Island National Park boundary.

This is a result of a project funded by the NPS to develop a protocol to utilize high resolution satellite imagery to map and monitor critical habitats within the North East Coastal Barrier Network of parks.

Purpose: This data was created as part of National Park Service funded project to develop a protocol for mapping terrestrial and submerged aquatic habitats using satellite imagery. The data presented here is to be used for park managers to monitor the status of critical park habitat.

Time_Period_of_Content:

Time_Period_Information:

Range_of_Dates/Times:

Beginning_Date: May 2004

Ending_Date: July 2004

Currentness_Reference: ground condition

Status:

Progress: Complete

Maintenance_and_Update_Frequency: None planned

Spatial_Domain:

Bounding_Coordinates:

West_Bounding_Coordinate: -73.313144

East_Bounding_Coordinate: -72.753105

North_Bounding_Coordinate: 40.785037

South_Bounding_Coordinate: 40.609369

Keywords:

Theme:

Theme_Keyword_Thesaurus: None

Theme_Keyword: Digital Images
 Theme_Keyword: Vegetation Mapping
 Theme_Keyword: Points
 Theme_Keyword: Quickbird-2
 Theme_Keyword: seagrass
 Theme_Keyword: Zostera
 Theme_Keyword: marina
 Theme_Keyword: eelgrass
 Theme_Keyword: Ruppia
 Theme_Keyword: maritima
 Place:
 Place_Keyword_Thesaurus: None
 Place_Keyword: Fire Island
 Place_Keyword: FIIS
 Place_Keyword: Long Island
 Place_Keyword: Great South Bay
 Place_Keyword: New York
 Place_Keyword: USA
 Access_Constraints: none
 Use_Constraints: none
 Point_of_Contact:

 Contact_Information:
 Contact_Person_Primary:
 Contact_Person: YQ Wang
 Contact_Organization: University of Rhode Island, Dept of Natural Resources Science
 Contact_Position: Professor
 Contact_Address:
 Address_Type: mailing and physical address
 Address: University of Rhode Island
 Address: Coastal Institute Building
 Address: 1 Greenhouse Rd
 City: Kingston
 State_or_Province: RI
 Postal_Code: 02881
 Country: USA
 Contact_Voice_Telephone: 401 874-4345
 Contact_Electronic_Mail_Address: yqwang@gso.uri.edu
 Native_Data_Set_Environment: Microsoft Windows XP Version 5.1 (Build 2600) Service
 Pack 2; ESRI ArcCatalog 9.0.0.535

Data_Quality_Information:

Attribute_Accuracy:

Attribute_Accuracy_Report: Accuracy assessment was conducted using ERDAS Imagine. 50 points were randomly selected within each category. Each point was reviewed by the image analyst and categorized independently using image and reference data. The reference data included, the original Quickbird-2 image, 2003 1:12,000 color orthophotography, NPS 2002 Vegetation mapping project data, field photos, and personal knowledge of the study site. Please see report Table 5. for producer and user accuracy for each class.

Quantitative_Attribute_Accuracy_Assessment:

Attribute_Accuracy_Value: 82.07 %

Attribute_Accuracy_Explanation: Overall Classification Accuracy

Quantitative_Attribute_Accuracy_Assessment:

Attribute_Accuracy_Value: .8141

Attribute_Accuracy_Explanation: Overall Kappa Value

Logical_Consistency_Report: This is a grid image with 2.5 meter pixels. No topology is present. Spatial and attribute accuracy was performed.

Positional_Accuracy:

Horizontal_Positional_Accuracy:

Horizontal_Positional_Accuracy_Report: All image processing was conducted using ERDAS Imagine software version 8.7. Each scene of QuickBird images was independently reregistered using 2003 color aerial orthophotography as the base. The reported accuracy of the orthophotography is documented in the meta-data delivered along with the image was 5.5 meters. Between 10 and 20 control points were selected for each image scene. Each scene was registered to an accuracy of 0.5 pixels or 1.25 meters, determined from the root mean square error term provided by the software (ERDAS Imagine). The classified result was not altered spatially from the original image scene therefore the original positional accuracy is the same for the classification result as for the image.

Quantitative_Horizontal_Positional_Accuracy_Assessment:

Horizontal_Positional_Accuracy_Value: 6.25

Horizontal_Positional_Accuracy_Explanation: Meters, the spatial accuracy of the registered and mosaiced image scene.

Vertical_Positional_Accuracy:

Vertical_Positional_Accuracy_Report: none reported

Lineage:

Source_Information:

Source_Scale_Denominator: 24000

Type_of_Source_Media: CD-ROM

Source_Time_Period_of_Content:

Time_Period_Information:

Range_of_Dates/Times:

Beginning_Date: May 2004
Ending_Date: July 2004
Source_Citation_Abbreviation: Digital Globe
Source_Contribution: Imagery purchased from Digital Globe
Process_Step:

Process_Description: All image processing was conducted using ERDAS Imagine software version 8.7. Each scene of QuickBird images was independently reregistered using 2002 color aerial orthophotography as the base. The reported accuracy of the orthophotography is documented in the meta-data delivered along with the image was 5.5 meters. Between 10 and 20 control points were selected for each image scene. Each scene was registered to an accuracy of 0.5 pixels or 1.25 meters, determined from the root mean square error term provided by the software (ERDAS Imagine). This would yield a combined accuracy of 6.75 meters between our registration and the reported accuracy of the base image.

Process_Date: Unknown

Process_Contact:

Contact_Information:

Contact_Person_Primary:

Contact_Person: YQ Wang

Contact_Organization: University of Rhode Island

Contact_Position: Professor

Contact_Address:

Address_Type: mailing and physical address

Address: 1 Greenhouse Rd

Address: University of Rhode Island

City: Kingston

State_or_Province: RI

Postal_Code: 02881

Country: United States

Contact_Voice_Telephone: 401 874-4035

Contact_Electronic_Mail_Address: yqwang@uri.edu

Hours_of_Service: 8:30-4:30 EST

Contact_Instructions: Phone or E-mail

Process_Step:

Process_Description: Image preprocessing. The registered image was clipped using a rough area of interest (AOI) to remove the majority of land pixels or water pixels depending on which was to be classified. Once registered the individual scenes were processed to mask the land pixels from the scene. The land mask was created by conducting a 2 class unsupervised classification using only the near infrared band. This technique accurately separates the wet areas from dry areas as water has a large influence on the return of near-IR radiation. The resultant classification was used to mask the land pixels from the image. The masking step was

not performed for the terrestrial classification as it was important to include the in-land water component for the classification purposes.

Process_Date: November 2005 to May 2005

Process_Step:

Process_Description:

Image Classification of seagrass habitats.

Each image scene was classified individually. This level of individual classification is necessary to compensate for subtle environmental differences observed in each scene. These differences include changes in surface condition caused by high winds or areas of varying fetch. The high winds cause surface waves which scatter incoming light reflecting as sky glint back to the sensor washing out the subsurface signature. A second factor is changes in water depth due to different tidal heights. If the images were taken on different dates the water depth will vary from scene to scene causing changes in bottom signatures. Finally, varying water column clarity, from day to day can affect the albedo of the seagrass signatures. The processing software uses changes in the reflectance of each pixel to decide what category that pixel should be classified as. If the all the scenes were mosaiced together these environmental differences would cause error in the resultant classification.

Each image scene was classified into 20 classes using an Isodata unsupervised classification. The convergence threshold was set to 0.95 and the maximum number of iteration was set to 20. All classifications performed reached the convergence threshold before the maximum number of iteration was reached. The resultant 20 classes are then reviewed by the interpreter. Ancillary information such as the 2002 SAV mapping data, the collected Virtual Video Field Reference Database, georeferenced point images, and the 2002 aerial orthophotography are used to guide the naming of each class into one of the three categories high density seagrass, low density seagrass, or sand.

Process_Date: May to July 2005

Process_Step:

Process_Description: Metadata imported.

Source_Used_Citation_Abbreviation:

I:\FIIS_Final_data\classifications\SAV\sav_final.img.xml

Cloud_Cover: <10 percent

Spatial_Data_Organization_Information:

Direct_Spatial_Reference_Method: Raster

Raster_Object_Information:

Raster_Object_Type: Pixel

Row_Count: 7692

Column_Count: 19554

Vertical_Count: 1

Spatial_Reference_Information:

Horizontal_Coordinate_System_Definition:

Planar:

Grid_Coordinate_System:

Grid_Coordinate_System_Name: Universal Transverse Mercator

Universal_Transverse_Mercator:

UTM_Zone_Number: 18

Transverse_Mercator:

Scale_Factor_at_Central_Meridian: 0.999600

Longitude_of_Central_Meridian: -75.000000

Latitude_of_Projection-Origin: 0.000000

False_Easting: 500000.000000

False_Northing: 0.000000

Planar_Coordinate_Information:

Planar_Coordinate_Encoding_Method: row and column

Coordinate_Representation:

Abcissa_Resolution: 2.400000

Ordinate_Resolution: 2.400000

Planar_Distance_Units: meters

Geodetic_Model:

Horizontal_Datum_Name: North American Datum of 1983

Ellipsoid_Name: Geodetic Reference System 80

Semi-major_Axis: 6378137.000000

Denominator_of_Flattening_Ratio: 298.257222

Entity_and_Attribute_Information:

Detailed_Description:

Entity_Type:

Entity_Type_Label: layer _1

Overview_Description:

Entity_and_Attribute_Detail_Citation:

Class descriptions are described in:

NC/ABI Vegetation Mapping Program, vegetation classification of Fire Island National Seashore and, William Floyd Estate, August 30, 2001, Final Draft by Lesley Sneddon, Association for Biodiversity Information, Boston, MA and Julie Lundgren, The Nature Conservancy, Providence, RI

Distribution_Information:

Distributor:

Contact_Information:

Contact_Person_Primary:

Contact_Person: Sara Stevens

Contact_Organization: National Park Service

Contact_Address:
 Address_Type: mailing and physical address
 Address: National Park Service
 Address: University of Rhode Island
 Address: Coastal Institute Building
 Address: Rm 105
 City: Kingston
 State_or_Province: RI
 Postal_Code: 02881
 Country: USA
 Contact_Voice_Telephone: 407 874-4603
 Contact_Electronic_Mail_Address: stevens@nps.gov
 Resource_Description: Downloadable Data
 Standard_Order_Process:
 Digital_Form:
 Digital_Transfer_Information:
 Transfer_Size: 0.000
 Fees: None
 Ordering_Instructions: Please call or e-mail
 Available_Time_Period:
 Time_Period_Information:
 Single_Date/Time:
 Calendar_Date: unknown
 Metadata_Reference_Information:
 Metadata_Date: 20060228
 Metadata_Contact:
 Contact_Information:
 Contact_Person_Primary:
 Contact_Person: YQ Wang
 Contact_Organization: University of Rhode Island Department of Natural Resources
 Science
 Contact_Position: Professor
 Contact_Address:
 Address_Type: mailing and physical address
 Address: University of Rhode Island
 Address: Coastal Institute Building
 Address: Department of Natural Resources Science
 City: Kingston
 State_or_Province: RI
 Postal_Code: 02881

Country: USA
Contact_Voice_Telephone: 401 874-4345
Contact_Electronic_Mail_Address: yqwang@uri.edu
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998
Metadata_Time_Convention: local time
Metadata_Access_Constraints: none
Metadata_Use_Constraints: none
Metadata_Extensions:
Online_Linkage: <http://www.esri.com/metadata/esriprof80.html>
Profile_Name: ESRI Metadata Profile

Appendix C: Metadata for SAV Map

Identification_Information:

Citation:

Citation_Information:

Originator: YQ Wang

Originator: Mike Traber

Publication_Date: Unpublished Material

Publication_Time: Unknown

Title: sav_final.img

Geospatial_Data_Presentation_Form: remote-sensing image

Description:

Abstract: Classification of Submerged Aquatic Vegetation (SAV) from Quickbird-2 Satellite imagery for the Fire Island National Seashore. An unsupervised classification was performed to classify the seagrass habitats only within the areas of the park boundary.

Purpose: This data was created as part of National Park Service funded project to develop a protocol for mapping terrestrial and submerged aquatic habitats using satellite imagery. The SAV data presented here is to be used for monitoring of critical seagrass habitat.

Time_Period_of_Content:

Time_Period_Information:

Range_of_Dates/Times:

Beginning_Date: May 2004

Ending_Date: July 2004

Currentness_Reference: ground condition

Status:

Progress: Complete

Maintenance_and_Update_Frequency: None planned

Spatial_Domain:

Bounding_Coordinates:

West_Bounding_Coordinate: -73.309229

East_Bounding_Coordinate: -72.752818

North_Bounding_Coordinate: 40.789466

South_Bounding_Coordinate: 40.616398

Keywords:

Theme:

Theme_Keyword_Thesaurus: None

Theme_Keyword: Digital Images

Theme_Keyword: Vegetation Mapping

Theme_Keyword: Points

Theme_Keyword: Quickbird-2

Theme_Keyword: seagrass

Theme_Keyword: Zostera
Theme_Keyword: marina
Theme_Keyword: eelgrass
Theme_Keyword: ruppia
Theme_Keyword: maritima
Place:
Place_Keyword_Thesaurus: None
Place_Keyword: Fire Island
Place_Keyword: FIIS
Place_Keyword: Long Island
Place_Keyword: Great South Bay
Place_Keyword: New York
Place_Keyword: USA
Access_Constraints: none
Use_Constraints: none
Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: YQ Wang
Contact_Organization: University of Rhode Island, Dept of Natural Resources Science
Contact_Position: Professor
Contact_Address:
Address_Type: mailing and physical address
Address: University of Rhode Island
Address: Coastal Institute Building
Address: 1 Greenhouse Rd
City: Kingston
State_or_Province: RI
Postal_Code: 02881
Country: USA
Contact_Voice_Telephone: 401 874-4345
Contact_Electronic_Mail_Address: yqwang@gso.uri.edu
Native_Data_Set_Environment: Microsoft Windows XP Version 5.1 (Build 2600) Service Pack 2; ESRI ArcCatalog 9.0.0.535
Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report: Accuracy assessment was conducted using ERDAS Imagine. 50 points were randomly selected within each category. Each point was reviewed by the image analyst and categorized independently using image and reference data. The reference data included, the original Quickbird-2 image, 2003 1:12,000 color orthophotography, 2003 NY DOS

manual delineation of seagrass coverage, underwater video transects, field photos, and personal knowledge of the study site.

Quantitative_Attribute_Accuracy_Assessment:

Attribute_Accuracy_Value: 74.7 %

Attribute_Accuracy_Explanation: Overall Classification Accuracy

Quantitative_Attribute_Accuracy_Assessment:

Attribute_Accuracy_Value: 0.62

Attribute_Accuracy_Explanation: Overall Kappa Statistic

Quantitative_Attribute_Accuracy_Assessment:

Attribute_Accuracy_Value: 80 %

Attribute_Accuracy_Explanation: High Density Seagrass, Producers Error

Quantitative_Attribute_Accuracy_Assessment:

Attribute_Accuracy_Value: 72 %

Attribute_Accuracy_Explanation: High Density Seagrass, Users Error

Quantitative_Attribute_Accuracy_Assessment:

Attribute_Accuracy_Value: 76.74 %

Attribute_Accuracy_Explanation: Low Density Seagrass, Producers Error

Quantitative_Attribute_Accuracy_Assessment:

Attribute_Accuracy_Value: 66.0 %

Attribute_Accuracy_Explanation: Low Density Seagrass, Users Error

Quantitative_Attribute_Accuracy_Assessment:

Attribute_Accuracy_Value: 69.35 %

Attribute_Accuracy_Explanation: Sand, Producers Error

Quantitative_Attribute_Accuracy_Assessment:

Attribute_Accuracy_Value: 86 %

Attribute_Accuracy_Explanation: Sand, Users Error

Quantitative_Attribute_Accuracy_Assessment:

Attribute_Accuracy_Value: 0.6

Attribute_Accuracy_Explanation: High Density Seagrass, Kappa Statistic

Quantitative_Attribute_Accuracy_Assessment:

Attribute_Accuracy_Value: .52

Attribute_Accuracy_Explanation: Low Density Seagrass, Kappa Statistic

Quantitative_Attribute_Accuracy_Assessment:

Attribute_Accuracy_Value: .76

Attribute_Accuracy_Explanation: Sand, Kappa Statistic

Logical_Consistency_Report: This is a grid image with 2.5 meter pixels. No topology is present. Spatial and attribute accuracy was performed.

Completeness_Report: All deep water habitats (> 2.0 meter MLW) were omitted from the classification due to conflicts of signature between deep water and seagrass. Areas with high surface sky glint due to surface roughness were also omitted for classification.

Positional_Accuracy:

Horizontal_Positional_Accuracy:

Horizontal_Positional_Accuracy_Report: All image processing was conducted using ERDAS Imagine software version 8.7. Each scene of QuickBird images was independently reregistered using 2003 color aerial orthophotography as the base. The reported accuracy of the orthophotography is documented in the meta-data delivered along with the image was 5.5 meters. Between 10 and 20 control points were selected for each image scene. Each scene was registered to an accuracy of 0.5 pixels or 1.25 meters, determined from the root mean square error term provided by the software (ERDAS Imagine). The classified result was not altered spatially from the original image scene therefore the original positional accuracy is the same for the classification result as for the image.

Quantitative_Horizontal_Positional_Accuracy_Assessment:

Horizontal_Positional_Accuracy_Value: 6.25

Horizontal_Positional_Accuracy_Explanation: Meters, the spatial accuracy of the registered and mosaiced image scene.

Vertical_Positional_Accuracy:

Vertical_Positional_Accuracy_Report: none reported

Lineage:

Source_Information:

Source_Scale_Denominator: 24000

Type_of_Source_Media: CD-ROM

Source_Time_Period_of_Content:

Time_Period_Information:

Range_of_Dates/Times:

Beginning_Date: May 2004

Ending_Date: July 2004

Source_Citation_Abbreviation: Digital Globe

Source_Contribution: Imagery purchased from Digital Globe

Process_Step:

Process_Description: All image processing was conducted using ERDAS Imagine software version 8.7. Each scene of QuickBird images was independently reregistered using 2002 color aerial orthophotography as the base. The reported accuracy of the orthophotography is documented in the meta-data delivered along with the image was 5.5 meters. Between 10 and 20 control points were selected for each image scene. Each scene was registered to an accuracy of 0.5 pixels or 1.25 meters, determined from the root mean square error term provided by the software (ERDAS Imagine). This would yield a combined accuracy of 6.75 meters between our registration and the reported accuracy of the base image.

Process_Date: Unknown

Process_Contact:

Contact_Information:

Contact_Person_Primary:

Contact_Person: YQ Wang

Contact_Organization: University of Rhode Island

Contact_Position: Professor

Contact_Address:

Address_Type: mailing and physical address

Address: 1 Greenhouse Rd

Address: University of Rhode Island

City: Kingston

State_or_Province: RI

Postal_Code: 02881

Country: United States

Contact_Voice_Telephone: 401 874-4035

Contact_Electronic_Mail_Address: yqwang@uri.edu

Hours_of_Service: 8:30-4:30 EST

Contact_Instructions: Phone or E-mail

Process_Step:

Process_Description: Image preprocessing. The registered image was clipped using a rough area of interest (AOI) to remove the majority of land pixels or water pixels depending on which was to be classified. Once registered the individual scenes were processed to mask the land pixels from the scene. The land mask was created by conducting a 2 class unsupervised classification using only the near infrared band. This technique accurately separates the wet areas from dry areas as water has a large influence on the return of near-IR radiation. The resultant classification was used to mask the land pixels from the image. The masking step was not performed for the terrestrial classification as it was important to include the in-land water component for the classification purposes.

Process_Date: November 2005 to May 2005

Process_Step:

Process_Description:

Image Classification of seagrass habitats.

Each image scene was classified individually. This level of individual classification is necessary to compensate for subtle environmental differences observed in each scene. These differences include changes in surface condition caused by high winds or areas of varying fetch. The high winds cause surface waves which scatter incoming light reflecting as sky glint back to the sensor washing out the subsurface signature. A second factor is changes in water depth due to different tidal heights. If the images were taken on different dates the water depth will vary from scene to scene causing changes in bottom signatures. Finally, varying water column clarity, from day to day can affect the albedo of the seagrass signatures. The processing software uses changes in the reflectance of each pixel to decide what category that pixel should be classified as. If the

all the scenes were mosaiced together these environmental differences would cause error in the resultant classification.

Each image scene was classified into 20 classes using an Isodata unsupervised classification. The convergence threshold was set to 0.95 and the maximum number of iteration was set to 20. All classifications performed reached the convergence threshold before the maximum number of iteration was reached. The resultant 20 classes are then reviewed by the interpreter. Ancillary information such as the 2002 SAV mapping data, the collected Virtual Video Field Reference Database, georeferenced point images, and the 2002 aerial orthophotography are used to guide the naming of each class into one of the three categories high density seagrass, low density seagrass, or sand.

Process_Date: May to July 2005

Cloud_Cover: <10 percent

Spatial_Data_Organization_Information:

Direct_Spatial_Reference_Method: Raster

Raster_Object_Information:

Raster_Object_Type: Pixel

Row_Count: 7574

Column_Count: 19427

Spatial_Reference_Information:

Horizontal_Coordinate_System_Definition:

Planar:

Grid_Coordinate_System:

Grid_Coordinate_System_Name: Universal Transverse Mercator

Universal_Transverse_Mercator:

UTM_Zone_Number: 18

Transverse_Mercator:

Scale_Factor_at_Central_Meridian: 0.999600

Longitude_of_Central_Meridian: -75.000000

Latitude_of_Projection_Origin: 0.000000

False_Easting: 500000.000000

False_Northing: 0.000000

Planar_Coordinate_Information:

Planar_Coordinate_Encoding_Method: row and column

Coordinate_Representation:

Abscissa_Resolution: 2.400000

Ordinate_Resolution: 2.400000

Planar_Distance_Units: meters

Geodetic_Model:

Horizontal_Datum_Name: North American Datum of 1983

Ellipsoid_Name: Geodetic Reference System 80
 Semi-major_Axis: 6378137.000000
 Denominator_of_Flattening_Ratio: 298.257222
 Entity_and_Attribute_Information:
 Detailed_Description:
 Entity_Type:
 Entity_Type_Label: Layer_1
 Attribute:
 Attribute_Label: ObjectID
 Attribute_Definition: Internal feature number.
 Attribute_Definition_Source: ESRI
 Attribute_Domain_Values:
 Unrepresentable_Domain: Sequential unique whole numbers that are automatically generated.
 Attribute:
 Attribute_Label: Value
 Attribute_Definition: Set of numbers representing the seagrass coverage for each pixel
 Attribute_Domain_Values:
 Enumerated_Domain:
 Enumerated_Domain_Value: 1
 Enumerated_Domain_Value_Definition: number given for High Density Seagrass
 Enumerated_Domain:
 Enumerated_Domain_Value: 2
 Enumerated_Domain_Value_Definition: Number given for low density Seagrass
 Enumerated_Domain:
 Enumerated_Domain_Value: 3
 Enumerated_Domain_Value_Definition: Number given for Sand or Unvegetated bottom
 Attribute:
 Attribute_Label: Count
 Attribute_Definition: number of pixels within each value
 Attribute:
 Attribute_Label: Red
 Attribute_Definition: color map red value
 Attribute:
 Attribute_Label: Green
 Attribute_Definition: color map green value
 Attribute:
 Attribute_Label: Blue
 Attribute_Definition: color map blue value
 Attribute:
 Attribute_Label: Class_names

Attribute_Definition: Names given to each class

Attribute_Domain_Values:

Enumerated_Domain:

Enumerated_Domain_Value: HDS

Enumerated_Domain_Value_Definition: High density Seagrass >50% cover

Enumerated_Domain:

Enumerated_Domain_Value: LDS

Enumerated_Domain_Value_Definition: Low Density Seagrass < 50% cover to > 10% cover

Enumerated_Domain:

Enumerated_Domain_Value: SND

Enumerated_Domain_Value_Definition: Sand < 10% cover

Distribution_Information:

Distributor:

Contact_Information:

Contact_Person_Primary:

Contact_Person: Sara Stevens

Contact_Organization: National Park Service

Contact_Address:

Address_Type: mailing and physical address

Address: National Park Service

Address: University of Rhode Island

Address: Coastal Institute Building

Address: Rm 105

City: Kingston

State_or_Province: RI

Postal_Code: 02881

Country: USA

Contact_Voice_Telephone: 407 874-4603

Contact_Electronic_Mail_Address: stevens@nps.gov

Resource_Description: Downloadable Data

Standard_Order_Process:

Digital_Form:

Digital_Transfer_Information:

Transfer_Size: 0.000

Fees: None

Ordering_Instructions: Please call or e-mail

Available_Time_Period:

Time_Period_Information:

Single_Date/Time:

Calendar_Date: unknown

Metadata_Reference_Information:

Metadata_Date: 20060226

Metadata_Contact:

Contact_Information:

Contact_Person_Primary:

Contact_Person: YQ Wang

Contact_Organization: University of Rhode Island Department of Natural Resources Science

Contact_Position: Professor

Contact_Address:

Address_Type: mailing and physical address

Address: University of Rhode Island

Address: Coastal Institute Building

Address: Department of Natural Resources Science

City: Kingston

State_or_Province: RI

Postal_Code: 02881

Country: USA

Contact_Voice_Telephone: 401 874-4345

Contact_Electronic_Mail_Address: yqwang@uri.edu

Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata

Metadata_Standard_Version: FGDC-STD-001-1998

Metadata_Time_Convention: local time

Metadata_Access_Constraints: none

Metadata_Use_Constraints: none

Metadata_Extensions:

Online_Linkage: <http://www.esri.com/metadata/esriprof80.html>

Profile_Name: ESRI Metadata Profile

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

NPS 615/120860, May 2013

National Park Service
U.S. Department of the Interior



Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

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