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Using Remote Sensing Information to Understand Landscape Change

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A key theme of President Obama's recent *Priority Agenda for Enhancing the Climate Resilience of America's Natural Resources* (https://www.whitehouse.gov/sites/default/files/docs/enhancing_climate_resilience_of_americas_natural_resources.pdf) is to "Foster climate-resilient lands and waters" by protecting "important landscapes and developing the science, planning, tools, and practices to sustain and enhance the resilience of the Nation's natural resources."

Migratory Bird Joint Ventures (JVs) and Landscape Conservation Cooperatives (LCCs) are at the forefront of developing such planning and tools to help meet this objective. But they need access to high quality biological and geospatial data to develop the best possible decision support tools to carry out effective conservation. In addition, the ability to monitor biological resources and changes in land cover composition over time is essential to understand the impacts of both our conservation actions and the effects of a changing climate to determine how far we have come towards achieving overarching goals.

"To pursue its mission in the face of complex and persistent challenges, the Fish and Wildlife Service (FWS) has adopted Strategic Habitat Conservation (SHC) as our conservation approach for sustaining populations of fish and wildlife in the context of landscape and system sustainability," said Paul Souza, Assistant Director for Science Applications. "Carrying out SHC involves developing shared, landscape-level, conservation goals, objectives, and strategies based on a scientific understanding of the landscape, including the implications of current and future environmental stressors. Integral to this is the exchange of applied science to carry out conservation strategies with products developed by the LCCs, JVs, and their partners. Remote sensing information is invaluable to this entire process of landscape definition and product development."

JV and LCC science coordinators have cultivated extensive networks of ecologists whose research may emphasize particular species or vegetative communities. However, most JVs and LCCs have not developed the same network of remote sensing

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Using Satellite Remote Sensing to Map Changes in Wetland Plant Cover in the Sacramento-San Joaquin River Delta of California

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Figure 1. The Sacramento-San Joaquin River Delta (box outline) in the San Francisco Bay Area of California. / State of California

The Sacramento-San Joaquin River Delta (hereafter referred to simply as "the Delta") can be viewed as an extensive agricultural landscape surrounded by urbanization, tidal freshwater wetlands, and major commercial waterways originating from California's two primary river systems—Sacramento and the San Joaquin—that flow into San Francisco Bay (see Figure 1). Much of the Delta's land cover is partitioned into discrete island tracts separated from open waters by human-made levees. Through decades of soil erosion, peat decomposition, and subsidence, many cropland tracts have fallen far (10 meters) below sea level, and active maintenance of the levee system is required to protect Delta farmlands from flooding.

Bird habitats of the Delta have been among the most modified by human activity in the United States. The Delta was once a great tidal marshland of peaty alluvial soils. Pre-settlement vegetation consisted largely of native "tule" (bulrush) and reed marshes that were periodically submerged, with narrow patches of riparian forest on the natural levees along the major stream channels. In the late 1800s, new and higher levees were built along the stream channels to protect the land from flooding, and the resulting complex of Delta island tracts were extensively drained, cleared, and planted to croplands.

Today the Delta may be the world's most extensively invaded estuary by exotic plant species. Water Hyacinth is one of the primary invasive weed problems in Delta waterways because of its prolific floating biomass that interferes with pumping equipment for agricultural water supply and recreational activities such as boating and fishing. Excessive Water Hyacinth biomass may alter water quality and provide habitat for undesirable disease-carrying insect species.

Researchers at NASA's Ames Research Center, located about 40 miles southwest of the Delta, are using satellite imagery from the Landsat sensor to regularly detect the location and abundance of Water Hyacinth (and potentially other emergent aquatic plant species) in all Delta waterways and in bird habitats throughout the San Francisco Bay Area (SFBA). The archive of Landsat images extends back to the early 1980s, making long-term change studies of wetland habitats uniquely feasible.

The mapping method starts from the selection of near cloud-free imagery from the U.S. Geological Survey Earth Explorer data portal (http://earthexplorer.usgs.gov/). An early September anniversary date window is targeted each year to minimize variation caused by seasonal vegetation growth and sun angle differences. The linear relationship between fresh (live) green biomass (LGB) of emergent aquatic vegetation in the SFBA and two Landsat bands was adopted from the study by Zhang et al. (1997; Ecological Applications, 7(3), 1039–1053; http://www.esajournals.org/doi/abs/10.1890/1051-0761%281997%29007%5B1039%3AMPCSMU%5D2.0.CO%3B2?journalCode=ecap). The equation for prediction of LGB was based on conversion of the simple ratio between the reflectance in the red band (centered at 0.655 micrometers) and the near-infrared (NIR) band (centered at 0.865 micrometers).

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Over 30 locations were visited by boat on October 1, 2014, to verify the presence and visually estimate the percent (water area) cover of Water Hyacinth dominated habitat in Delta waterways. Geo-coordinate locations and digital photographs were recorded for floating patches of Water Hyacinth that were nearly 30x30 meters in water coverage area. Several control locations dominated by tule reeds (and no apparent Water Hyacinth) were also recorded. The percent area coverage of Water Hyacinth plotted against estimated LGB of emergent aquatic vegetation from September 2014 Landsat imagery showed a 80 percent overall accuracy. Nearly all locations observed first-hand in October 2014, that were estimated to have greater than 50 percent Water Hyacinth cover, also were estimated by Landsat to have greater than 3,000 grams LGB per square meter. It was projected from the satellite imagery that a total of 3,180 acres of Delta waterways were covered by greater than 50 percent Water Hyacinth in late 2014.

Delta waterways (foreground) and native wetlands (background) infested by Water Hyacinth, surrounding abandoned farming equipment in 2014. / Chris Potter

For a closer examination of changes in wetland biomass cover over the past 25 years, The Nature Conservancy's bird-friendly Staten Island provides an outstanding case study. The Nature Conservancy bought the 9200-acre island tract in 2001, mainly to safeguard Delta habitat for migratory birds. Fifteen percent of all Greater Sandhill Crane—a California threatened sub-species—that fly into the Central Valley each year along the Pacific Flyway use Staten Island as wintering habitat. The flyway is a crucial migratory pathway for more than five million birds, and Staten Island is the winter home for hundreds of swans, geese, ducks, herons, and shorebirds such as plovers and sandpipers.

Staten Island is presently managed to be wildlife-friendly. After the corn that is grown on a large portion of the island is harvested in September, the stubble is mulched to provide optimal foraging for cranes, which feed on the leftover grain. The island is then flooded with fresh river water by pumps to promote the growth of invertebrates as bird food and to create crane roosting sites and habitat for other birds such as waterfowl, shorebirds. Cranes roosting in the shallow water gain some protection from predators (e.g., coyotes).

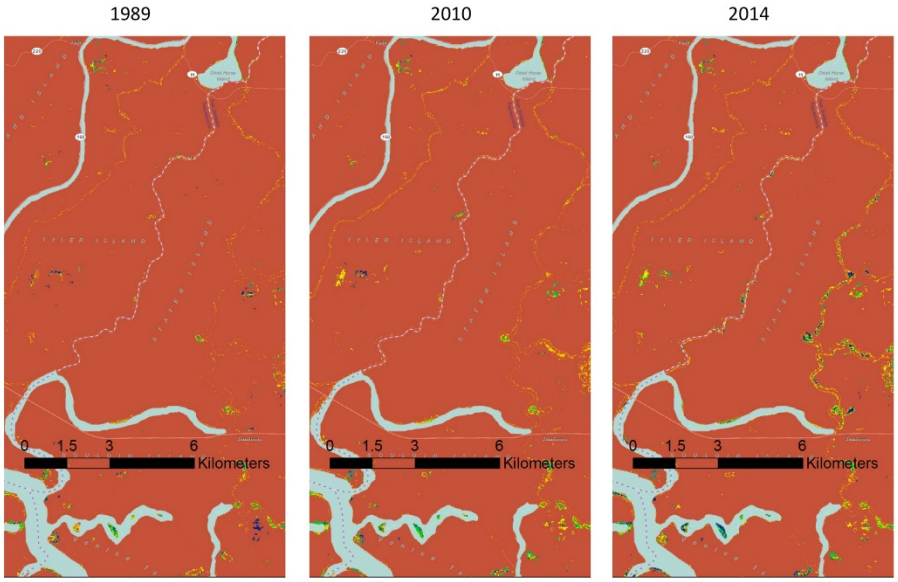

Figure 2. Landsat image products from 1989 to 2014 for the Delta area around Staten Island. Color legend: Brown – Cropland, Yellow/Green – Low biomass wetlands, Dark Blue – High biomass wetlands, Light Blue – Open waterways. / Chris Potter

A time series of Landsat images starting in 1989, was used to map changes in wetland LGB around Staten Island (see Figure 2). This 25-year record of change shows a proliferation of high biomass cover associated with invasive aquatic weeds after 2010, in the river courses mainly to the east and south of Staten Island. Infestation by Water Hyacinth in these wetlands can crowd out native plants and make transfers of river water for irrigation onto Delta Islands more difficult and expensive.

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Landsat imagery has several advantages over other (aircraft-mounted) sensors used periodically to detect aquatic wetlands plants. Landsat images are acquired by NASA every two weeks throughout the year everywhere in the United States, and are free of charge for download. Monthly mapping of wetland plant biomass by Landsat can be undertaken for all bird habitats and flyways in the nation, including the reconstruction of several recent years of region-area coverage before and after treatment for weed removal by local officials.

Full map coverages for the Legal Delta of emergent aquatic plant biomass are being posted and updated regularly for download on the internet viewer, which is publicly accessible at http://cquest.arc.nasa.gov:8399/flexviewers/sf_wetlands/.

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Above: Newly cropped field on Staten Island in April. / Chris Potter
Below: During the post-harvest winter season with Sandhill Cranes. / The Nature Conservancy