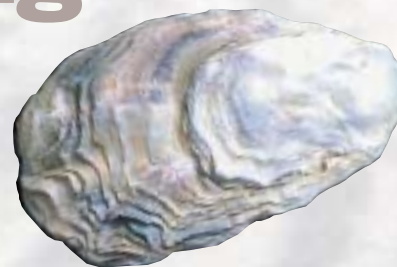


# South Carolina Leverages New Aerial Imaging Technique to Map Oyster Beds



## GeoVantage Offers Multiple-Camera Solution

**Kevin P. Corbley**

**H**arvesting shellfish is a favorite pastime—and a big business—in coastal South Carolina. Especially popular are intertidal oysters, which lay exposed above the water line at low tide, making them easily accessible to both commercial shellfishermen and recreational shellfish harvesters. Last year, this local delicacy pumped more than \$1 million into the state economy through commercial sales.

Intertidal oysters attach themselves to shellfish reefs and other hard surfaces in the shallow bays and estuaries of South Carolina's extensive coastal zone. Teeming with marine life, these areas comprise a complex network of organisms often under stress from pollution, development, and—in the case of oysters—the threat of over-harvesting. Managing this valuable resource is the responsibility of the South Carolina Department of Natural Resources (DNR).

As geospatial technology became popular in the 1980s, DNR determined that it could manage shellfish more effectively by mapping the locations and conditions of intertidal oyster beds using a geographic information system (GIS). Management practices were ultimately enhanced through the GIS project, but the actual mapping effort proved too expensive and time-consuming to repeat with any frequency.

"Surveying the sites in boats or on foot was the only viable mapping technique at the time and literally took years



*Fringing oyster reef at low tide on lower Hamlin Creek study area*

to complete," said Bob Van Dolah, Oyster Survey Project Manager and Director of DNR's Marine Resources Research Institute in Charleston.

DNR often collaborates on marine resource management programs with the National Oceanic and Atmospheric Administration's (NOAA) Coastal Services Center (CSC) in Charleston. Both organizations are savvy users of GIS and remote sensing technologies, routinely acquiring satellite imagery and aerial photography to map upland, coastal, and marine habitats. With the exception of an experimental false-color infrared imaging flight in the 1970s, neither had attempted to use remote sensing techniques for intertidal oyster mapping until 2002. DNR and CSC collaborated on a pilot project that demonstrated the utility of high-resolution aerial imagery for oyster reef mapping.

"A primary challenge of this approach is that imagery must be acquired during a three-hour negative tidal window that only happens about twice a month," said Steve Raber, CSC's Coastal Remote Sensing Program Manager. "Very few aerial or satellite imaging platforms have the flexibility and scalability to exploit that small a window and cover the entire South Carolina coastal area in a timely fashion."

A practical and affordable solution was offered in 2003 by GeoVantage Inc., a digital aerial imaging firm in Swampscott, Massachusetts. The company had developed and built 22 lightweight, high-resolution multispectral cameras that could be transported inexpensively to the project site and mounted on leased aircraft. The company's unique solution was to put six to 10 planes in the air during each tidal window and map 1,500 square miles in less than two flying seasons.



"The pilot project demonstrated that GeoVantage could exploit the short acquisition window with multiple aircraft and that its GeoScanner cameras were capable of capturing the oyster reefs in digital imagery," said Van Dolah. "With a potential for application in numerous other intertidal resource management programs, the South Carolina project was initiated to collect digital imagery throughout the coast, with funding provided by NOAA's National Marine Fisheries Service (NMFS)."

### Exploiting the Window

Oysters are considered "keystone" species because the reefs they form benefit numerous organisms. Built just below the surface in shallow marine environments, these reefs serve as substrates for other shellfish to dwell upon, hiding places for crabs and fish, and protective near-shore barriers for fragile wetland vegetation. In South Carolina, 95 percent of oysters live on intertidal reefs composed of mud, dead oysters, and discarded shells.

Mapping the entire reef structure from the air is difficult because turbid tidal waters obscure the formations when submerged, and the reef is only fully exposed during extremely low tides, called lunar lows, which occur five or more days each month. Complicating matters is a typical reef's narrow footprint and proximity to shore, where the oysters can be hidden in the shadows of marsh grasses much of the day. They can only be photographed



SCDNR staff setting up target over specific oyster strata to calibrate later overflight of GeoVantage imagery

from above during times of high sun angle, leaving just a few three-hour windows per month when the sun and moon cooperate.

"These windows are predictable, but a suitable window can easily be disrupted by high winds pushing tide water into the estuaries or clouds casting shadows over acquisition targets," said Mark Finkbeiner, CSC's Benthic Mapping Project Leader. "Acquisition flexibility is a critical requirement for these aerial photo missions."

Another significant requirement was high-resolution, multispectral imaging. DNR and CSC knew that sub-meter spatial detail would be needed to adequately map the extent of the reefs. And just as significantly, a combination of spectral and spatial data would be necessary to differentiate healthy live oyster clusters from the muddy, shell-covered reef substrate. Derived with advanced image processing techniques at CSC, this information would be crucial in assessing oyster populations.

Fortunately, along with GeoVantage's ability to deploy a squadron of sensors over South Carolina during the desired acquisition windows, its GeoScanners were also able to satisfy the rigorous imaging specifications of the project. Each GeoScanner consists of four coregistered sensors operating in the red, green, blue and near-infrared portions of the spectrum. With a spatial resolution of 0.25

meters, a single data set allows users to create a multitude of panchromatic, visible, and false-color band combinations.

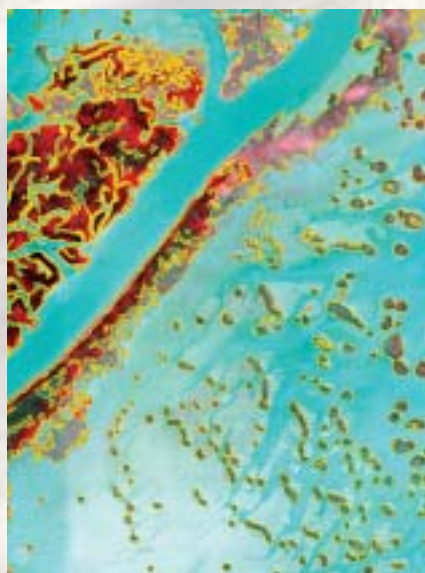
### Imaging Oyster Beds

For planning purposes, project participants divided South Carolina's coastal region according to USGS digital ortho quarter-quad (DOQQ) coverage areas. A total of 122 DOQQs would have to be imaged to map all of the state's shellfish beds. Because of the limited acquisition windows, flights would be spread over two years.

In preparation for the 2003 flights, GeoVantage contracted with aviation rental services at several local airports to reserve up to 10 Cessna 152, 172, and 182 aircraft on the pre-determined target dates. A significant advantage of the GeoVantage camera design is that nearly any high-wing aircraft can be used because no camera port is needed. The GeoScanner bolts onto the undercarriage of most small airplanes with fixed landing gear.

"Another cost-saving benefit for a project like this is that we can hire local pilots with experience doing aerial photography," said Matthew Herring, GeoVantage Vice President, Sales and Marketing. "It takes just an hour or two for them to learn our highly automated flight management system."

GeoVantage planned the flight lines for each mission in ESRI's ArcView software. This process was extremely complicated because of the number of planes involved and the delimiting acquisition conditions. Safety and flexibility were key considerations. With up to 10 aircraft flying over the South Carolina coast simultaneously at the same 2,500-foot altitude, pilots were each assigned



Patch and fringing reef oyster reef perimeters (in orange) generated by FeatureAnalyst in upper Hamlin Creek study area



SCDNR staff field digitizing an oyster reef with differential GPS receiver to determine reef perimeter





separate DOQs on a given day to minimize any chance of collision.

Clouds and wind both presented unpredictable challenges that had to be considered. GeoVantage built flexibility into the acquisition program by planning primary and alternative missions for each aircraft in one day. Flight lines for each mission were uploaded as Shape Files from ArcView into GeoPlan, the firm's mission management software.

Running on a laptop computer with a touch screen in the cockpit, GeoPlan linked with an onboard GPS and inertial measurement unit (IMU), developed by GeoVantage using military technology, to display the exact location of the aircraft and its intended flight lines. The software precisely guided the pilot onto the correct heading and triggered the camera to collect images at pre-assigned points. If the aircraft deviated from the flight line, the software instantly notified the pilot to fly it again.

When bad weather moved into an area, the pilot simply clicked to an alternative mission plan and headed for that target area. The software kept track of collected vectors, even if they were partial flight lines. For instance, pilots sometimes had to manually turn the cameras off in the middle of a flight line due to encroaching clouds. Rather than lose the work completed, the software saved it and



*Conventional color aerial photography (Kodak 2448 film) flown at 1:5000 scale (2,500 feet altitude) over Hamlin Creek study area*

guided the pilot back later to pick up the flight line where it had been interrupted.

"The pilots are very good at predicting cloud movements and getting shadow-free imagery before the clouds moved into their areas," said Herring.

With up to 10 planes in the air at once and each one guaranteed to collect useable data regardless of weather due to the multiple mission plans, GeoVantage collected data over 100 DOQs in 2003, about 70 of which were covered completely. After each day's flights, digital files were downloaded from the onboard systems and sent to GeoVan-

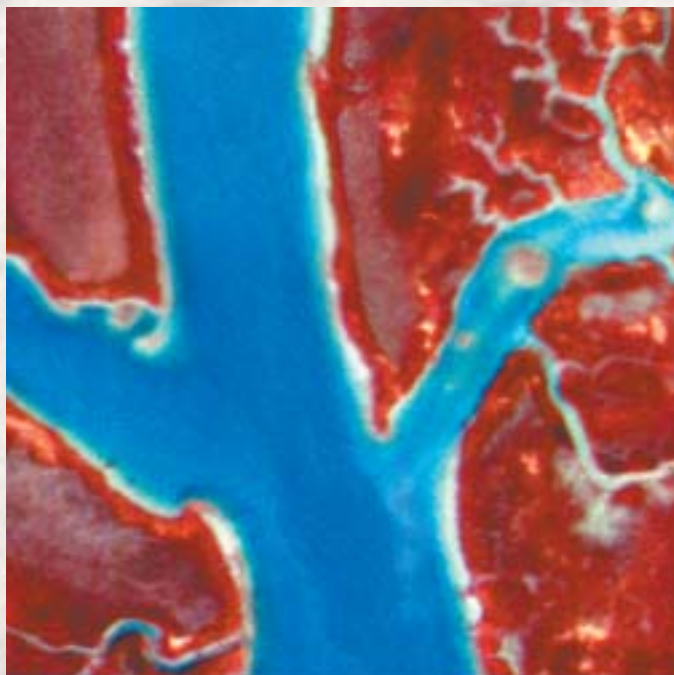
tage's Swampscott, Massachusetts headquarters for processing.

Customized processing software for the GeoScanner data uses automated algorithms to mosaic and color-balance the flight lines and orthorectify the imagery into a four-band product ready for GIS analysis and enhancement. At CSC's request, the South Carolina data sets are being delivered in the IMG format compatible with ERDAS IMAGINE software.

### Analyzing the Imagery

With the 2004 acquisitions set to begin in May, DNR and CSC spent much of the winter focusing on developing and refining image analysis techniques to extract information from the data quickly and accurately. The CSC remote sensing facility in Charleston operates primarily in an ESRI and ERDAS (now Leica Geosystems) environment and is assessing the utility of automated and semi-automated feature extraction tools for enhancement and analysis of satellite and aerial imagery.

Geospatial technicians found that oyster beds were visible to the naked eye in the processed imagery, and the extent of the reefs could be readily measured and mapped using automated routines in Feature Analyst software. Identifying clusters of live oysters and assessing their condition, however, is a more complex process.



*Geovantage false-color image (near-infrared, red, and green). Half-meter spatial resolution of Hamlin Creek study area.*



*Geovantage false-color image (near-infrared, red, and green). Quarter-meter spatial resolution of Hamlin Creek study area.*



"These reefs are muddy mixtures of oysters, dead shells, and other materials, and the color of the oysters is very similar to the mud," said Bill Stevenson, a CSC Image Analyst. "The challenging task is to classify each quarter-meter pixel into one of four categories—mud, high-relief oysters, low-relief oysters, or dead shells. Once this is accomplished, each reef can be characterized on a continuum from a robust, healthy reef to a remnant unproductive reef."

The high-relief class is the most important because it contains live oysters. In general, healthy, live intertidal oysters sit upright in clusters with the edges of their shells sticking into the air. Oysters that are lying down in low-relief may be dead or healthy single oysters. Dead shells have been emptied of their content by predators or left on the reef by harvesters.

"The key to classification is interpreting the texture of the reefs. The vertical, high-relief clusters have a different texture from the other feature classes," said CSC's Finkbeiner. "We are using automated algorithms in the software that combine spatial and multispectral data to differentiate classes and characterize oyster reefs by texture."

The process is still being refined, and technicians can currently perform about 70 percent of the individual oyster reef delineation work using these automated routines. The remainder of the image interpretation must be carried out by human eyes, but CSC believes that a greater percentage



Upper Hamlin Creek study area classified data set. Produced by spectrally clustering GeoVantage 1/4 m imagery using NDVI and isodata algorithm



Lower Hamlin Creek study area classified data set with FeatureAnalyst generated polygon showing extent of fringing oyster reef

of classification will eventually be accomplished with a high level of accuracy by automated techniques.

"Automated classification will never be perfect because every reef will have slightly different characteristics due to sun angle or mud composition," said Finkbeiner.

The production-level oyster mapping work is planned to be carried out by private industry, where the methodologies developed in this project and subsequent investigations will be available for use.


### Applying Information

Once completed, South Carolina DNR will input the oyster bed maps into their shellfish management GIS to update and possibly compare with the 1980 data. DNR will use the new information to calculate commercial harvesting lease acreages and look for signs of over-harvesting and reef building. The GIS maps will be accessible to recreational users on the Web and shared with the state agency that decides where new docks can be built. Most importantly, DNR will examine the imagery for oyster population changes.

The funding agency, NOAA's NMFS, sees enormous potential in the new mapping solution. Its Restoration Center in Silver Spring, Maryland, hopes to one day incorporate the oyster maps into a centralized Web-accessible GIS that will include details on thousands of marine restoration

projects across the country. Other coastal states, such as North Carolina, Georgia, and Florida, are carefully watching the South Carolina project in hopes it will eventually help them better manage their intertidal oysters.

In terms of cross-over application, DNR already is considering using the new acquisition technique to map marsh grasses, hammock islands and other fragile resources in the intertidal zone.

"This is a new application of remote sensing, and the fact that GeoVantage could put 10 cameras in the air for this sort of mission was a decisive factor in making the application a reality," said Finkbeiner. 

### About the Author

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### For More Information

To learn more about GeoVantage, visit [www.geovantage.com](http://www.geovantage.com). Contact GeoVantage directly at (781) 599-4664 or [info@geovantage.com](mailto:info@geovantage.com).

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Fringing reef oyster reef perimeters generated by FeatureAnalyst in lower Hamlin Creek study area