EXELIS

Visual Information Solutions

Case Study : NOAA Maps and Extracts Detailed Information about Sea Floor Habitats Using ENVI Image Analysis Software

Imagery Provides Critical Information

Organizations involved in environmental management and conservation work employ a variety of technologies to manage human interactions with the environment. Today, geospatial imagery is increasingly being used for its up-to-date, accurate information about geographic areas of interest and is of critical importance for organizations involved in conservation efforts. Crucial information can be extracted from imagery using advanced image analysis software and used to address challenges ranging from evaluating biodiversity to monitoring the effects of development.

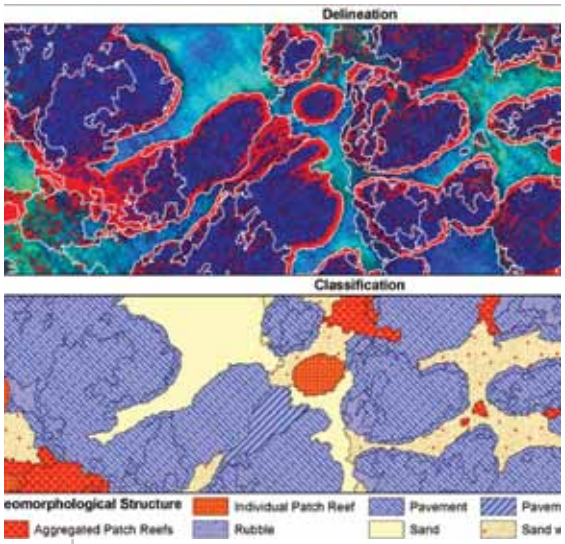
The National Oceanic and Atmospheric Administration (NOAA) utilizes geospatial imagery for a variety of environmental management and conservation efforts including conserving and managing coastal and marine ecosystems and resources. NOAA provides these services to academic, state, federal and private sector partners. NOAA recently assisted one of these partners to map and extract detailed information about seafloor habitats within a marine protected area. In order to do so efficiently, NOAA needed to develop a new semi-automated approach that would allow them to process, analyze and fuse different types of geospatial imagery and provide their partner with the fundamental data needed to make informed decisions.

National Park Service Needs Help

The National Park Service (NPS) asked NOAA to map and extract detailed information about seafloor habitats in Buck Island Reef National Monument off the U.S. Virgin Island of St. Croix, which has been dubbed "one of the finest marine gardens in the Caribbean Sea." The Monument is one of only a few fully marine protected areas in the U.S. National Park System and is home to a coral reef ecosystem that supports a large variety of native flora and fauna, including several endangered and threatened species, such as hawksbill turtles and brown pelicans. The NPS called upon NOAA's Biogeography Branch to assist by providing products to inform ecosystem-based management in the Monument. To do this, NOAA needed an efficient and effective method to map and assess the distribution and ecology of living marine resources.

Synopsis

- NOAA used ENVI to extract and fuse information from sonar, LiDAR and optical imagery so that sea floor depths and habitats could be determined.
- The integration of ENVI and ArcGIS enabled NOAA to easily move habitat maps and other information derived from imagery in ENVI into ArcGIS for additional analysis and the creation of applications.
- Habitat maps created in ENVI provide up-to-date, accurate information that help resource managers determine the best rules, regulations and practices to preserve and conserve vital habitats.

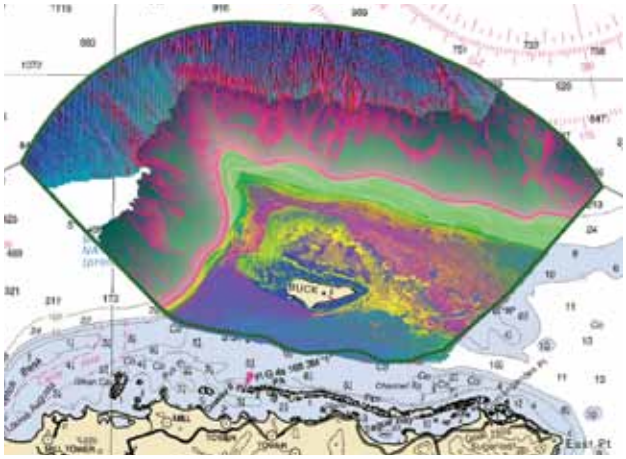


NOAA used the feature extraction tool in ENVI to "pull out" unique habitats from the sea floor around Buck Island (above) and assign attributes to the features (below). Image courtesy of NOAA.

The resources in Buck Island Reef National Monument are impacted by its visitors, boaters, snorkelers and scuba divers as well as pollution, climate change and extreme weather events like hurricanes. The habitat map that NOAA needed to provide Monument resource managers will be used to understand the current state of the area and how things are changing so that they can determine the best rules, regulations and practices to preserve and conserve its habitats well into the future.

"The new methods that were developed coupled with the power of ENVI allow us to integrate the strengths of multiple acoustic sensors, multispectral and LiDAR imagery and produce a seamless product across the entire extent of our study areas"

- Sam Tormey
Marine Spatial Analyst, NOAA



NOAA used ENVI to produce a PCA surface – the foundation for their mapping methodology – from four different acoustic and multispectral datasets spanning the Monument's 20,000-acre extent. Image courtesy of NOAA.

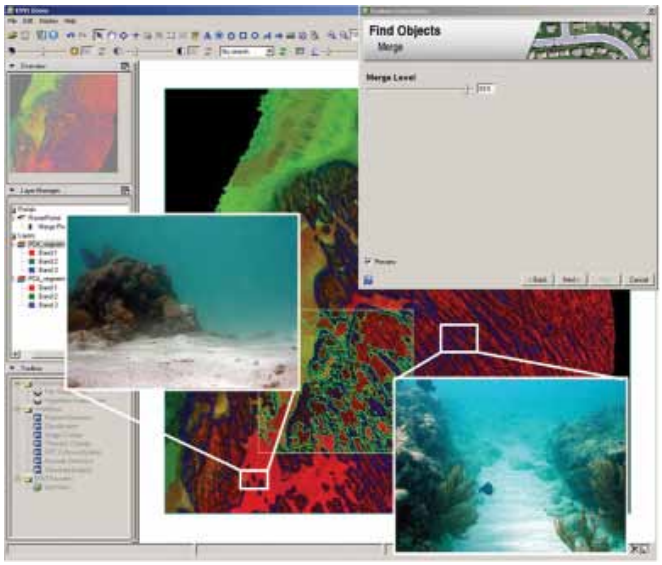
After evaluating the area, NOAA determined that traditional marine mapping methods that rely on the manual interpretation of optical imagery couldn't produce a comprehensive habitat map of the Monument given its depths, which extend from the coastline of Buck Island to 1,800 meters at its deepest extent. "We had a very unique problem," said Tim Battista, an Oceanographer at NOAA. "There is no one technology or sensor that allowed us to collect the data we needed in the range of depths present at the Monument. We had to devise an innovative method that would allow us to both measure sea floor depths as well as characterize its habitats across the entire seascape in the Monument."

NOAA ultimately devised a new method that fuses the strengths of four different sonar, LiDAR and optical imagery sensors to gather the information they needed. NOAA chose ENVI image analysis software as a key part of their solution because it combines the latest spectral image processing and image analysis capabilities with automated workflows, allowing users to obtain scientifically proven, accurate results quickly and efficiently. Because ENVI gives users the capability to fuse multiple data modalities such as radar, LiDAR, optical, hyperspectral, stereo, thermal, acoustic and more, the strengths of different sensors can be exploited together, which creates a rich geospatial context that aids decision making.

NOAA recorded depth and other characteristics of shallow areas in the Monument using multispectral and LiDAR imagery. This imagery was acquired from planes that flew over areas up to about 30 meters in depth, the point at which light is unable to penetrate to the seafloor. At depths of more than five meters, NOAA used sonar technology located onboard vessels and ships, such as the Nancy Foster to scan the sea bed. The Nancy Foster emits more than 3,500 pings per second and receivers on the ship record the time and angle of the echoes returning from the sea floor. Days spent sailing and employing sonar technology yielded bathymetry or depth information. The intensity of the echo also provided information about the sea floor, such as how hard, soft, rough or smooth it is, which often indicates discrete habitats such as coral, sand and sea grasses.

The LiDAR and acoustically collected bathymetry was also used to calculate a suite of complexity metrics in ArcGIS such as slope, rugosity and curvature, which emphasize the differences between habitats on the sea floor. As part of their preprocessing work, NOAA used Principle Component Analysis (PCA) to reduce redundancy in the data and better understand the complexity on the sea floor. This information, along with ancillary data such as intensity information, was loaded into ENVI, allowing the researchers to draw distinctions between softer and harder sediments in flatter areas of the sea floor.

NOAA then performed segmentation in ENVI using the software's feature extraction tool. Segmentation divides an image into discreet, real-world objects through the identification of edges and the grouping of individual pixels into contiguous regions. The automated workflow in ENVI walks users step-by-step through this process. The first step is specifying the degree to which an image is broken into discrete regions. NOAA set this setting very high so that as many distinct objects as possible were identified in the imagery. Next, similar segments of contiguous objects were merged. These two steps identified the edges of unique features on the sea floor that could then be attributed with habitat information. The technologically advanced approach to feature extraction in ENVI is quick and simplistic compared to traditional methods of extracting features, namely time-consuming manual digitization of objects of interest in an image.



The feature extraction tool in ENVI allows the analyst to adjust segmentation parameters and see the results real-time in a preview window, thus playing a pivotal role in NOAA's efforts to automate their mapping process while also incorporating analysts' understanding of seafloor habitat features. Image courtesy of NOAA.

"ENVI allows us to pan around an image using a preview window so that we can immediately see the effects of our segmentation settings. This enables us to adjust the settings as necessary before processing the entire data set to come up with the best results," said Bryan Costa, Geospatial Scientist contracted with NOAA through CSS-Dynamac. "This saves us time and allows us to extract a large variety of features found in the Monument in the most accurate way possible."

Following image segmentation, the workflow in ENVI provides users with several options for classifying or assigning attributes to the features in their imagery. Users can choose example segments in the imagery that are representative of feature classes or create rule set definitions that must be met in order to assign segments to feature classes. Users can also apply existing GIS or field data to supplement the classification. NOAA chose to classify features by selecting locations with unique acoustic or optical signatures, and performed ground validation using still and video cameras operated by divers and Remotely Operated Vehicles (ROVs). NOAA's classification scheme used to describe these sites takes into consideration what the sea floor is made out of, what is growing on top of it and the quantity of cover.

NOAA then took the segments and classified ground validation points and employed a free ENVI add-on called RuleGen, which was developed by an ENVI user and includes a classification and regression tree. Since ENVI is developed using the powerful IDL development language, its advanced image analysis tools can be easily customized and additional features and functionality can be added. NOAA found RuleGen well-suited for their acoustic datasets and applied its classification tree functionality to the spatial, spectral and textural metrics that were calculated for each segment using the feature extraction tool in ENVI. They then returned to the field and verified the accuracy of this output – a draft classified habitat map.

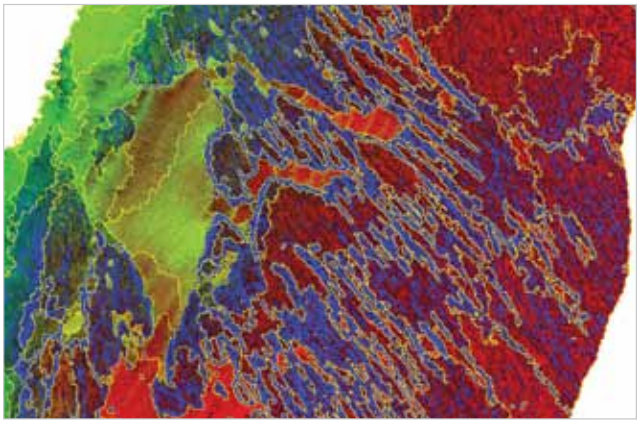
"Acoustic data is often very noisy and heterogeneous, which makes classification difficult using traditional pixel-based approaches," said Sam Tormey, Marine Spatial Analyst contracted with NOAA through CSS-Dynamac. "ENVI has allowed us to overcome these challenges, so we are no longer classifying a pixel, but rather, an object. We are now able to more objectively and efficiently deal with heterogeneity and make products that meet our partners' needs."

Integrating GIS and Imagery

Finally, NOAA took the habitat maps and other information derived from imagery and moved it into ArcGIS for additional analysis and the creation of applications. This information includes the structure, biological cover and percent cover – key pieces of information that resource managers need to make effective ecosystem management decisions. Information extracted from imagery and added to a GIS provides a complete picture of a geographic area of interest that includes pertinent, current information. ENVI makes it seamless to update ArcGIS with information from geospatial imagery by delivering image analysis tools directly from the ArcGIS desktop and server environments.

One application that NOAA develops for some partners is a Web-based mapping portal so that partners have the option of displaying each habitat class separately, overlaying ground-truth points, viewing the videos and images that were captured and creating custom maps. These portals are especially useful for partners that may not be familiar with traditional GIS software. "The seamless integration of ENVI and ArcGIS allows us to leverage the image analysis capabilities of ENVI with the geospatial tools and statics in ArcGIS, which gives us tremendous analytical power," said Costa. "It also allows us to put our habitat maps on the Web for anyone to see and use."

NOAA will be delivering the final habitat maps, information derived from imagery, still images and videos and related applications that are developed to Monument managers very soon. "Our past mapping efforts were conducted by manually digitizing and interpreting optical imagery," said Tormey. "This limited the areas we could monitor, was very time-intensive and depended on the experiences and interpretation skills of the analyst, which isn't highly replicable. The new methods that were developed coupled with the power of ENVI allow us to integrate the strengths of multiple acoustic sensors, multispectral and LiDAR imagery and produce a seamless product across the entire extent of our study areas. We are also able to produce products at a much finer spatial scale, so maps are more reflective of the true features on the ground."



The feature extraction process, created with ENVI, identifies unique objects and habitat types on the ocean floor from a depth-derived PCA surface. Image courtesy of NOAA.

Additional Resources

- The National Park Service and NOAA produced a video documenting the scientific work underway at Buck Island Reef National Monument.

- Buck Island BIOMapper – a fully interactive, online feature designed to let users explore benthic habitat mapping data. This portal contains a comprehensive collection of data, including aerial imagery, acoustic imagery, benthic habitat shapefiles, ground validation sites, underwater video and still photography.

ENVI

To find out more about ENVI, call 303.786.9900 or visit **www.exelisvis.com/ENVI**.

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