GIS for the Oceans

January 2011

Introduction by Prof. Dawn Wright, Oregon State University

“This is the time, perhaps as never before, and never again, for a new ethic: to do for the oceans in the 21st century—through technologies, through new understanding, through new insights—what was done in the 20th century for aviation, for aerospace.

“Where does GIS come in to all of this? I'll put it another way. Where *doesn't* GIS come in to the understanding of the ocean? After all, marine ecosystems, just as those on the land, are geospatial, and therefore so are the solutions that we must craft as we go forward.”

—Dr. Sylvia Earle

Keynote Address at the 1999 Esri International User Conference

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What Is GIS?

Making decisions based on geography is basic to human thinking. Where shall we go, what will it be like, and what shall we do when we get there are applied to the simple event of going to the store or to the major event of launching a bathysphere into the ocean's depths. By understanding geography and people's relationship to location, we can make informed decisions about the way we live on our planet. A geographic information system (GIS) is a technological tool for comprehending geography and making intelligent decisions.

From routinely performing work-related tasks to scientifically exploring the complexities of our world, GIS gives people the geographic advantage to become more productive, more aware, and more responsive citizens of planet Earth.

GIS for the Oceans

The ocean environment is unique. Sensors on satellites and aircraft are effective at seeing the surface of the ocean but generally cannot look deeply into the water column where the electromagnetic energy they rely on is dissipated. What can be perceived of the water column and ocean floor must be done mostly with the aid of sound (acoustic remote sensing), as sound waves are transmitted both farther and faster through seawater than electromagnetic energy. In order to "see" the ocean floor, sound is essential not only for determining depth to the bottom but also for detecting varying properties of the bottom. As the speed of sound in seawater varies linearly with temperature, pressure, and salinity, the conversion of travel time to depth must take this into account. In addition, the intensity of this reflection, or backscatter, can be used to resolve the shapes of objects or the character of the bottom.

Advances in remote sensing have made it possible to collect data on features and processes in the ocean over very broad scales, and GIS technology has made it possible to organize and integrate this data, make maps, and perform scientific analysis to increase our understanding and help us make critical decisions. The initial impetus for developing a marine specialty in GIS was the need to automate the production of nautical charts and to more efficiently manage the prodigious amounts of data now being collected at sea. Using GIS to synergize different types of data (biological, chemical, physical, geological) collected in multiple ways from multiple instruments and platforms (ships, moorings, floats, gliders, remotely operated vehicles, aircraft, and satellites) has provided the oceanographic community and policy decision makers with more information and insight than could be obtained by considering each type of data separately. GIS in this realm has moved from solely displaying data to multidimensional visualization, simulation and modeling, and decision support.

A myriad of challenges related to exploration, ecosystems, energy, and climate change face the marine science community in the coming 10 to 20 years. Confronting all these challenges requires a broad, interdisciplinary approach. GIS is a powerful, unique technology that is crucial to helping us manage the oceans in the most sustainable way. This e-book presents an overview of the use of GIS technology in the areas of exploration, ecosystems, energy, and climate change, as well as case studies illustrating what some people have already done with GIS in these areas.

—Dawn Wright

Dawn Wright is professor of geography and oceanography at Oregon State University and a fellow of the American Association for the Advancement of Science. Her research interests include geographic information science; marine geography; benthic terrain and habitat characterization; and the processing and interpretation of high-resolution bathymetry, video, and underwater photographic images. Wright received her PhD in physical geography and marine geology from the University of California, Santa Barbara.

There Is Still Much We Don't Know about the Ocean

> "Put into a larger context, more than 1,500 people have climbed Mount Everest, more than 300 have journeyed into space, and 12 have walked on the moon, but only 5 percent of the ocean floor has been investigated and only 2 people have descended and returned in a single dive to the deepest part of the ocean. On the other hand, no part of the ocean remains unaffected by human activities, such as climate change, eutrophication, fishing, habitat destruction, hypoxia, pollution, and species introductions. Therefore, the scientific study of the ocean should be an international priority."
>
> —Valdes, L., L. Fonseca, and K. Tedesco, 2010. "Looking into the future of ocean sciences: An IOC perspective." *Oceanography,* 23(3): 160–175.

How can we understand and mitigate the impacts of climate change, clean up oil spills, protect species, sustain fisheries, and so forth, if we still have not explored and fully understood the deep water column and the ocean floor? The 2010 Gulf of Mexico oil spill has shown us how much ocean exploration is needed, especially in acknowledging that there was indeed an underwater plume of oil and how to track and understand its impacts.

The application of remote-sensing techniques *in* and *on* the ocean will make further exploration possible. Examples of remote sensing *in* the ocean include towed acoustic sensors, vertical line arrays, omnidirectional acoustic sensors that can sense in all directions with one acoustic ping, multibeam sonars on ships, and upward-looking sonars towed under ice. In the water column, as well as on the ocean bottom, there will continue to be small autonomous underwater vehicles (AUVs), larger remotely operated vehicles (ROVs), and still larger human-occupied vehicles (HOVs, aka submersibles), all with the ability to georeference observations and samples for many geospatial applications.

—Dawn Wright

Autonomous Underwater Vehicle Mission Planning with GIS

The U.S. Naval Research Laboratory at Stennis Space Center, Mississippi

Highlights

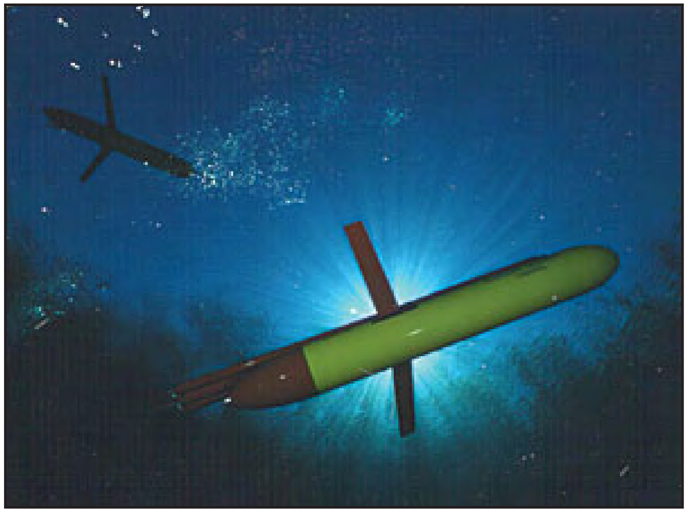
- NRL creates custom solutions.
- GIS helps cut through computational complexity and difficult visualization for better decision making.
- NRL can integrate its existing legacy software with advanced solutions.

Today, there is much concern about human impacts on the environment. Often, however, it's vital to focus on the environment's impact on humans and their activities. When considering the environment's impact, mission planning for underwater vehicles is a complex process. To make realistic predictions of a mission's achievability, one must take into account such factors as bathymetry, currents, water density, waves, boat traffic, and geopolitical boundaries. Distilling this information into a visual process where an operator can rapidly make decisions is a daunting task. The goal of the research described in this article is to make this a simpler, yet more informed, process.

The U.S. Naval Research Laboratory (NRL) at Stennis Space Center, Mississippi, has developed a mission planning and monitoring system prototype that incorporates the impact of the ocean environment on mission performance for underwater vehicles. As with aircraft missions, consideration of the environment is paramount for underwater vehicles, and a flexible, common, standards-based software system is needed.

One type of underwater vehicle that is managed by this system is called a glider, a type of autonomous underwater vehicle (AUV) that is particularly susceptible to environmental conditions. This vessel does not have any propeller or mechanical propulsion system. Rather, it has a bladder, and the filling and emptying of this bladder allows the vehicle to ascend and descend in the water; wings attached to the glider body generate forward motion as the buoyancy is altered. This allows the gliders to expend little energy, and thus the missions they carry out can be extended for months over large expanses of the ocean. However, this mode of propulsion realizes speeds of less than a knot, which is less than the ocean current in many areas of interest.

The state of the art in underwater mission planning is typically custom-made, vehicle- specific software systems that marginally incorporate environmental conditions. These packages are based on different languages and toolsets and typically comply with few, if any, existing standards. For the organization purchasing these systems, this results in independent mission planning and monitoring software for each different type of vehicle and the high life cycle costs that are typically associated with custom software. Economically, it makes sense to move toward a standard command-and-control system.



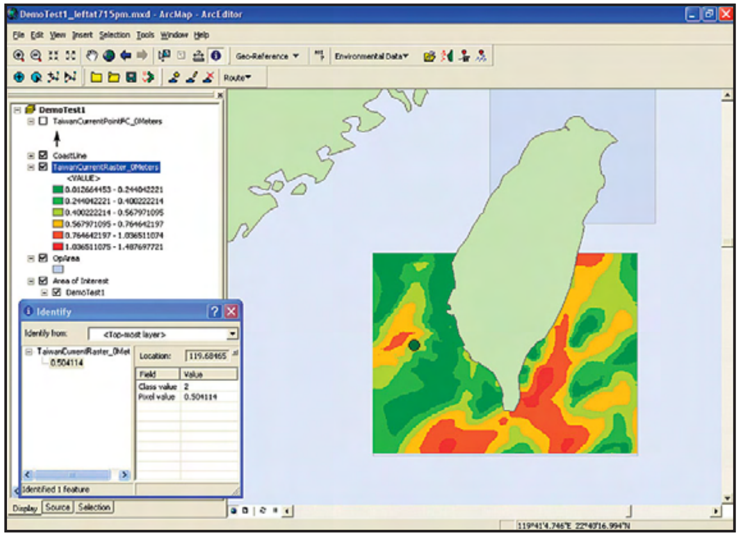
Two views of the Slocum Glider autonomous underwater vehicle.

NRL examined current systems and concluded that mission planning and monitoring are fundamentally exercises in geospatial/temporal decision making. Consequently, the supporting software should be built on a GIS foundation, as opposed to the existing practice of adding ad hoc GIS capabilities to existing custom-made and vehicle-specific command-and-control systems. The Commercial Joint Mapping Toolkit (CJMTK), provided by the National Geospatial-Intelligence Agency (NGA), is the U.S. Department of Defense's standard GIS and thus a natural choice for the development of a common mission planning and monitoring system; the foundation of CJMTK is the ArcGIS Engine framework.

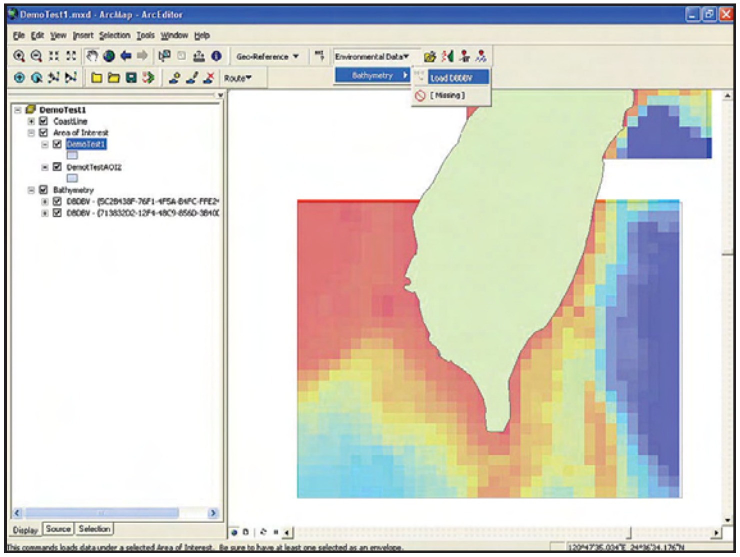
By having a system built around CJMTK, NRL's customers will enjoy significant cost savings for life cycle maintenance. NRL is realizing significant development savings due to the extensive functionality already provided, including data ingest and management; coordinate conversions and projections; common symbology; standardized geographic user interfaces (GUI); and multilayer operations, control, and visualization.

Most of NRL's development has been in the .NET environment using the C# language to interact with the ArcGIS Engine object framework, creating custom solutions. This is being done by making use of the geodatabase, ArcGIS Spatial Analyst, ModelBuilder, and geoprocessing tools to create, store, and perform analysis and comparisons on both raster and feature datasets.

As mentioned, the task of underwater mission planning is complicated. During a mission, one is dealing with navigating a vessel in a three-dimensional volume and factoring



Because mission planning and monitoring are fundamentally exercises in geospatial/temporal decision making, the supporting software is built upon a GIS foundation. Top: The numeric value of the current magnitude (loaded as a layer) is under the green dot. Bottom: Loading bathymetry.



in time-variable conditions, such as current, vehicle energy state, and ocean-sampling goals. Consequently, the decision space is represented by a three-dimensional volume over time (thus 4D), with N constraints: a 4D x N decision problem. All of this creates significant computational complexity and a very difficult visualization process for decision making.

Because NRL is trying to facilitate rapid decision making, it is not necessarily interested in displaying every parameter to the decision maker. For example, salinity and pressure to establish water density, current intensity, and current direction are used to determine what areas are navigable for the vessel. NRL, however, only wants to display the impact this data has on a proposed mission, so it has devised a method using a familiar icon, which it calls Traffic Light Analysis (TLA), for this process. With TLA, NRL takes all the data it has and, using user-specified constraints on that data, computes what volumes in the 4D mission area are within those constraints (i.e., navigable for the vessel). Rather than displaying multicolored, multidimensional, time-variant figures to the user, the system simply displays a two- or three-dimensional volume. This volume is divided into "go" and "no go" sectors.

Further, by compressing the time variable, NRL is able to significantly flatten the decision space and reduce the data size by a factor of 1,000. With the resulting TLA, if a decision maker can visualize a clear path area through the mission space volume, then a path can be constructed for the vessel with a reasonable expectation of mission success. However, if there is no way to get from point A to point B in this collapsed volume, NRL must factor time into the planning equation. This results in a slightly more complicated visualization problem for the operator, as some volumes may be navigable at certain points in time and nonnavigable at others. Still, NRL has reduced the original decision space to a much more manageable one that can be easily understood by the mission planner.

Historically, most of the software written to perform these planning functions was written in C for the UNIX operating system. By using the ArcGIS Engine object framework, NRL has been able to integrate the existing legacy software as a temporary solution while it develops more advanced, native solutions.

In addition, NRL can also use fuzzy logic to allow it to represent areas of uncertainty. Obviously, some constraints are "hard" constraints, such as the ocean floor and land masses. Currents, either in an awkward direction or at a high velocity, are often considered softer constraints, and fuzzy logic can help NRL represent this.

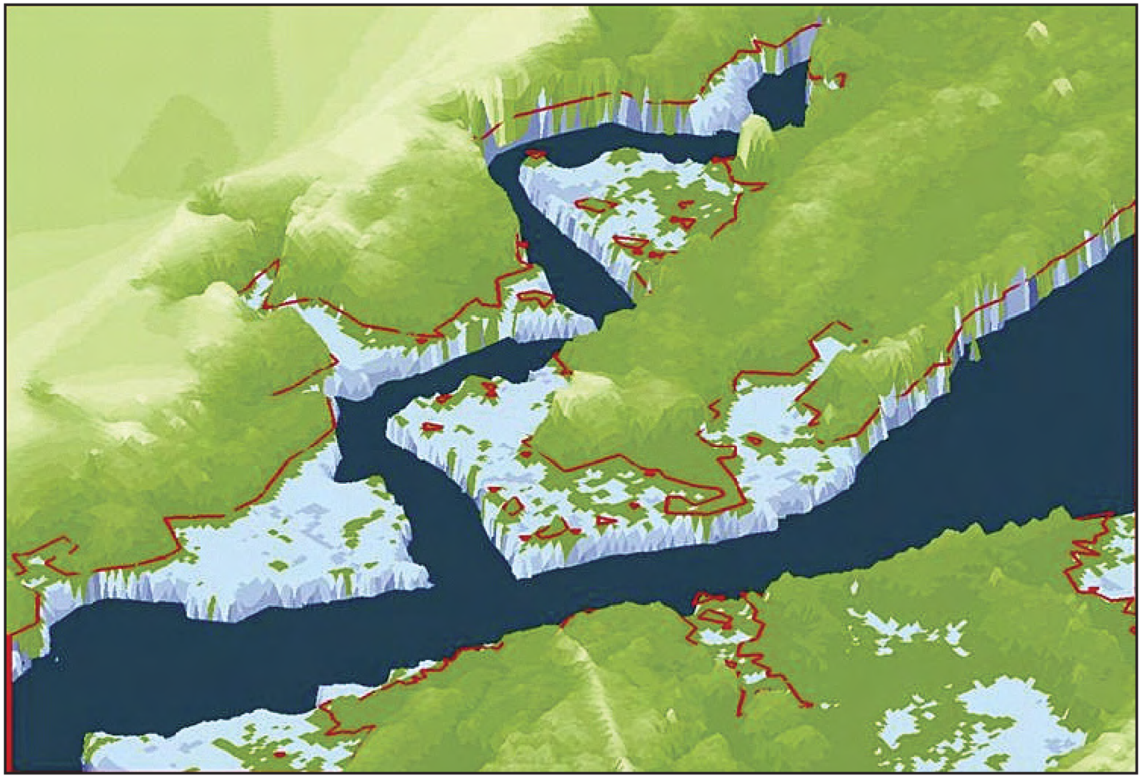
NRL's initial work has shown that its staff's intuition was correct: building this mission planner on top of CJMTK has allowed NRL to not only share information with colleagues more easily but also create a more intuitive mission planner.

(Reprinted from the Winter 2007/2008 issue of *ArcNews*)

The Virtual Estuary

New GIS tool for exploration and analysis

By Sandra Fox, St. Johns River Water Management District, and Stephen Bourne, PBS&J



In this portion of the estuary displayed in ArcScene, the high tide polygon (red line) and low tide polygon (solid dark blue) along with a digital elevation model (DEM) of the area.

A GIS tool developed by a team of experts is helping scientists more effectively study complex coastal and estuary systems.

Coastal flooding from extreme weather events threatens millions of lives and properties along U.S. coastlines every year. Especially hard hit are areas along the Atlantic Ocean and the Gulf of Mexico where over 60 percent of homes and businesses are within 500 feet of the shoreline. Yet, the ability to explore and study complex coastal environments with accuracy and speed has been limited, if not impossible. Affordable hydrologic models that work well on inland studies simply don't translate to coastal applications. However, more sophisticated supercomputer-based modeling techniques are cost prohibitive.

In a pioneering effort, the St. Johns River Water Management District (SJRWMD) led a team of experts from academia, government, and industry in the development of the Analytical Framework for Coastal and Estuarine Studies (ACES) GIS tool, one of the first comprehensive coastal and estuarine tools. Still under development, ACES is designed to help scientists accurately monitor and manage the health of a complex estuary from within the Arc Hydro hydrologic environment. [Arc Hydro is a data model template for use with water resources applications that has been developed by Esri in collaboration with key state, national, and international contributors.]

This tool has been used to support estuarine and coastal studies for the Guana/Tolomato/Matanzas Estuary, also a National Estuary Research Reserve for SJRWMD, as well as water quality studies in the Gulf of Mexico. [The National Estuarine Research Reserves are "living laboratories" that help researchers better understand coastal communities and find methods for dealing with the challenges these areas face.]

Cooperative Development

SJRWMD is responsible for regulating water use and protecting wetlands, waterways, and drinking water supplies along Florida's sensitive eastern coastline from Fernandina Beach to Vero Beach. The agency's Surface Water Quality Monitoring (SWQM) has used Arc Hydro to develop specialized hydrologic tools such as an automated pollution load screening model and a drainage area spatial data summary tool.

Yet, while greatly beneficial, these hydrologic tools were unable to account for tidal influences, which directly impact water quality in estuarine waters. This limited the agency's ability to accurately manage water quality throughout the region.

SJRWMD put together a technical team to develop ACES that included experts from SJRWMD, University of Florida, The Nature Conservancy, U.S. Geological Survey, and PBS&J, a consulting firm. The agency also put in place an expert review team that would be responsible for evaluating the end product developed by the technical team. The review team included the members from the Center for Research in Water Resources at the University of Texas, Austin; U.S. Army Corps of Engineers' Engineer Research and Development Center; and PBS&J.

The technical team's first task was to establish a master plan for the tool development from proof of concept to production. SJRWMD stipulated that the tool must be applicable to all SJRWMD estuaries and include existing GIS-based tools and enhanced Arc Hydro geodatabases developed by SWQM. Goal-driven brainstorming sessions helped keep the technical team on track throughout the development process. The initial brainstorming sessions and literature review focused on the nature of an estuary, estuarine hydrodynamics, estuarine classification, existing GIS-based modeling technologies for estuaries, and synthetic modeling of water quality in estuaries.

The St. Augustine Inlet to the Guana/Tolomato/Matanzas Estuary is a barrier that was accurately characterized with the ACES tool. The Matanzas Inlet is one of Florida's few remaining natural, unmanaged inlets.

The team found that the first step in approaching the study of estuaries was the creation of a GIS-based workbench tool that could integrate multiple sources. Water in coastal areas frequently comes from multiple sources. These might include surface water flow, incoming tides, manmade waterways, and even in some cases groundwater. The tool had to allow for the creation of virtual estuaries and estimation of bulk parameters of the estuaries and facilitate development and integration of other models into the same framework.

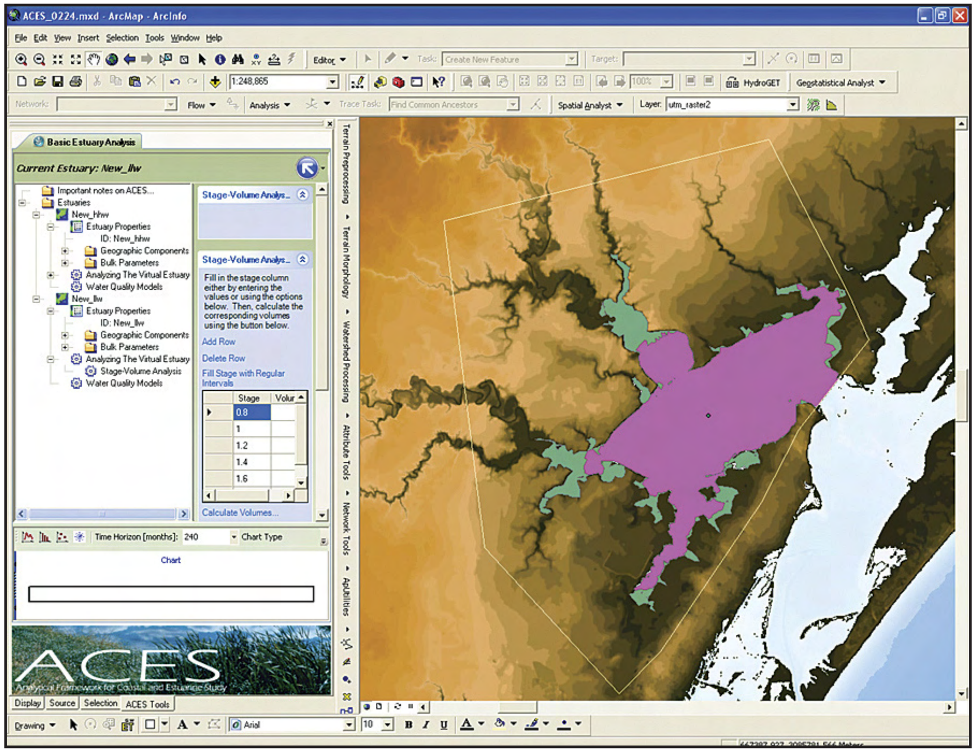
Conceptual Controls

In the initial development phase of the ACES project, the technical team developed an estuary control volume conceptual model that connects features in the estuary physical model with elements contributing to the control volumes such as waters from coastal bases, oceanic constituents, riverines, and intracoastal waterways. Groundwater influence was not considered in this initial application since the influence is likely small as compared to the other elements.

The team relied on a simple multiple linear regression (MLR) tool for evaluating relationships between constituents emanating from drainage areas and the measured values of water quality in the control volume. A more robust estimate of contributing areas may be obtained by using an iterative process that compared predicted and measured values while modifying the drainage area contribution. Throughout the effort, the team communicated extensively regarding various topics ranging from the deceptively simple, such as the definition of an estuary, to the complex and controversial modeling approach.

Coastal Possibilities

The ACES prototype tool is composed of a GIS-based database of spatial and temporal data that describes the environment and an accompanying ArcMap-based toolset. Using ACES, scientists can essentially build a virtual model of the estuary they are interested in using topographic, bathymetric, and tidal datum data.



ACES was used to find the volume of Copano Bay in Texas at several tidal levels to estimate pollutant loadings in the bay. Each colored polygon shows the shoreline for a different water level.

Within an Arc Hydro model, ACES can be used to determine estuarine bulk parameters (such as total area, high and low tide, volume, depth, and tidal flow) related to the shape of the estuary. With data related to flow rates into and out of the estuary, more complex parameters can be derived, such as residence time (the time water stays within a system) and flushing potential (an estuary's ability to flush a harmful substance).

Using this information, the relative importance of tidal versus land-based flow on estuarine hydrodynamics can be assessed. Relationships between estuary water quality and flow rates can also be investigated. Using the ACES regression model capabilities, scientists can find the correlative relationships between the influential factors of upstream riverine drainage, coastal drainage, and estuarine non-point source pollution.

Prototype in Action

An ACES prototype was used to support estuarine and coastal studies for the Guana/Tolomato/Matanzas Estuary, which is also a National Estuary Research Reserve for SJRWMD. Guana/Tolomato/Matanzas encompasses approximately 73,000 acres of salt marsh and mangrove tidal wetlands, oyster bars, estuarine lagoons, upland habitat, and offshore seas in northeast Florida. Along the northern section of the reserve, the Tolomato and Guana rivers meet the waters of the Atlantic Ocean. The southern section follows the Matanzas River, which extends from Moses Creek south of Pellicer Creek.

The ACES tool was also used to support a water quality study of Copano Bay in south Texas, a project sponsored by the Texas Commission on Environmental Quality. A popular fishing and recreation site, Copano Bay is a large watershed with source waters from Aransas Bay and several rivers. Dr. Stephanie Johnson, then a doctoral student in the Center for Research in Water Resources at the University of Texas under Dr. David Maidment, wanted to develop an accurate water quality model for the bay. Johnson had already acquired estuary depth measurements, which she converted to volumes to model the processes within the bay.

"To complete this study, I needed basic information, such as the bay volume and symmetry, which I could have calculated by hand using available contour maps, though it would have been a tedious process," said Johnson. Working with the ACES development team, Johnson used the ACES program to automatically develop the necessary estuary volume versus depth curve for use when computing the total maximum daily load of pollutants. "Through the ACES program, I was also able to create highly visual images that I incorporated into my larger water quality model and used to communicate with various nontechnical stakeholders," added Johnson.

In the near future, environmental scientists at SJRWMD will use ACES to explore the estuaries along the northeastern coast of Florida, including the mouth of the St. Johns River, the Indian River Lagoon, and the Nassau and St. Marys rivers. ACES presents a wealth of possibilities for the exploration and analysis of estuaries at universities and within water management districts. This tool will continue to evolve in functionality and application to help coastal experts more easily explore and understand complex coastal environments.

About the Authors

Sandra Fox is an environmental scientist with St. Johns River Water Management District (SJRWMD).

Stephen Bourne is a project manager with the PBS&J Water Resources Technology group.

(Reprinted from the Spring 2010 issue of *ArcUser* magazine)

Setting a New Standard

Coral mapping advances conservation efforts

By Barbara J. Brunnick and Stefan E. Harzen

The first full fledged coral mapping project carried out in the Bahama archipelago has resulted in a highly precise map of the marine area that identifies different habitat types and locates individual species.

A mapping project of the coral reef and other benthic communities surrounding Peterson Cay, Grand Bahama, resulted in a highly precise map of habitat types and individual species location, such as the endangered elkhorn coral.

Considered among the most complex and diverse environments on earth, coral reefs play a key role in the health of our planet's oceans. Pollutants, algae blooms, overfishing, damage due to development, and mooring are well-known threats to the health of reefs. Recent changes in the global climate are causing additional stresses including a rise in water temperature and acidity. The result is further decimation of existing reefs and the creatures that live in them and underpin the ocean's food web.

Most knowledge of coral reefs and benthic habitats is based on monitoring data gathered through a range of methods, mostly reef surveys, varying from rapid monitoring by trained volunteers to highly detailed, species-level observations. [Benthic *refers to the ecological region that is at the lowest level of a body of water.*]

However, these surveys provide little, if any, information on adjacent benthic habitats, such as sea grass beds or hard bottom, and, more importantly, fail to appropriately address and document the spatial component of the marine ecosystem. While coral reef mapping in itself is not new, most of these maps may differentiate shallow from mixed reef areas, but they do not provide further detail nor do they include adjacent areas of sea grass beds or other benthic habitats.

Caring for coral reefs is dependent on knowing far more about these extraordinary benthic environments, the associated ecosystems they host, and the establishment of baseline data against which future assessments of ocean health can be measured.

With these goals in mind, the Taras Oceanographic Foundation has embarked on a multiyear program to generate highly accurate maps of coral reefs that will set a new standard in the field of marine science and provide an invaluable tool for the monitoring, management, and preservation of these fragile environments worldwide.

After refining analytical skills and ground-truthing methodology over the last two years, the foundation chose the coral reef adjacent to Peterson Cay National Park off the southern shore of Grand Bahama Island as the site for the first full-fledged coral mapping project.

Density variations of reefal hard bottom

The site was selected because the coral reefs of the Bahama archipelago are in a near-crisis situation, like many other coral reefs around the world. Mapping this reef complex provides tangible benefits to those responsible for managing the marine resources. In addition, the reef complex was large enough to be significant, yet small enough to be charted in the available time.

The reef map of Peterson Cay integrates aerial and satellite imagery with GPS data and onsite field surveys in ArcGIS. Spatial information was combined with the marine habitat classification framework defined by the Ecological Society of America (ESA) and the National Oceanic and Atmospheric Administration (NOAA) Office of Habitat Conservation. This framework provides for the distinction of community types and density variations therein.

The delineation of these benthic community types resulted in a highly precise map of the marine area surrounding Peterson Cay. The map distinguishes between different habitat types that range from bare ocean floor to algae, sea grass, and coral reef and highlights density variations in each type. The map also pinpoints the exact location of individual species of interest such as the endangered elkhorn coral.

Furthermore, with ArcGIS, it was possible to determine with impressive precision the spatial expansion of each marine habitat across the study site. The coral reef, in its various expressions of density, covers 208 acres, and the sandy bottom—with various degrees of sea grass, spreads out over 263 acres. Areas of hard pad with algae (generally red and brown algae) covers 209 acres, although the density of algae coverage in two-thirds of these areas is less than 10 percent.

The ability to accurately locate individual corals or territorial fish species is essential for successful management and conservation programs. For instance, observations of the invasive Indo-Pacific lionfish (*Pterois volitans*), which poses a significant risk to native species, can be charted on the map, facilitating its capture and eradication. Having a visual representation of the entire reef, or a number of reefs stretched out across a larger area, is the best means of determining where to install fixed monitoring devices such as sedimentation traps.

The comprehensive understanding of spatial features across the reef will also facilitate the identification of additional dive sites suitable for commercial scuba operators. Increasing the number of dive sites will alleviate the pressure on those currently used every day by multiple groups. Marking mooring sites adjacent to shallow reefs will help avoid reef damage caused by boat traffic and anchors.

Last, but not least, knowing the exact location, dimensions, and composition of the reefs will help develop sustainable land-use plans for coastal projects so they can benefit from these natural jewels rather than harming or destroying them.

By documenting the actual environmental conditions, the relationship between different habitat types and the larger reef ecosystem is better understood. In addition, it will monitor the expansion or decline of certain habitats. Conducting similar studies on adjacent reefs will eventually lead to a larger-scale map and a deeper understanding of both local and regional reef ecosystems and their processes.

Although this new mapping technology doesn't necessarily represent the natural state of any ecosystem, it can at least provide a baseline against which we can compare future observations, thus establishing a powerful framework for conservation and management. And that's what the map of Peterson Cay's coral reef will do. By combining traditional observational recordings with precise spatial information, it provides new insight into the fascinating world just below the water's surface.

Acknowledgments

The authors thank the entire expedition team, especially Lieutenant (Navy) Joseph Frey, as well as Michael T. Braynen, director of the Department of Marine Resources, for granting the research permit.

This expedition would not have been possible without the support of Graham Torode, president and CEO of the Grand Bahama Development Company, who hosted the expedition and underwrote all of the expedition's finances. Thanks also go to the shareholders of Grand Bahama Port Authority, Limited (GBPA), and Grand Bahama Development Company (GB Devco) and especially to Sir Jack Hayward. Additional support came from Linda Osborne of International Underwater Explorers Society Ltd. (UNEXSO); Nakira Wilchcombe, environmental manager of the Grand Bahama Port Authority; and the Ministry of Tourism.

About the Authors

Barbara Brunnick serves as the director of the Research and Conservation Program of the Taras Oceanographic Foundation. She is well known for her groundbreaking research on Atlantic spotted dolphins in the Bahamas and her instrumental role in pioneering the use of georectified maps in conservation of marine and wetland habitats throughout the Bahama archipelago. Brunnick holds a doctorate in biology from Union Institute & University, Cincinnati, Ohio.

Barbara J. Brunnick

Stefan Harzen is a scientist, consultant, and entrepreneur who serves as the executive director of Blue Dolphin Research and Consulting, Inc., a distinguished science consulting firm working at the frontier of sustainability. Harzen's expertise includes marine mammals, coral reefs, and wetlands as well as natural resource management and sustainable business practices. He holds a doctorate in natural sciences from the University of Bielefeld, Germany.

Stefan E. Harzen

Brunnick and Harzen, a husband and wife team, have been included in *Adventurous Dreams, Adventurous Lives,* a Who's Who of international exploration.

For more information on this topic, visit esri.com/training to learn more about *Creating and Integrating Data for Natural Resource Applications,* a Web course.

(Reprinted from the Summer 2009 issue of *ArcUser*)

Communicating Ocean Science with GIS

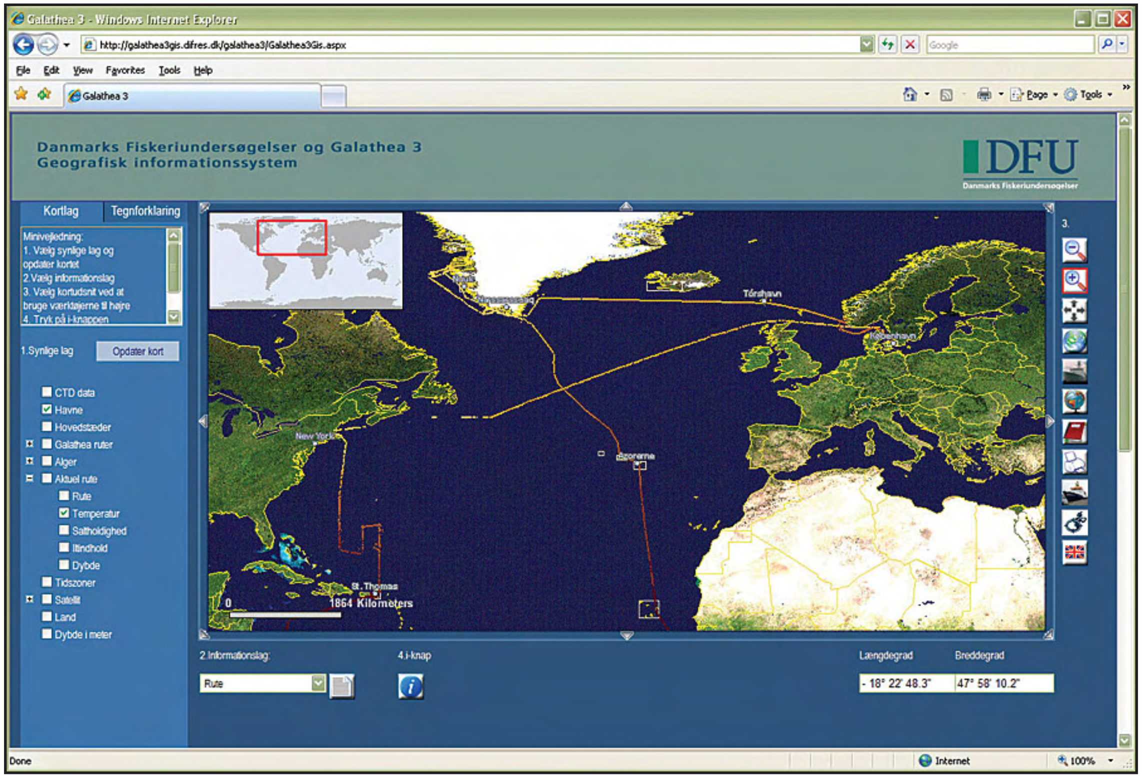
The Galathea 3 Expedition Included 48 Different Research Projects on Both Land and Water

Highlights

- GIS made it possible to display the route and the vessel on a globe in 3D.
- GIS and the Ship Information System monitored data in near real time.
- Expedition information was communicated to the public via an ArcIMS software-based Web site.

Since the Vikings, Denmark has been known as a seafaring nation. In 1845, 231 sailors and scientists set off on a scientific journey, named Galathea 1, that would take them south around Africa to India, visiting Tranquebar and the Nicobar Islands. It was a tough journey, and 20 men lost their lives. The results of the expedition, which had been ordered by Danish King Christian VIII, were to be delivered in a beautifully decorated book, but unfortunately the king died shortly after the expedition returned, and the scientists argued so much that the book never became a reality.

Where the first Galathea had support from the king, the second got it from the public. In 1952, when the deep-sea expedition Galathea 2 returned to Denmark after two years, 20,000 Danes greeted it at Langelinie quay in Copenhagen. The main reason for the support was that the forces behind the expedition had understood the power of communication. Reporters and journalists were onboard the ship, and every week movies about it were shown in the local theaters.



The public could follow the Galathea *3 scientific expedition in real time.*

In 2006, the Galathea 3 expedition began a nine-month-long research journey at sea. This time, the expedition had the support of both the public and royal family. Frederik, the Crown Prince of Denmark and protector for Galathea 3, while introducing the expedition at the Geological Institute in Copenhagen before the ship sailed off, said, "As individuals, we all have a curiosity to explain and demystify. We want to know, explain, and tell all what we experience as humans."

This time, GIS technology also played a part in the expedition's objective to strengthen Danish research and make young people more interested in the natural sciences.

Ship Information System Integrated with GIS

The Galathea 3 expedition included 48 different research projects on both land and water. Most of the projects were carried out on the 112.5-meter-long expedition ship, *Vædderen* (the ram). The National Institute of Aquatic Resources at the Technical University of Denmark (DTU Aqua) was brought in to transform the *Vædderen* from a surveillance ship to a modern research ship. The many different research projects included examining Greenland's current and historic climate and its geological development and following the European eel on its journey from Europe to the Sargasso Sea, south of Bermuda.

To collect background data for the many projects on board the ship, DTU Aqua developed—among other things—a Ship Information System (SIS) customized for the expedition. The development of SIS was based on experiences from previous voyages with DTU Aqua's own research vessel *R/V DANA,* but for the first time SIS was integrated with GIS.

With the previous version of SIS, prior to integration with GIS, scientists onboard a ship could monitor and visualize their collected data. Through SIS, navigation data, such as position and depth, could be viewed. Weather data (temperature, wind, etc.) was recorded, and the ship used a water intake system positioned approximately five meters below the ocean surface that measured salinity, water temperature, and more as the ship sailed along. Scientists could visualize data in 2D and tables, and the data was automatically related to a GPS point in SIS.

But, by supplementing SIS with GIS and geography, data is displayed in a much more intuitive way. DTU Aqua developed the customization using ArcGIS Engine 9.1 and the ArcGlobe application in 3D Analyst to create a mapping tool that made it possible to display the route and vessel on a globe in 3D at both its current position and its direction. The instruments used by the researchers could be viewed in 3D as well, related to the place where they were employed.

The surveillance ship Vaedderen (the ram) was converted to a modern research ship (photo: Hempel A/S Copenhagen).

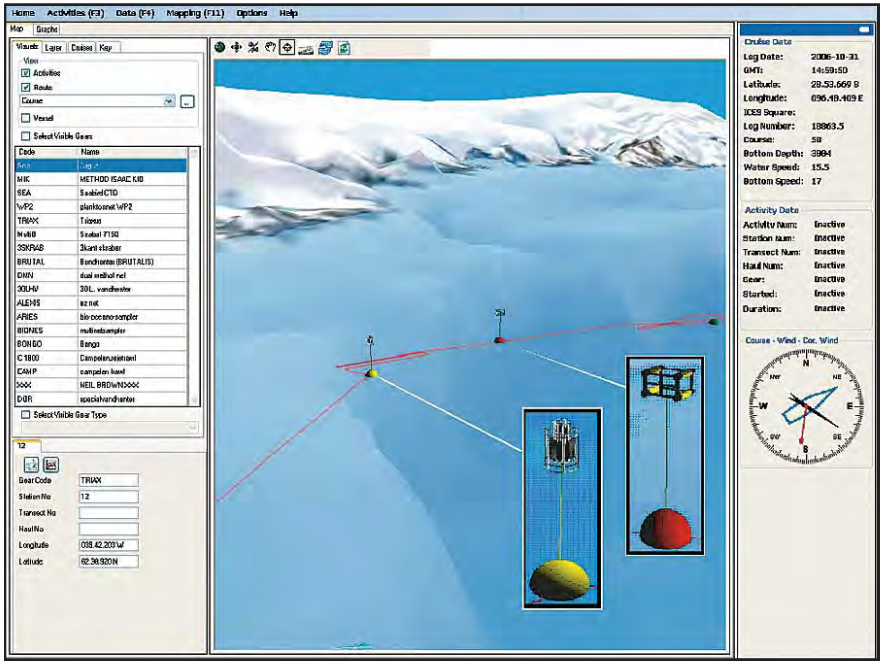
ArcGIS software was already implemented and used day-to-day at DTU Aqua, so when the task of preparing *Vædderen* for its scientific journey arrived, the choice of GIS technology was easy. The IT developers at DTU Aqua were already familiar with the ArcGIS interface, and the data formats matched. Another reason for choosing ArcGIS was that SIS was programmed in C#, which can also be used with ArcGIS Engine. By choosing ArcGIS technology, the diverse needs were fulfilled. With ArcIMS, DTU Aqua could update data live on the Internet. ArcSDE was used to store the data shown in ArcIMS and ArcEditor and to integrate both the background data and new data from the ship. With ArcGIS Engine, data could be visualized on a globe through the SIS application.

The Geographic Entrance

The mapping tool became a geographic entrance to searching, viewing, and analyzing the data, giving a new intuitive access point to the data. Combining GIS with SIS opened the opportunity to monitor the quality of the data acquired in near real time, thus making it possible to quickly discover problems, such as sensor malfunctions or activities performed at erroneous locations, and correct them. Working under sometimes difficult conditions with heavy seas, the scientists found the ease of SIS/GIS a great help.

Near Real-Time Data

The information gathered by SIS/GIS was also communicated to the public via a Web site developed by DTU Aqua using ArcIMS. Data was sent from a server on the ship via a satellite connection to a server at DTU Aqua every hour. The Web site then showed the route and displayed satellite images showing the landscape when the ship was close to land. It was the first time a Danish expedition could be followed as it happened. The information from the water intake system, for instance, was also rendered nearly live via the Internet through ArcIMS at DTU Aqua.



Integrating the Ship Information System with GIS allowed researchers to view the route traveled on a globe in 3D.

The Results

Scientists are still working on analyzing the vast amount of data collected on the expedition. The Galathea 3 expedition is well known by the Danish public—a survey shows that more than 80 percent of the public have heard about the expedition and that more than 60 percent thought it was a good idea to let research, science, and communication go hand in hand.

More Information

For more information, contact the National Institute of Aquatic Resources (Web: aqua.dtu.dk/English.aspx).

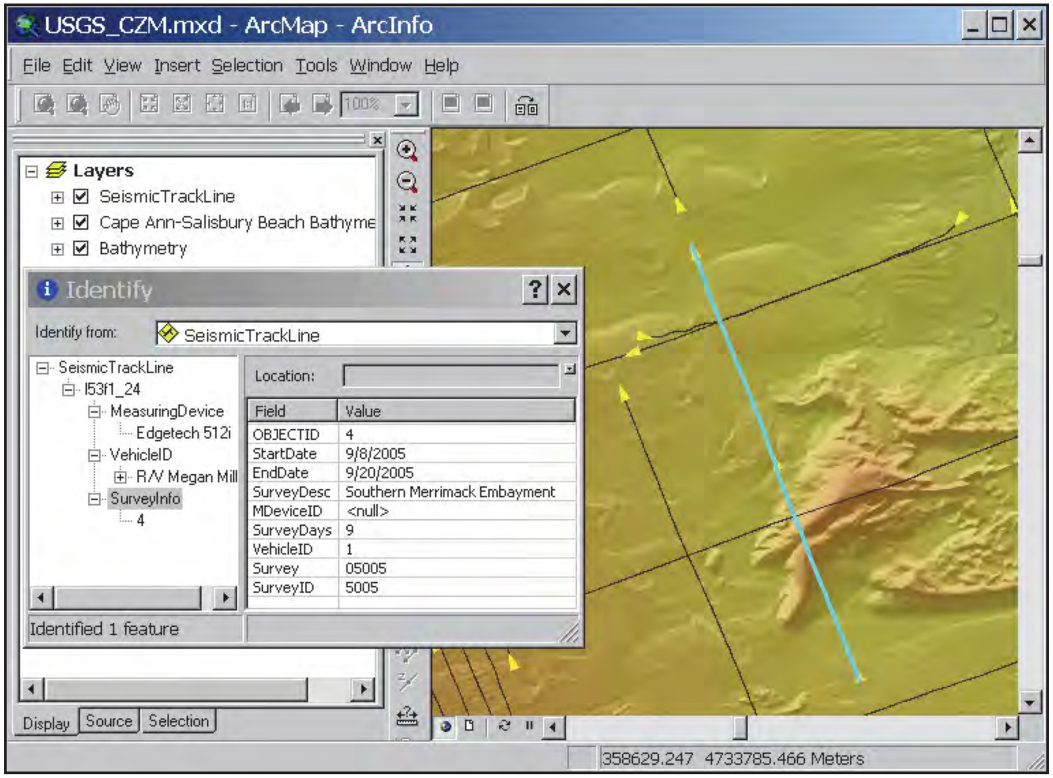
(Reprinted from the Spring 2008 issue of *ArcNews*)

Federal/State Mapping Program Supports Ocean Management and Research

Brian D. Andrews, USGS, and Seth Ackerman, USGS/CZM

The U.S. Geological Survey (USGS), in partnership with the Massachusetts Office of Coastal Zone Management (CZM), is conducting mapping off the Massachusetts coast to characterize the geology of the seafloor. The primary goal of the project, which began in 2003, is to produce high-resolution geological information and maps that support ocean-resource management and marine research. The seafloor maps show the distribution of bottom types (i.e., rock, gravel, sand, and mud) and seafloor topography (i.e., water depths) in an area covering about 1,300 km^2 of the inner continental shelf. Knowledge gained from this project supports new ecosystem-based approaches to managing fisheries in nearshore state waters and enhances the ability to predict the impacts of storms and coastal erosion on adjacent sandy beaches.

Managing the large amounts of survey data is a key issue in a large mapping program like the USGS/CZM project. Each survey day can collect 10–20 gigabytes of data and cover 8–12 km^2 of the seafloor. A three-week survey generates 200–300 gigabytes of data from several types of sonars, underwater camera systems, and sediment grab-sampling devices. To date, the program has acquired 7,000 km of high-resolution sonar data, 2,800 bottom photographs, and 275 sediment samples in six separate surveys. Clearly, this large volume of high-resolution data requires a data management system to provide standardized, documented access by federal and state agencies involved in the project.

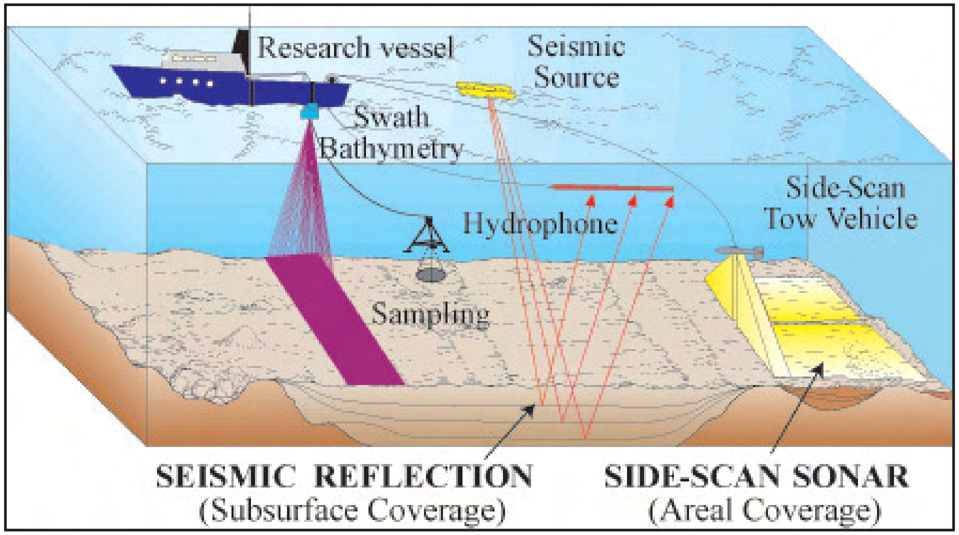


These results from the Identify tool show the three common attributes measuring device, vehicle ID, and survey information used to manage project survey data.

Finding the Right Data Model

The USGS/CZM mapping program collaborated with the Esri Arc Marine Working Group to tailor the schema and design of the data model to accommodate several types of marine geophysical data routinely collected by the USGS/CZM project. The mapping program required a database that would organize the multidimensional data collected from the marine surveys and provide a logical representation of this complex data in the object-oriented framework of the geodatabase. The Arc Marine data model supplies both the basic building blocks to represent or model common marine data types and the tools for extending these basic representations to more complex marine objects through relationships and custom behaviors. This extensible feature is at the core of Arc Marine's value in the USGS/CZM project and is further described as a case study in *Arc Marine: GIS for a Blue Planet* (Esri Press, 2007).

The basic design of the data model used by the project is summarized in the following description of a typical survey. On each survey (SurveyID) a research vessel (VesselID) collects data along planned track lines with one or more sonars or sampling devices (DeviceID). These are the three basic attributes (SurveyID, VesselID, DeviceID) and tables currently utilized by the project to manage the survey data collected from different surveys, years, research vessels, and sonars. Each point, line, or polygon feature representing data collection locations has at least these three common survey attributes that are linked to a table through a relationship class. The geographic information science portion of this project is now focused on extending these basic objects and adding supplemental data types such as sound velocity profiles and oceanographic model outputs (bottom current, bottom stress). This complementary data will move us along the path toward an integrated science approach to investigating the inner continental shelf off the coast of Massachusetts.



The above is a typical survey configuration for the USGS/CZM project including a survey vessel and swath bathymetry, side-scan, and seismic sonars.

A Method for Multidisciplinary Science

Each year, new technologies allow us to collect coastal and marine data faster, at higher resolutions, and with more precision and accuracy. These advances in mapping technologies should also enable us to extract empirical information from the data at similar rates and resolutions. One method to achieve a corresponding advance in geographic information science is leveraging the tools in the geodatabase and Arc Marine framework to build smarter data models of real-world features and represent them in the digital form of an object-oriented relations database.

The Arc Marine data model proved to be an excellent framework to internally manage large volumes of marine geophysical data for the USGS/CZM project. The spatial data collected in the project is published in Arc Marine format so that other researchers studying the same geographic area can easily incorporate their own data using the marine data model framework.

The USGS/CZM cooperative mapping program is now entering the next five-year project cycle with advanced tools in both the mapping and geographic information sciences that will produce more detailed and comprehensive views of the seafloor. For example, the ability to manage and analyze different types of marine data may shed new light on the health of a marine ecosystem and its ability to rebound from catastrophic events.

Multidisciplinary science and *integrated science* are two terms often used in coastal and marine research. This type of research cannot be achieved without first adopting a method, such as the Arc Marine data model, to analyze different types of marine data collected in the same geographic area.

(Reprinted from the Summer 2008 issue of *Federal GIS Connections*)

GIS and Ecosystem-Based Management

A continuing challenge in marine sciences is understanding how various ecosystems function and interrelate—from microscopic primary producers at the base of the food chain to coral reefs to large marine ecosystems—as well their biodiversity. Further, how will these ecosystems respond to factors such as human uses and waste input, coastal development, coastal storms and flooding fueled by climate change, and invasive species? What is the resilience of coastal ecosystems (plant and animal species), as well as coastal communities of humans? The marine science community appears to have coalesced on the efficacy of an ecosystem-based approach, where biological elements are not studied in isolation but with physical factors and human presence/human impacts as well. This has led to the establishment of ecosystem-based management (EBM) as a core principle guiding marine resource management decisions.

GIS has made a real impact in this area as scholars and developers worldwide have developed scores of GIS tools for the implementation of EBM. A good example of this is the EBM Tools Network (ebmtools.org/), where tools are organized under several categories such as data collection/processing/management, stakeholder engagement, conceptual modeling, visualization, project management, monitoring and assessment, modeling and spatial analysis, and the all-important decision support.

In addition, remote sensing of ocean color radiance from space (e.g., SeaWiFS/MODIS) will continue to make a huge contribution in this area as this is how marine scientists can assess the amount and type of phytoplankton in the ocean, which also gives indicators of ocean nutrient levels (ocean health) and ocean currents. Phytoplankton are at the base of the marine food chain, so as they go, so go the various ecosystems depending on them. With budget uncertainties and the like, future international collaborative efforts will be needed to sustain and bring online new satellite sensors; calibrate and validate data; develop new sensor algorithms; and integrate with geospatial observations from ships, buoys, and aircraft.

—Dawn Wright

Fishing Catch Data Mapped Off the East Coast of India

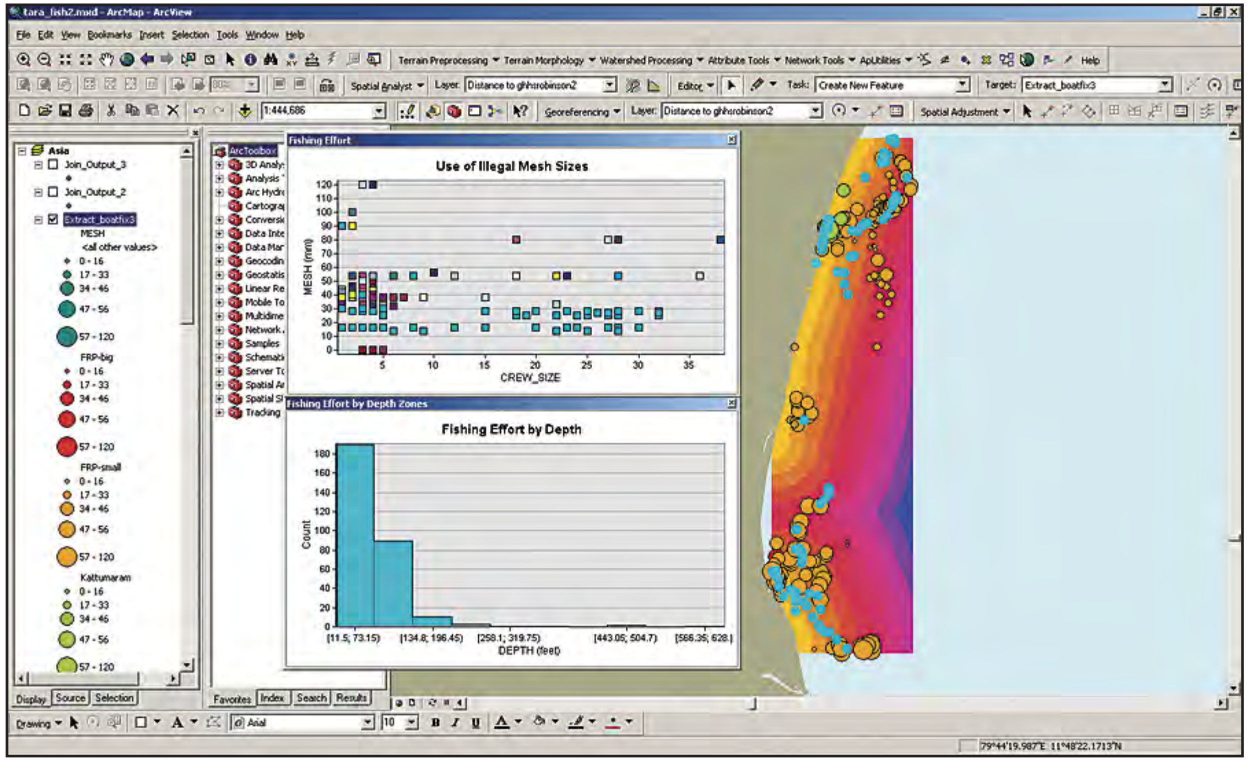
By Tara N. Lawrence, Neil W. Pelkey, and R. S. Bhalla

Coastal fishing in small boats with ragged nets, refurbished motors, and overworked crews is a dangerous occupation. These days, catches seldom contain big fish complete with bragging rights. If a catch fetches enough cash for tomorrow's diesel fuel, it's a good day. If not, fish harder, deeper, and longer tomorrow.

For decades, it was clear that some form of regional management was necessary on the east coast of India. In 2004, the Banda Aceh tsunami provided both the motivation and the funding to get this under way. Boats, nets, motors, GPS units, and fish finders were distributed in nearly every community.

However, the management tools used at the government level at that time were hampered because the data used in the analysis was limited to information collected at the jetties where hundreds of men and women sold fish.

But, of course, fishing itself happens at a place, depth, and time with real boats, real people, real gear, and real fish of certain weights and species. The proper information to govern fisheries needs to have "what," "when," "where," "who," "how deep," and "with what" data. This information is also critical for fisheries governance in India since traditional and mechanized craft have different legally defined fishing zones.



Fishing data is linked to maps and shows the use of illegal mesh sizes at the respective depths and distances. This shows a clear lack of implementation of specified rules and regulations.

A nonprofit research organization called the Foundation for Ecological Research, Advocacy and Learning (FERAL) purchased a commercial license in 2003, and researchers at FERAL have been using ArcGIS since then for various mapping applications within research projects. This fisheries dataset required the ability to explore the complex relationships between fishing and gear, catch, and location—a task that ArcGIS is ideally suited for. The researchers linked the dynamic mapping and graphics capabilities in ArcGIS to explore and demystify this data. They then transferred the on-screen dynamic displays to publication-quality graphs using the ggplot2 graphic plotting system designed by Hadley Wickam of Rice University, Houston, Texas.

The "what" is quite detailed, as there are roughly 243 species of fish recorded that are caught, sold, and consumed. The "where" and "how deep" questions were covered by a straightforward

GIS application using existing coastline maps, GPS, and a Humminbird echo sounding device. The "when," "who," and "with what" data was supplied by observation as researchers traveled standard fishing routes in three regions of the Coromandel Coast in the Bay of Bengal. Catch data would no longer be 300 kilos of shad, but rather, for example, 300 kilos of shad caught at 79.38765 E, 12.345 N at a 20-meter depth in sandy soils by five men using 25 millimeter nets who fished from 7:00 a.m. to 8:30 a.m. on January 3, 2008.

The researchers "pinged" the fishing coordinates, depth, and substrate where they found men fishing. They also collected data on type of gear, mesh size, and target species. All data was integrated and fed into ArcGIS.

ArcGIS software's dynamic data visualization and exploratory analysis helped immediately identify data entry errors, but more importantly, it illuminated the "where" of artisanal fisheries. Researchers were also able to move the data quickly into the R programming language and ggplot2 to create publication-quality statistical graphics.

The combination of graphs linked to the map display showed many Marine Fisheries Regulation Act (MFRA 1983) violations in terms of location and gear type. It was also clear that the fish cluster, and hence so do the fishermen. The often-told story that plenty of illegal fishing occurred in these waters turned out to match the data. Banned nets and mesh sizes were used, and large trawl boats regularly fished well within the 3-nautical-mile limit.

The distance tool, combined with the extraction tool in the ArcGIS Spatial Analyst extension, provided accurate measurements of distance to shore. Knowing the distance from shore is critical, because mechanized craft are not allowed to fish less than 3 nautical miles from shore, and motorized craft cannot go beyond 12 nautical miles without additional licenses. This creates tension, since the big trawl catches of shrimp are often within 3 nautical miles of the shore and the big long-line catches of the motorized boats are often beyond the 12-nautical-mile limit.

A huge plus of the GIS was the ease and rapidity of visualizing and analyzing the data. It took less than an hour to pull data from multiple sources; create and add the different layers; and define categories, such as boat size by depth or crew size by boat. After that, it was a simple matter of cleaning up errors, adding the distance grid, and redefining categories. The dynamic analysis and publication-quality maps were only a few clicks away.

A large mechanized boat comprising up to 80 fishermen. The ring seine net often extends for kilometers, therefore resulting in considerably large catches of sardines or mackerel.

Visualizing the data in ArcGIS and R was a quick and efficient way of visually exploring theories and perceptions on the fisheries sector. It took only nine days of sampling to map more than 250 boats fishing in the same zone in only a part of the Coromandel Coast. The ease with which this assessment could be done in so little time presents a useful tool for fisheries management. It was cost-effective in terms of time spent collecting the data and analyzing it and therefore could be used frequently to map fishing efforts on both coasts of India.

The real impact of the kind of fishing effort expended on a daily basis will only hit home then. Catches can no longer satiate this massive demand. Overfishing is a real issue that needs to be addressed on several levels in this complex yet dynamic sector, and a spatial context can solidify/silence any arguments raised on the ground.

About the Authors

Tara N. Lawrence is a marine biologist with the Foundation for Ecological Research, Advocacy and Learning, Pondicherry, India. Her current position as a junior research fellow involves building a qualitative and quantitative profile for the traditional and motorized sector in fisheries along the Coromandel Coast of India. Dr. Neil Pelkey is an associate professor at Juniata College, Huntingdon, Pennsylvania, whose area of expertise involves ecological modeling and environmental economics. R. S. Bhalla is a senior research fellow and trustee of FERAL. He is a landscape ecologist whose area of expertise also involves GIS and remote sensing.

(Reprinted from the Fall 2010 issue of *ArcNews*)

Understanding Spatial Dimensions Helps Small-Scale Fisheries

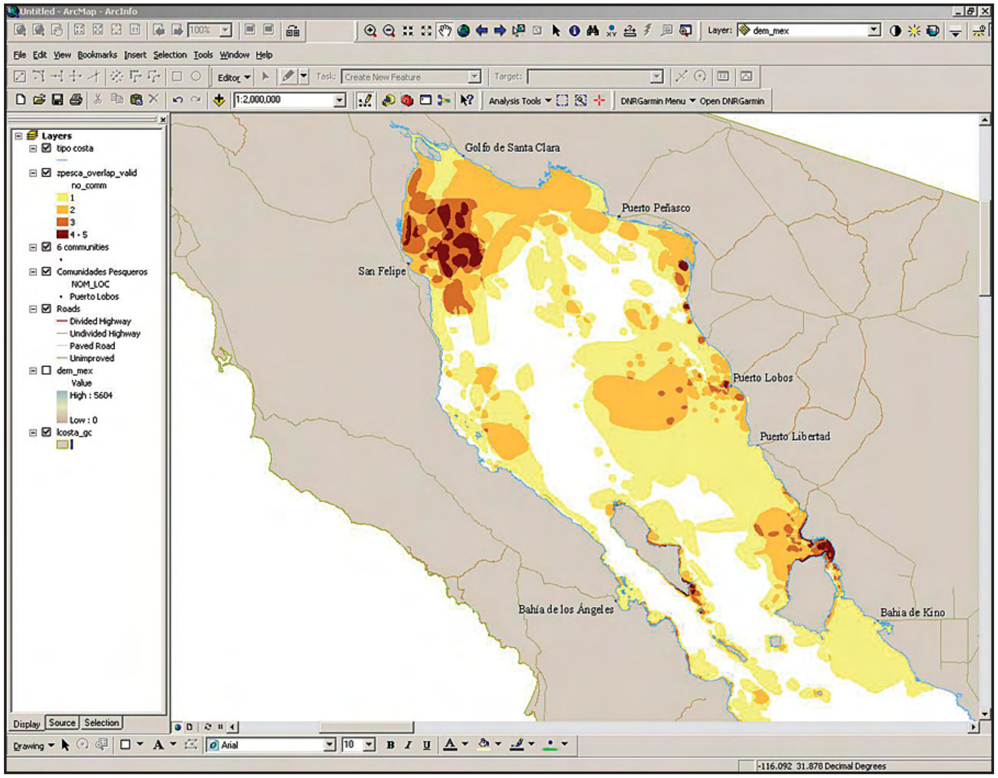
In the Northern Gulf of California, Mexico, GIS Helps Visualize Marine Ecosystems

Highlights

- Multidisciplinary team collects and integrates local knowledge at a regional level.
- Direct use of local knowledge is spatially integrated and validated using ArcGIS.
- Environmental managers use GIS and information to design fisheries management plans.

The sun is rising over the Gulf of California as three fishermen depart for the day in their small fishing skiffs called pangas. Pinks, reds, and yellows fill the sky and reflect across the calm water as the men silently prepare their nets, with only the noise of the whirring engines filling the air. Like the thousands of other small-scale fishermen, these men come from a strong fishing tradition. Their fathers and grandfathers worked the sea, and they deeply understand its importance to their livelihood and culture. But unlike past generations, these men may never pull in a giant grouper or a totoaba once abundant in the region.

Recent declines in important marine populations around the world have alarmed fishermen and scientists alike. Unfortunately, the Gulf of California is no exception. Just south of the international boundary with the United States, the narrow gulf, separated from the Pacific Ocean by Baja California on the west and framed by the states of Sonora and Sinaloa, Mexico, on the east, is one of the most productive marine ecosystems in the world. Important commercial species and rare animals, such as the Vaquita, an endangered species of porpoise, inhabit these waters.



Map showing where fishing activities by communities overlap, resulting in high-use areas.

The Gulf of California alone provides most of Mexico's fishery harvest and is a major supplier of seafood to the southwestern United States and eastern Asia. But fishing practices over the last 25 years have led to the near extinction of many important commercial species, and current practices will lead to the further exhaustion of important fisheries resources.

The need for an innovative and creative approach for fisheries management of the Gulf of California drove the formation of PANGAS. Named after the word in Spanish for a traditional fishing boat, the name Pesca Artesanal del Norte del Golfo de California: Ambiente y Sociedad means Small-Scale Fisheries of the Northern Gulf of California: Environment and Society. PANGAS is a collaborative effort involving Mexican and U.S. researchers in the biological, physical, and social sciences, as well as small-scale fishermen and other important stakeholders. Past failure in the management of small-scale fisheries in the Gulf of California and worldwide is due in part to approaches that have ignored the structure and connectivity among populations of marine organisms.

A primary gap has been the lack of integration with ecosystem, socioeconomic, and natural resources management in a GIS database. As a result of this necessity, the geospatial information component was established in the project. This component's primary goal and objectives include giving support to PANGAS partners, researchers, and stakeholders by providing tools to make sound decisions based on the best available information.

Through a university site license, researchers concluded that ArcGIS has the capacity for integrating in a standard-based platform complex data with a spatial and temporal component. The software also provides the tools for applying spatial analysis, managing data, and mapping the results of the biophysical and socioeconomic research. With ArcGIS Desktop, the complex spatial systems influenced by feedbacks between biophysical and human processes were addressed and analyzed.

To begin their monumental task, researchers of the PANGAS project took printed maps of the northern Gulf of California into 17 fishing communities. Over a period of a year and a half, the team interviewed and worked with local fishermen, creating hard-copy maps based on regional knowledge. These maps included the distribution of historical and actual fishing activities. More than 700 maps with information were compiled and digitized using ArcEditor and the Georeferencing toolbar. Once integrated, the information collected revealed details about the temporal and spatial aspects of fishing activities in the northern Gulf of California that were not previously understood. This resulted in a collection of local knowledge combined with recently collected scientific information, such as bathymetry and landmarks.

After the initial assessment, the team brought the compiled information back to two communities to validate the data previously collected. To small gatherings of 20 fishermen, a group of researchers presented the spatial distribution of the northern gulf fisheries. The fishermen were amazed when they saw the maps projected on the wall using ArcGIS Desktop and eagerly assisted in the validation and refinement of the information. The validation approach involved the introduction of ancillary information and utilized ArcEditor. PANGAS researchers were able to adjust the information in situ together with the fishermen. The approach capitalized on the analytical and visualization capacities of ArcGIS Desktop in order to facilitate the interactivity among workshop participants.

Image of the traditional Mexican fishing boat called a panga, for which the project is named.

The geospatial information coordinator from PANGAS, Marcia Moreno-Baez, understands the importance of GIS to the project, stating, "It would be impossible to understand at this level, at this scale, the distribution of fisheries activities. We wouldn't be able to visualize the spatial dimension of fisheries activities in the northern Gulf of California without GIS."

PANGAS is comprehensively mapping the entire northern gulf's small-scale fisheries activities on a regional scale.

With ArcGIS Desktop, PANGAS has successfully visualized the spatial/temporal distribution of fishing activities and the social-biophysical linkage affecting this distribution. Now PANGAS is able to aid in the development of management recommendations for small-scale fisheries in the northern Gulf of California. In the near future, PANGAS will present its findings to fisheries managers, scientists, and government officials for decision-making purposes. ArcGIS Desktop has facilitated the decision-making process by helping design and develop management practices grounded in regional, biophysical, social, and political realities.

PANGAS is the first fisheries research project of this scale attempting to incorporate geospatial information and can only do so through the invaluable participation and time that small-scale fishermen of the northern Gulf of California, Mexico, devoted to this study.

More Information

This study was made possible thanks to financial support from the David and Lucile Packard Foundation; the University of Arizona; the Consejo Nacional de Ciencia y Tecnología (CONACYT), México; and the Wallace Research Foundation. This is a scientific contribution of the PANGAS project (pangas.arizona.edu).

(Reprinted from the Spring 2009 issue of *ArcNews*)

Prioritizing Seagrass Restoration Sites

Study examines predictors of seagrass bed recovery

By Amy V. Uhrin and Kevin Kirsch

Summary: Ecologic researchers are modeling the impact of vessel grounding to seagrass beds using GIS in the Florida Keys National Marine Sanctuary. The surface creation tools in the ArcGIS 3D Analyst extension help assess both the damage and recovery of these seagrass beds.

Modeling vessel groundings in GIS is helping determine the extent of the damage suffered by seagrass beds and identify factors that contribute to their recovery.

Seagrass beds are an integral component of the Florida Keys National Marine Sanctuary (FKNMS) ecosystem with nearly 1.4 million acres of seagrass growing within sanctuary boundaries. Seagrass beds provide nurseries, feeding grounds, settlement sites, and refuge areas for a large number of commercially and ecologically important shellfish and finfish species. The ability of seagrass beds to reduce current velocities, dampen wave energy, and stabilize sediments enables this coastal resource to afford shoreline protection and habitat stability during storm events.

A vessel grounding site with propeller scar, berm, and blowhole features.

Propeller Scars, Blowholes, and Berms

Each year, more than 600 motorized vessel groundings are reported in the FKNMS, primarily within seagrass beds. Vessel groundings result in the formation of at least one of three injury features: propeller scars, blowholes, and berms.

Propeller scars occur as a boat's propeller tears into seagrass blades and the underlying sediment creating a shallow, narrow, linear trench that is typically devoid of plants. As the boat continues to move forward, the hull of the boat digs into the seagrass bed and may eventually come to rest. It is not uncommon for the boat operator to attempt to "power off" the seagrass bed by fully engaging the engine, resulting in a deep, large excavation called a blowhole.

Much of the sediment that is excavated from the blowhole is blown onto the seagrass bed fringing the blowhole creating a berm. Because vessel groundings directly remove seagrass plants, these events have the ability to alter the abundance and distribution of many marine organisms as well as the local hydrology, resulting in an unstable seagrass bed and environmental modification on a local scale.

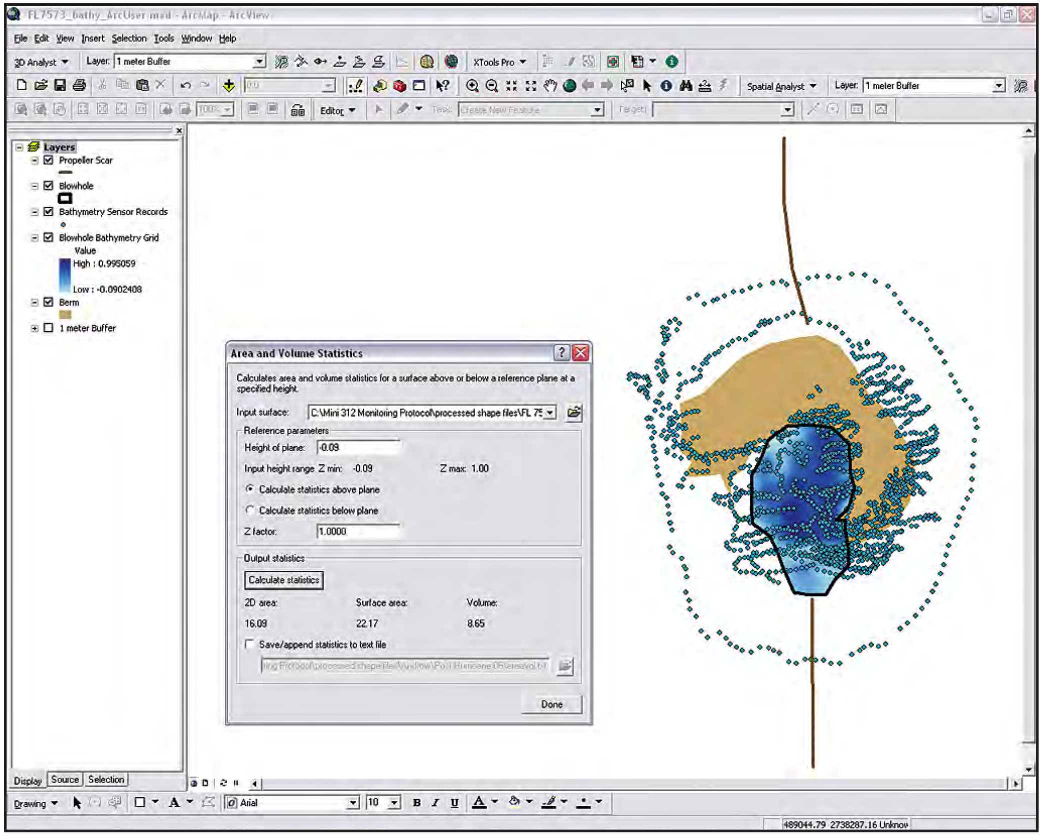
Given the continued popularity of marine recreation activities, such as scuba diving and fishing, as well as commercial fishing in the Florida Keys, vessel groundings will continue to occur. Within FKNMS, natural resources such as seagrasses are protected. Any party responsible for the loss, injury, or destruction of a sanctuary resource is liable to the United States for assessment and restoration of the damaged resources.

Assessing Damage

As government trustees, the National Oceanic and Atmospheric Administration (NOAA) and the Florida Department of Environmental Protection are authorized to seek restitution from the responsible parties. Since 2000, the two agencies have cooperatively conducted impact assessments and drafted restoration plans for vessel injuries to seagrass resources utilizing protocols and analyses established under the auspices of the Mini-312 Seagrass Restoration Program (darrp.noaa.gov/partner/mini312/index.html). *[The program is named for a section of the National Marine Sanctuaries Act.]*

Mapping for Managing Restoration

This assessment protocol incorporates several facets of GIS to determine the extent of damage to a site and monitor its recovery. Grounding sites are mapped by physically tracing the outline of the features (i.e., berm, blowhole) that result from the vessel grounding using a differential GPS. In this case, Trimble GPS Pathfinder Pro XR receiver and Trimble TSC1 data collector were used. For shallow sites, the differential GPS (DGPS) antenna is pole mounted and outlines are traced by walking the injury perimeter. Where deeper water precludes walking, the DGPS unit is attached to an inflatable boat that is then floated around the injury perimeter under the direction of a snorkeler. Injury feature coordinates are downloaded to Trimble GPS Pathfinder Office software, then exported into ArcGIS. Using ArcMap, the extent of the damaged area is calculated in square meters.

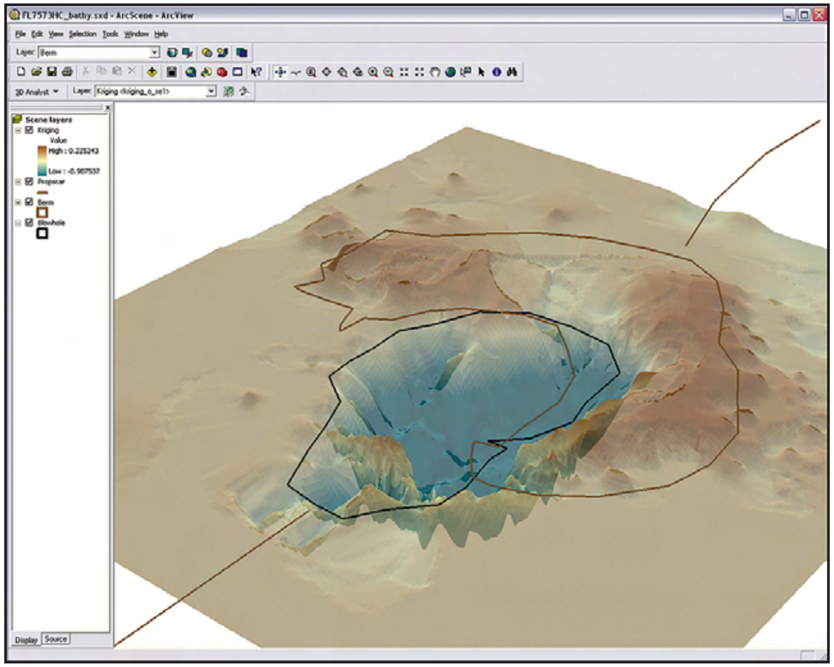


Injury feature outlines, the bathymetric grid layer generated from sensor records, and blowhole area and volume calculations using the surface analysis tools in the ArcGIS 3D Analyst extension.

To restore a blowhole to the natural grade of the undisturbed seafloor surrounding requires determining the amount of sediment that has been excavated. To estimate this volume, NOAA researchers integrated a Lowrance LCX-15MT, a commercially available depth sounder, with the DGPS unit and mounted the system on the stern of a small inflatable boat. A bathymetric survey of the injury site is recorded as georeferenced depth soundings logged while the boat is slowly floated back and forth across the blowhole. Care is taken to collect a sufficiently dense scattering of points to describe the topographic variations (i.e., the peaks and valleys) within the blowhole.

The resulting files are downloaded to Trimble GPS Pathfinder Office software and exported to ArcGIS. An interpolated bathymetric grid surface that was limited to the area of the blowhole was created using the inverse distance weighting (IDW) function, a tool available from ArcToolbox when the ArcGIS Spatial Analyst or 3D Analyst extensions are loaded. The small interpolation areas (ranging from 10 to 500 square meters) combined with concentrated depth records made IDW an ideal technique for interpolating the bathymetric surface of blowholes. Blowhole volume was calculated in cubic meters using the Surface Analysis tool available with the ArcGIS 3D Analyst extension.

Three-dimensional images of blowholes are generated by first applying ordinary kriging to the sensor records file by choosing Interpolate to Raster from the ArcGIS 3D Analyst toolbar. The kriging layer was opened in ArcScene, an application in the 3D Analyst extension, and the layer properties were manipulated to generate the desired three-dimensional effect.



Three-dimensional representation of the volume of a blowhole that resulted from a vessel grounding. The blowhole perimeter is indicated with a black line, and the berm is indicated with a brown line.

Benefits of GIS Use

The accuracy of GIS technology and its use in the Mini-312 Seagrass Restoration Program has enabled NOAA to georeference the occurrence of vessel groundings in the FKNMS as well as to gather critical data on the size, shape, and volume of damage that is used in drafting restoration plans and preparing settlement claims. The ability to accurately return to a grounding site to conduct follow-up assessments allows NOAA to compare the natural recovery of the site over time. Modeled recovery projections are a means of evaluating the overall success of the program and determining which restorative actions (if any) are required on a per-incident basis.

The authors selected 27 documented vessel grounding cases that occurred in the FKNMS for reassessment. They examined the extent of natural recovery in the absence of mitigated restoration. Indications that a damaged site is recovering include decreases in the original area and volume of a blowhole and significant seagrass regrowth in the area.

By teasing apart the relationships between the level of observed natural recovery and specific characteristics of the damage (such as when it occurred and the original volume of the blowhole), in addition to environmental parameters (such as sediment type and wave exposure), the authors expect they will be able to provide sanctuary managers with a model that can be used for predicting the potential recovery dynamics of a given site based on threshold values for the previously listed parameters. This will allow managers to set restoration priorities for recent grounding events.

Initial modeling results indicate that, although all of the parameters have been found to contribute to natural recovery (or lack thereof), the date of the grounding and a site's level of exposure to wave energy are the prominent factors. Groundings that have occurred within the last two years and were highly exposed to wave energy experienced minimal recovery. The ability to set restoration priorities will greatly enhance the Mini-312 Seagrass Restoration Program's efficiency by targeting restoration to damaged sites most at risk of expanding with the passage of time.

The authors continue to refine the model with the inclusion of additional case reassessment data as it becomes available from sanctuary staff. For more information on the Mini-312 Seagrass Restoration Program, visit NOAA's Damage Assessment, Remediation, and Restoration Program at darrp.noaa.gov.

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Kirsch, K. D., K. A. Barry, M. S. Fonseca, P. E. Whitfield, S. R. Meehan, W. J. Kenworthy, and B. E. Julius. 2005. "The Mini-312 Program—An Expedited Damage Assessment and

Restoration Process for Seagrasses in the Florida Keys National Marine Sanctuary," *Journal of Coastal Research.* SI40: pp. 109–119.

For More Information

To find out more about three-dimensional modeling in GIS, see *Learning ArcGIS 3D Analyst,* a Web course available at esri.com/training.

About the Authors

Amy V. Uhrin is a research ecologist at NOAA's Center for Coastal Fisheries and Habitat Research in Beaufort, North Carolina. She began her career with NOAA in 2000, and her research interests include disturbance ecology and recovery dynamics of seagrass ecosystems, seagrass restoration ecology, and fishing gear impacts on marine ecosystems. She holds a master's degree in biological oceanography from the University of Puerto Rico, Mayagüez.

Amy V. Uhrin

Kevin Kirsch is a regional resource coordinator with NOAA's Office of Response and Restoration in St. Petersburg, Florida, where he responds to hazardous materials and vessel groundings and assesses the impact of these events on the marine environment. He began his career with NOAA in 2000 and spent five years assessing impacts to seagrass resulting from vessel groundings in the FKNMS. He holds a master's degree in marine science from the University of South Alabama.

Kevin Kirsch

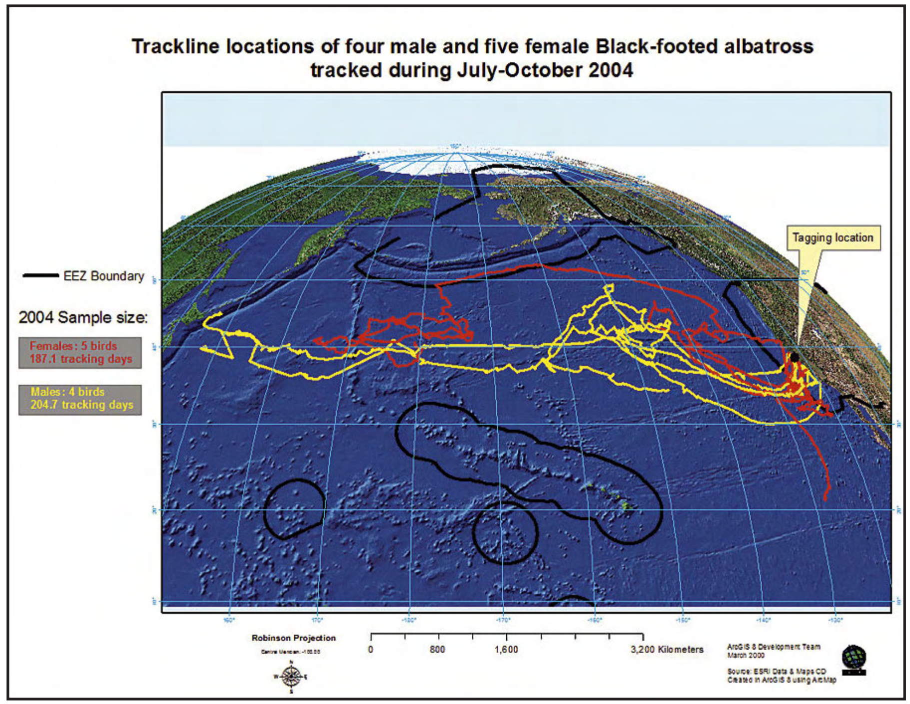
(Reprinted from the Summer 2008 issue of *ArcUser*)

Turning the Tide for Troubled Albatross

For centuries, the world's largest seabird, the albatross, has been woven into the fabric of maritime lore. Its giant wings enable the albatross to stay aloft on nearly imperceptible winds, thus making it the harbinger of good sailing to mariners. Unfortunately, seamen have not returned the goodwill in kind. Each year, thousands of albatross die at the end of fishing hooks. Since the long-term monitoring studies at breeding colonies began in the 1960s and 1970s, some albatross species have decreased by 90 percent, with annual declines of up to 7 percent. The global conservation status of albatross continues to worsen, with two species listed as "critically endangered," seven considered "endangered," and ten regarded as "vulnerable," according to the International Union for the Conservation of Nature. Of the three North Pacific albatross species, the black-footed and the Laysan were recently upgraded to "endangered" and "vulnerable," respectively. The third species, the short-tailed albatross, was down-listed to "vulnerable."

Michele Hester (Oikonos) and David Hyrenbach (Duke University) banding a black-footed albatross.

Because of the worsening status of North Pacific albatross populations, the National Fish and Wildlife Foundation provided funding for a study on the postbreeding movements of the black-footed albatross. This species is facing a projected population decline of 60 percent over the next three generations (56 years) and remains susceptible to bycatch in domestic and foreign longline fisheries across the North Pacific Ocean. Longlines are single-stranded fishing lines, up to 40 miles in length, equipped with hundreds—and sometimes thousands—of baited hooks. The birds are attracted to the bait, get hooked, then are dragged under the water and drowned. Since 2002, pelagic long-lining on the U.S. Pacific coast has been banned in areas designated as the Exclusive Economic Zone (EEZ), which extends 200 miles offshore. But albatross remain threatened because they travel well beyond the safe zone into unregulated waters. Demersal long-lining still occurs off the Pacific coast of the United States and in the Aleutian and Bering Sea continental slope.



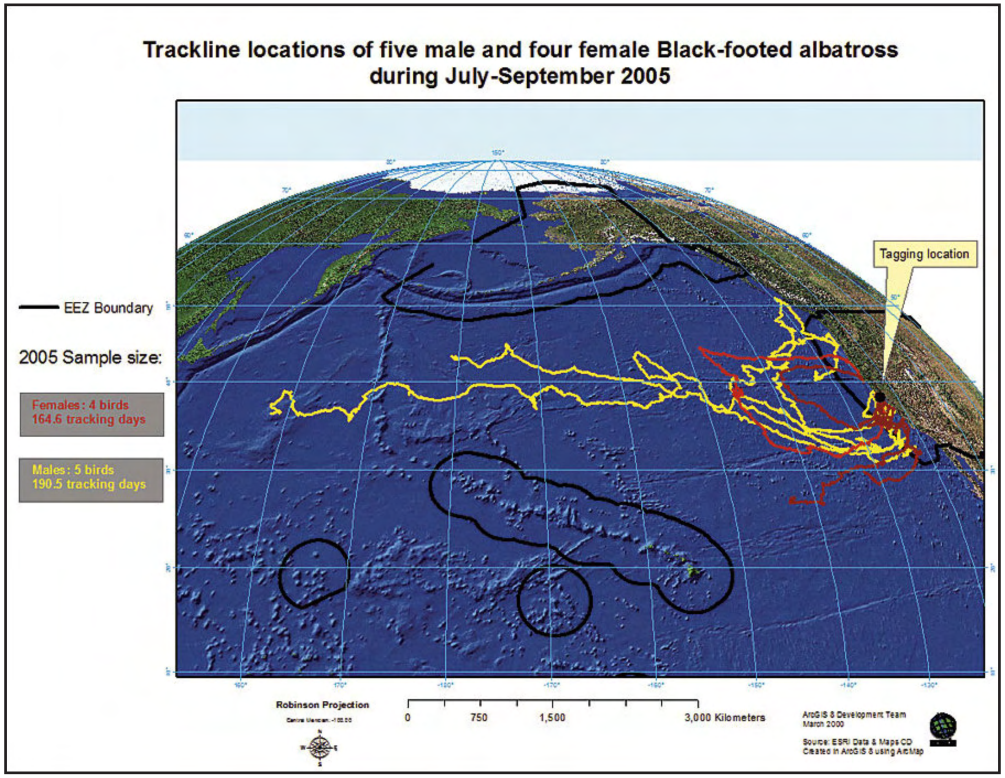
Tracks of four male (yellow) and five female (red) black-footed albatross followed for a total of 392.5 tracking days during the summer and fall of 2004. Black lines indicate the extent of the U.S. Exclusive Economic Zone.

This threat of loss to albatross populations has made these birds a priority for conservation action. Scientists are using GIS to gather information about albatross movements to identify those fisheries and nations with conservation responsibilities for these far-ranging seabirds. This information will improve the bird's chances for survival by focusing international management actions toward important foraging areas and potential fishery threats. GIS may be the harbinger of good fortune for troubled albatross populations.

Tracking Movements

Although large population declines have been projected, very little is known about the movements and threats faced by individual albatross at sea, especially during their postbreeding dispersal. Oikonos Ecosystem Knowledge is a nonprofit organization that is applying its GIS program to investigate how albatross habitats and longline fisheries are distributed spatially and temporally. Esri provided Oikonos with a grant for GIS software, which is enabling the organization to map large-scale regions of the North Pacific Ocean and overlay point and polyline data with EEZ and U.S. National Marine Sanctuary polygon shapefiles to calculate the amount of time spent by bird species in specified regions. Oikonos and collaborators (Duke University, the Claremont Colleges, and the U.S. Geological Survey—Moss Landing Marine Laboratories) submitted findings to the National Fish and Wildlife Foundation as part of the foundation's albatross study.

During 2004–2005, the project team of scientists used Kiwisat Argos-linked transmitters to track the postbreeding movements of 18 black-footed albatross tagged in California's Cordell Bank National Marine Sanctuary. Albatross are known for flying long distances, and the study confirmed these incredible journeys. The duration of the birds' tracking sessions ranged from 22 days to an amazing 57 days. One bird traveled as far as Hokkaido, Japan, a linear distance of more than 7,300 kilometers from the tagging site. Overall, four out of nine males traveled west of the international dateline (180º W) yet only one of the nine tracked females ventured into the western North Pacific. This preliminary data suggests that male and female birds segregate at sea. This is an exciting possibility with important conservation implications.



Tracks of five male (yellow) and four female (red) black-footed albatross followed for a total of 355.1 tracking days during the summer and fall of 2005.

Evaluating Distributions

Oikonos used ArcGIS Desktop (ArcInfo) to evaluate spatial distributions of albatross telemetry locations throughout the North Pacific and performed a spatial analysis of mapped points, polylines, and polygon shapefiles. It evaluated differences in distribution between male and female albatross by comparing the extent of their foraging ranges, though this comparison showed no significant gender-based differences in the maximum distances traveled. Using the satellite-tagged birds and remotely sensed information from satellites, scientists are currently investigating and quantifying bird movements in association with sea surface temperature, chlorophyll concentration, and wind speed and direction. GIS analysis is also being used to identify those nations with responsibility for the conservation of this far-ranging species throughout the bird's life cycle. Using GIS, scientists are assessing the albatross distributions relative to management zones and protected regions. Findings to date showed that postbreeding black-footed albatross do not remain within the Cordell Bank National Marine Sanctuary or the U.S. EEZ waters but range widely across high seas areas harvested by pelagic longline fisheries.

Currently, based on the known breeding colonies, Japan and the United States have jurisdiction over the black-footed albatross. During the postbreeding season, however, the birds tracked during this study ranged within territorial waters of Canada, Japan, Mexico, and Russia. These impressive movement patterns represent a great challenge for albatross conservation, since fisheries management in the high seas is hampered by the lack of standardized bycatch data collection and enforcement mechanisms across fishing fleets. By overlapping albatross satellite telemetry tracks with boundaries of jurisdictional waters and fishing effort data, ArcGIS graphically highlights those fisheries and countries with responsibilities for albatross conservation.

Black-footed albatross ready for release by biologist Sue Abbott.

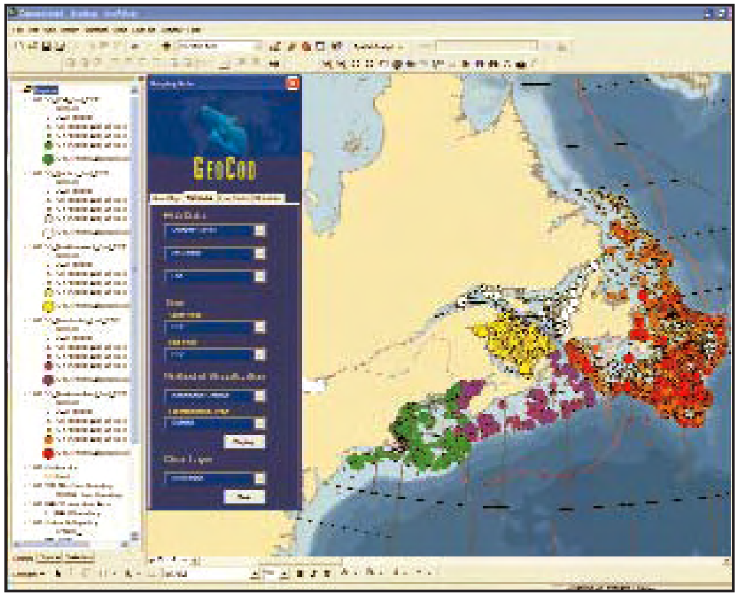
Results from this study have been provided to the black-footed albatross status assessment, currently under way by the U.S. Fish and Wildlife Service, and will be made available to BirdLife International's global procellariiform tracking database. This multinational database has been used to identify important seabird foraging grounds and migration corridors in the southern ocean and will provide a conceptual foundation for future important bird area delineation in the North Pacific.

Conservation of far-ranging albatross species requires accurate knowledge of their movement and distribution at sea. This study is the first of its kind to track the incredible postbreeding movement and habitats of the black-footed albatross across the North Pacific. Increasingly, the integration of satellite tracking, remote sensing, and GIS mapping is empowering resource managers to tackle large-scale conservation questions.

(Reprinted from the Spring 2006 issue of *ArcNews*)

GIS for the Sustainable Management of Fish Stocks

With nearly 18,000 students, Memorial University of Newfoundland is the largest university in Atlantic Canada. Its department of Geography offers bachelor, master's, and PhD degrees where students can specialize in GISciences (GIS, Cartography, and Remote Sensing). In addition to these degrees, Memorial University offers an undergraduate diploma in GISciences where students can add practical experiences to their academic training. GIS technology is utilized extensively for teaching and research purposes. Research in GIS within the department of Geography ranges from modeling the impact of climate change on vegetation, supporting conservation of endangered marine species, and analyzing the seabed morphology to identifying structures related to oil and gas reservoirs.



Proportional symbols map produced by the GeoCod system showing the abundance of Cod in Atlantic Canada in 1992.

The marine environment plays an important role in Canadian society. More than 71% of the world's surface is covered by oceans. Canada has the world's longest coastline, the second largest continental shelf, and about 23% of the population lives in coastal communities, many depending on the sea to make a living. Worldwide, more than 1 billion people rely on the ocean for food. Canada's oceans generate a considerable number of jobs and economic activity.

However, the United Nations has estimated that more than 75% of the world's fish stocks are either fully exploited or overexploited. Eastern Canada, and more specifically Newfoundland and Labrador, is one of the major world regions that has experienced extensive overfishing. In addition to overfishing, it has been suggested that climate change has also had a negative impact on fish stock dynamics. To date, more than 40,000 jobs have been lost due to the closure of the Northern cod fishery in Newfoundland in the 1992 moratorium. This has been compared to the effect of closing every manufacturing plant in Ontario.

The GeoCod project is a 2-year research project spearheaded by Memorial University and cofunded by the Canadian GEOIDE Network of Centres of Excellence and the Canadian Center for Fisheries Innovations (CCFI) that began in January 2006. The project is focused on the North West Atlantic region of Canada and aims to provide a comprehensive picture of marine fish and invertebrate distribution and abundance for these biological species, cod, capelin, shrimp, and crab, through the use of GIS.

A major part of this project focuses on the development of a GIS-based decision support tool that has been developed as an extension to ArcGIS. The prototype of the extension will be made available to the different partners of the project, which include Fisheries and Oceans Canada, Fisheries and Aquaculture Newfoundland, and the World Wildlife Fund. In turn, these partners will be able to use this GIS-based tool to analyze and visualize the database compiled to better understand fish dynamics in the study area over the last few decades.

"Decision-makers in fisheries management traditionally relied upon statistics, tables, charts, and other data sources, and haven't fully utilized the power of GIS to conduct spatial analysis which provides the framework for a more comprehensive understanding of fisheries data," said Dr. Rodolphe Devillers, GeoCod Project Leader, Memorial University.

The Department of Fisheries and Oceans Canada (DFO) has been collecting data in Canadian waters for decades to assess the state of fish stocks. The database compiled in the GeoCod project to date includes oceanographic data (temperature, salinity, and nutrients), biological data (Canadian and US Fisheries scientific surveys as well as Fisheries observer program information) for the four biological species, and remote sensing data (sea-surface temperature and biological productivity). Prior to leveraging GIS to analyze these data, analysis was done by employing traditional statistical techniques that do not have a spatial dimension. Project stakeholders decided that GIS and its associated spatial characteristics offer more effective means by which the spatial context of fisheries-related data can be most rigorously examined. model that has made it suitable for subsequent analyses and visualization," said Dr. Devillers.

Original datasets have been delivered in various formats (Excel spreadsheets, text fi les, etc.) and have been integrated in a common data model. All of the fisheries data have been integrated into a single geodatabase, storing both the data and the associated metadata. Many other datasets related to the environment and fisheries management units were also collected. Fisheries data typically include observations made at sea at a specific location and at a specific time of the year. The kriging tools available with ArcGIS Spatial Analyst and Geostatistical Analyst have been used to interpolate the sample locations to generate continuous surfaces of the fish abundance. An extension for ArcMap was developed in Visual Basic and adds several functions that allow users to select the data they want to visualize (fish species, region, year), choose between the sample locations or the interpolated surfaces, produce thematic maps of fish distribution and abundance, and produce animated maps of changes in abundance through time. Users are also able to compare spatial and temporal changes in fisheries data, explore the data for potential relationships between changes in fish occurrence/abundance and changes in the physical environment.

"Our application is so user-friendly that almost anyone can analyze and visualize fi sheries information geographically," added Dr. Devillers. "The spatial analysis characteristics of the application represent a significant leap forward with respect to being able to more effectively communicate fisheries information. We expect that it will be a powerful decision support tool that will contribute to the fight against declining fish stocks in our oceans."

(Reprinted from Volume 10 No. 2, 2007 issue of *ArcNorth News*)

Looking to the Oceans for Energy

Recent oil spills and continuing concern over climate change have many people thinking again about the urgent need to find alternative forms of energy. Is it possible to develop viable sources of alternative energy from the ocean that could meet, say, 10 percent of U.S. energy needs? An exciting challenge for marine science, as well as marine engineering, is the development of ways to produce electricity from ocean wave, offshore wind-on-water, and tidal energy. A related challenge is the development of ways to power the many devices in the ocean that are used for scientific and military purposes (such as wave or solar energy for underwater gliders, autonomous underwater vehicles, and other kinds of "robots"). So with the potential proliferation of these devices in the nearshore and continental shelf (e.g., wave energy buoys, wind-on-water turbines), what are the ocean space use conflicts that will arise? We need to consider commercial and recreational fishing, shipping lanes, conservation areas or protected habitat, military training and use, shipwrecks and other obstructions, recreational boating and sailing, liquid natural gas sites, scientific and telecommunication cables, and more. Ocean space is definitely a human dimensions research problem as well; where one is examining people's perceptions, biases, and prejudices, economics comes into play, and politics are nontrivial.

There is much potential for the use of geospatial technologies in the future of energy in the ocean space. GIS in general (and coastal Web atlases in particular) provide the "engine" to implement marine spatial planning (MSP): in this case, the necessary data and interactive, collaborative environment in which to map out the potential use conflicts. MSP needs to be guided by specific policies and regulations governing usage of the ocean and the conditions that apply with an eye toward those possible conflicts that may arise. Therefore, MSP experts may not always be GIS experts. So for many of us in the mapping community, we see ourselves as providing the enabling technologies that the MSP experts and policy makers need, along with cautionary advice about how to use the data and technology properly. And when there is a crisis involving offshore energy extraction, as in the 2010 Gulf of Mexico oil spill, satellite/aircraft remote sensing and GIS are key technologies for tracking the crisis and mapping out areas of risk and where response efforts are taking place.

—Dawn Wright

Emerald Isle's Coastal Contingency Plan

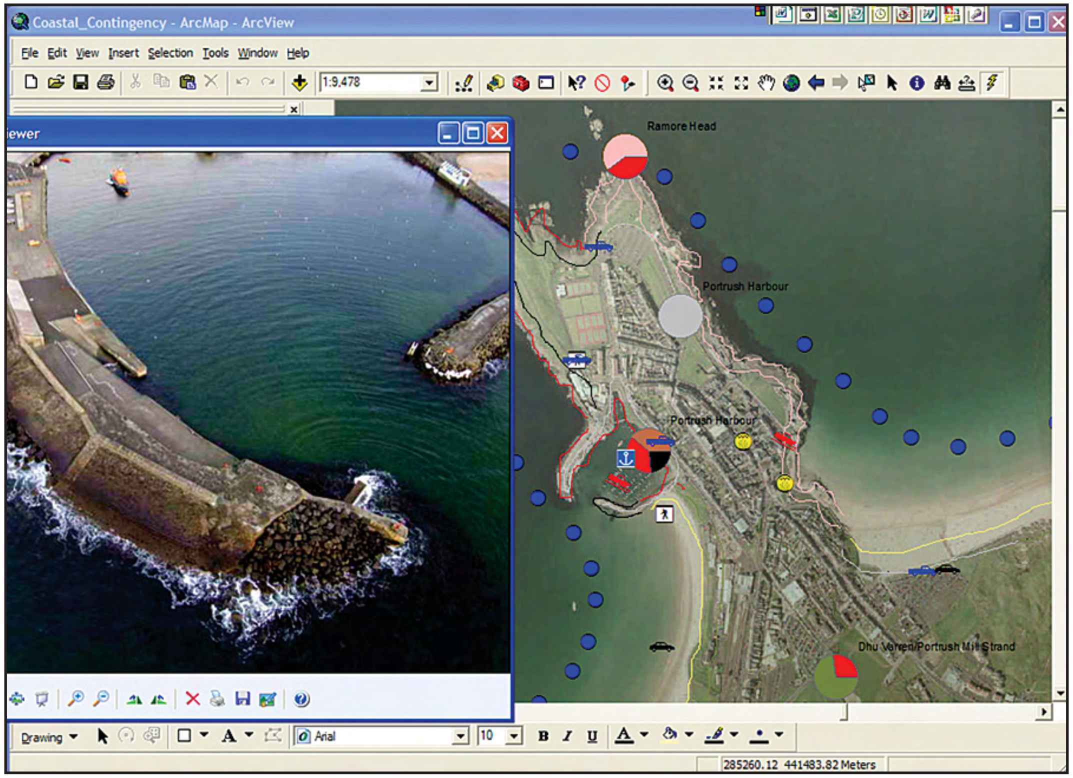
Northern Ireland Environment Agency Quickly Responds to Pollution and Shipping Incidents with GIS

Highlights

- ArcGIS is used to create charts and graphs showing characteristics of the Northern Ireland coastline.
- Voluminous information is accessible via an online spatial data catalog served from ArcGIS Server.
- Enterprise GIS enables the NIEA Coastal Survey Team to represent more than 40 layers of data spatially.

Northern Ireland Environment Agency (NIEA) is the largest agency within the Department of the Environment in Northern Ireland, with approximately 700 staff. NIEA takes the lead in advising on and implementing the government's environmental policy and strategy in Northern Ireland. The agency carries out a range of activities that promotes the government's key themes of sustainable development, biodiversity, and climate change. Its overall aims are to protect and conserve Northern Ireland's natural heritage and built environment, control pollution, and promote the wider appreciation of the environment and best environmental practices.

NIEA is the body responsible for coordinating the response to any pollution incident that may affect the coastline of Northern Ireland and is a partner in the Emergency Response to Coastal Oil, Chemical and Inert Pollution from Shipping (EROCIPS) project jointly funded by Interreg IIIb (a European Union-funded program that helps Europe's regions form partnerships to work together on common projects), the United Kingdom's Department of Communities and Local Government, and NIEA.



Ortho maps and aerial photographs are used in coastal contingency planning.

The EROCIPS project aims to develop "a transferable methodology that communicates relevant information to responders and decision-makers involved in shoreline counter pollution operations following a shipping incident." In the context of EROCIPS, a shipping incident is considered to be the large-scale accidental discharge of hydrocarbons, chemicals, or inert material (timber, plastics, etc.), carried as cargo, into the coastal marine environment. The incident may result in contamination of coastal habitats and/or pollution damage to the natural, human, and built resources they support.

Migrating the Information

NIEA is the repository for a diverse range of coastline information concerning, for example, vehicle access points, pedestrian access points, equipment lay-down areas, wastewater treatment discharge points, coastal assets, booming sites, and National Trust areas—in total, more than 40 distinct types of data. This information is held in both hard- and soft-copy formats, sitting in disparate locations throughout the agency. On examination, all this information was found to have a spatial component, and as a result, a GIS was determined to be the ideal platform on which to integrate and communicate this information.

The challenge was to migrate all this information to a GIS platform that would enable the NIEA Coastal Survey Team to integrate all the information NIEA held on coastal assets and communicate this information to external stakeholders, such as local councils, port authorities, other government bodies, cleanup contractors, and waste management companies, which also play their part in the response to a large incident.

Conor Symington, EROCIPS and coastal contingency planning officer at NIEA, comments, "In 2002, I was tasked with compiling the data required to populate the data directory component of a coastal contingency plan for Northern Ireland. I spent the next 18 months or so out on the coastline carrying out surveys of all aspects of the physical coastal environment and liaising with a large variety of external and departmental agencies in order to draw together all the requisite datasets. My thinking at all times was toward producing a GIS-enabled set of layers and maps of all the data so that responders during a major coastal pollution incident (e.g., from a shipping casualty) would have at their fingertips all the necessary data and tools to mount a timely, effective, and appropriate response to the incident facing them."

Building on the Enterprise Environment

After examining the technology options, ESRI Ireland, Esri's distributor in Ireland, was engaged to advise and assist NIEA in building a GIS platform to meet its needs under the EROCIPS project. To meet the objectives of the agency, Esri Ireland carried out a requirements analysis that considered

- The nature of existing datasets and their readiness for inclusion in GIS
- How to collect new information and collate it for ultimate use within GIS
- How to synchronize and share information of common interest to multiple business units within the agency
- The technical specification of a GIS hardware and software platform that could store, integrate, analyze, and communicate this data

Following the requirements analysis, a decision was made to build on the enterprise GIS environment already implemented within NIEA. This solution is based on the

ArcGIS 9 technology suite and utilized ArcGIS Server for the management, visualization, and dissemination of spatial data. ArcGIS Desktop (ArcEditor) clients are used for desktop visualization, analysis, and data capture.

Accessing and Visualizing Mapping

The solution was delivered through the development of an online spatial data catalog served from ArcGIS Server. Using ArcGIS Desktop, agency users can now access and visualize all basemapping from Ordnance Survey Northern Ireland—including all large-scale mapping and aerial photography—in conjunction with the NIEA Coastal Survey Team's own business layers that include hyperlinks to additional nonspatial data.

Aerial photography taken from an oblique angle.

Rapid response is key to the effective management of any pollution incident. With the simple click of a mouse on a digital map, the agency's incident managers can now access all relevant information such as the harbor booming plans for Belfast Lough, where booms would be erected in the event of a disaster; ground-level photographs; additional aerial perspective photography (taken at oblique angles by coastal marine helicopters); and various vector datasets. Access to hyperlinked photographs of harbor piers, beach entrances, slipways, and other coastal assets will allow the Coastal Survey Team to ascertain the likely specifics of deploying beach cleaning equipment at the best possible vantage points.

Although pollution incidents cannot be readily predicted, contingency planning is undertaken by the agency. This is where the analytic capability of ArcGIS has been particularly valuable. The system has been used to create charts and graphs showing the characteristics of the Northern Ireland coastline section by section. Users are able to view shoreline substrate types and, as a result, determine the type of cleanup response required for that particular substrate type. This allows the agency to predetermine likely appropriate responses to various incident types, thereby feeding into the rapid response at the time of an incident.

A Model of Data Management

The enterprise GIS environment has enabled the Coastal Survey Team to represent more than 40 layers of data spatially; see spatial patterns emerge; make informed decisions in planning response to minor and major shipping incidents, such as ship spillages; and visualize ship accident "black spots" and ship traffic density of the Northern Ireland coastline.

"The outcome has been extremely useful," remarks Symington. "The user-friendly desktop data management and planning tool has been as good as, if not better than, we had originally hoped for prior to the project completion. One of the most pleasing aspects of the finished tool is that it has an in-built versatility, because not only is it loaded onto the enterprise server within NIEA and therefore can be shared across the agency, but it also has offline capabilities, meaning that the datasets and tools can be utilized in the field using a notebook PC and an external hard disk drive, without being connected to the NIEA network. Other teams have expressed an interest in following our model."

More Information

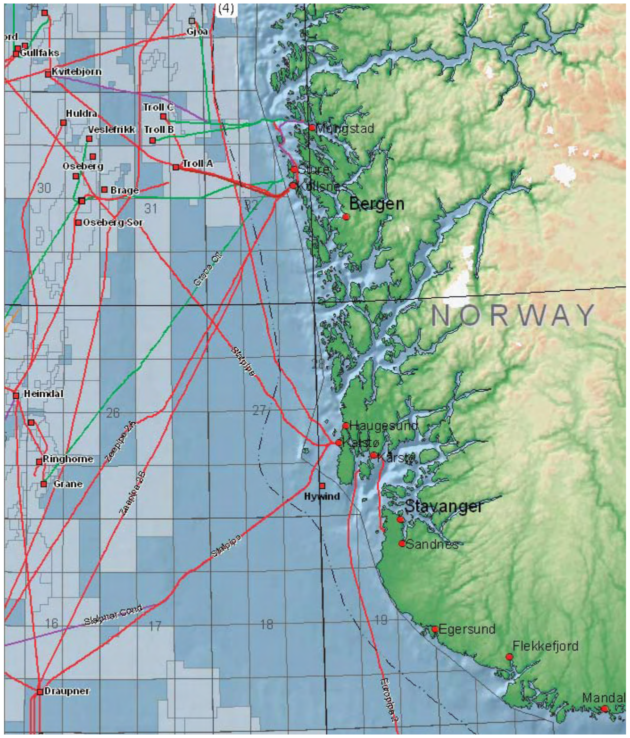
For more information, visit erocips.org.

(Reprinted from the Summer 2009 issue of *ArcNews*)

A Data Management Challenge

After Joining Forces, Two Energy Companies Merge Their Spatial Data

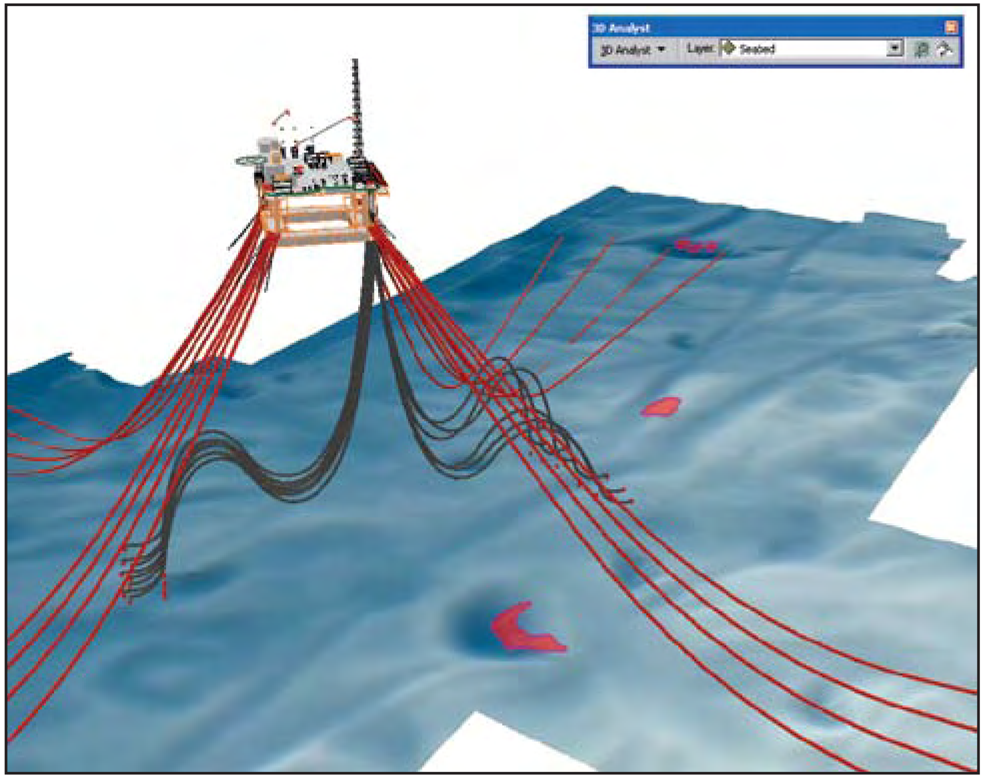
From the early 1970s, the Norwegian energy companies Statoil and Norsk Hydro have been key players in the petroleum industry through their activities on the Norwegian Continental Shelf. In October 2007, Statoil merged with Norsk Hydro's oil and gas division. The new company was temporarily named StatoilHydro, and it reached a size and strength for considerable international expansion. In November 2009, its name changed to Statoil. With more than 30,000 employees worldwide, operations in 40 countries, and strong international growth, Statoil has emerged as an innovator in petroleum technology.



Petroleum infrastructure, such as pipelines and installation data, is managed by GIS users and made accessible with other base data through ArcGIS.

GIS technology plays a large role in Statoil's business processes. Company-wide, there are more than 800 registered ArcGIS users, not only in Norway but also throughout North and South America, Africa, Asia, Europe, and the Middle East.

Statoil uses GIS software in all phases of its business processes that have a geographic component including business development, exploration, field development, production, and downstream in retail. For Statoil, geography is important because knowing where things are located and predicting where things happen are fundamental to the success of the organization.



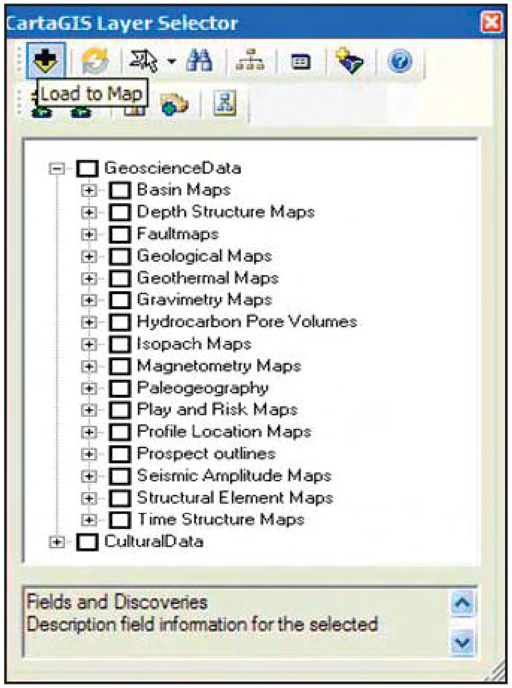
ArcGIS helps to visualize a platform in 3D with risers and anchoring system along with seabed topography.

With advances in the technology that have broadened its capabilities, made it easier to use, and increased awareness of GIS, the number of GIS users has grown dramatically. From mapping and analysis to remote sensing and data management, GIS activities at Statoil are integrated into every division that deals with spatial data. Exploration activities include international regional studies, basin modeling, and seismic surveys. Also, facilities development, installation and operational support, pipeline inspections, marine surveillance, and environmental studies are current activities with a GIS component.

Integrating GIS Data

Before the merger, both companies had extensively used GIS technology for many years. As a result of the merger, data management and storage issues became major concerns for the growing number of GIS users.

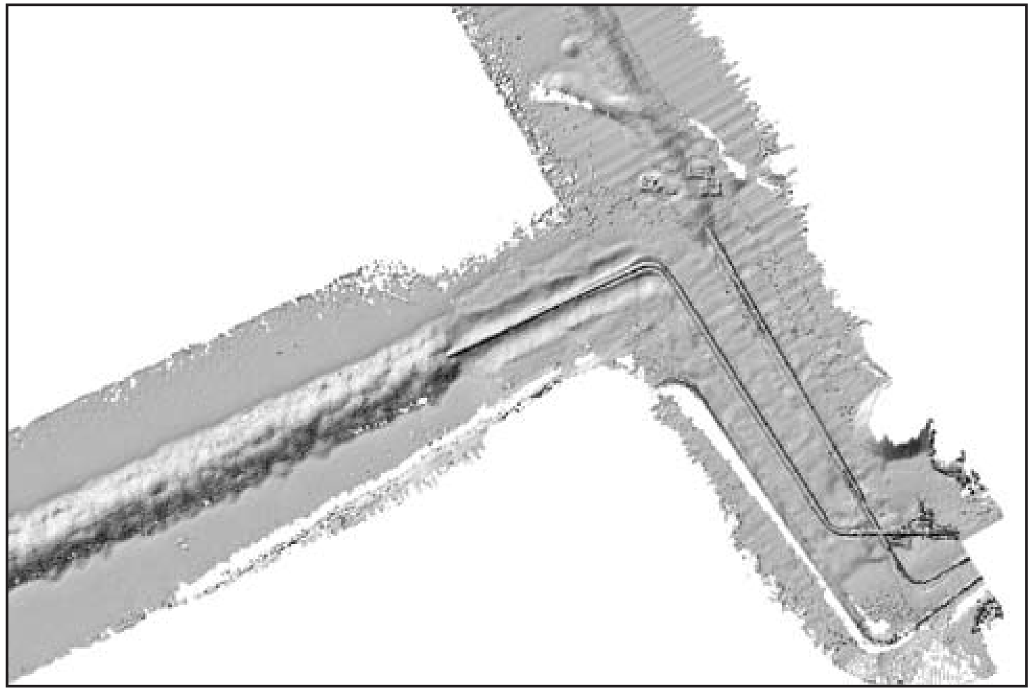
To ensure a smooth transition, the newly formed company established a working group on GIS integration to conduct an assessment of the strengths and weaknesses inherent in its current work processes. The group focused on data integration, data delivery, and data access. To evaluate the situation, members examined datasets, dataflows, resources, tools, and workflows and looked for redundant data sources and other inefficiencies. Input from key GIS users helped identify issues such as flexibility, distribution, and performance. The group studied possible solutions for integrating Statoil and Hydro spatial data, standardizing GIS applications, and improving data management processes.



ArcGIS Desktop plug-in gives users immediate access to updated geoscience and cultural basemap data.

Opportunities and Constraints

Some of the shortcomings the group found were that GIS data was stored in many folders and databases and that duplicate datasets existed. Metadata was often missing or undocumented, and data management was not centralized; often, databases were managed on an individual basis. Procedures for cleanup and updating were not standardized, and many users who needed immediate access to data found response time to be slow.



Detailed high-resolution bathymetry and hillshades are stored in a raster catalog.

Statoil and Norsk Hydro each brought assets from which the data integration project could benefit. The HydroGIS tool from Norsk Hydro structured data into ArcGIS and complied with industry standards. Statoil's GisMap plug-in provided easy access to data and consisted of an organized set of layer files for common datasets. It was standards based with naming conventions and was convenient to use for map layouts. The merger brought together many highly skilled GIS users who were motivated to improve GIS data management, and they had the commitment from management to address the database issues.

Prioritizing and Implementing Recommendations

The working group recommended synchronizing and integrating ArcGIS data to enable easy access to accurate updated information, loading or indexing sources into a redefined Statoil GIS database, establishing corporate-wide data management routines, providing a raster data storage and distribution solution, and improving IT support for GIS. The goal of these recommendations was to provide new tools for GIS users that would increase efficiency, improve productivity through the centralization of data sources, and establish one common enterprise GIS.

The current project work focuses on locating duplicate sources, refining the database schema, prioritizing datasets for upload, documenting dataflows, and establishing automatic tools for data loading. The group is also working toward developing interfaces with other databases including ArcGIS Server, securing storage, controlling access, and implementing raster data storage. A raster data strategy has also been included in the project scope including defining image services for satellite data and using a raster catalog for visualizing detailed bathymetric and topographic data.

Quality assurance is a main concern for Statoil, and to address that, users have begun to prioritize datasets including seismic navigation data, basin modeling data, interpreted surfaces, prospects, selected cultural data, and imagery and raster data. Currently, some datasets have been made available, and resource requirements are being evaluated.

Future GIS Plans

The GIS vision for the future at Statoil includes a GIS portal where all subsurface data is stored in one structured database or indexed from other corporate datasets. GIS users will have easy access to the data within this enterprise GIS data management system that is powered by ArcGIS Server and distributes the data over standard Web services and feature image services.

Visit statoil.com.

(Reprinted from the Winter 2009/2010 issue of *Petroleum GIS Perspectives*)

Risks to Boston Harbor Islands Graphically Displayed

GIS Provides Decision Support to National Recreation Area Stakeholders

By Jennifer Bender Ferré, Ph.D.

Highlights

- Boat traffic is analyzed with ArcGIS Desktop.
- ArcGIS Spatial Analyst identifies sensitive and vulnerable areas.
- GIS tools aid decision makers in defining boat routes.

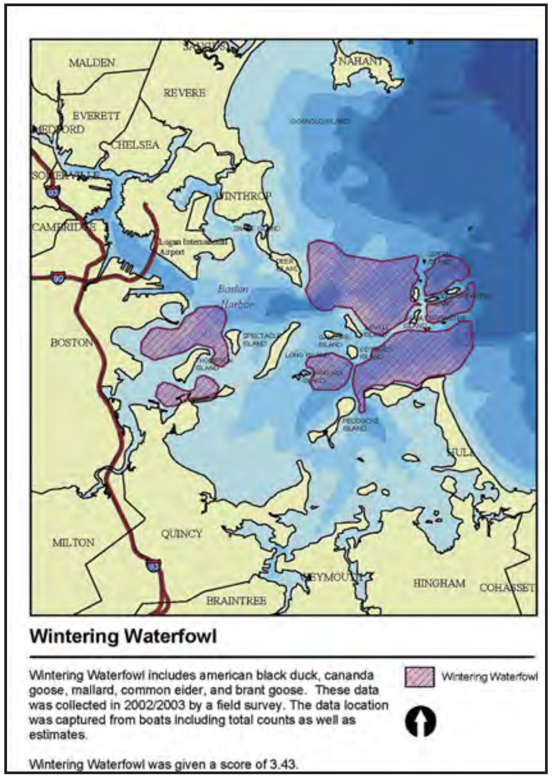
The Boston Harbor Islands National Recreation Area is a national park created in 1996 by an act of Congress and is made up of 34 islands near the Greater Boston shoreline. The park is designed to protect the islands through public/private decision making that takes into account overarching goals, such as improving access; providing education; and conserving, protecting, and managing the natural and cultural resources for public use and enjoyment of the islands. The legislation defined a new model wherein the National Park Service (NPS) owns none of the islands, and the park is funded through a partnership of federal, state, and local governments and the private sector.

To meet criteria in the enabling legislation, such as educating the public, visitation to the islands had to increase. The resulting rise in boat traffic likely impacts wake effects, nesting habitats, shellfish beds, water turbidity, changes in rocky/soft intertidal communities, pollution, and noise. Researchers from Boston University's Geography Department used GIS to better visualize the effects of this traffic and support decisions related to managing this area.

Understanding Nature

Though the park does not include the watershed surrounding the islands, the water and the islands are interdependent in ways that must be taken into account in developing an integrated management plan. The intertidal, coastal, adjacent ocean, and terrestrial island areas represent a complex and dynamic environment in which chemical, geological, biological, meteorological, and estuarine processes take place. These habitats are interlinked and should be considered a unified system; this underlying sea/land interaction is at the center of the ecological learning opportunity in the park.

The National Park Service has been directed to operate as a nonlandowning participant in the partnership with the responsibility, but not the authority, to make decisions directly related to the congressional mandate to achieve ecological, educational, recreational, and economic goals. Authority to determine policy and make decisions rests instead with each island owner. A 13-member body of representatives from public and nongovernmental organizations coordinates management. Furthermore, the Advisory Council has 28 members, including representatives of municipalities, education and cultural institutions, environmental organizations, business and commercial entities, and Native American interests. Members of the partnership are appointed by the Secretary of the Interior and the Advisory Council by the director of the National Park Service.

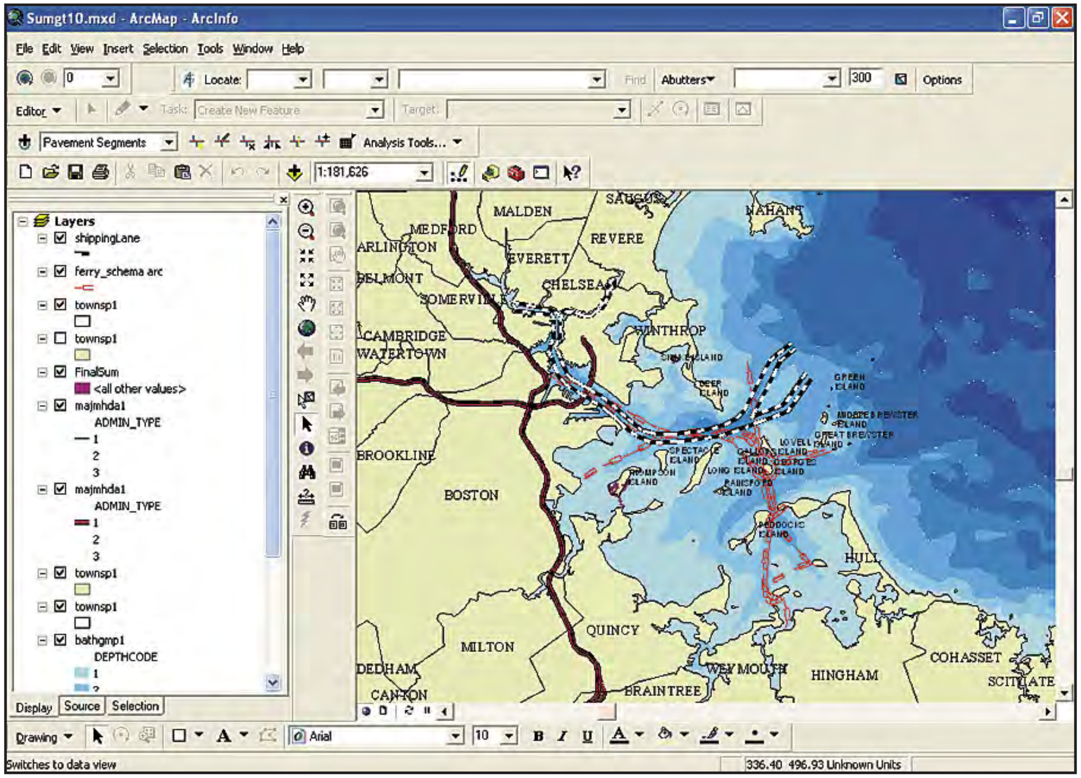


The shaded area indicates gathering areas for wintering waterfowl, such as American black ducks and mallards.

An overview of environmental problems and governance structures in the park revealed specific management problems and challenges. Ecosystem management, an integrated approach to management that considers the entire ecosystem, is a necessary piece in the decision-making process. Linking marine governance to the paradigm of sustainable development based on an ecosystem approach requires the creation of new GIS tools.

Mapping Vulnerable Areas

Researchers used ArcGIS Desktop software—the NPS standard—and the ArcGIS Spatial Analyst extension to analyze the park and the impact of boat traffic. GIS is an ideal tool to support group-based decisions regarding boat traffic management in the area because it permits visualization of the complex ecological data and goals generated from the partnership. The maps displayed environmental concerns and their associated goals relative to increased boat traffic. The results enabled mapping and defining areas that are or potentially are sensitive and vulnerable.



Ferry paths and shipping routes were mapped to better evaluate areas that are vulnerable to increased boat traffic (map sources: USGS, Woods Hole Oceanographic Institute, MassGIS).

The maps included information on turbidity, shellfish beds, salt marsh and eelgrass beds, multiple bird layers, and two intertidal layers. All these layers were built upon color orthodigital photos downloaded from Massachusetts Geographic Information System (MassGIS), with an overlay of a bathymetry layer from the National Oceanic and Atmospheric Administration. Of the nine layers mapped, four layers were analyzed in detail to illustrate the interconnectedness among measures. These measures underscored the complexity of the system because they were dependent on one another. They included turbidity, shoreline nesting habitat (tern productivity), and salt marsh.

These GIS maps used a simple algorithm to quantify the grid cell throughout locations in the Boston Harbor Islands area. Different layers and grids were assigned values based on partner-established criteria. The results were displayed as a raster or grid map.

The innovation for decision support involved having members of the partnership, along with other stakeholder agencies, such as the Environmental Protection Agency, Massachusetts Audubon Society, Urban Harbors Institute, and World Wildlife Federation, define goals for the area. This method prioritized the ecological goals according to stakeholder input and scientific opinion and enables policy makers and stakeholders to view the system in its entirety.

The analysis captured one issue—that of boat activity as a stressor—in the whole island system, then it was quantified scientifically and applied spatially, and interrelationships were examined. The evidence demonstrated that potential disturbance exists. Therefore, to put a priority on what needs protection, this type of scientific evidence must inform policy decisions.

The GIS model also identified the spatial patterns of ecological vulnerability to boat traffic in the islands and surrounding waters. The result was an intuitively appealing, comprehensive, and interactive tool that would aid decision makers and managers in choosing boat routes and defining "no-go" areas for boats.

The project shows how GIS can bridge the gap between scientists, policy makers, and a multitude of stakeholders and shape data into a policy-relevant mechanism through which decision makers receive a comprehensive overview of an issue.

The administration of the park is a complicated undertaking. Many of the factors that Congress weighed in creating the park affect other national parks as well. Mixed ownership, public/private partnerships, and diverse sources of funding are often considered in the design of strategies to protect and preserve scarce natural resources. The park collaborative model will represent an increasingly important precedent as it matures and as lessons are learned about the decision-making process and the outcomes of various choices.

About the Author

Jennifer Bender Ferré, Ph.D., is a consultant for the Stellwagen Bank National Marine Sanctuary. Her work has focused on the development of a decision support tool to assess environmental vulnerability combined with a model that facilitates the integration of scientific knowledge with stakeholders' concerns.

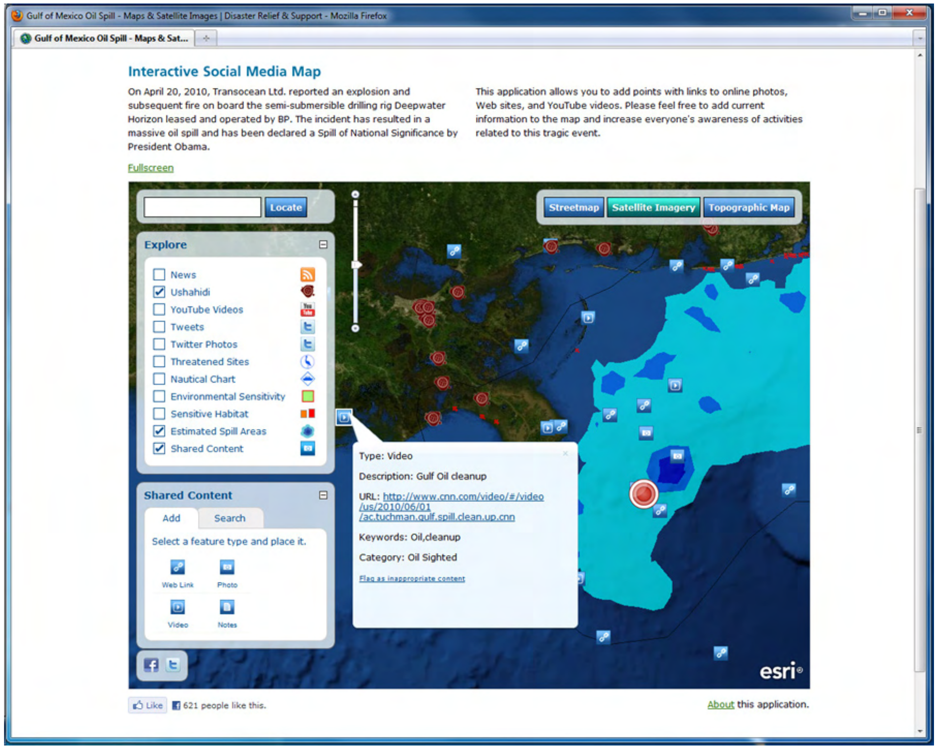
(Reprinted from the Spring 2007 issue of *ArcNews*)

GIS Used to Respond to Oil Spill Disaster

Esri Provides Software, Services, and Around-the-Clock Support

By Jesse Theodore, Esri Writer

First responders, government officials, environmental experts, and commercial companies are using GIS technology to monitor the oil spill in the Gulf of Mexico and identify potential impacts to natural resources, including wildlife. GIS analysis and data help responding agencies collaborate by increasing situational awareness to support command and control.



The Interactive Social Media Map lets you add points with links to Web sites, YouTube videos, and online photographs.

Agencies are using GIS to make better decisions to manage the spill's repercussions. GIS technology supports incident management efforts by delivering current, accurate information to these organizations using a powerful common operating picture (COP).

The spill began in late April after an explosion on the BP-operated drilling rig Deepwater Horizon. In the Gulf of Mexico, Esri continues to work closely with dozens of agencies and the GIS community. Esri's disaster response team is providing assistance to users in local, state, and federal government agencies as well as in the private sector. The team is supplying software, technical support, GIS data, and personnel.

Dozens of agencies have responded to the oil spill, with many using GIS for situational awareness, data collection, and analysis. For example, participants in a Spill of National Significance (SONS) exercise used GIS to compile and consolidate information in a spatial context, providing incident commanders with a COP.

"Since the spill is accruing over a large geographic area, various analysis techniques are being employed to verify placement of boom assets used to mitigate the effects of oil on the shoreline," says David Gisclair, technical assistance program director, Louisiana Oil Spill Coordinator's Office. "By using GIS technology, field information can be processed into products [that are] useful in the incident command decision-making process."

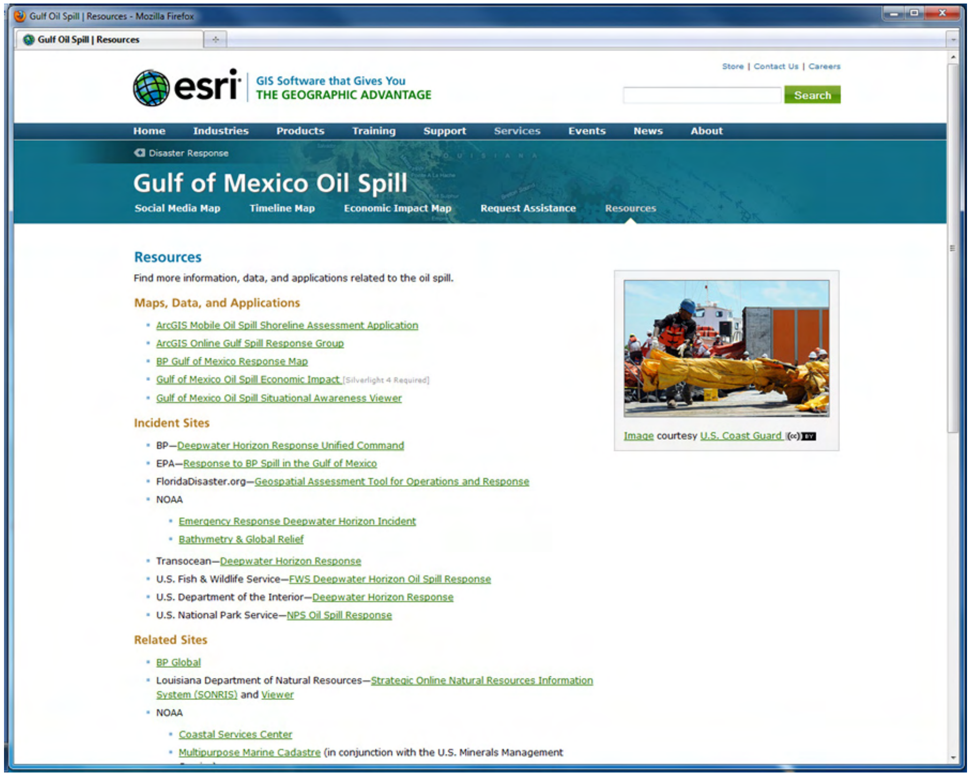
Texas A&M University Sends in "GIS Smoke Jumpers"

Devon Humphrey, geospatial intelligence officer and instructor, Texas A&M University, Corpus Christi, discussed how he and his staff came to help. "We see ourselves as kind of GIS smoke jumpers," says Humphrey. "We came in to fight the spill and set things up so that others can rotate through over the next several years. The plan is for these GIS professionals to train replacement GIS staff as they rotate through the Houma command post and provide them with certification from the National Spill Control School at Texas A&M University. The training will be conducted here in the GIS lab and will include a combination of GIS for oil spill and National Incident Management System [NIMS] training required to work on this spill."

The GIS group at the incident command post, located in Houma, Louisiana, and coordinated by Humphrey and his team, was able to collate all collection data (imagery and maps) from state and federal agencies on oil boom and oil slick information. All this geographic information was posted to allow the situation to be rapidly assessed in a visual way by senior officials in the field.

"GIS folks were able to rapidly change layers of information to match user needs," says Lt. Col. Roy Worrall, Incident Awareness and Assessment (IAA), supporting civil authorities, U.S.

Army National Guard. "For example, they built a product for the state leadership that reflected information on engineering projects, such as breakwaters, Tiger Dams, and sandbagging operations. All this was done on a daily basis, and products were updated continuously as information became available."



Esri provides many resources related to the oil spill.

Data Management and Collection also Critical

URS Corporation, an engineering, construction, and technical services firm, has been successfully using GIS to provide data management and decision support to the myriad of businesses and government entities responding to the oil spill.

"The coordination of spatial data for so many agencies, companies, and entities is daunting at best," says Eric Songer, GISP, URS Corporation. "Every federal agency dealing with natural resources is present as well as the state agencies of four different states and all the contractors brought in to help with the response. There are dozens of entities, all with varying degrees of spatial awareness."

Esri's ArcGIS Mobile 10 also was deployed.

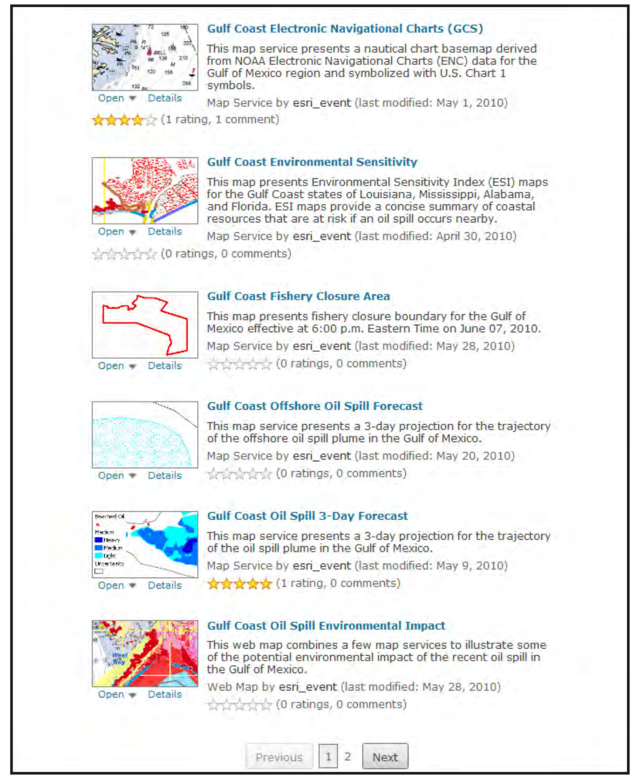
"Alabama used ArcGIS Mobile 10 to collect the locations and condition of deployed booms," says Lynn Ford, GIS manager for the Alabama Department of Environmental Management. "The application allows the marine police and resources officers to stream GPS coordinates to a laptop, attribute the line, and edit the attributes. The data is sent to a server in near real time to provide the data to the planners."

Esri Sets Up Disaster Response Web Site

Esri continues to offer support and services for the gulf oil spill through its disaster response Web site. Resources include continuously updated maps, data, and applications as well as links to incident-related Web sites. These resources provide responders with tools to anticipate any adverse effects and respond proactively.

As part of its Web site, Esri launched an interactive map application that allows users to add volunteered geographic information (VGI) in the form of links to online photos, Web sites, and YouTube videos. By doing so, volunteers can add current information to the map and increase everyone's awareness of activities related to the spill.

ArcGIS Online was used to rapidly set up portals for situational awareness. The applications, services, data, and maps shared via ArcGIS Online assist with response efforts and help meet mitigation requirements. The site also includes links to relevant map services and downloadable data, maps, and



You can find maps and map services related to the oil spill at arcgis.com.

layer packages. Services include an oil spill plume trajectory model, an environmental sensitivity index map, and electronic navigation charts.

Learn More

For more information, visit the Esri disaster response Web site at esri.com/services/disaster-response.

(Reprinted from the July 2010 issue of *ArcWatch*)

Oceans Are Key to Earth's Climate

Marine scientists are still trying to understand exactly how the ocean modulates Earth's climate, and conversely how climate change affects ocean circulation, the distribution of heat, marine ecosystems, sea level rise, how changes in ocean temperature and CO_2 concentration will affect the rate of ocean acidification, and so forth. A huge question is, How do we predict the outcomes and impact of climate change, then adapt and mitigate accordingly?

GIS is a key technology for visualizing sea level rise scenarios and potential impacts (e.g., sites of potential flooding, coastal erosion, bluff failure, adequate presence of dikes or levees, impacts on wetlands) and for analyzing how sea level rise may increase the frequency of tidal floods.

In addition to GIS tools, there are also many GIS-based portals that are helping meet the climate change challenge. One example is a coastal Web atlas, which organizes and coordinates interactive Web mapping, premade digital maps, GIS datasets, and remotely sensed imagery, often with supplementary GIS decision support tools, tables, photography, and other kinds of information, all through a single Web portal. As such, many of these atlases play an important role in informing regional decision and policy making across several themes, including climate change impacts, marine spatial planning, coastal conservation and protected areas management, and resource availability and extraction.

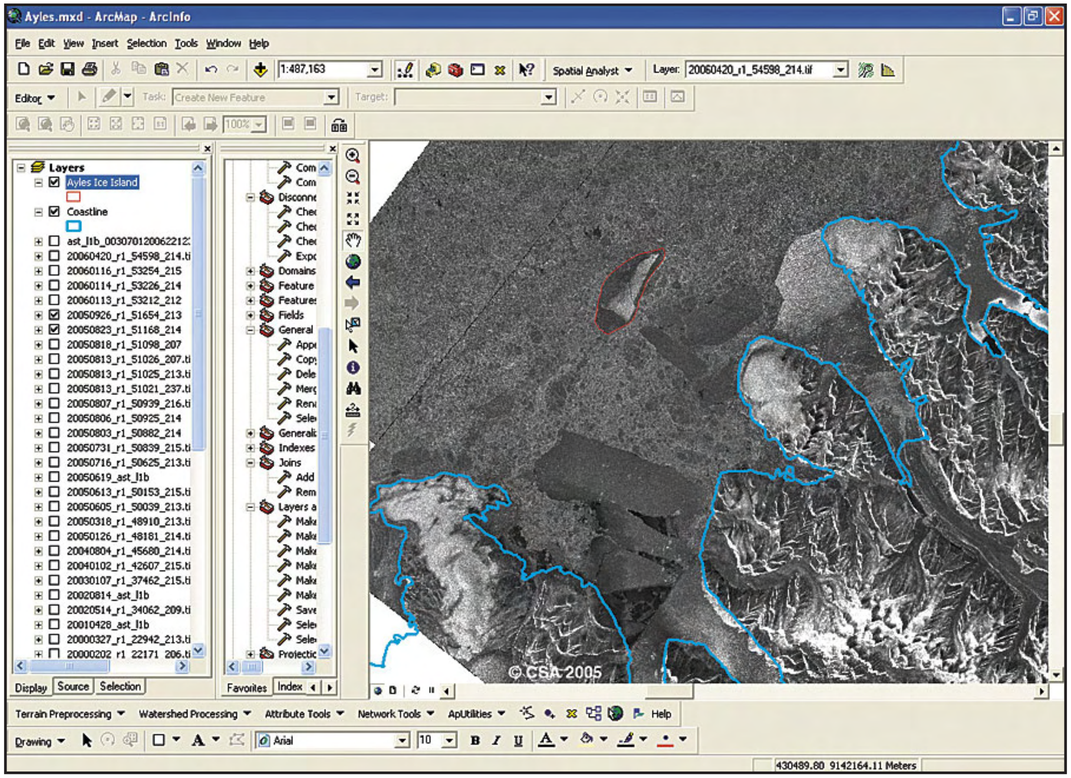
—Dawn Wright

Mapping the Ayles Ice Shelf Break

GIS Tracks 33-Square-Mile Ice Island in the Arctic

Highlights

- Volume of ice loss calculated with GIS.
- ArcInfo helps visualize causes of the break.
- Unique "microbial mat" habitat also analyzed.



Ayles ice island, delineated by a red polygon, broke from Ellesmere Island (outlined in blue) on August 13, 2005. The RADARSAT background images were processed by the Alaska Satellite Facility at the University of Alaska in Fairbanks.

It was the Arctic ice shelf collapse heard around the world: this past New Year's weekend, the BBC, the Canadian Broadcasting Corporation, CNN, the *New York Times,* and other media organizations broke the story that the ancient Ayles Ice Shelf in Canada had cracked from its mooring in an Ellesmere Island fjord and floated into the Arctic Ocean.

The ice shelf calving was discovered by Laurie Weir of the Canadian Ice Service in September 2005 while she was comparing satellite images of the ice shelves. She contacted Luke Copland from the Laboratory for Cryospheric Research at the University of Ottawa in Canada, who launched a scientific investigation into what occurred. Though the news spread in some scientific circles and was reported at a conference, journalists did not catch word of the story for 15 months.

With the possible culprit being global warming, all eyes turned north, where the newly formed ice island sits safely—so far—in sea ice about 10 miles off Ellesmere. "Right now it's frozen in off the coast," says Derek Mueller, a geographer and postdoctoral researcher at the Geophysical Institute University of Alaska Fairbanks, who helped to investigate and write a paper about what happened to the 33-square-mile Ayles Ice Shelf.

Though the ice island has only traveled a short way since the August 13, 2005, incident and there's no obvious current danger to ships or oil drilling platforms, the chance of trouble ahead exists, Mueller says. "It could break away at any time and float further down to the south, and it would likely start breaking up as it floats," he states. "These ice islands will be tracked by the Canadian Ice Service so that ships will be warned," adding that the possibility exists, though slim near term, that the ice island could drift down toward the coast of Alaska with the Beaufort Gyre current and into shipping lanes and toward oil drilling operations. "Worst-case scenario, if it did hit one of the oil drilling platforms, it could cause a lot of damage," Mueller adds.

Though not enough evidence exists to blame global warming for the collapse of the Ayles Ice Shelf, Mueller says that what occurred is consistent with other signs of climate change in the Arctic. "Taken together, all of these signs are worrisome," he says.

Sizing Up the Ayles Ice Shelf

Having studied the ecosystems on the Ellesmere Island ice shelves as part of his Ph.D. research in biology, Mueller was invited to help investigate the Ayles Ice Shelf breakup and contribute to a paper the researchers were writing about the calving. In his work, through the university's Esri campuswide site license, Mueller used ArcInfo software to create a map that helped researchers visualize the chain of events and learn how much ice was lost from the fjord on the north end of Ellesmere Island.

A Moderate Resolution Imaging Spectroradiometer (MODIS) image of the Ayles Ice Shelf breaking away from Ellesmere Island (August 13, 2005, at 20:45 Coordinated Universal Time (UTC). (Image courtesy of NASA.)

"The break was visible, but what we wanted to know was, What was the size of the ice island when it broke away?" Mueller says, adding that mapping and analysis showed it shrank from about 41 square miles to 33 square miles. "Aside from the loss of the Ayles Ice Shelf, 20 percent of the nearby Petersen ice shelf was also lost just after August 13, 2005. And some multiyear landfast sea ice (MLSI) that had been there since the 1940s was lost from Yelverton Bay to the west of Ayles Fjord."

After georeferencing and projecting RADARSAT images (provided to the Alaska Satellite Facility by the Canadian Space Agency and its private partners) before and after the ice shelf breakup, Mueller imported the geographic TIFF (GeoTIFF) format into ArcInfo. With vector layers, such as coastline contour lines, from the Canadian government laid down, he traced polygons over the top of the RADARSAT images of the ice shelf taken at different times.

"Using GIS, I put down several images that I could flick back and forth showing where the ice was before any of the activity, calculated the square kilometers—the area of that polygon—then looked again and saw where ice wasn't located," he says. "Then we could essentially calculate the ice loss," which was about 54 square miles, according to Mueller.

"GIS also helps interpret satellite images," Mueller states. "What is good about that method is you can keep those polygons and flick the image to another time. Sort of like a time machine, you can flick backward in time and forward in time and watch for changes. And if you have a polygon or a vector overlay in ArcInfo, then you can look for your border underneath and, if it alters over time, you know you've got a change."

In studying the Ayles Ice Shelf breakup, the researchers found that factors in addition to possible long-term climate changes likely contributed to the calving.

In addition to higher-than-usual temperatures that summer, Ellesmere Island was struck by strong winds, according to Mueller. "A lot of the multiyear landfast sea ice broke away from the shore—from the front of the Ayles Ice Shelf—and a lot of the sea ice was pushed away as well," he says. "That was caused by very strong winds pushing offshore and alongshore. Those winds pushed away the sea ice, and that allowed the ice shelf itself the freedom to move away."

Though the new ice island stayed put in the summer of 2006, Mueller says it's not stuck permanently. "It may last another year. It may last another few months. It's not necessarily stable ice."

Even in winter, the humongous chunk of ice could begin moving again. "It's fairly exposed to all the currents that are churning around in that area," Mueller says.

Mapping Ice Types

Mueller also used ArcInfo several years ago when he mapped ice types while studying microbial mats on the ice shelves. Microbial mats, often present in extreme environments, are this planet's oldest known ecosystems.

"I was interested in looking at cold-tolerant organisms in ecosystems that are ice dependent, he says, adding that "microbial mats composed of algae, microinvertebrates, and bacteria are commonly found on the surface of Arctic ice shelves. The ice shelves are a unique habitat for microbial mats, which can perhaps provide some clues as to what types of life existed when the planet was younger and how that life evolved."

Eric Bottos from McGill University, Derek Mueller from the Geophysical Institute at the University of Alaska, and Alexandra Pontefract from McMaster University sample microbial mats on the Markham Ice Shelf (August 2005). (Photo courtesy of Denis Serrazin).

In ArcInfo, he mapped the ice types, such as the marine "basement" ice and the meteoric or atmospheric iced firn, and also noted the sites where he took samples of microbial mats. Mueller will use that map to refer to as he continues studying the changes in the Arctic ice shelves in the years ahead.

"I'm looking for baseline information on the cryosphere—the cold parts of the earth—to look for changes due to climate warming." He adds. "Ice shelves may be a valuable indicator of climate change. When the ice shelves disintegrate, it represents a loss of habitat." He is concerned that the ice shelves may completely break up within his lifetime based on predicted warming of the Arctic.

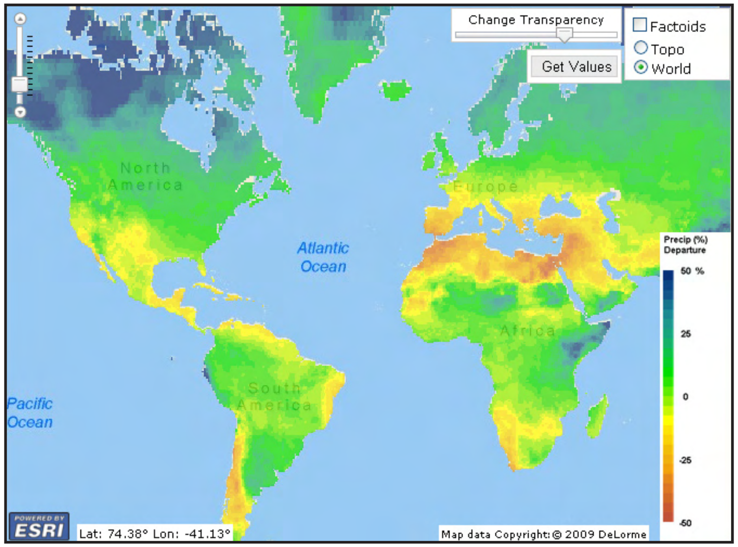
"Working to preserve habitats and biodiversity is important," Mueller concludes. "These ice shelves may harbor some cold-adapted organisms that could be interesting for biotechnology. Or you might simply value the habitats that we are losing from our landscape."

(Reprinted from the Spring 2007 issue of *ArcNews*)

The Nature Conservancy Deploys Esri Technology for Climate Trend Analysis

Climate Wizard Delivers Climate Change Data and Models

The Nature Conservancy Climate Wizard, powered by Esri, displays free maps of historic climate change and future projected change. Climate Wizard offers scientists, planners, environmentalists, and public users an intuitive means to understand and compare climate change models useful to decision making.



Esri has had a longtime commitment to environmental sciences and is working with many organizations dedicated to meeting the challenges of climate change (esri.com/climate). For many years, Esri has supported Nature Conservancy efforts to protect our planet by providing environmental expertise and GIS technology.

The new Esri-powered version of Climate Wizard was first demonstrated at the 2009 United Nations Climate Change Conference (COP-15) in Denmark. It allows anyone to click a map location and get up-to-date data of climate change trends. A user can also choose between different climate change models to predict impacts on that location.

Climate Wizard uses 16 models from the Coupled Model Intercomparison Program (CMIP 3) published for the United Nations Environment Programme and the World Meteorological Organization Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report. The user selects a model or ensemble of models from a menu and displays them on a GIS map interface.

These new displays replace previous static climate map images with live Web mapping services. An important new capability available due to this improvement enables users to query the 16 different climate change projections for three carbon emissions scenarios at specific locations. They can see the range of future climate projections in graph and tabular formats and view and analyze dynamic data using GIS functionality to see highly specific details relevant to their unique projects. They can also download the climate change data in GIS format.

An extension of Climate Wizard—a future climate model comparison application—allows users to directly compare different model outputs for a chosen area.

The Nature Conservancy launched Climate Wizard in January 2009, with the intent of making climate change a place-based issue so that people would consider how changes in the earth's climate affect them. The original objective was to build a state-of-the-art framework that could easily accept new data as it is coming from modeling agencies and put this information into the hands of researchers quickly and easily. The addition of ArcGIS Server technology to the tool in December 2009 has made a big step toward achieving this objective by providing live Web mapping services and maps that can be queried on the fly, as well as improved Web application mashup capabilities. The Climate Wizard project is a collaborative effort of the University of Washington, The Nature Conservancy, the University of Southern Mississippi, and Esri.

"ArcGIS Server has made it possible for our vision of Climate Wizard to come into fruition," says Evan Girvetz, senior scientist with the Conservancy Global Climate Change Program. "We feel this tool is now on the cutting edge of GIS technology. The framework is there, and users can get the maps and information they need to better plan for future climate in specific places."

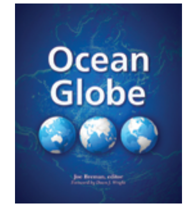
Chris Zganjar, information specialist for the Conservancy Global Climate Change Program, has been dedicated to the project since its inception. "GIS brings sophistication to the Climate Wizard. We can now serve vital climate change data to the practitioner with an easy-to-use tool," notes Zganjar. "Real data that virtually scales down to a person's backyard brings the issue into personal space."

In its development of the GIS framework for Climate Wizard, Esri Applications Prototype Lab used the beta version of the next release of ArcGIS Server.

(Source: February 2010 news release)

Further Reading

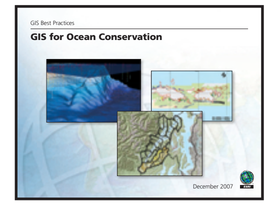
Ocean Globe



Ocean Globe details recent progress in seafloor documentation, bathymetry, and related GIS ocean and marine mapping projects. There is particular focus on bathymetry—the study of underwater depth of the third dimension—within the context of work done to collaboratively map and study the ocean floor.

esriurl.com/ocean1

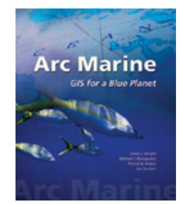
GIS for Ocean Conservation



Marine habitats and the life they contain are threatened by global warming, extreme weather, natural and man-made pollution, overharvesting, and additional human disturbances. GIS technology can show at-risk areas in danger of biodiversity loss, habitat degradation, and resource depletion. It also acts as an aid in monitoring and examining the effectiveness of conservation practices and protected areas to ensure the preservation of the earth's oceans.

esriurl.com/ocean2

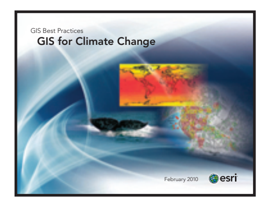
Arc Marine: GIS for a Blue Planet



Arc Marine: GIS for a Blue Planet presents the initial results of a successful effort to create and define a data model for the marine community. The data model not only provides structure to storing and analyzing marine data but helps users create maps and three-dimensional scenes of the marine environment in ways invaluable to decision making.

esriurl.com/ocean3

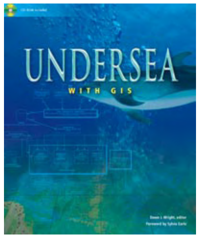
GIS for Climate Change



GIS users represent a vast reservoir of knowledge, expertise, and best practices in applying this cornerstone technology to the science of climate change. These eleven case studies illustrate how GIS is helping us to gain a better understanding of the impact of climate change on natural and human systems.

esriurl.com/ocean4

Undersea with GIS



The development in the last 10–20 years of sophisticated technologies for ocean data collection and management, including GIS, hold tremendous potential for mapping and interpreting the ocean environment in unprecedented detail. *Undersea with GIS* focuses on technical advances in mapping the deep oceans, coasts, and estuaries with GIS, as well as nautical charting and scientific visualization.

esriurl.com/ocean5

GIS for the Oceans

Since 1969, Esri has been giving customers around the world the power to think and plan geographically. The market leader in geographic information system (GIS) solutions, Esri software is used in more than 300,000 organizations worldwide including each of the 200 largest cities in the United States, most national governments, more than two-thirds of Fortune 500 companies, and more than 5,000 colleges and universities.
Esri applications, running on more than one million desktops and thousands of Web and enterprise servers, provide the backbone for the world's mapping and spatial analysis. Esri is the only vendor that provides complete technical solutions for desktop, mobile, server, and Internet platforms. Visit us at **esri.com**.

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