EcoGIS – Demonstration of GIS Tools
for Ecosystem-based Fisheries Management

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Abstract

EcoGIS, a collaborative project between NOAA Fisheries, NOAA's Ocean Service, and the four fishery management councils for the Atlantic and Gulf of Mexico, has developed a set of GIS tools to better enable both fisheries scientists and managers to adopt ecosystem approaches to fisheries management. We will present models and live demonstrations of the ArcGIS tools to address four high-priority functional areas: general ecosystem characterization, commercial fishery effort mapping, bycatch analysis, and quantification of interactions between fishing gear and bottom habitat. These tools are developed as an extension for ArcGIS 9.x, and generate spatial and temporal analyses using specified criteria from a variety of data sources, including base map layers, commercial fishery observations and vessel trip reports.

Introduction

Ecosystem Approaches to Management are adaptive, geographically specified, take account of ecosystem knowledge and uncertainties, consider multiple external influences, and strive to balance diverse societal objectives (NOAA 1999, Garcia et al. 2003). With the recognition that traditional single-species Fishery Management Plans do not meet all of these criteria, Ecosystem Approaches to Management are gaining favor among fisheries managers and scientists (SAFMC 2004, Murawski 2005). Regional Fishery Management Councils are developing Ecosystem Pilot Projects and Fishery Ecosystem Plans (SAFMC 2004), which will help fisheries managers to meet future requirements put forth by the Magnuson-Stevens Act (Public Law 94-265). Spatial analysis using Geographical Information Systems (GIS) is recognized as an essential tool in moving towards Ecosystem Approaches to Fisheries Management (Busch et al. 2003).

The EcoGIS project was launched in September 2004 to develop a custom suite of GIS tools to use with diverse marine datasets to better enable both fisheries scientists and managers to adopt ecosystem approaches to fisheries

management. EcoGIS is a collaborative effort between NOAA's National Ocean Service (NOS), National Marine Fisheries Service (NMFS), and four regional Fishery Management Councils. The need for these types of tools was highlighted in a September 2004 workshop in Charleston, SC, attended by fishery scientists and managers from NOAA, Fishery Management Councils, academia, and NGOs (NOAA 2004). GIS needs expressed at the workshop ranged from simple map-based queries to complex ecosystem modeling. Additional input from the EcoGIS steering committee and users narrowed the project's tool development focus to four priority areas:

Fishing Effort Analysis - Where, when, and how do fisheries operate within a given area? How have fisheries been impacted as a result of regulatory changes?

Area Characterization - Within a selected area, what are the physical parameters (e.g. sediment type), and biological parameters (e.g. species abundance), and regulatory framework?

Bycatch Analysis - What are the trends in bycatch among different fisheries, geographic areas, time periods, depth ranges, and habitat types?

Habitat Interactions - What types and amount of habitats have been fished using bottom-tending gear?

These tools are being developed as an extension for ArcGIS 9.x, and generate spatial and temporal analyses using specified criteria from a variety of data sources, including base map layers and fishery-dependent and -independent data. The end products will enable simplified and more efficient data query, the ability to visualize data over time and to synthesize multidimensional data from diverse sources, and to provide new information for analyzing specific issues from an ecosystem perspective. Ultimately these abilities will result in better understanding of fisheries and better support for decision-making.

Objectives

The objectives of the EcoGIS Project are to:
• Build a collaborative team from within NOAA's National Ocean Service (NOS), National Marine Fisheries Service (NMFS), Fishery Management Councils, and other organizations.
• Define the priority needs of fishery managers and scientists for applying ecosystem approaches to management.
• Acquire existing data sets and evaluate existing ecosystem-based tools to guide the development of EcoGIS.
• Develop a suite of GIS tools that will be immediately useful within current data, science and decision-making environments.

• Identify and document data gaps, including metadata, to bring attention to the need for such data sets to be collected and metadata to be developed.
• Define additional management questions and scientific hypotheses that can be addressed within a blueprint for future development.

Priority Tools

Fishery Mapping Tool
The Fishery Mapping Tool creates time-and-area summarized maps of fishing effort and catch from logbook, observer, or fishery-independent survey data sets. This ArcGIS extension (DLL) allows a user to query the selected source data by species and gear, specify a time frame and time step, set up bins for spatial summary (regular grid or predefined polygons), and choose the variable to summarize (catch, discards, effort). Source data may come from Oracle, Microsoft Access, or file-based formats such as CSV files.
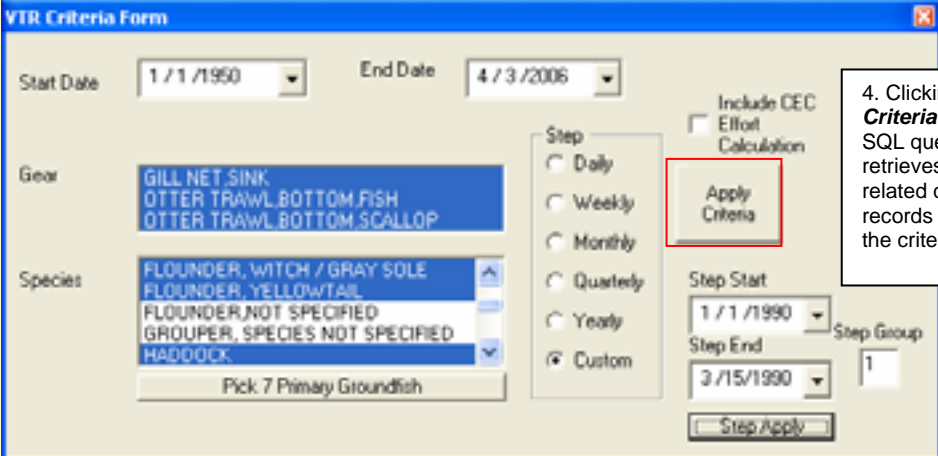
In this Case Example, the Fishery Mapping Tool is applied to New England Vessel Trip Report (VTR) data. The first step in the mapping process is to define query conditions, time range, and time steps.

1. Launch EcoGIS tool with first button on toolbar.

2. User selects data set of interest – in this case, logbook. Users may also import other data sets and specify fields.
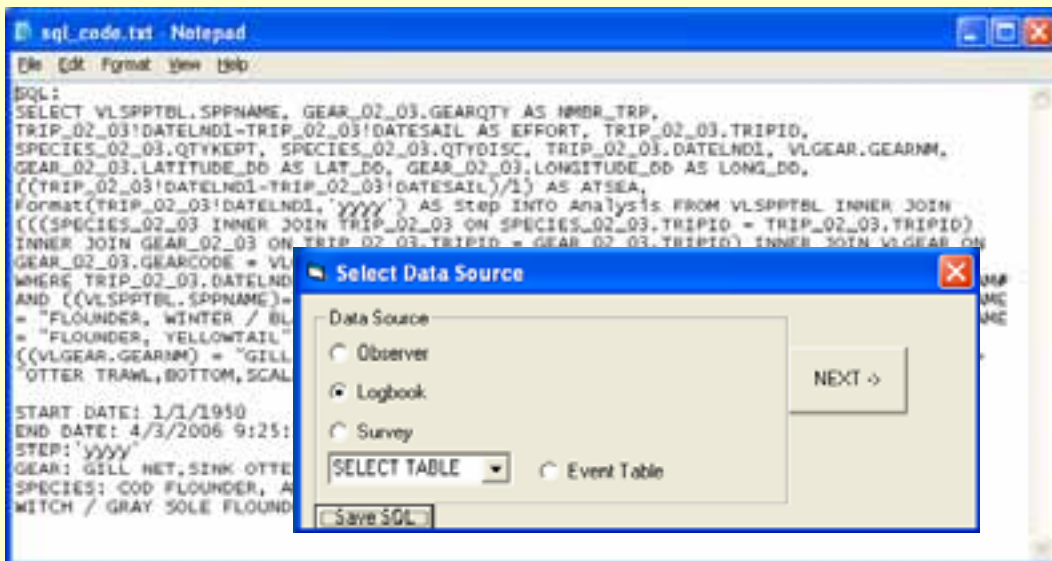
3. User chooses the time period, time step, one or more gear, and one or more species.

4. Clicking *Apply Criteria* executes a SQL query that retrieves all trips and related catch/discard records that meet the criteria.

The *Save SQL* button then becomes highlighted so one can archive the query parameters

After clicking *Next* a map layer of points is created. Each point represents the location where a species was caught. The user is prompted to save this point layer to a shapefile.
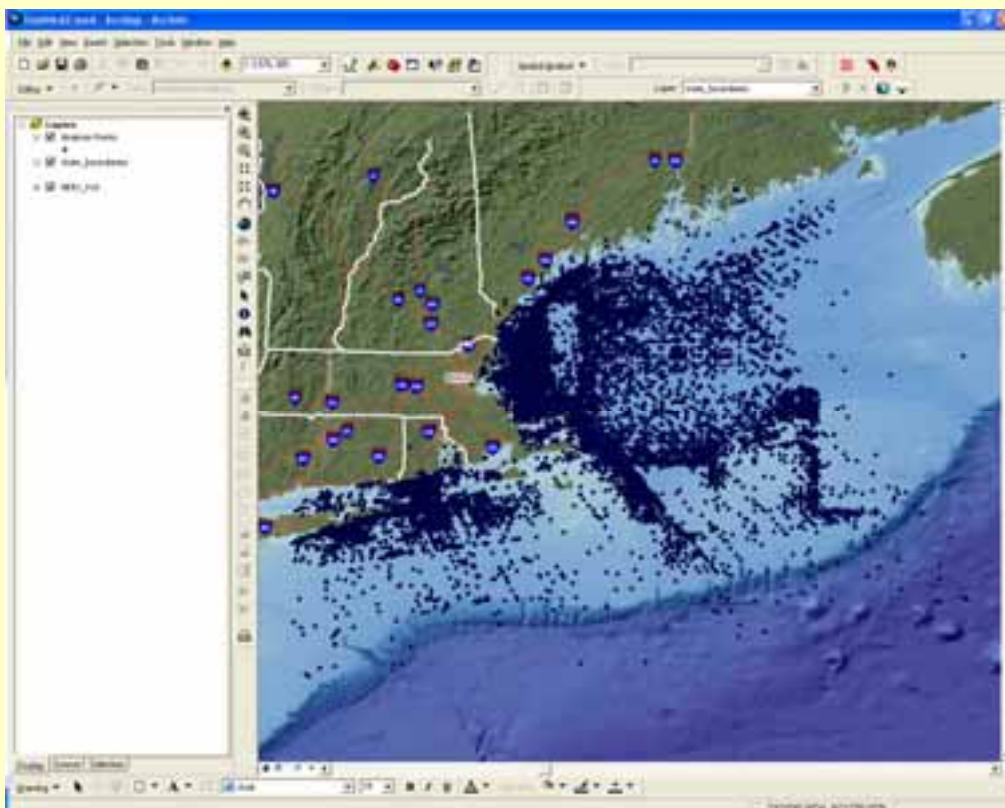
Next the user must choose how to summarize the data geographically. Spatial analysis "bins" may be specified by creating a grid (see example below), drawing polygons on the screen, or selecting preexisting polygons.

5. Spatial extent and cell size of analysis area are specified.
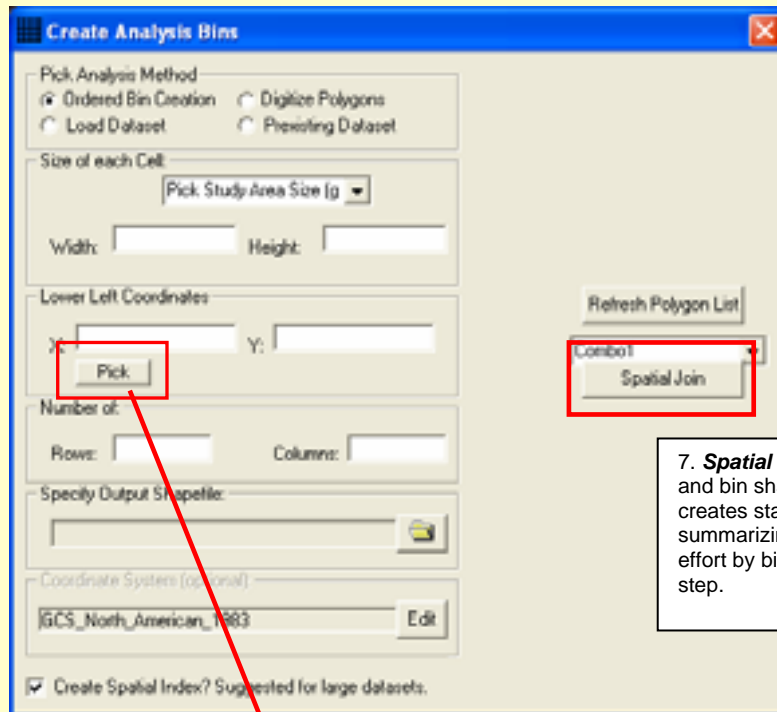
7. *Spatial Join* of point and bin shapefiles creates standalone table summarizing catch and effort by bin and time step.

6. Selected area is autopopulated with specified bins, then saved as a shapefile.
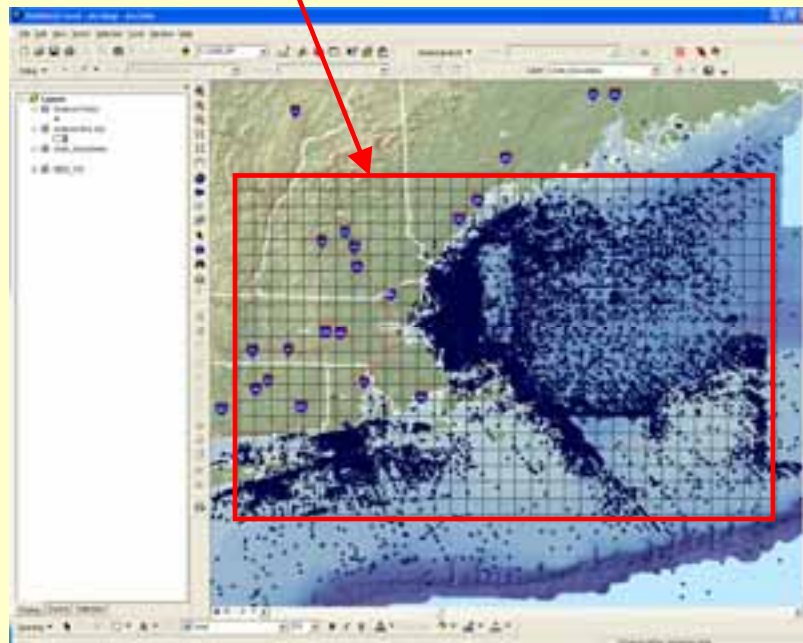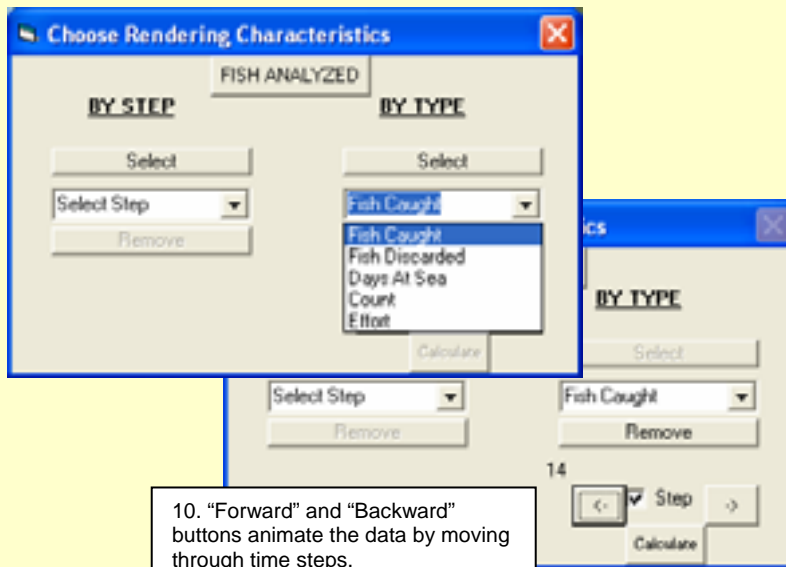
The second button on the EcoGIS Fishery Mapping toolbar allows the user to render catch and fishing effort through time. The user specifies how to summarize the binned data temporally and display by time-step.
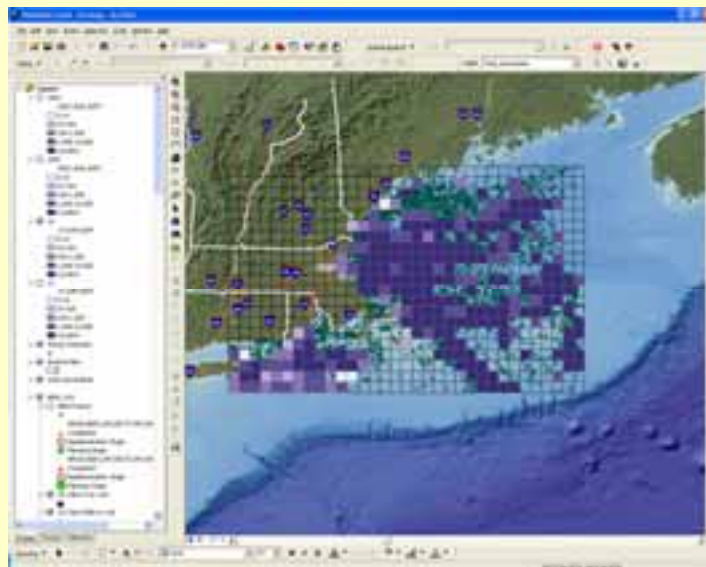
8. Second button on the EcoGIS toolbar launches the renderer, a "data slice" tool that allows the user to examine all variables for one time step, or all time steps for one variable.

Create Rendering Patterns

9. The user selects a variable to display through all time steps.

Choose Rendering Characteristics

FISH ANALYZED

BY STEP   **BY TYPE**

Select   Select

Select Step   Fish Caught

Remove

Fish Caught
Fish Discarded
Days At Sea
Count
Effort

Calculate

BY TYPE

Select

Select Step   Fish Caught

Remove   Remove

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Step

Calculate

10. "Forward" and "Backward" buttons animate the data by moving through time steps.

The third button on the EcoGIS Fishery Mapping toolbar allows a user to explore relationships between fishery data and environmental base layers. A user applies bin algebra to summarize how changes in a given variable (e.g. days absent or effective effort) are apportioned to a variable represented by another map layer. For example, a measure of effort from two time periods can be apportioned to different habitat types to compare the amount of effort in time period "a" that is applied to each habitat type versus the amount of effort in time period "b" applied to each habitat type. This might be useful in comparing the interactions between fishing activities and habitat before and after some regulatory or environmental change. Available habitat layers include bathymetry, sediment type, sea surface temperature, and other environmental parameters.

11. The third button on the EcoGIS toolbar allows the user to apply "bin algebra" to summarize how changes in a given variable (e.g. days absent) between to time periods are apportioned to a variable represented by another map layer (e.g. sediment).
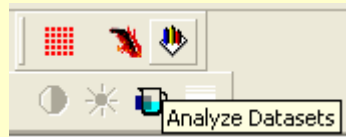
A. One time period is subtracted from another to get the differences between the two.

B. The spatial bins are intersected with sediments to determine the percent sediment within each bin.
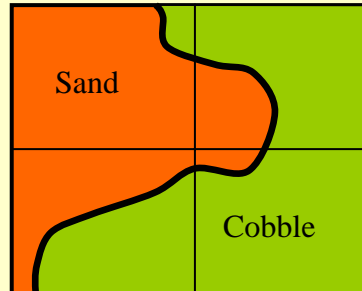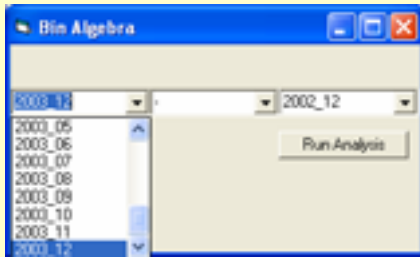
C. Days absent, catch, and/or discards for both time periods is totaled up for each sediment type.

The distribution of the fishery variable over sediment can then be compared between time periods.
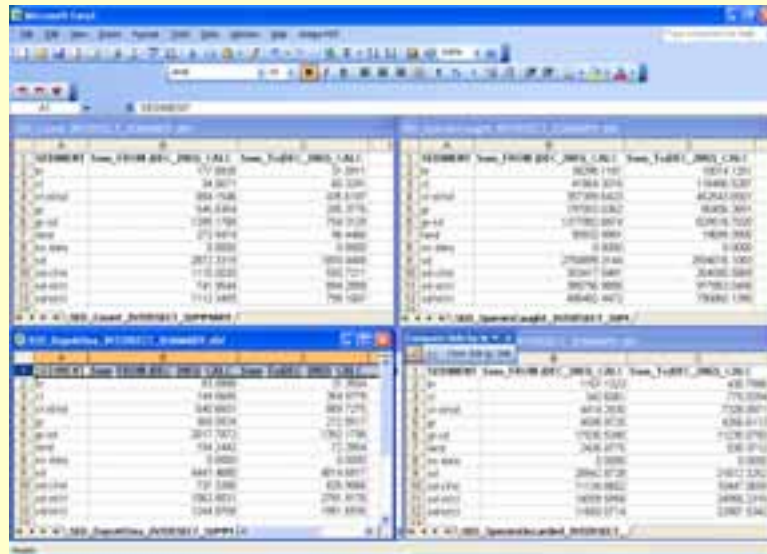
The remainder of the EcoGIS priority tools are in the conceptual design phase. Prototypes for these tools will be developed in FY07.

Area Characterization Tool
Managers and scientists need to define an area for regulatory, project consultation, or research purposes and to characterize that area in terms of Essential Fish Habitat (EFH), Habitat Areas of Particular Concern (HAPCs), critical habitat, fishing fleet characteristics, and species abundance and life stage distribution. The characterization report might be used in management reports or plans, for public meetings, or as background for NEPA documents.

The area characterization tool will use simple map overlay techniques to provide a report for a user-defined area. The user can define the area of interest interactively on screen or by entering coordinates. The tool identifies available data layers that have data within the area of interest. The user can then select one or more of these layers and specify a time period of interest for the report. The characterization report could be saved in a variety of formats for use in word processing documents, presentations, spreadsheets, and databases.

Bycatch Analysis Tool
Bycatch exists because of the imperfect nature of fish capture, the limited selectivity of certain fishing gear, the behavior and distribution of fish, and the structure of management programs. Time/area closures are one management measure that is used to attempt to reduce bycatch and discards when location and time are the primary contributing factors. Managers and scientists have a need to analyze bycatch data to find locations and time periods where high bycatch and discards are occurring. When these areas are identified, the underlying causes can be researched, such as species migrations or shared habitat between commercially valued species and non-commercially valued species.

Given an area or series of areas and bycatch locations from survey and observer data, this tool would create maps and reports summarizing bycatch. Maps and reports could be generated for user-defined time periods, depth ranges, habitat types, or other variables. This tool would be used for general exploration of spatial or statistical patterns in the data.

Fishery/Habitat Interaction Tool
Managers need to quantify the types and amount of habitat that has been fished using bottom-tending gear such as trawl nets or scallop dredges. This tool would quantify the types and amount of habitat fished by bottom-tending fishing gear. First, the areas fished for each "haul" would be determined by expanding the one-dimensional vessel track or haul vector into two dimensions using characteristics of the gear fished. Then, these "footprints" would be intersected with a habitat map. The resulting map layer would show the areas of habitats that were covered for each gear. Another series of map intersections could also

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determine how much of the "fished" habitat was considered Essential Fish Habitat (EFH) or a Habitat Area of Particular Concern (HAPC).

The Way Forward
By the end of 2006, the EcoGIS project intends to accomplish several additional objectves:
• Deploy beta-version tools with interested users to perform their own analyses. Provide training and documentation as needed.
• "Lather, Rinse, and Repeat" - continue to refine the Fishery Mapping tool based on user feedback from fisheries managers and scientists.
• Design and develop the Bycatch Analysis, Habitat Interaction, and Area Characterization tools to work with available regional data sets.
• Coordinate efforts with related projects within NOAA, Fishery Management Councils, and NGOs.
• Adapt tools to fit data sets in other regions, such as the Gulf of Mexico, Pacific Coast, Caribbean, and Western Pacific.
• Write a vision document that will describe the role that GIS will play as we move toward a greater ability to model and understand ecosystems. This document will describe the new tools and capabilities that a GIS will need to keep pace with fisheries science and management.

For More Information – visit http://www.st.nmfs.gov/ecogis

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