A Web Accessible Modeling Tool for Fisheries

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Abstract: - Many salt marsh restoration and creation projects have been implemented in the Galveston Bay System during the past 20 years. Salt marshes have many valuable functions for the surrounding habitat and the animals living there. Some of these functions include physical functions such as protecting shorelines from erosion, stabilizing deposits of dredged material, dampening flood effects, trapping water-born sediments, and serving as nutrient reservoirs. Biological functions include acting as tertiary water treatment systems to rid coastal waters of contaminants, serving as nurseries for many juvenile fish and shellfish species, serving as habitat for various wildlife species, and providing plant material for the base of a detritus-based food web. Each year more marshes are being built, and yet very little information is available concerning the success of past restoration projects. In an effort to assist the Fishery Ecology Branch (FEB) of the National Marine Fisheries Service (NMFS) Galveston Laboratory monitor created marshes and obtain information concerning their success [1]. A prototype project to map and monitor these marsh habitats was undertaken. Further, a prediction model of the density and population of different fishery species in Galveston Bay was developed.

Keywords: Model Development, Physically-based Models, Environmental Modeling

1 Overview and scope of project

A geographic information system (GIS) using ArcView software, developed by Environmental Systems Research Institute (ESRI), was created to map marsh habitats in Galveston Bay. The GIS is a system of hardware and software used for the storage, retrieval, mapping, and analysis of geographic data. The tracking of marsh habitats is accomplished by storing spatial features (features of marsh habitats) in a coordinate system (latitude/longitude, state plane, UTM, etc.). In this system descriptive attributes in tabular form are associated with spatial features. Spatial data and associated attributes in the same coordinate system can then be layered together for mapping and analysis.

This GIS was also used to implement a prediction model to predict density and population of fishery species in Galveston Bay. Datasets of marsh habitats in Galveston Bay were provided by the NMFS. A series of regression equations developed by the NMFS staff was used to develop the prediction model for the marsh habitats. Density distributions provided by the NMFS for a given fishery species were correlated with distances from water-marsh interface. The prediction model generates density distributions for 1-meter intervals within both marsh and water from the marsh-water interface in visual form.

Two user-friendly interactive tools were developed. The first tool provides a means to rapidly estimate the population size of a selected fishery species within an area of interest based on the prediction model. The second tool is an interactive Internet tool for clipping, extracting and saving the fisheries marsh habitat datasets of Galveston Bay on the client-side using a Web browser.

2 Clipping tool for the GIS

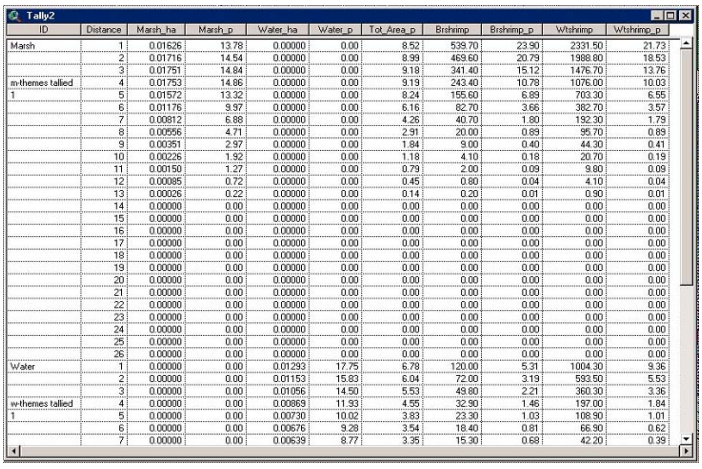
The clipping tool on the graphical user interface (GUI) of the GIS provides the user with a means to rapidly estimate the population size of a selected species within a user-drawn polygon area on a marsh-habitat digital map. The Avenue programming language, an ArcView software tool, was used to develop and implement the clipping tool. To use the tool requires prior knowledge of the densities of each species in each habitat type. The tool performs a refined calculation of a population based on a species density distribution as it relates to distance within and between habitats. The tool utilizes the marsh habitat vector datasets (or Shapefiles). A Shapefile stores non-topological geometry and attribute information for the spatial features in a dataset. The geometry for a feature is stored as a shape comprising a set of vector coordinates.

The following algorithm was used to develop the clipping tool:

a. Retrieve active themes in active document
b. Retrieve the selected graphics (user drawn polygon area of interest)
c. Select all the spatial features circumscribed by graphics (polygons).
d. Copy all the attributes of selected features to new attribute table
e. Create a new Shapefile and assign the new attribute table to the file
f. Calculate the relevant statistics about the circumscribed area using the appropriate regression equation and new Shapefiles
g. Summarize the statistics about population and area for selected species in a database (dbf format) table

2.1 Script "ClippingTool"

This script asks the user to draw a polygonal area of interest and select the species about which the user is interested. The script then runs the regression analysis for that particular species on the dataset enclosed by the polygon and calculates the area and population for that particular species corresponding to its mean density and regression coefficients stored in a reference table. The script also summarizes the results in a separate table (see Figure 1).



Tally2

ID	Distance	Marsh_ha	Marsh_p	Water_ha	Water_p	Tot_Area_p	Brshrimp	Brshrimp_p	Wtshrimp	Wtshrimp_p
Marsh	1	0.01626	13.78	0.00000	0.00	8.52	539.70	23.90	2331.50	21.73
	2	0.01716	14.54	0.00000	0.00	8.99	469.60	20.79	1988.80	18.53
	3	0.01751	14.84	0.00000	0.00	9.18	341.40	15.12	1476.70	13.76
n-themes tallied	4	0.01753	14.86	0.00000	0.00	9.19	243.40	10.78	1076.00	10.03
1	5	0.01572	13.32	0.00000	0.00	8.24	155.60	6.89	703.30	6.55
	6	0.01176	9.97	0.00000	0.00	6.16	82.70	3.66	382.70	3.57
	7	0.00812	6.88	0.00000	0.00	4.26	40.70	1.80	192.30	1.79
	8	0.00556	4.71	0.00000	0.00	2.91	20.00	0.89	95.70	0.89
	9	0.00351	2.97	0.00000	0.00	1.84	9.00	0.40	44.30	0.41
	10	0.00226	1.92	0.00000	0.00	1.18	4.10	0.18	20.70	0.19
	11	0.00150	1.27	0.00000	0.00	0.79	2.00	0.09	9.80	0.09
	12	0.00085	0.72	0.00000	0.00	0.45	0.90	0.04	4.10	0.04
	13	0.00026	0.22	0.00000	0.00	0.14	0.20	0.01	0.90	0.01
	14	0.00000	0.00	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
	15	0.00000	0.00	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
	16	0.00000	0.00	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
	17	0.00000	0.00	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
	18	0.00000	0.00	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
	19	0.00000	0.00	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
	20	0.00000	0.00	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
	21	0.00000	0.00	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
	22	0.00000	0.00	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
	23	0.00000	0.00	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
	24	0.00000	0.00	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
	25	0.00000	0.00	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
	26	0.00000	0.00	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
Water	1	0.00000	0.00	0.01293	17.75	6.78	120.00	5.31	1004.30	9.36
	2	0.00000	0.00	0.01153	15.83	6.04	72.00	3.19	593.50	5.53
	3	0.00000	0.00	0.01056	14.50	5.53	49.80	2.21	360.30	3.36
w-themes tallied	4	0.00000	0.00	0.00869	11.93	4.55	32.90	1.46	197.00	1.84
1	5	0.00000	0.00	0.00730	10.02	3.83	23.30	1.03	108.90	1.01
	6	0.00000	0.00	0.00676	9.28	3.54	18.40	0.81	66.90	0.62
	7	0.00000	0.00	0.00639	8.77	3.35	15.30	0.68	42.20	0.39

Figure 1. Summary table as a result of clipping tool

The script also adds the new theme corresponding to the regression of the water and marsh for the area enclosed by the polygon (see figure 2). By default, the script saves the new Shapefile in the working directory. If the projection of the view is changed, rerun the script to calculate an accurate area for that projection and hence population.

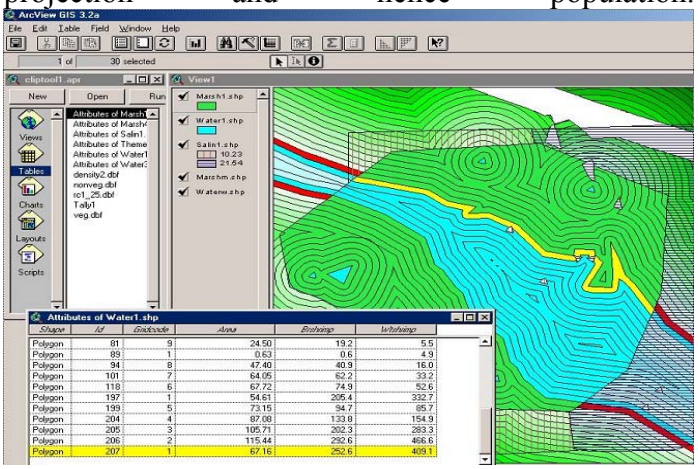


Figure 2 New datasets as a result of clipping tool

2.2 GIS Clipping tool for the Internet

The following software and equipment were used to implement the GIS for the Internet:

- Data: Marsh habitat datasets processed as described above
- Webserver: Microsoft Internet Information Services (IIS) with ServletExec ISAPI4.1 for Microsoft IIS to support servlets
- Software Packages: ArcView3.2, ArcIMS 4.0.1, HTML Image Mapper 3.1 extension for ArcView, Java 2 Runtime Environment Standard Edition v1.4.0, Axl Viewer
- Programming languages: Avenue, ArcXML, Javascript, ArcIMS, and HTML
- Equipment: Toshiba P25-S607 2.8 GHz Intel Pentium 4 processor with hyperthreading technology, 512 DDR SDRAM
- Operating system: Windows XP professional

3 ArcIMS Internet GIS technology

ArcIMS technology by ESRI was used for publishing the GIS datasets on the Internet. ArcIMS technology dynamically generates an HTML page with the map displaying the marsh habitat datasets embedded as JPEG or PNG format.

Typically the client requests information from an Internet or Intranet server. The server processes the request and sends the information back to the client viewer. The ArcIMS server technology is part of a multitier architecture. The ArcIMS framework consists of clients, services and data management (see figure 3). It establishes a common platform for the exchange of Web-enabled GIS data and services.

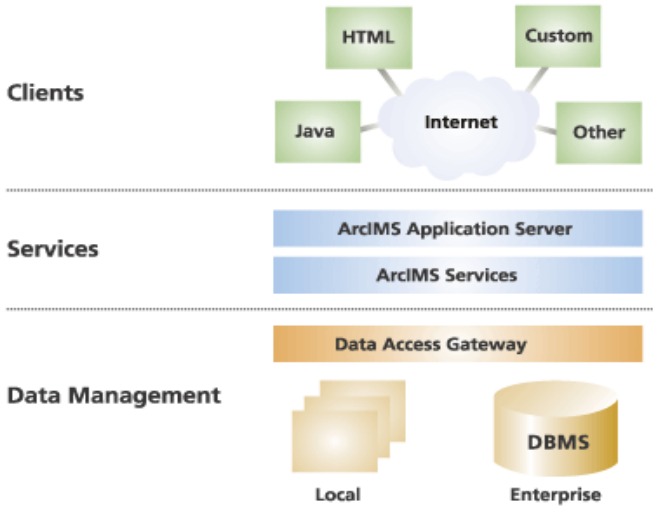


Figure 3 ArcIMS Internet GIS framework

3.1 ArcIMS Technology

ArcIMS technology, a GIS map server developed by ESRI, was used to serve marsh habitat datasets on the Internet with the clipping and extraction functionality for saving the clipped datasets on the client-side. The ArcIMS 4 architecture and functionality have been engineered specifically to serve geographic data and services on the Internet. It communicates with clients using ArcXML, which is a GIS extension to standard Xtensible Markup Language (XML). By manually inserting ArcXML elements and appending element attributes in a map configuration file, additional rendering and labeling options, data subsets, tabular joins and other capabilities, not available through the ArcIMS Author interface, can be accessed.

3.2 ArcIMS architecture configuration

A Web server (for example, in this project we used Microsoft Internet Information Services 5.0) handles requests from a client using Hyper Text Transfer Protocol (HTTP). The Web server forwards a request to the appropriate application and sends a response back to the requesting client (see figure 4). ArcIMS requires a Java Runtime Environment (JRE) or Java Developer Kit (JDK), which has a Java Virtual Machine to support the Java 2 components of ArcIMS. We use JRE1.4.0 to support ArcIMS components. ArcIMS also requires a servlet engine. ServletExec 4.1.1 ISAPI Servlet Engine has been utilized for this project. ServletExec Servlet Engine is an in-process web server plug-in that adds high-performance servlet and JSP support to Microsoft IIS Web Server. ServletExec/ISAPI is the plug-in servlet engine for Microsoft IIS on Windows NT/2000/XP/2003 (see figure 5).

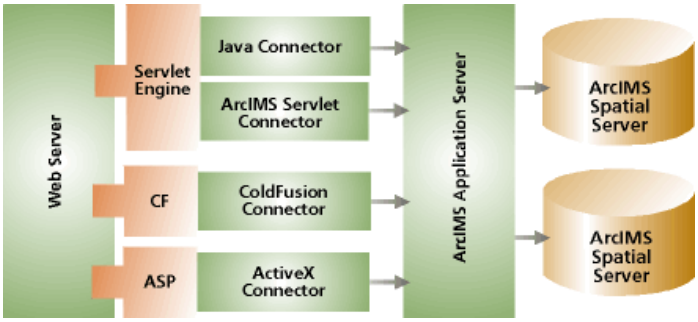


Figure 4 ArcIMS configuration

When an ArcIMS request is made, it is first handled by the Web server, passed through one of the connectors, and then forwarded to the ArcIMS Application Server. The ArcIMS Application Server connectors link the Web server to the ArcIMS Application Server (see figure 5). The Application Server, in turn, dispatches a request to an ArcIMS Spatial Server for processing. Servlet, Java, ColdFusion or Active X Connectors can be used to connect the Web server to the ArcIMS Application Server. The Servlet connector is the default connector used in this project, which uses ArcXML, the ArcIMS language, to communicate with the Application Server. Java, ColdFusion and Active X connectors translate their own languages into ArcXML language.

Figure 5 ServletExec ISAPI configuration

3.3 ArcIMS Spatial Server

An ArcIMS Spatial Server is the workhorse of ArcIMS. It provides the functional capabilities for accessing and bundling maps and data into the appropriate format before sending the data back to a Web browser.

4 Implementation of ArcIMS GIS Web Site for Serving Marsh Habitat Datasets

A map configuration file has been created using the Author interface of ArcIMS. This file describes how a map should be rendered including the list of layers used and their symbology. The map configuration file was edited manually to include ArcXML code to provide clipping and extraction functionality to ArcIMS HTML Web site.

Image service script was created in the ArcIMS administrator to service the request for marsh habitat

datasets (Shapefile) map as defined in the map configuration file.

Using ArcIMS Designer interface and the image service, a Web page is created. Designer interface creates some of the basic functionality of GIS using HTML pages and Javascript that forms the foundation for the ArcIMS HTML viewer Web site [2].

JavaScript function files were created and included in the HTML Viewer to perform the following functions:

- configure the HTML Viewer
- perform buffering
- respond to clicks on the map or buttons
- create general utility functions
- create templates for adding custom functionality
- create and use Cascading Style Sheets (layers in Netscape)
- perform address and intersection matching
- perform basic query functions including identify and hyperlink
- manage map layers
- manage the graphic legend
- basic mapping functions
- interactive map navigation such as zooming and panning
- create a Web page layout suitable for printouts
- perform attribute query, for example, Query, Find, and Search tools
- create text strings used for the interface
- perform spatial selection such as selections by rectangle and shape
- perform basic XML communication with the servers

The HTML viewer configuration function script file is located in the Web site directory. All other files are located in the Web site \javascript directory. Two additional javascripts were added to the Web site \javascript directory. They were customized to add the clipping and extraction functionality to the Web site.

The HTML viewer configuration function script is customized to add the clipping tool and enable the functionality of the clipping tool on the toolbar of HTML viewer Web site of the marsh habitat. Some of the other html and javascript files created by the Designer interface of ArcIMS are also customized for appearance, functionality and the need of serving the datasets on the Internet.

5 Conclusion and Significance

We have implemented a GIS for mapping and monitoring of marsh habitats and provided a software tool to automate the processing of marsh habitat datasets. Two user-friendly interactive tools were developed in this project. The first tool was developed for use in ArcView GIS, which provides the user with a means to rapidly estimate the population size of a selected fishery species within an area of interest based on the prediction model. The tool was implemented in the Avenue language, a proprietary programming language used within ArcView. The second tool is an interactive Internet tool for clipping, extracting and saving the fisheries marsh habitat datasets of Galveston Bay. The ArcIMS Web site of marsh habitat was customized using HTML, ArcXML and Javascript

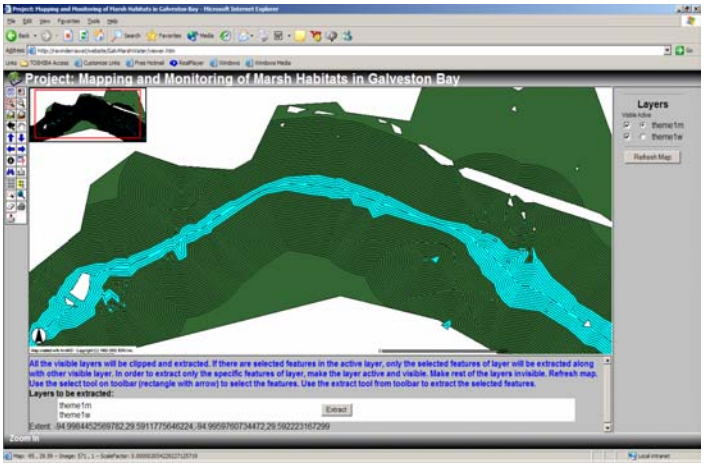


Figure 6 ArcIMS Web site interface with clipping functionality

The GIS developed in this project helps the user to locate and estimate changes in the amount of each restored marsh habitat, and to evaluate the success and development of restored marsh habitats through the years. The GIS clipping tool allows the user to run regression analysis for areas of interest and generate relevant statistics about the area. This tool will help fisheries scientists to predict the fishery species population for the following year. The tool gives these scientists a potential way to evaluate impacts of environmental factors and pollutants on the population of fishery species. The population sizes of species can be useful information for evaluating the potential economic impacts where changes in land use are proposed, e.g. areas where the removal of salt marshes for urban or industrial development might be proposed.

Real-time ArcIMS GIS Web site will help scientists to publish the datasets and other relevant information about marsh habitats on the Internet. The Web site will help researchers in this field to study marsh habitats and fishery. This Web site will also help managers of fishery

companies and other related institutions to understand the importance and relevance of marshes as a habitat of fishery species. Prediction information for the following year and the interactive use of clipping tool for the GIS and for the Internet in real time will allow the fishing industry to prepare their fishing operations for the following year.

The next step in this project will be to improve the clipping tool by developing the functionality of adding the dynamic layer of clipped data to the ArcIMS HTML viewer, which will help GIS communities to visualize the datasets before downloading. ArcIMS 4.0.1 technology doesn't offer a good tool through ArcIMS Designer interface to overlay the clipped marsh habitat dataset in HTML viewer and to add the functionality of running the regression analysis on the clipped datasets on client side. This provides the opportunity to look into integrating other Internet and DBMS technologies, which can run the regression analysis and can visualize the clipped datasets in ArcIMS.

References

[1] EFH Project site for the National Marine Fisheries Service, Galveston Laboratory. Section III. Monitoring created salt marshes. http://galveston.ssp.nmfs.gov/efh/changes/default_new.htm #Salt_marshes (visited Nov 1, 2002).

[2] Environmental Systems Research Institute (ESRI Redlands, Calif.).*Customizing ArcIMS 4.0 HTML Viewer.* ESRI Redlands, Calif. 2003.