

# Development of a Web-based Geographic Information System as a Decision Tool to Support Fisheries Science and Management: A Case Study of Diani-Chale, Kenya

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## ABSTRACT

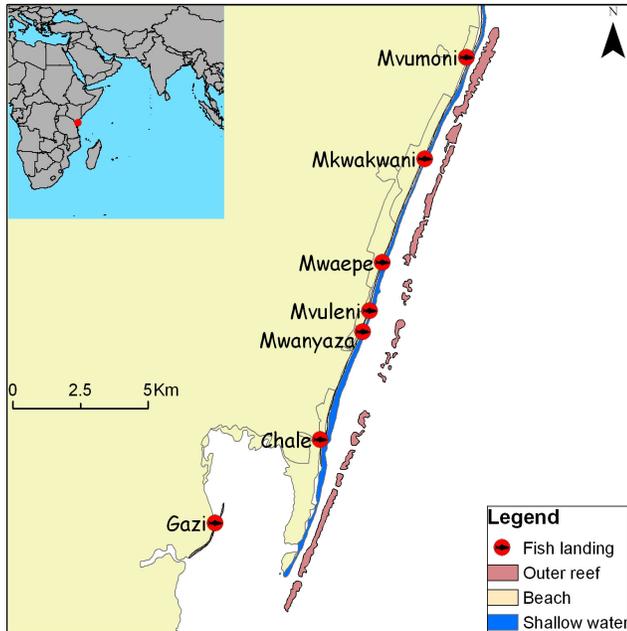
By treating many spatial components simultaneously GIS technologies provide opportunities to integrate and use large amounts of information in simple visual graphics to assist in managing natural resources. A spatial perspective can be useful in a fisheries context to suggest prospective management measures to resource managers. Here we present artisanal fishery data in a novel GIS-enabled format. Data was collected through a participatory monitoring programme in the Diani-Chale area of southern Kenya from 1997 to 2007. Analyses were conducted to provide spatial and temporal statistics on fishing sites, total catches, catch per unit effort (CPUE), catch composition and benthic attributes. Data was organized in ArcGIS and uploaded using HTML scripting onto a web based Internet Map Service (IMS) platform, ESRI's ArcIMS. This enables a user to view the GIS through a standard internet/web browser or ESRI client application, such as ArcGIS or ArcExplorer/ArcReader. Users are able to query, search, pan, zoom and identify any geospatial data

layers for display. With the database installed on a personal computer, users can also add data layers and annotate their version to suit their purposes. The database is provided on an accompanying CD-ROM as well as on an 'esite' on CORDIO's website ([www.cordioea.org](http://www.cordioea.org)). The interactive provision of spatial datasets is being done to promote information sharing among marine resource scientists and managers and to test emerging technologies in assisting accurate and informed decision-making.

## INTRODUCTION

The Diani-Chale area is located 25 km south of Mombasa in Kwale District, along the southern Kenya coast (Fig. 1, 4031' S and 39050' E), and extends from the Tiwi river in the north to Chale island and Gazi bay in the south (Slim & Gwada, 1993). The area represents one of the most degraded coral reef systems in East Africa (McClanahan & Obura, 1995) and is characterized by high fishing effort, high levels of conflict among fishers and other coastal resource users and relatively poor enforcement (Alidina 2005).

*Obura, D.O., Tamelander, J., & Linden, O. (Eds) (2008). Ten years after bleaching - facing the consequences of climate change in the Indian Ocean. CORDIO Status Report 2008. Coastal Oceans Research and Development in the Indian Ocean/Sida-SAREC. Mombasa. <http://www.cordioea.org>*



**Figure 1.** The general location of Diani-Chale area on the South Coast of Kenya and fishing/landing sites.

The development of a local system of resource management in Diani-Chale is an evolving process and is of interest to a number of organizations active in the area.

The Diani-Chale area on the south coast of Kenya has been the focus of much of the participatory monitoring work undertaken by CORDIO East Africa (Obura et al. 2002). The efforts of CORDIO East Africa have focused on the use of participatory monitoring and research approaches as a strategy to create awareness among fishers and engage them to be more involved in resource management (Obura 2001; Obura et al, 2002).

This paper describes a web based geographic information system that can be used as a decision support tool for fisheries analysis and management. The application emphasizes the dynamic presentation of geographic information, which enhances the power of visual data communication, increases user interactivity, and improves the usefulness and value of spatial data.

## The Technology

The tremendous growth in Internet use has resulted in an increased demand for the delivery of geographic data, maps, and applications over the Internet. Through ESRI's ArcIMS, organizations can author maps and geo-referenced datasets centrally and publish them to a Web site of their own creation, complete with map navigation and query tools regardless of the scale or complexity of their needs. Web-based GIS puts an "atlas" of information into the hands of the client – quickly, cost-effectively, and in a way that is open for growth and change. Web GIS uses three predefined templates – an HTML viewer and two Java viewers; the HTML viewer offers wide browser support and does not rely on Java applets but can use only a single Image MapService. Java viewers provide enhanced functionality and support feature streaming technology. With a Web GIS, one can:

- Publish and access documents and URLs based on map features.
- Create "views" of all or part of the geographic area of interest and its various features.
- Change the look of and label selected map features to emphasize their display.
- Quickly generate a hard copy map.
- Integrate with PowerPoint for map publishing and presentation.
- Integrate with Excel for sophisticated tabular processing and output.
- Link associated tabular data to a map layer's features without having to know anything about the database, its structure or how to connect to it.

## THE DIANI-CHALE SPATIAL DATABASE

To demonstrate the interactive online GIS concept, a web GIS of the Diani-Chale participatory monitoring programme of CORDIO was assembled, to help support fisheries analysis and management.

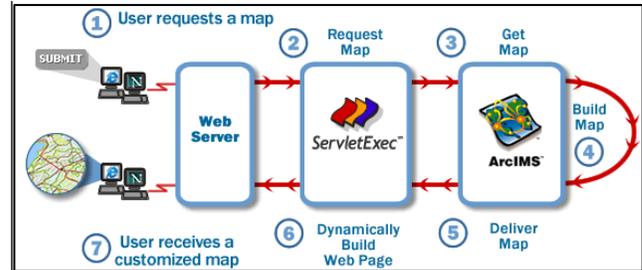
## Data Acquisition

In order to provide a comprehensive Web GIS Database, topographic map layers at a scale of 1:50,000 from the Survey of Kenya were obtained and overlaid with a LandSat7 +ETM image (from 22 January 2000). The LandSat7 image was geometrically corrected to the topographic map of the Kenya coastline. A supervised image classification was done with the application of the nearest neighbour resampling method. Classification of pixels with similar spectral characteristics representing various habitat classes was carried out using the cluster module (Richards, 1993) to produce beach and intertidal layers. Point data of fishing sites in the reef area were collected through participatory mapping and later converted into polygons to approximately represent fishing grounds.

Digital processing for the work was performed using Erdas Imagine 8.6 for image processing and Arc GIS 9.1 for GIS work and display (ESRI 1996) Attribute data for all the map layers was added interactively at the time of initial data capture in the field and tested for attribute code consistency, topology errors and attribute field definition correctness. All map layers were projected to the same co-ordinate system (Transverse Mercator WGS 1984 Zone 37s).

## Implementation of Diani-Chale eSite

A number of software packages were customized to implement the eSite. ESRI's Internet Map Server (ArcIMS) package was chosen as it provides a high level of functionality for spatial analyses and creates innovative tools to allow users to import georeferenced data, make spatial selections, perform spatial analyses and output the results for further analysis. ArcIMS is part of ESRI's ArcGIS line of Geographic Information System (GIS) software products and can be installed on a range of different World Wide Web (web) servers. ActiveX Connector was used to develop a custom client application using Visual Basic and Active Server Pages (ASP) scripting language to deliver data and information. ASP, a form of server-side



**Figure 2.** The transaction process of Web GIS. The user sends requests and the web server handles and sends responses.

scripting, allows the programmer to use JavaScript or Visual Basic Script (VBScript) to generate custom HyperText Markup Language (HTML or web pages) on-the-fly, and to perform some basic scripting functions such as data checking and database integration and hence build solutions and deploy them to users without requiring the presence of ArcGIS Desktop applications (ArcMap, ArcCatalog, ArcToolbox).

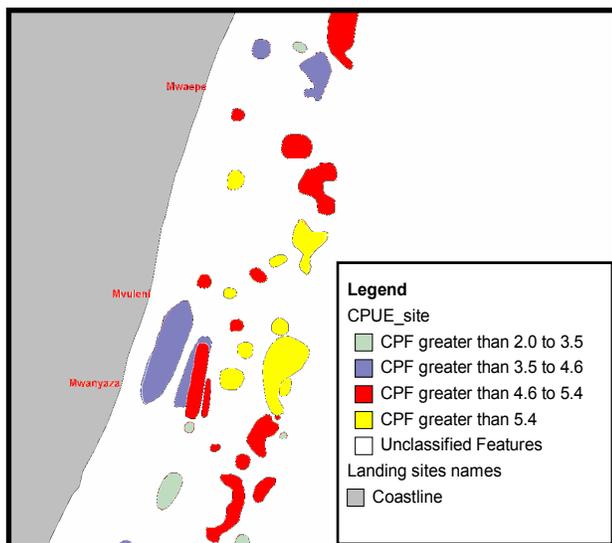
ArcIMS gives a choice of two different map viewers, the HTML viewer and the Java Viewer. The HTML viewer is simpler and requires a smaller download for the client (User's browser), but it cannot perform some of the advanced functionality available through ArcIMS. The Java Viewer is a highly customizable interface capable of the full functionality of ArcIMS, including feature and metadata services, but requires uploading a larger java applet (program) to the client. For the Diani-Chale esite, the advanced features of the Java Viewer were not needed, and the customization features and wide browser support available in HTML viewer were sufficient.

Web GIS uses hypertext transfer protocol (HTTP), the rules for transferring information over the Web. A web server handles requests from a client using HTTP and uses a servlet engine to send a response. (Fig. 2).

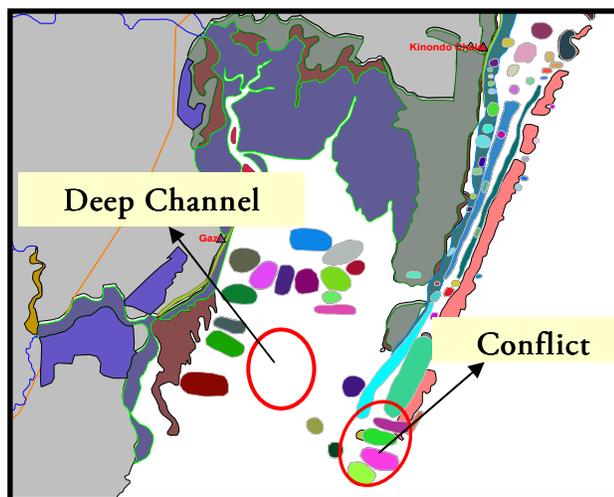
## Overview of the Interface

When an atlas is opened its default topic is loaded and the information associated with that topic is displayed in six windows

1. The Map Layers Window lists all the topic's map layers. By turning a map layer on and off, you can see the various relationships and information in the map view. "Possible Active Layers" are green and have an asterisk (\*) in front of them. These layers can be made active by clicking on them. When they are active, one can select features, identify features, and find features on that map layer.
2. The Tips Window provides useful tips on using the system.
3. The Topics Views Window lists the atlas' topics along with any views the user creates. These dictate what information in the atlas is available for use. A 'Topic' is a group of map layers, data sets, and documents that are always shown when a user launches Dynamic Maps or logs onto the web site. Topics focus the users' attention on an item or area of interest while providing information that is tailored to meet specific needs.
4. The Related Information Window lists the map layers that have related information, and lists the name of the related information object. Clicking on the object's name will launch the



**Figure 3.** Spatial distribution of CPUE within selected fishing sites.

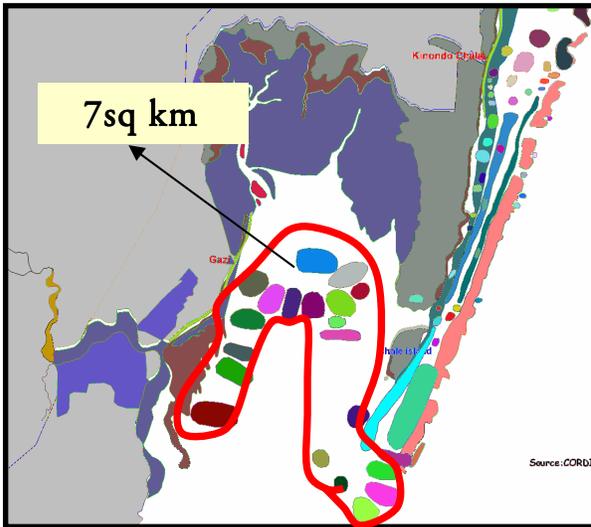


**Figure 4.** Spatial distribution of fishing sites within Gazi bay and possible conflict with adjacent fish landing sites.

5. The Spreadsheet Window provides the interface between the tabular data and the map layer, and shows the fields and values for the records in a data table or query. The records in the Spreadsheet are linked with their relative map features.
6. Tabular data window: This window lists the tabular datasets and any queries generated. Clicking on a dataset will launch it in the spreadsheet and will make its associated map layer visible.

## INITIAL RESULTS

Using the Diani-Chale spatial database, we wanted to view fish catch for different fishing sites. Sites were classified into six classes from the lowest to highest catch per unit effort (CPUE) in kg/trip/fisher (Fig. 3). The resulting map shows that most of the fishing sites have CPUE greater than 4 kg/trip/fisher, and that higher-catch sites are grouped near the outer reef with



**Figure 5:** The approximate area of Gazi fishing zone (7 sq km).

lower catches in the central lagoon areas and close to the beach.

Another view was created to show the spatial distribution of fishing sites within Gazi bay (Fig. 4). The fishing sites cluster around the edges of the bay, the fishermen avoiding fishing in the deep center of the bay. It also shows an overlap of fishing zones between Gazi and Chale fishermen, which leads to some conflict between them (Obura et al. 2001).

The spatial analysis functionality of the esite was used to determine approximate area of the Gazi fishing zone (Fig. 5). This was measured using the customised tool for area calculation and produced an approximate area of 7 km<sup>2</sup>. It is interesting to note that named fishing sites do not cover 100% of the sea area – large zones between named sites are apparently not used, or at least not specifically named by local fishers.

## DISCUSSION

Web GIS can be used as a tool in the policy-making toolbox. A marine resource advisory committee could use a mapping website to share its advice with the

public. As an online tool, it can reach a larger group through libraries and other public access areas. Maps and other interactive or multi-media educational materials are easily included in online materials. As a CD-based platform it can also be easily disseminated to locations with poor internet access.

Negotiated rule making is used when stakeholders have strong and opposing opinions. Preparing information on an esite and visualization of diverse values would enhance stakeholder understanding of the issues. A GIS analysis tool could focus disagreements over the consequences of certain positions, by immediately showing the effects of various actions.

Prior to public meetings and hearings, access to online maps would make information available before the event, allowing stakeholders to be better prepared for discussions. The same maps that are shown online could also be shown at the meeting or hearing, where a visual representation of data allows for greater understanding and more effective communication.

On its own, the interactive mapping component offers the most possibilities for augmentation of existing public participation mechanisms. As a tool for data sharing, communication, and education of stakeholders, it could be incorporated into many existing processes.

## Limitations

In designing and building the Diani-Chale esite and application, a number of limitations have become apparent:

### *User interface*

Designing a simple, yet powerful user interface for the esite was a challenge. For an official implementation of esite, a skilled web interface designer should be consulted to design the interfaces of the interactive esite. The educational goals of the site will determine the content of the web pages, while the expected audience will determine the design and complexity of the mapping site. Brevity and clarity should be a priority, with simplicity for novices and adequate

detail for expert users. The issues addressed should be well explained, along with the mechanisms used in the application.

### **Cost**

The software used for the site includes a number of expensive packages from ESRI. It was possible to do this at CORDIO East Africa because of a grant of a site license, but this would pose a serious problem for an agency with a limited budget.

## **CONCLUSION**

The Diani-Chale esite showed that an online interactive GIS tool can be used as a decision-support tool to support fisheries science and management. Acting as an educational tool, a decision-making tool, or the basis for a new public participation process, this new tool can enhance existing techniques. Through improved inclusion of science and engaging visual display of data and decision criteria, Web GIS can bring decision making processes into the world of the Internet. It has the potential to improve communication with and education of stakeholders, and to build capacity among stakeholders for participation in the decision-making process.

Despite limitations, particularly in data availability, Web GIS can streamline the public participation process for conservation and management of marine resources. It can encourage the development of a dynamic, communitarian process in which all stakeholder values are taken into account, and which enhances the quality and fairness of the decisions produced through public participation.

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