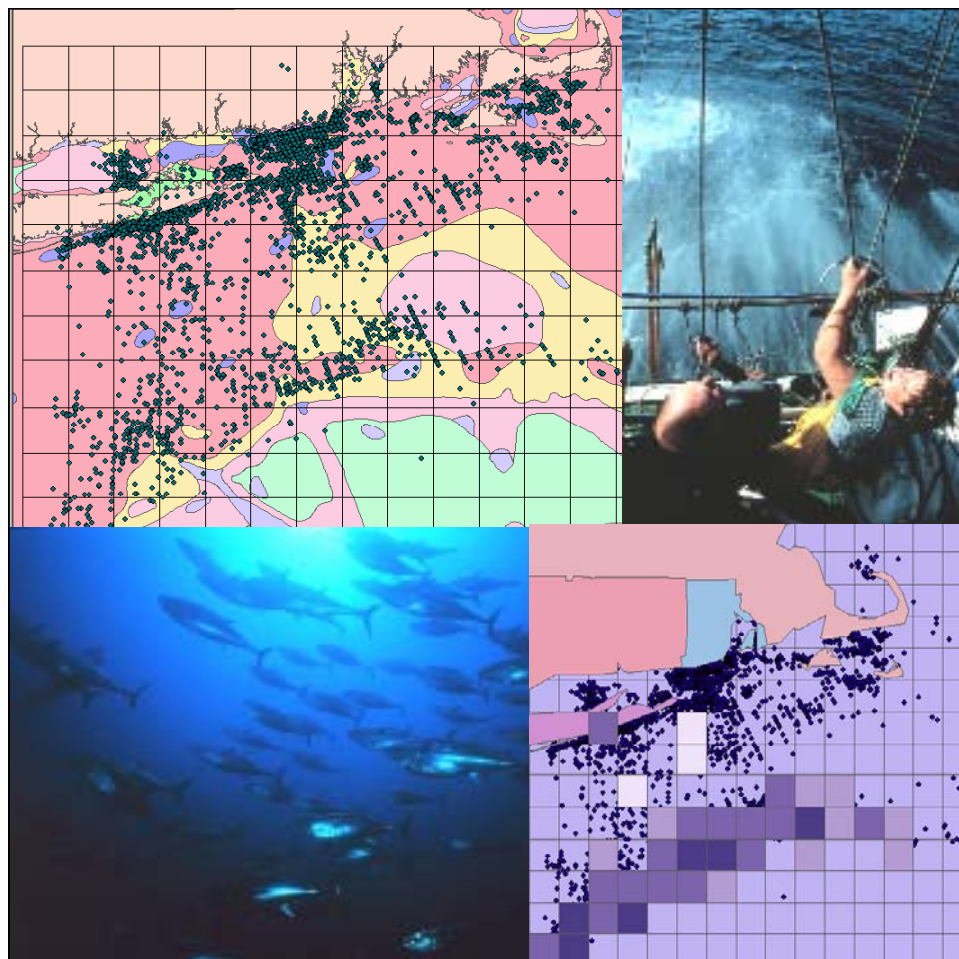


EcoGIS – GIS Tools for Ecosystem Approaches to Fisheries Management



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EcoGIS – GIS Tools for Ecosystem Approaches to Fisheries Management

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Executive Summary

The EcoGIS project was launched in September 2004 to investigate how Geographic Information Systems (GIS), marine data, and custom analysis tools can better enable fisheries scientists and managers to adopt *Ecosystem Approaches to Fisheries Management* (EAFM). EcoGIS is a collaborative effort between NOAA's National Ocean Service (NOS) and National Marine Fisheries Service (NMFS), and four regional Fishery Management Councils.

The project has focused on four priority areas: *Fishing Catch and Effort Analysis*, *Area Characterization*, *Bycatch Analysis*, and *Habitat Interactions*. Of these four functional areas, the project team first focused on developing a working prototype for catch and effort analysis: the Fishery Mapper Tool. This ArcGIS extension creates time-and-area summarized maps of fishing catch and effort from logbook, observer, or fishery-independent survey data sets. Source data may come from Oracle, Microsoft Access, or other file formats. Feedback from beta-testers of the Fishery Mapper was used to debug the prototype, enhance performance, and add features.

This report describes the four priority functional areas, the development of the Fishery Mapper tool, and several themes that emerged through the parallel evolution of the EcoGIS project, the concept and implementation of the broader field of Ecosystem Approaches to Management (EAM), data management practices, and other EAM toolsets. In addition, a set of six succinct recommendations are proposed on page 29.

One major conclusion from this work is that there is no single "super-tool" to enable Ecosystem Approaches to Management; as such, tools should be developed for specific purposes with attention given to interoperability and automation. Future work should be coordinated with other GIS development projects in order to provide "value added" and minimize duplication of efforts.

In addition to custom tools, the development of cross-cutting Regional Ecosystem Spatial Databases will enable access to quality data to support the analyses required by EAM. GIS tools will be useful in developing Integrated Ecosystem Assessments (IEAs) and providing pre- and post-processing capabilities for spatially-explicit ecosystem models.

Continued funding will enable the EcoGIS project to develop GIS tools that are immediately applicable to today's needs. These tools will enable simplified and efficient data query, the ability to visualize data over time, and ways to synthesize multidimensional data from diverse sources. These capabilities will provide new information for analyzing issues from an ecosystem perspective, which will ultimately result in better understanding of fisheries and better support for decision-making.

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/NMFS 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, Pikitch et al. 2004). Regional Fishery Management Councils are developing *Ecosystem Pilot Projects* and *Fishery Ecosystem Plans* (SAFMC 2004, NOAA/CBO 2006), which will help fisheries managers to meet requirements put forth by the Magnuson-Stevens Act (Public Law 94-265). One of the provisions of the 2006 re-authorization is that NOAA and the Councils will study the state of science for integration of ecosystem considerations in regional fisheries management (NOAA/NMFS 2007a). Spatial analysis using Geographical Information Systems (GIS) is recognized as an essential tool to integrate ecosystem information from various sources (Battista and Monaco 2004, Busch et al. 2003, Monaco et al. 2005). An experienced GIS user can run many analyses using off-the-shelf software and readily available data sets – but customized tools can streamline the workflow of these analyses, and make them feasible for someone with less expertise.

The EcoGIS project was launched in September 2004 to investigate how GIS, marine data, and custom analysis tools can better enable fisheries scientists and managers to adopt *Ecosystem Approaches to Fisheries Management*. EcoGIS is a collaborative effort between NOAA's National Ocean Service (NOS) and National Marine Fisheries Service (NMFS), and four regional Fishery Management Councils.

Objectives

The objectives of the EcoGIS Project were to:

- Build a collaborative team from within NOAA, regional 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.

Outreach and Needs Assessment

The initial scope and objectives of the EcoGIS project were based on the results of a workshop held in Charleston, SC in September 2004 (NOAA 2004), with participation by fishery scientists and managers from NOAA, Fishery Management Councils, academia, and non-governmental organizations (NGOs). GIS needs expressed at the workshop ranged from simple map-based queries to complex ecosystem modeling. After the workshop, a website was launched to promote the project and communicate results (<http://www.st.nmfs.gov/ecogis>). A steering committee was formed in January of 2005 (see Appendix A), which recommended that the project team focus their efforts on four priority areas:

Fishing Catch and 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), biological parameters (e.g. species abundance), and regulatory framework?

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

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

Based on these recommendations and available resources, the project team chose to concentrate on fishing catch and effort analysis, and developed a prototype tool called the Fishery Mapper.

The EcoGIS team then conducted a series of meetings with Fishery Management Council and NMFS staff to demonstrate the prototype tool, get feedback and new ideas, recruit potential users and learn their specific needs (see ***Appendix B - Meetings and Conferences***). The project team has also engaged with NOAA's and NMFS' GIS Committees (NOAA 2006, NOAA/NMFS 2006), NatureServe's *EBM Tools Network* (NatureServe 2006) and other groups to share ideas and keep abreast of related efforts.

Developing the Priority Tools

Conceptual descriptions of the four functional areas identified by the needs assessment follow. A detailed description of the tool for fishery catch and effort mapping, the Fishery Mapper, is provided in the *Fishery Mapper Tool Details* section.

Fishery Mapper Tool for catch and effort analysis

The Fishery Mapper Tool creates time-and-area summarized maps of fishing effort and catch from logbook, observer, or fishery-independent survey data sets. The tool 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. Figure 1 illustrates some of this tool's capabilities. For an in-depth look at the Fishery Mapper's functionality, see the section on *Fishery Mapper Tool Details* below.

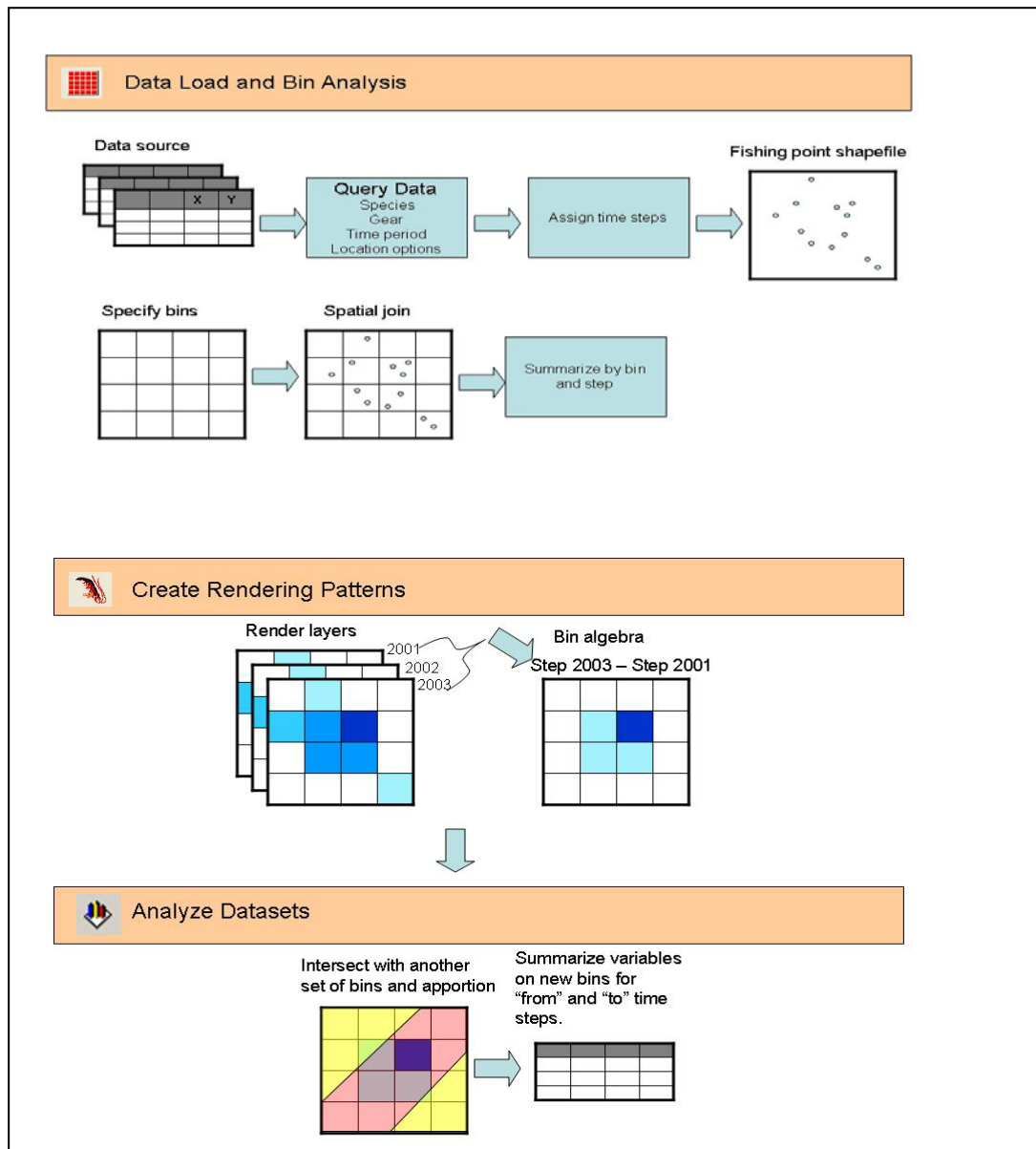


Figure 1. Schematic representation of the EcoGIS Fishery Mapper's capabilities.

Area Characterization

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 could be used in management reports or plans, for public meetings, as background for NEPA documents, or as a source report for Integrated Ecosystem Assessments.

An Area Characterization tool would 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 select one or more of these layers, specify a time period of interest, then run the query to generate a table of summary results. The characterization report could be saved in a variety of formats for use in word processing documents, presentations, spreadsheets, and databases.

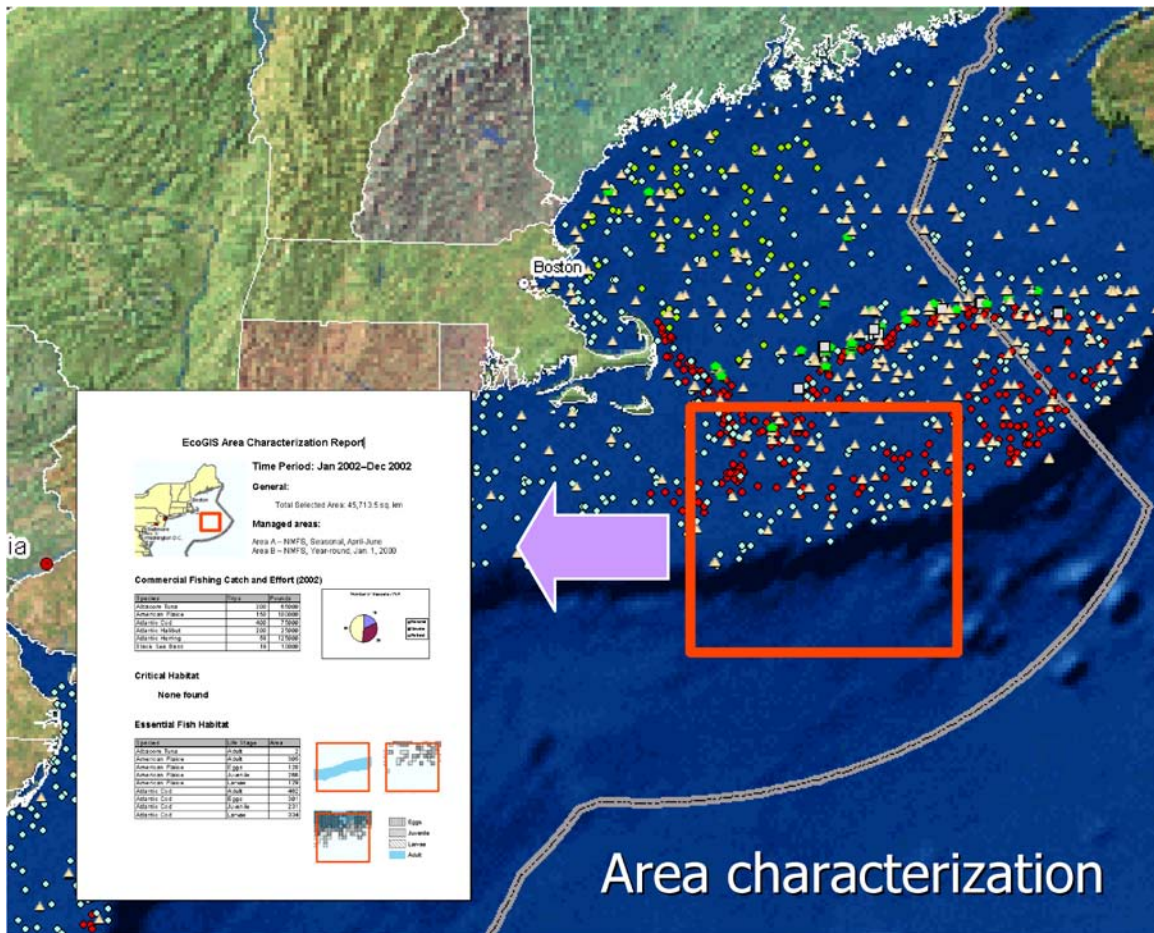


Figure 2. Area characterization.

Conceptually similar tools have been developed for marine area characterization in other regions. For example, a cooperative effort in California has developed a system using ESRI's Internet Mapping Service (ArcIMS) in support of that state's Marine Life Protection Act, which includes an online decision support tool (*Doris*) for interactive characterization and comparison of Marine Protected Areas (UCSB 2007, McClintock pers. comm.) with tabular output. Because this tool uses only publicly-available, non-confidential data sources, it is especially well-suited as a web-based instead of a desktop application.

There are several regional ArcIMS services which allow web-based mapping and access to public data. For direct applicability to fisheries management, one has been developed by the South Atlantic Fishery Management Council (SAFMC 2007) in cooperation with the Florida Fish and Wildlife Research Institute, providing access to spatial data, imagery, videography and documents related to coral and other habitats of the South Atlantic ecosystem. In the Northeast and Mid-Atlantic, ArcIMS sites are provided by the Gulf of Maine Ocean Data Partnership (GOMODP 2004) and Chesapeake Bay Program (CBP 2005) and in the Gulf of Mexico by NOAA's National Coastal Data Development Center (NCDDC 2007). The Pacific Coast Groundfish EFH Mapper is a good example from the U.S. West Coast (PSMFC 2008). These web services are regional in scope, and to our knowledge such a capability has not been developed at the National scale.

Bycatch Analysis

Bycatch and discards exist 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 (NOAA/NMFS 2004).

Managers and scientists need to analyze harvest data to find locations and time periods where high bycatch and discards are occurring. When these areas are identified, the underlying causes can be studied, such as species migrations or shared habitat between commercially valued species and non-target species. Given an area or series of areas and catch locations from survey and observer data, this tool would create maps and reports summarizing bycatch and discards. 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.

The Fishery Mapper tool could be used for basic discard distribution/density analysis, but most issues are complex and would require additional custom tools to be developed.

Fishery / Habitat Interaction

In order to address the issue of interaction between bottom-tending fishing gear (e.g. trawl nets or scallop dredge) and benthic habitats, fishery managers need to quantify the types and amount of habitat that has been fished. A *Fishery/Habitat Interaction* tool would map this interaction by combining habitat data with fishery-dependent data such as vessel logbooks or observer data and Vessel Monitoring System (VMS) data where available. With VMS data alone, the tool would need to filter out fishing activity (i.e. when fishing gear is deployed) from transit time to and from port. Logbook or observer data could be used, either alone or with VMS data, to identify fishing activity tracks. Logbook, observer, and VMS data are usually confidential, so the tool would need to ensure the security of these data.

With fishing activity tracks and habitat data in hand, the areas fished for each "haul" would be determined by expanding the one-dimensional vessel track or haul vector into two dimensions using knowledge of the characteristics of the gear fished (width, behavior on the bottom and in the water column, etc.). Then, these areal "footprints" would be intersected with habitat map features such as bottom sediment, bathymetry, etc. The resulting map layer would depict and quantify the areas of habitats that were fished by each gear type. Another series of map intersections could also determine how much of the "fished" habitat was considered Essential Fish Habitat (EFH) or a Habitat Area of Particular Concern (HAPC). These analyses would be useful in the assessment of the interaction between fishing gear and benthic habitats.

Fishery Mapper Tool Details

The Fishery Mapper Tool - Application development

The working prototype, EcoGIS Fishery Mapper – beta, was developed in Visual Basic 6 as an extension for ArcGIS 9.2, and was released for testing to a select number of users in early 2007 along with documentation (NOAA 2007).

Observer, Vessel Trip Report (VTR or logbook), and fishery-independent trawl survey data for development and testing of the tool were acquired from NOAA/NMFS Northeast Regional Office and Northeast Fisheries Science Center Woods Hole Laboratory (NMFS/NEFSC 2005), and loaded into a duplicate Oracle database environment at the NMFS Office of Science and Technology in Silver Spring, Maryland. These data were also loaded into a *Microsoft Access* database for testing of the tool in a non-networked setting.

The project team also acquired access rights through the Atlantic Coastal Cooperative Statistics Program (ACCSP 2006) to confidential trip ticket and landings data for the entire Atlantic Coast, and has adapted the Fishery Mapper Tool to connect to and utilize data from the ACCSP data warehouse. GIS layers representing habitat parameters such as shoreline and bathymetry (NOAA/NOS 2007), sediment type (Poppe and Polloni 2000, Reid et al. 2005), sea surface temperature, and others were acquired to demonstrate various analyses (Table 1)

Table 1. Source data for development of GIS prototype tools.

<i>Title</i>	<i>Format and Type</i>	<i>Source</i>
Medium-Resolution Shoreline	Vector – line	NOS 2006
Bathymetry	Vector – polygon	NOS 2006
Bottom Sediment	Vector – composite	Poppe and Polloni 2000 (USGS)
Bottom Sediment	Vector – composite	Reid et al. 2005 (USGS)
Northeast Vessel Trip Report	Vector – point	NMFS/NEFSC 2005
Observer	Vector – point	NMFS/NEFSC 2005
Fishery-Independent Trawl Survey	Vector – point	NMFS/NEFSC 2005
Southeast Vessel Trip Report	Vector – polygon	ACCSP 2006
Gulf of Mexico EFH Layers	Vector – composite	GIS Solutions, Inc. 2005
Gulf of Mexico Base Layers	Vector – composite	Sheridan and Caldwell 2002

The Fishery Mapper Tool – How it works

The Fishery Mapper's capabilities are illustrated in this example, using Northeast Vessel Trip Report (VTR) data (NMFS/NEFSC 2005), with each step identified sequentially as a storyboard in Figures 3 through 7. The first step in the mapping process is to define query conditions, time range, and time steps using a series of dialog boxes as a front-end to SQL (Structured Query Language) (Figure 3). When the query has run, the SQL parameters can be saved, and the selected points are saved as a shapefile (Figure 4).

1. Launch EcoGIS tool with first button on toolbar.

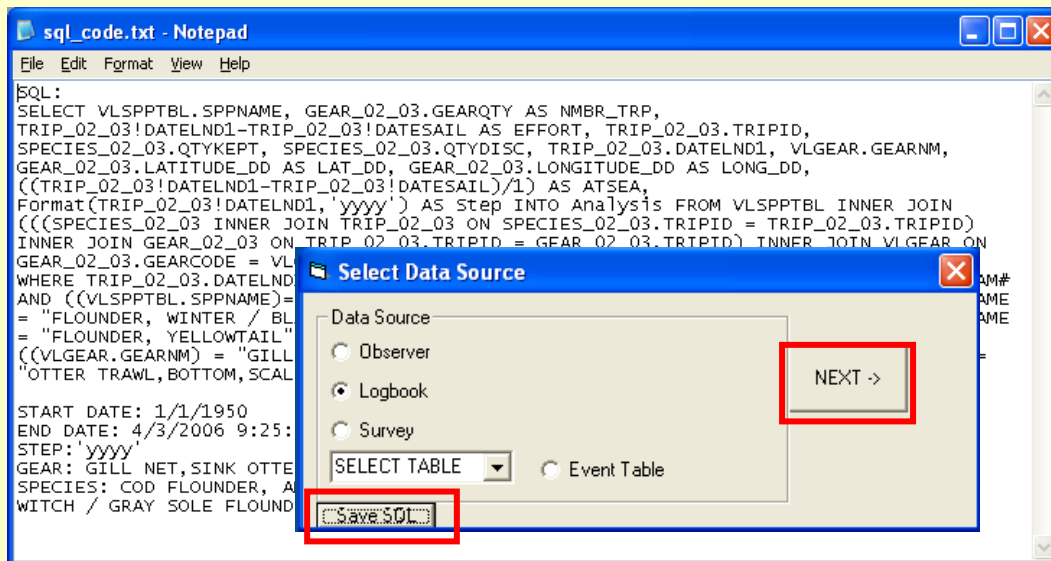
2. User selects data set of interest – in this case, logbook. Users may also import other data sets and specify fields.

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.

Figure 3. Launching the Fishery Mapper DLL in ArcGIS, accessing source data, and developing SQL query.

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.

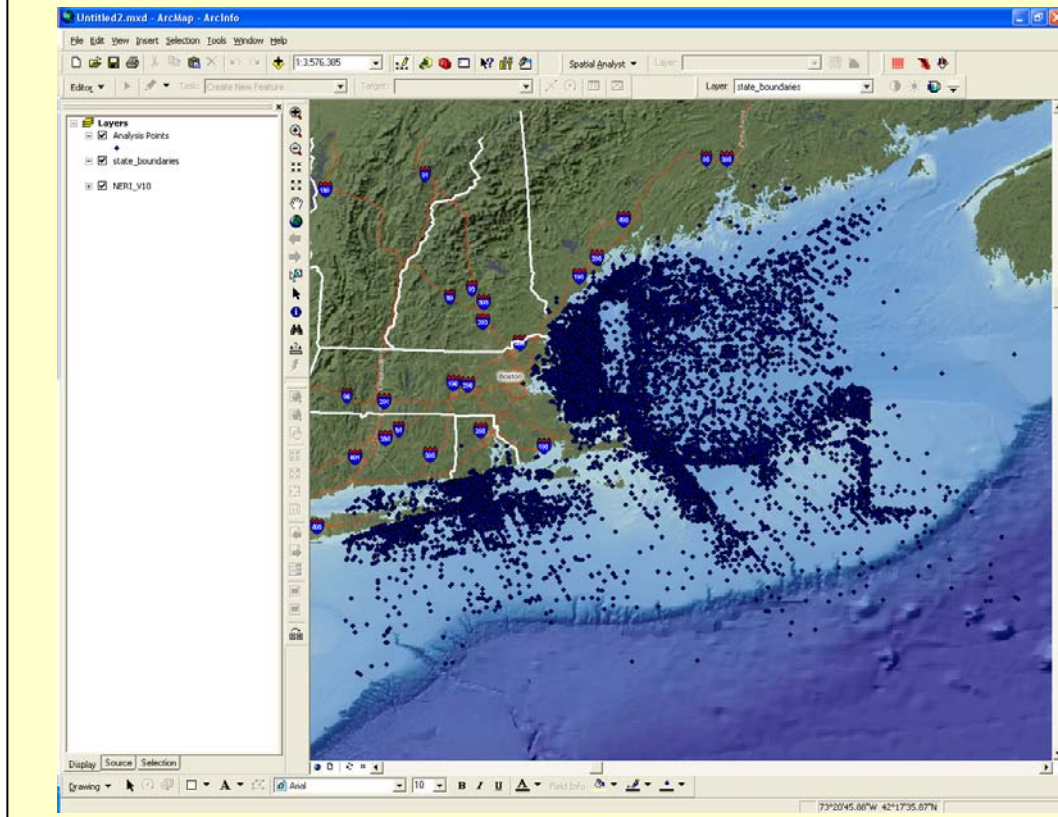


Figure 4. Running SQL query and saving results in shapefile.

Next the user chooses how to summarize the data geographically. Spatial analysis “bins” may be specified by creating a grid (Figure 5), drawing polygons on the screen, or selecting preexisting polygons from a shapefile.

5. Spatial extent and cell size of analysis area are specified.

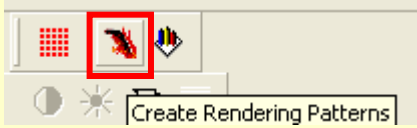
7. **Spatial Join** of point and bin shapefiles creates standalone table summarizing catch and effort by bin and time step.

6. Selected area is autopopulated with specified bins, then saved as a shapefile.

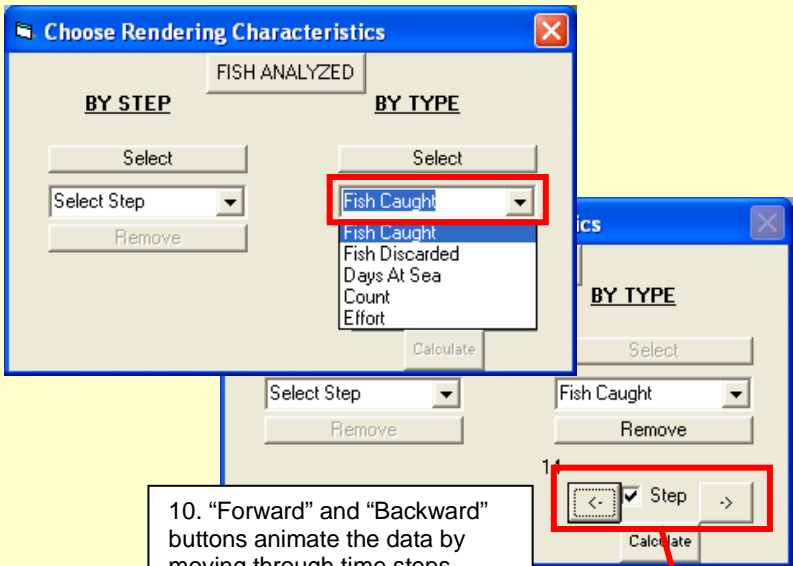
Figure 5. Specifying bins (polygons) to join with selected points for spatial summary.

The second button on the EcoGIS Fishery Mapper toolbar (Figure 6) 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.



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



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

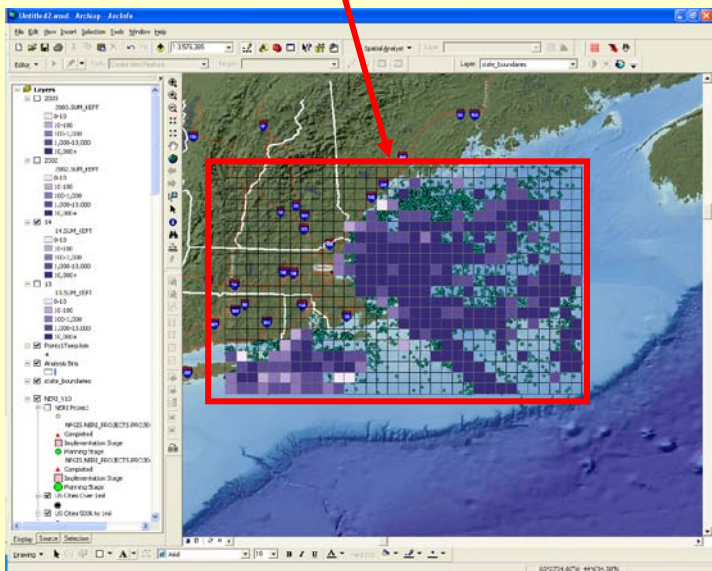
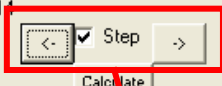
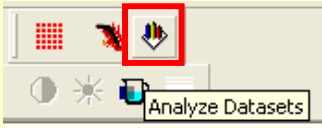


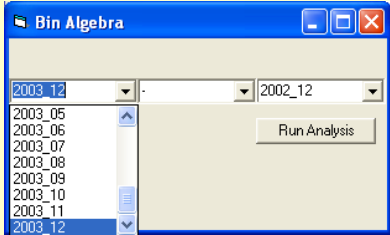
Figure 6. Rendering fishing catch and effort through time.

The third button on the EcoGIS Fishery Mapper toolbar (Figure 7) 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. fishing 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 a regulatory or environmental change that may have shifted fishing effort. Available habitat layers include bathymetry (NOAA/NOS 2007), sediment type (Poppe and Polloni 2000, Reid et al. 2005), sea surface temperature, and other environmental parameters.

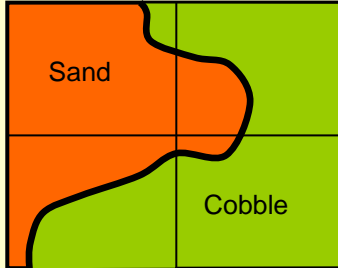
11. The third button on the EcoGIS toolbar allows the user to apply “bin algebra” to summarize how changes in a given variable (e.g. days absent) between to time periods are apportioned to a variable represented by another map layer (e.g. bottom sediment type).



A. One time period is subtracted from another to get the differences between the two.

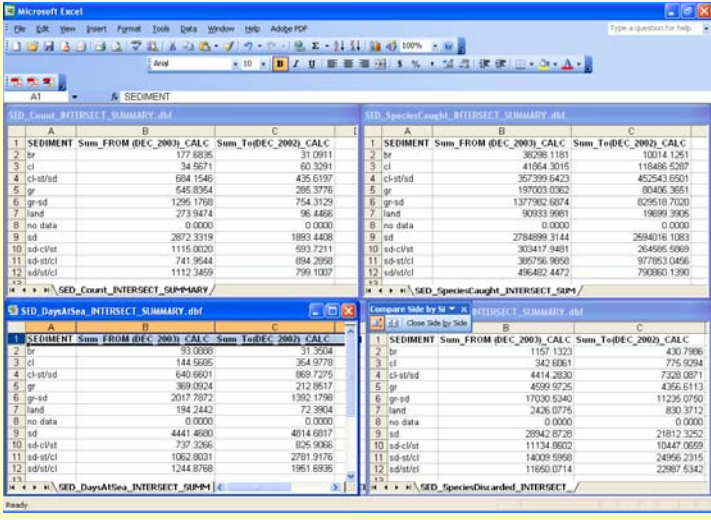


B. The spatial bins are intersected with sediments to determine the percent sediment within each bin.



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.



SEDIMENT	Sum_FROM (DEC_2003)_CALC	Sum_To(DEC_2002)_CALC
1 br	177 8836	31 0911
2 cl	34 8271	60 3291
3 cl-st/sd	684 1546	435 6197
4 gr	645 8364	265 3776
5 gr-sd	1295 1768	754 3129
6 land	273 9474	96 4466
7 no data	0 0000	0 0000
8 sd	2872 3319	1893 4408
9 sd-cl/st	1115 8020	593 7211
10 sd-sd/cl	741 8544	894 2860
11 sd-st/cl	1112 3459	799 1007

SEDIMENT	Sum_FROM (DEC_2003)_CALC	Sum_To(DEC_2002)_CALC
1 br	36298 1181	10074 1251
2 cl	41654 2015	110488 5207
3 cl-st/sd	357399 6423	452543 6501
4 gr	197003 0362	80406 3651
5 gr-sd	1377982 6874	829518 7020
6 land	90333 9961	19859 3605
7 no data	0 0000	0 0000
8 sd	2784899 3144	2584016 1083
9 sd-cl/st	303417 9481	264885 5969
10 sd-sd/cl	395766 9659	977953 0466
11 sd-st/cl	456482 4472	750880 1390

Figure 7. Exploring the relationship between fishing and habitat parameters.

The Fishery Mapper Tool - Lessons learned in its development

With the help of staff at the Councils, Science Centers, and Regional Offices, the project team has learned a great deal about how commercial fishing catch, effort, and economic data are represented, and the capabilities and limitations of those data. Two of the issues encountered include the quality of fishery-dependent data used in the analyses, and the calculation of fishing effort from those data.

Data Quality: Data quality is an issue with all fishery-dependent data. The spatial resolution of fishery-dependent data is frequently too coarse for application to place-based ecosystem science. For example, much of the data held by the Atlantic Coast Cooperative Statistics Program (ACCSP 2006) is georeferenced by large one-degree-square statistical areas. These data may be suitable only for region-wide analyses; however, with additional habitat or fleet coverage data for specific species it may be possible to make these catch locations more precise. This may be a functional area for future tool development.

Data quality issues prompted the team to provide additional ways for users to input data to the Fishery Mapper Tool. Many users commented that their workflows do not utilize data directly from Fisheries Science Center and Regional Office Oracle databases. In most cases these data are extracted from the databases, quality checked, and processed or transformed in other ways prior to analysis. Most users use desktop or server applications such as SAS, Microsoft Access, or Excel to accomplish this. For this reason we added an option for users to input their own data from comma-separated text files to the Fishery Mapper.

Calculation of Fishing Effort: Another challenge in developing the Fishery Mapper was finding agreement among scientists regarding the calculation of fishing effort. At this time there is no universally accepted means of estimating fishing effort – it varies between regions, gear types, species, etc. In our prototype, we have included simple effort calculations (e.g. days absent), and one complex one based on vessel horsepower, gross tonnage, and days absent (Demarest 2002). These two methods have been useful in demonstrating the capabilities of the prototype, but much more work must be done in either establishing a suite of standard effort calculation methodologies, developing a flexible way (such as a formula builder) within the Fishery Mapper for users to define their own ad-hoc methodologies, or simply allowing users the ability to summarize their data on any pre-populated column.

Other Issues: Additional issues identified from feedback by beta-testers of the Fishery Mapper include:

- Coordinate closely with related projects to add value and avoid duplication of efforts.
- The Fishery Mapper Tool must ensure the confidentiality of individual catch and revenue in fishery-dependent data.

- The tools must be able to use a variety of fishery-dependent data sources, including ACCSP, Vessel Trip Report (logbook), and observer data. In addition, users should be able to import their own data sets (shapefile, geodatabase, dbf), and not be hard-coded to prescribed data sources.
- The tools must be able to use Microsoft Access as a local data source, and also allow log-in to Oracle or other server-based database management system (DBMS).
- The tools may have unexpected uses, not related to fisheries management – such as creating a summary grid from benthic sampling points.
- Many users need to filter, analyze, and quality check their data before submitting it to the Fishery Mapper, while others want the ability to do quick exploration of the data directly from Oracle.
- Retain the ability to summarize spatially on regular grids or on any polygon layer.
- Split up the procedural steps, or “componentize” the tool so that a user can, for example, animate a bin/step summary table that was created in a previous run of the tool.
- When using the Observer data set, allow summary on protected species incidental takes along with the observer sets/hauls.
- Integrate oceanographic data into the summaries, such as SST, oxygen, and salinity.
- Enable querying and processing of Vessel Monitoring System (VMS) data for mapping of vessel tracks and filtering of transit vs. fishing time.

The Role of GIS and Tool Development in an Ecosystem Approach to Management

For decades GIS has been a critical tool, with timely and accurate data a critical resource, for implementing NOAA's mission. GIS is used every day across the agency in responding to agency mandates. What is the future role for GIS as the agency evolves to take more of an ecosystem approach to management?

Through the research and development of the EcoGIS project, several themes have emerged:

- Quality data directly from the source will be important for integrated ecosystem science; however, pre-assembled Regional Ecosystem Spatial Databases will be required to support regional collaboration, multi-sector analyses and products such as Integrated Ecosystem Assessments.
- Many tools must be brought to bear to address regional ecosystem issues. There is no one super tool. GIS and custom GIS tools are a small part of the whole; thus, tools must be developed to be interoperable with "scriptable" components.
- There is a clear trend toward more spatial complexity in ecosystem modeling and analysis. Most ecosystem models, however, are not built within a GIS environment. GIS will be used as an important pre-processor, post-processor, and visualization engine for models.

The following sections discuss these themes in more detail.

Access to Quality Data

The development of web-based software and high-speed connections have enabled ready access to a wide spectrum of geospatial data useful for marine ecosystem management. Web mapping services such as ArcIMS enable online users to develop custom maps and run fairly simple analyses, or select and download spatial data to import into desktop applications such as ArcGIS. ArcIMS sites used by marine fisheries managers are generally developed with a regional scope and scale, including the South Atlantic (SAFMC 2007), Gulf of Maine (GOMODP 2004), Chesapeake Bay (CBP 2005), Gulf of Mexico (NCDDC 2007), State of California (UCSB 2007), and Pacific Coast (PSMFC 2008, PaCOOS 2008).

While existing web-based services now provide a wide range of static data, we can expect near real-time integrated oceanographic data to become available through the development of the Integrated Ocean Observing System (IOOS) (Oceans.US 2006). Core variables include water temperature, salinity, sea level, surface currents, and ocean color (NCDDC 2007). This will greatly enhance the feasibility of using advanced tools to develop robust ecosystem models, ecological forecasts, and other capabilities (Murawski and Matlock 2006, Valette-Silver and Scavia 2003).

Regional Ecosystem Spatial Databases

Spatial data provide the basic foundation for ecosystem assessments, but NOAA does not have a consistent, fully documented, and up-to-date spatial database that is common between all member science and management offices within each regional ecosystem.

Currently, most scientists gather their data on demand directly from a variety of distributed online sources or local databases. This eases data management issues for data stewards, and provides the most up-to-date data to users; however, this places an increased burden on users for searching, downloading, and processing data. Also, direct access to distributed data may not be feasible due to the volume of data and slow network speeds, and an “everyone for themselves” approach does not lend itself to consistency and standards for collaborative work. For these reasons, Regional Ecosystem Spatial Databases can provide many benefits

Regional Ecosystem Spatial Databases would develop a common spatial database for each regional ecosystem based on requirements from data collectors and users in the region. Base maps may include bathymetry, coastlines, maritime boundaries, marine managed areas, survey strata, fishery statistical areas, and raster nautical charts in the marine environment, and place names, urban areas, roads and highways, hydrography and hydrologic unit codes, and census geography and statistics for terrestrial areas. As they are available, layers from analyses within Ecoregional Assessments (DeBlieu et al. 2005, Ferdaña et al. 2006), Biogeographic Assessments (NOAA 2003, NOAA/NCCOS 2006), and EFH Amendments (PFMC 2005, NEFMC 2007) could be included if they are developed at the appropriate spatial scale and regional extent. Physical oceanographic and human use data may also be appropriate, but real- or near-real-time data may need to be accessed from the data source.

Each regional database would serve as a master database that could be replicated to field offices within the regional ecosystem. The database could also be accessed via IOOS-compliant web services and formats such as the OpenGIS Consortium Web Map Service (WMS) and Web Feature Service (WFS), and the newly adopted Keyhole Markup Language (KML) format. Some regional data warehousing operations, like the PaCOOS West Coast Habitat Server (PaCOOS 2008) have made strides in this direction.

As the name implies, Regional Ecosystem Spatial Databases would be limited spatially to a particular regional ecosystem. Many issues, however, are cross-regional, national, or global, so where possible, national or global standards should be adopted so regional data sets can be seamlessly combined at a higher level. Such an effort should be coordinated with other regional-national programs such as NOAA's Fisheries Information System (NOAA/NMFS 2008).

With Regional Ecosystem Spatial Databases in place, all collaborators within a regional ecosystem would literally be “on the same map.” This would save time, unify staff from

many offices and areas of expertise, and result in products that are more reliable, consistent, and defensible. A common spatial database would also facilitate the development of standard tools and applications within a regional ecosystem.

Data Confidentiality

The trend towards easy access to all data is not universal, nor should it be. Many of the original fishery-dependent sources that would be likely used with the Fishery Mapper such as Vessel Trip Report (VTR) and Observer data sets include information for individual vessels and their operators that are strictly private (e.g. catch, revenue, identity). While some fisheries managers and scientists have legal access to these data in order to analyze a fishery in detail, the confidentiality of the original data must be maintained to ensure individual privacy. These data may be aggregated to coarser spatial and temporal units and made publicly available – but the resultant information would be less useful for the detailed analyses performed by many fishery scientists. In some cases, confidential fishery-dependent data can be successfully provided via web applications with stringent security precautions, with different levels of aggregation for confidential expert and general public users (ACCSP 2006).

Component Tools

Issues that can benefit from an ecosystem approach to management are as diverse as ecosystems themselves, the drivers of the issues, and the societal objectives of stakeholders. Although there will be some commonality to the solutions to ecosystem issues, each solution will be unique. Thus, there is no one “super-tool” that can be applied in all places and times. In addition, some functions are better suited as desktop applications (e.g. in-depth analysis), whereas others are feasible as web services (data portal and basic mapping).

Instead of a one-size-fits-all solution, tool developers must break their tools into functional components that can be mixed and matched to provide a tailored solution and workflow. The many purposes of these tools may include data management, data processing, conceptual modeling and analysis, scenario generation and visualization, decision support, project management, stakeholder communication and engagement, and monitoring and assessment (NatureServe 2004, 2006)

Components must also be “scriptable,” that is, they must be callable from other tools directly via a common application framework (COM, .Net, J2EE, etc.), or “glued” together using scripting languages such as Python or Perl. With the increasing demands of an ecosystem approach to management and stagnating or shrinking budgets, scientists and managers must be able to do more with less. One way to squeeze out more scientific knowledge and advice is to automate work flows. Scientists’ valuable time should not be spent manually supervising tools; rather, tools must be strung together so they can be automatically (and iteratively) run with a minimum of human intervention. Scientists will need to provide critical decisions and judgment, but rote data entry and manual execution of tools must be eliminated.

In order for tools to be callable by other tools or by a scripting language, they must provide a well-defined interface. An interface defines the properties of a tool that can be set or retrieved, and the functions that can be performed by the tool. At the very minimum, tools must be callable from an operating system command line. Ultimately tools should be developed as software components that can be treated as functional objects either in scripts, or through programming languages that can be compiled into applications (again, with a method of invoking the application via the command line). These components could also be deployed to server environments, which could extend their functionality in web-based applications and data analysis.

Some tools are inherently exploratory in nature and cannot be supplied with predefined inputs. The vast majority of tools, however, can be designed or retrofitted such that they can be automated.

Spatial Fisheries Ecosystem Modeling

Scientists are turning to ecosystem models to help them understand the complexity of ecosystem components and processes. These components and processes may include physical forcing (oceanic currents, nutrient upwelling, temperature), food webs, fishing fleet dynamics, and socioeconomic inputs. GIS platforms such as ArcGIS can be customized to perform some basic modeling procedures such as habitat suitability modeling and comparative scenario analyses (Gill et al. 2001, Battista and Monaco 2004), but they are not the preferred platform for developing state-of-the-art ecosystem models.

In addition to the traditional non-spatial ecosystem models and the basic habitat models that have been historically used in fisheries management, several sophisticated desktop ecosystem modeling platforms have been developed in recent years with a spatially-explicit component (Plagányi 2007). In a fisheries context, Ecopath with Ecosim/Ecospace is the leading ecosystem model in use worldwide (Pauly et al. 2000, Plagányi 2007). Atlantis is another leading model, originally developed in Australia (Fulton et al. 2005, Smith et al. 2007) and now being applied in the U.S. to the California Current Ecosystem (Brand et al. 2007). Plagányi (2007) provides a good and thorough discussion on other models in use today.

Habitat distribution, fish species distribution and movement, physical oceanographic and climatic drivers, fishing fleet dynamics, coastal development, nutrient / sediment / pollution sources, and management measures are just a few of the ecosystem drivers, components and processes that vary spatially. As such, there is an increasing trend toward including greater spatial resolution and detail in models (Plagányi 2007, Babcock et al. 2005).

Plagányi provides a summary of the spatial detail incorporated into ecosystem models. The least detailed, such as earlier virtual population analysis (VPA) models, allow for no spatial variation. Ecopath with Ecosim/Ecospace allows a grid of up 100x100 cells, but

for practical reasons many users limit their extent to 20x20 cells (Walters 2007). At the higher end of the spectrum, Atlantis has been used to model oceanographic processes on 10-km grid cells and other components using 62 horizontal and 7 depth zones (Harvey pers. comm.).

Ecosystem models are extremely large and complex in a software development sense. For example, Atlantis is developed in C++, and contains hundreds of thousands of lines of code. Although these models do not run within a GIS environment *per se*, the trend is towards developing greater spatial resolution in the models. The amount and complexity of spatially-explicit data needed to feed these models will increase, and GIS will be an important tool for processing these data for input into models, and for visualizing outputs from the models.

Version 6 of Ecopath with Ecosim/Ecospace is being redeveloped in the object-oriented .NET programming environment (Christensen et al. 2007). The new version will allow coupling with other models, and feature a modular system of "plug-ins" enabling modelers to add their own modules especially if working in .NET (Christensen pers. comm.). Another key improvement is the ability to import geospatial data such as habitat base layers (Chagaris pers. comm.). Other leading spatially-explicit models such as Atlantis do not yet have this kind of capability (Harvey pers. comm.). This could represent one area where the EcoGIS project can enhance the utility of spatial fisheries ecosystem modeling.

Tools for Integrated Ecosystem Assessments

Fisheries is just one component of the larger scope of ecosystem-based management. True ecosystem-based management requires consideration of how all of the physical, biological, and socio-economic components function and interact. An *Integrated Ecosystem Assessment* (IEA) is a formal synthesis and quantitative analysis of existing information on natural and socio-economic factors in relation to specified ecosystem management objectives (Levin et al. 2008). IEA pilot projects have been launched for the Gulf of Mexico (NCDDC 2007), California Current (Brand et al. 2007, TNC 2007), and Puget Sound (Levin et al. 2009). They are recognized as a necessary component of Ecosystem-Based Management, because they will provide a framework into which ecosystem data can be integrated at a regional scale.

All of the themes discussed above will be important in the development of Integrated Ecosystem Assessments. IEAs will require extensive collaboration both within NOAA and between NOAA and other agencies, and Regional Ecosystem Spatial Databases will be a critical resource. Ecosystem models, like Atlantis, will play a key simulation role and custom GIS tools will be needed for data pre- and post-processing. To automate the process of developing IEAs, GIS and non-GIS tools must be built as interoperable components.

The Fishery Mapper Tool: The Way Forward

Feasible Improvements to the EcoGIS Fishery Mapper

To date, development of the Fishery Mapper beta prototype has focused on fishery catch, effort, and discards from the commercial fishery and from the Northeast trawl surveys. Based on the successes and lessons learned, the project team has identified a set of feasible improvements to the Fishery Mapper - to expand the use of this tool to any point observation data, and to break the tool into generic interoperable components. The results of these improvements would be a suite of very useful software components that will be available as separate buttons and menus in ArcGIS, through a wizard-like interface that will guide a user through a typical query, mapping, and summarization process, and as functions and geoprocessing scripts that can be incorporated in other models and tools.

Key benefits of this approach would include:

- Data profiling and query building capabilities allow application of the Fishery Mapper tool to many contexts.
- The Fishery Mapper tool components could automate the process of spatial and temporal summarization, saving time and allowing biologists to spend more of their time examining more complex ecosystem relationships.
- The animation capabilities of the Fishery Mapper tool give EBM practitioners the ability to visualize changes over time, which is important for understanding the ecosystem dynamics.
- Developing the components as separate ArcGIS geoprocessing tools allows them to be reassembled in a model or script in many ways and integrated with other models or tools to customize workflow.

The EcoGIS Fishery Mapper tool should in the future be broken out into the following reusable software components:

- 1) Query builder: allows the user to choose a local or database table or view, and filter their data on any combination of columns. Criteria may be defined by picking one or more values from a list (for text or number columns), or by defining a value range (for number columns), or a date range (for date columns). Multiple criteria may be combined together with logical operators. The output from this component is a SQL query string that can be used in later operations.
- 2) Make XY query layer: this component submits any SQL query string to a database, creates a recordset, and creates an XY layer from the recordset. Requires that user specify the X and Y columns, a spatial reference, and location of the shapefile or geodatabase feature class.
- 3) Time step definition: Given a range of dates, the user can define a series of continuous or discontinuous time steps for which the variables of interest will be summarized. The output from this component is a local table containing the from- and to-dates for each time step and a step identifier.
- 4) Regular polygon grid generator: creates a shapefile or feature class using two of the following: spatial extent, number of rows and columns, and cell size. Whatever two are provided the other is calculated. A spatial reference must also be provided. The GUI version of this component will allow a user to set an extent by drawing a rectangle on their map extent, and to interactively set a spatial reference.
- 5) Summarization definition: given a table, the user specifies:
 - a. grouping columns: summary statistics will be calculated for each unique combination of values in the grouping columns.
 - b. One or more columns and the statistic to be calculated for each (min, max, sum, average, std. dev, first, last)
 - c. If the table is denormalized (contains redundant data, usually due to joining multiple tables that have a many-to-one relationship), the user can specify key fields within the table. Values for a column will only contribute to its statistics once for each unique value of the key field.

All choices will be stored in an XML file so they can be reused.

- 6) Summary engine: given a table and summarization choices, the summarization engine produces a summary table that contains one row for each unique combination of the group columns, with one field for each requested statistic.

- 7) Data slicer by rows: given a list of columns (the combined value of which provides a “slice” value), a value column (for symbolizing), and a layer file (.lyr) that defines a symbology, this component will create one layer for each slice value with the values in the value column symbolized according to the layer file.
- 8) Data slicer by columns: given a layer, a column or group of columns and a particular value for the combined value of those columns, this tool will select only the features in the layer that meet the given value, then for each column in the bin/step summary table, create a layer for each column using the column’s values for symbolizing. Optional parameters would include a renderer for each new layer (single simple, unique values, graduated color, etc).
- 9) Layer algebra: this component will add, subtract, multiply, or divide the selected columns of two polygon layers. The two layers must have identical polygons and columns. A new shapefile or feature class is created that contains the “from” columns, the “to” columns, and the result columns.
- 10) Polygon value apportionment: given a polygon “source” layer that has at least two columns representing two “states” of a variable (total fish caught for two time steps, for example), a “target” polygon layer, and a list of columns (like the two catch columns described above), and a column in the source layer that will be used for summarizing, this tool will intersect the two polygon layers, determine the percentage each intersected polygon is of the original source polygon, apportion the source values in the given columns to the intersected polygons based on this percent, then total the values based on the given summary column in the target layer (for example, sediment type). The result is a table that shows, for each unique value of sediment for example, the total fish catch from the two time steps. This table can then be joined back into the target polygon layer for symbolization.

Accomplishing these ten improvements would greatly improve the utility of the EcoGIS Fishery Mapper as a stand-alone desktop extension for spatial analysis of fisheries data. Table 2 summarizes the proposed improvements, along with their associated input and output, and suggests how they would enable a user to invoke the Fishery Mapper’s component tools as part of their workflow with other applications. For example, a vector-based polygon layer developed through an analysis using the Fishery Mapper could be converted to a raster grid using ArcGIS’ Spatial Analyst extension, and used in a raster-based procedure such as Habitat Suitability Modeling (Brown et al. 2000, Rubec et al. 1999), or as an input layer for a spatial ecosystem model.

Table 2. Features for further development of the Fishery Mapper

Component:	GUI	Function	Geoprocessing tool	Inputs	Outputs
Query Builder	X			Database connection; table name; user filtering selections	SQL query string
Make XY Query Layer	X	X	X	Database connection; SQL query string; X column name; Y column name; shapefile/feature class name	Shapefile or feature class
Time step definition	X	X	X	Date range start; Date range end; step start date; step end date; step group; seasonal option	Table containing, for each step within date range, step identifier; step start date; step end date
Regular polygon grid generator	X	X	X	Cell size X; Cell size Y; grid extent (min x, maxx, miny, maxy); Number of rows; number of columns; spatial reference; shapefile/feature class name	Shapefile or feature class
Summarization choice	X			SQL query string; user summarization choices (column names, optional key field for each column, statistics for each column)	XML file describing summarization choices
Summary engine	X	X	X	Table; summarization choices XML file name	Summary table
Data slicer by rows	X	X	X	Feature class; slice column name(s); value column name; layer file name	One layer per unique value in the slice column, symbolized on value column according to symbol defined in layer file
Data slicer by columns	X	X	X	Feature class; slice column name(s); slice value; column names; renderers	One layer per specified column, filtered on slice value, symbolized as specified by renderer
Layer algebra	X	X	X	Source polygon layer; target polygon layer; value column name; mathematic operator; shapefile or feature class path/name	Shapefile or feature class
Polygon intersect with value apportionment	X	X	X	Source polygon layer; source column names; target polygon layer; target layer summary column name; shapefile or feature class path/name	Table with source column values totaled on each unique value of the target summary column

Example Scenarios

Three additional scenarios where the Fishery Mapper could be used in ecosystem-based fisheries management include fishing effort displacement, oceanography and fishery interactions, and species distribution and abundance mapping.

Fishing effort displacement: An analyst is testing an hypothesis that commercial fishing effort has been displaced shoreward due to regulatory or environmental changes. Using commercial trawl observer data detailing catch and effort of seven primary groundfish species, the analyst creates maps showing total catch and effort on a 10-minute grid for a period of five years before and five years after the “event” in question. The analyst then uses “layer algebra” to subtract the “after” grid from the “before” grid to see where there have been gains and losses in catch and effort. Using out-of-the-box ArcGIS tools, she then calculates the distance from each grid cell’s centroid to the shoreline, and looks for correlations between catch and effort and distance to shore. If it appears that fishing effort has been forced shoreward, then she may begin to look at interactions this shifting fleet has with habitats or migrating animals.

Oceanography and fishery interactions: A research vessel conducting a multi-year bird survey also has observers on board recording the type of marine debris (wood, metal, plastic) encountered along each transect. After the survey, an oceanographer uses the Fishery Mapper to filter out those observations of debris smaller than 40cm, and then calculate the total monthly debris count (normalized by observation time) for each of 200 irregular survey strata polygons. He then uses the Fishery Mapper to create a separate map layer for each month, and animates the layers to visualize changes over time. The animation reveals polygons where consistently high debris counts per unit effort are observed. The analyst uses this information to plan additional surveys to document the marine communities that are aggregated around these marine debris (and potentially susceptible to by-catch in this area).

Species abundance and distribution mapping: Biologists use fishery-independent survey data (location of survey hauls, catch, and detailed biologic measurements of samples) to determine the distribution (on a 15-minute grid) of three different life stages (larval, juvenile, adult) of dozens of species over a 20-year period. In a Python script, the biologists use the EcoGIS query builder and summarization choice geoprocessing tools to connect to their database, choose a table or view, and define levels of aggregation and statistics to generate. The resulting data are then fed into the summarization engine component along with a 15-minute polygon grid shapefile. This process is repeated within the Python script for each of the dozens of species the biologists need to analyze. The resulting maps are then used as source materials for defining Essential Fish Habitat for each species.

Web-based versus Desktop Tool Development

The answer to the question of web-based versus desktop tool development depends on the primary users' computing environment, the purpose of the tool, and how the tool fits into the scientific/management workflow. As background, there are substantial differences in desktop versus server GIS products.

Desktop GIS packages are typically powerful, with many features. Users have the flexibility of using data from files and databases (local, LAN file servers, or remote servers), or web services. Users have complete control over their user experience, and can even customize the user interface and write automation macros.

The quality of cartographic display with a desktop GIS is very good. A rich suite of point, line, and polygon symbols are included along with advanced methods for labeling and exerting "cartographic license" on output products. We expect that scientists will continue to prefer desktop GIS as their platform-of-choice because it offers the most flexibility, analytical power, autonomy, and output capabilities. The desktop is also where they perform much of their data analysis with non-spatial analytical software such as Excel, MatLab, SAS, etc.

Server GIS, on the other hand, is intended to serve up large quantities and/or a large variety of geospatial data to a wide audience with limited GIS functionality. Users typically use web browsers to view and explore these data, and perform simple operations like turning layers on and off, navigating the map (pan, zoom in, zoom out), measuring distances, identifying features (clicking on map features and displaying their attributes), creating buffers, and selecting features based on their proximity to others. Cartographic symbolization is minimized to increase performance.

Server GIS are available with advanced geoprocessing, but only the building blocks are provided. It is up to the host agency to build the applications that their users require, which are usually focused on specific tasks (for example, logging and displaying marine mammal stranding reports). Server GIS is not suitable for rigorous scientific inquiry and experiments.

Server GIS also requires expensive infrastructure to implement. Typically one needs a web server, a database server, and a map server, although in small operations these can be the same machine. IT staff are also needed to manage these servers and their environments, and to set up and maintain the GIS software and databases. In contrast, a standard PC and the GIS software is all one needs to get started on the desktop.

Maintenance of server-based applications is much simpler than desktop applications – because users access a server-based application through web browsers, changes to the application on the server are immediately available to

all users. Changes to desktop applications require that new program executables or extensions be downloaded to each user's computer, which is logistically more difficult and is fraught with a host of configuration issues. While server applications hold the advantage in this regard, a desktop GIS's ability to deliver more robust and flexible analytical capabilities outweighs this advantage.

With these differences in mind, desktop GIS is the preferred platform for the development of tools that can be applied to ecosystem science. Although web-based services provide a great means of providing spatial data, desktop GIS provides the most opportunities for rigorous spatial analysis.

The fact that most spatial analysis occurs on desktops is in conflict in some ways with the way that most NOAA offices store their data. More and more, mission-critical data are being stored in relational databases such as Oracle. Many users do basic query and statistical analysis on servers, then download the results for spatial processing and analysis on the desktop. In the future, in situations where the server infrastructure can support it, geoprocessing capabilities can be moved to the server to be close to the data, while the user interface, visualization, and output capabilities would remain on the desktop. Server-based geoprocessing works well when all data and processing is centralized, but the matter is complicated when dealing with distributed data. Geoprocessing is very processor and data-intense, and trying to perform geoprocessing on remote datasets will likely not yield acceptable performance. Data replication may provide one solution to the problem of distributed data, but again, this involves more complexity and expense. This type of infrastructure has potential in the future, but until then desktop GIS will continue to be the platform of choice for tool deployment.

Based on the discussion above, Table 3 provides a summary of some of the considerations in the question of further development as a desktop-based ArcGIS extension versus a web-based application such as ArcGIS Server. Table 4 provides *very rough* estimates for some of the associated costs. In each case, the largest cost is staff time (salary, benefits, and overhead) of the programmer/developer, and we expect that the required programming effort would be greater in the ArcGIS Server environment. In addition, both hardware and software costs are expected to be higher for development as a web-based application. Actual software costs cannot be accurately estimated, as they depend on the licensing agreements the host agency has with software firms such as Microsoft, ESRI, and Oracle.

Table 3. Considerations in the further development of Fishery Mapper as desktop (ArcGIS) vs. web (ArcGIS Server) application.

	ArcGIS (desktop-based)	ArcGIS Server (web-based)
Data access	Local, intranet, or web	Local, intranet, or web
Staff support	Developer	Developer + Network Admin
Hardware - host	Standard PC for development	Fast and powerful server(s)
Hardware - user	Standard PC	Standard PC
GIS software – host	ArcGIS	ArcGIS Server
GIS software - user	ArcGIS	None required
DBMS software	Microsoft Access (user)	Oracle, SQL, or other (host)
Cost	Moderate	High

Table 4. Comparison of rough-estimated costs to develop Fishery Mapper as desktop (ArcGIS) vs. web-based (ArcGIS Server) application.

	ArcGIS (desktop application)	ArcGIS Server (web-based application)
Staff - developer	12 months – est. \$120K	18 months – est. \$180K
Staff – other	Staff Support – est. \$10K	Network Admin. – est. \$20K
Hardware	Standard PC – est. \$3K	Powerful server(s) – est. \$10K
GIS Software	ArcGIS – est. \$3K/yr	ArcGIS Server – est. \$30K/yr
DBMS Software	Microsoft Access – est. \$1K	Oracle or SQL – est. \$10K/yr
Total	\$137K	\$240K

Other Tools for Ecosystem Approaches to Fisheries Management

Given that there is no single method, tool, or approach to address all of the questions inherent in Ecosystem-based fisheries management, it is helpful to mention some of the tools that are available.

Fishery Analyst (<http://www.mappamondogis.com>) Mappamondo GIS's Fishery Analyst is a commercially-available extension of ArcGIS. Its main purpose is similar to the EcoGIS Tools (mapping and analyzing spatial and temporal distributions of marine observations), but the implementation methods of the two tools are significantly different. Fishery Analyst is a graphical user interface (GUI) application with automation capabilities whereas the proposed EcoGIS Tools will be developed as generic geoprocessing tools.

Others: There are many other GIS tools which may be useful in Ecosystem Approaches to Fisheries Management, as described by NatureServe (2004), NOAA's MPA Center (2004), and in other summary documents. NatureServe's *Ecosystem-Based Management Tools Network* (NatureServe 2006) maintains an online directory of over 150 tools that may be applicable – including off-the-shelf ArcGIS extensions, open-source data collection and processing tools, ecosystem and hydrodynamic models, and decision support tools. Several of these are mentioned in this report, but rather than try to summarize all of them here, we encourage an interested reader to browse the EBM Tools Network website at <http://www.ebmtools.org/> .

Summary of Recommendations

Based on our experience in developing the EcoGIS Fishery Mapper Tool, and from considering the needs of users and of parallel tool development efforts, we offer several concise recommendations:

- Further develop the EcoGIS Fishery Mapper as a desktop-based tool to enhance the analytic capabilities of fishery managers, and to function as a set of component tools that can function in multi-application workflows. Since ESRI's ArcGIS is still the platform-of-choice for off-the-shelf GIS software, this tool can be further developed as an extension for current and future versions of ArcGIS . Details of the proposed improvements are provided in this report and summarized in Table 2.
- Develop an additional desktop tool for assessing fishery-habitat interaction using confidential Vessel Monitoring System (VMS) data. Both the data sources and workflows needed for this analysis are different from those in the Fishery Mapper Tool, so this could either be developed as a stand-alone tool, or a separate module within the Fishery Mapper Tool.
- Develop a system of replicated regional ecosystem spatial databases, and provide public access to these data through web-based regional data portals. These portals would provide high-quality data sets for many types of analyses, including Integrated Ecosystem Assessments. Although web-based mapping applications such as ArcIMS do not yet allow sophisticated geospatial analyses, they do provide a means of extending basic mapping capabilities and data download services to many users. At the same time, continue to explore the feasibility of developing web-based applications for spatial analysis using an advanced platform such as ArcGIS Server.
- Foster the development of tools – both desktop and web-based – that are interoperable with the input and output of platforms for spatial ecosystem modeling and analysis such as Atlantis and Ecopath with Ecosim/Ecospace. The spatial capabilities of these ecosystem modeling platforms continue to advance, and specialized GIS tools can provide a means for pre- and post-processing, and display of results.
- Continue to develop IOOS and regional Ocean Observing Systems to provide access to real-time oceanographic data for spatial modeling and forecasting, and ensure that commonly used desktop applications and custom tools can readily use these data.
- Encourage developers to engage with groups such as NOAA's GIS Committees, NatureServe's Ecosystem Based Management (EBM) Tools Network, and professional organizations and conferences to survey the needs of users, extend results and promote use, give-and-take feedback and provide value-added, and avoid duplication of efforts.

Literature Cited

- ACCSP. 2006. ACCSP Data System Users Guide. Atlantic Coastal Cooperative Statistics Program, Washington, DC. 52 p. Available at <http://www.accsp.org/DOCUMENTS/trainingmanual.PDF>.
- Babcock, E.A., E.K. Pikitch, M.K. McAllister, P. Apostolaki, and C. Santora. 2005. A perspective on the use of spatialized indicators for ecosystem-based fishery management through spatial zoning. *ICES J. Mar. Sci.* 62:469-476.
- Battista, T.A., and M.E. Monaco. 2004. Geographic Information System Applications in Coastal Marine Fisheries. Pp. 189-208 in W.L. Fisher and F.J. Rahal (eds.). *Geographic Information Systems in Fisheries*. American Fisheries Society, Bethesda, MD.
- Brand, E.J., I.C. Kaplan, C.J. Harvey, P.S. Levin, E.A. Fulton, A.J. Hermann, and J.C. Field. 2007. A spatially explicit ecosystem model of the California Current's food web and oceanography. NOAA Tech. Memo. NMFS-NWFSC-84. 145 pp.
- Busch, W.D.N., B.L. Brown, and G.F. Mayer (eds). 2003. *Strategic Guidance for Implementing an Ecosystem-based Approach to Fisheries Management*. Prepared for the Marine Fisheries Advisory Committee by the Ecosystem Approach Task Force. NOAA/NMFS, Silver Spring, MD. 62 pp.
- CBP. 2008. Chesapeake Bay Program – Data Hub. U.S. EPA Chesapeake Bay Program. <http://www.chesapeakebay.net/dataandtools.aspx> .
- Chagaris, D. Personal communication, February 2008. Florida Fish and Wildlife Research Institute, St. Petersburg, FL.
- Christensen, V. Personal communication, March 2008. Univ. British Columbia, Fisheries Centre, Vancouver BC.
- Christensen, V., C.J. Walters, and D. Pauly. 2005. *Ecopath with Ecosim: A User's Guide*. Fisheries Centre, Univ. British Columbia, Vancouver. November 2005 Edition. 154 pp. (available online at www.ecopath.org) .
- Christensen, V., J. Buszowski, S. Lai, and J. Steenbeek. 2007. *Ecopath with Ecosim 6 – overview, linking, and coupling*. Presentation at *Biogeochemical Processes and Fish Dynamics in Food Web Models*. International Centre for Theoretical Physics, Trieste, Italy, Nov. 26-27, 2007.
- DeBlieu, J.S., M.W. Beck, D. Dorfman, and P. Ertel. 2005. *Conservation in the Carolinian Ecoregion – An Ecoregional Assessment*. The Nature Conservancy, Arlington, VA.
- Demarest, C. 2002. *Tradeable fishing effort in the New England groundfish fishery*. M.A. Thesis, Brown Univ., Center for Environmental Studies.
- Ferdaña, Z., M.W. Beck, and D. Dorfman (eds.). 2006. *Improving Methods for Marine Regional Assessments: Examples from the Pacific Northwest*. The Nature Conservancy, Arlington, VA.

Fulton, E.A., A.D.M. Smith, and A.E. Punt. 2005. Which ecological indicators can robustly detect effects of fishing? *ICES Journal of Marine Science* 62:540-551.

Garcia, S.M., A. Zerbi, C. Aliaume, T. Do Chi, and G. Lasserre. 2003. The ecosystem approach to fisheries – Issues, terminology, principles, institutional foundations, implementation and outlook. FAO Fisheries Technical Paper No. 443. 71 pp.

Gill, T.A., M.E. Monaco, S.K. Brown, and S.P. Orlando. 2001. Three GIS tools for assessing or predicting distributions of species, habitats, and impacts: CORA, HSM, and CA&DS. Pp. 404-415 in Nishida, T. (ed.), Proc. First Intl. Symp. on GIS in Fishery Science.

GIS Solutions, Inc. 2005. Gulf of Mexico Essential Fish Habitat Geographic Information System (GIS). Folio + 3 DVDs. GIS Solutions, Inc., St. Petersburg, FL.

GOMODP. 2004. Gulf of Maine Ocean Data Partnership.
<http://research.usm.maine.edu/gulfofmaine-census/data-mapping/data-and-mapping-portal/>

Levin, P.S., M.J. Fogarty, G.C. Matlock, and M. Ernst. 2008. Integrated Ecosystem Assessments. NOAA Tech. Memo. NMFS-NWFSC-92, 20 p. Available at
http://www.nwfsc.noaa.gov/assets/25/6801_07302008_144647 IEA_TM92Final.pdf

Levin, P.S., M.J. Fogarty, S.A. Murawski, and D. Fluharty. 2009. Integrated Ecosystem Assessments: Developing the Scientific Basis for Ecosystem-Based Management of the Ocean. *PLoS Biology* 7(1):e1000014. Available at
http://biology.plosjournals.org/archive/1545-7885/7/1/pdf/10.1371_journal.pbio.1000014-L.pdf

McClintock, W., personal communication. 2007. Univ. California – Santa Barbara, Marine Science Institute.

Monaco, M.E., M.S. Kendall, J.L. Higgins, C.E. Alexander, and M.S. Tartt. 2005. Biogeographic Assessments of NOAA National Marine Sanctuaries: The Integration of Ecology and GIS to Aid in Marine Management Boundary Delineation and Assessment. Pp. 2-12 (Chapter 1) in Wright, D.J., and A.J. Scholz (eds.), *Place Matters: Geospatial Tools for Marine Science, Conservation, and Management in the Pacific Northwest*. Oregon St. Univ Press, Corvallis OR.

MPA Center. 2004. An inventory of GIS-Based Decision-Support Tools for MPAs. NOAA National Marine Protected Areas Center, Silver Spring, MD.
http://www.mpa.gov/pdf/publications/FINAL_Decision%20Sup%20Rpt.pdf .

Murawski, S. 2005. Strategies for Incorporating Ecosystem Considerations in Fisheries Management. *In* Witherell, D. (ed). *Managing Our Nation's Fisheries II: Focus on the Future*. Proceedings of a conference held in Washington, DC, March 24-26, 2005. Available at <http://www.managingfisheries.org> .

Murawski, S.A., and G.C. Matlock. 2006. Ecosystem Science Capabilities Required to Support NOAA's Mission in the Year 2020. NOAA Tech. Memo. NMFS-F/SPO-74.

NatureServe. 2004. Tools for Coastal-Marine Ecosystem-Based Management – A survey of utility, sustainability, and opportunities for further development. Final Report by NatureServe for the David and Lucile Packard Foundation. NatureServe, Arlington VA. 59 pp. Available at

http://www.natureserve.org/prodServices/ebm/pdf/NatureServe_EBM_Tools_Survey.pdf .

NatureServe. 2006. Ecosystem-Based Management Tools Network.

<http://www.ebmtools.org/> .

NEFMC. 2007. Essential Fish Habitat (EFH) Omnibus Amendment. Draft Supplemental Environmental Impact Statement (DSEIS) - Phase 1. New England Fishery Management Council, Newburyport, MA. Available at <http://nefmc.org/habitat/index.html> .

NMFS/NEFSC. 2005. Unpublished data - Northeast Vessel Trip Report, Fishery Observer, and Fishery-Independent Trawl Survey. NOAA/NMFS Northeast Fisheries Science Center, Woods Hole, MA.

NOAA. 2003. A Biogeographic Assessment off North/Central California: To support the Joint Management Plan Review for Cordell Bank, Gulf of the Farallones, and Monterey Bay National Marine Sanctuaries: Phase I – Marine Fishes, Birds, and Mammals (CD-ROM w/PDF report). NOAA/NOS, Silver Spring, MD. 145 pp.

NOAA. 2004. Workshop Summary – GIS Tools Supporting Ecosystem Approaches to Management, Charleston SC, September 8-10, 2004. NOAA Fisheries and National Ocean Service, Silver Spring, MD. Available at

<http://www.st.nmfs.gov/ecogis/Workshop2004/> .

NOAA. 2006. NOAA GIS Committee.

http://www.cio.noaa.gov/IT_Groups/noaa_cio_GIS_Committee.html

NOAA. 2007. EcoGIS Fishery Mapper – Beta 1, February 2007. Users Guide, Release Notes, and Testing Introduction. NOAA NMFS and NOS, Silver Spring, MD.

NOAA/CBO. 2006. Fisheries Ecosystem Planning for Chesapeake Bay. NOAA Chesapeake Bay Office. American Fisheries Society, Trends in Fisheries Science and Management 3, Bethesda, MD. 450 pp.

NOAA/NCDDC. 2007. Regional Ecosystems Data Portal. NOAA's National Coastal Data Development Center <http://ecowatch.ncddc.noaa.gov/search/catalog>

NOAA / NCCOS. 2006. An Ecological Characterization of the Stellwagen Bank National Marine Sanctuary Region: Oceanographic, Biogeographic, and Contaminants Assessment. NOAA Tech. Memo. NOS NCCOS 45. 356 pp.

NOAA/NMFS. 1999. Ecosystem-Based Fishery Management – A Report to Congress by the Ecosystem Principles Advisory Board. NOAA National Marine Fisheries Service, Silver Spring, MD. 54 pp. Available at <http://www.nmfs.noaa.gov/sfa/EPAPrpt.pdf> .

NOAA/NMFS. 2004. Evaluating bycatch: a national approach to standardized bycatch monitoring programs. NOAA Tech. Memo. NMFS-F/SPO-66, 108 pp. Available at http://www.nmfs.noaa.gov/by_catch/SPO_final_rev_12204.pdf

- NOAA/NMFS. 2006. NMFS GIS Committee. <http://www.nmfs.noaa.gov/gis/index.htm>
- NOAA/NMFS. 2007. Magnuson-Stevens Fishery Conservation and Management Act – Public Law 94-265, as amended through January 12, 2007.
- NOAA/NMFS. 2008. Fisheries Information System – National Vision, Joint Decisions. NOAA/NMFS Office of Science and Technology, Silver Spring MD. <http://www.st.nmfs.noaa.gov/fis/>
- NOAA/NOS. 2007. NOAA's National Ocean Service – Data Explorer: <http://oceanservice.noaa.gov/dataexplorer/welcome.html> .
- Ocean.US. 2006. The first U.S. Integrated Ocean Observing System (IOOS) Development Plan. The National Office for Integrated and Sustained Ocean Observations. Ocean.US Pub. No. 9.
- Pauly, D., V. Christensen, and C. Walters. 2000. Ecopath, Ecosim, and Ecospace as tools for evaluating ecosystem impacts of fisheries. ICES Journal of Marine Science 57:697-706.
- PaCOOS. 2008. PaCOOS West Coast Habitat Server – Map Viewer, Data Portal, and Fish Viewer. Pacific Coast Ocean Observing System - NOAA/NMFS Northwest Fisheries Science Center, Oregon State University, and Pacific States Marine Fisheries Commission. <http://pacoos.coas.oregonstate.edu/index.htm> .
- PFMC. 2005. Amendment 19 to the Pacific Coast Groundfish Fishery Management Plan. Essential Fish Habitat Designation and Minimization of Adverse Impacts EIS. Pacific Fishery Management Council, Portland, OR. Available at <http://www.pcouncil.org/groundfish/gffmp/gfa19.html> .
- Pikitch, E.K., et al. 2004. Ecosystem-Based Fishery Management. Science 305:346-347.
- Plagányi, E.E. 2007. Models for an ecosystem approach to fisheries. FAO Fisheries Technical Paper No. 477. 108 pp.
- Poppe, L.J., and C.F. Polloni. 2000. USGS East-Coast Sediment Analysis: Procedures, Database, and Georeferenced Displays. U.S. Geological Survey Open-File Report 00-358 (CD-ROM).
- PSMFC (Pacific States Marine Fisheries Commission). 2008. Pacific Coast Marine Habitat Program. <http://marinehabitat.psmfc.org/interactive-maps.html>.
- Reid, J.M., J.A. Reid, C.J. Jenkins, M.E. Hastings, S.J. Williams, and L.J. Poppe. 2005. usSEABED: Atlantic Coast Offshore Surficial Sediment Data Release, version 1.0. U.S. Geological Survey Data Series 118 (CD-ROM).
- SAFMC. 2004. Action Plan – Ecosystem-based management: Evolution from the Habitat Plan to a Fishery Ecosystem Plan. SAFMC, Charleston, SC. Available at http://www.safmc.net/Portals/0/FEP%2012_04.pdf .

SAFMC. 2007. Geographic Information Systems
<http://www.safmc.net/Default.aspx?tabid=62> .

Sheridan, P., and P. Caldwell. 2002. Compilation of Data Sets Relevant to the Identification of Essential Fish Habitat on the Gulf of Mexico Continental Shelf and for the Estimation of Shrimp Trawling Gear on Habitat. NOAA Tech. Memo. NMFS-SEFSC-483.

Smith, A.D.M., E.J. Fulton, A.J. Hobday, D.C. Smith, and P. Shoulder. 2007. Scientific tools to support the practical implementation of ecosystem-based fisheries management. ICES Journal of Marine Science 64:633-639.

TNC. 2007. Advancing Ecosystem-Based Management: a decision support toolkit for marine managers. The Nature Conservancy. CD-ROM and website
<http://www.marineebm.org/> .

UCSB. 2007. MarineMap Case Study – California Marine Life Protection Act Initiative. Univ. California – Santa Barbara. <http://marinemap.org/index.html> ,
<http://www.dfg.ca.gov/MRD/mlpa/> .

Valette-Silver, N.J., and D. Scavia. 2003. Ecological Forecasting: New Tools for Coastal Ecosystem Management. NOAA Tech. Memo. NOS NCCOS 1. 116 pp.

Walters, C. 2007. Ecopath with Ecosim/Ecospace – User's Guide, Version 6. Fisheries Centre, Univ. British Columbia, Vancouver BC, Canada.

Appendix A – Project Team and Steering Committee

Project Team

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Steering Committee

The EcoGIS Steering Committee was formed in January 2005 and is co-chaired by **Steve Murawski** of the NMFS Office of Science and Technology and **Mark Monaco** of the NOS Center for Coastal Monitoring and Assessment.

Members of the committee are:

Steve Atran, Gulf of Mexico Fishery Management Council
Steve Capps, NMFS Northwest Regional Office
Chad Demarest, New England Fishery Management Council
Tom Hoff, Mid-Atlantic Fishery Management Council
Tony Lavoie, NOAA Coastal Services Center
Tom Noji, NMFS Howard Marine Sciences Lab
Josh Nowlis, NMFS Southeast Fisheries Science Center
Roger Pugliese, South Atlantic Fishery Management Council

The EcoGIS Steering Committee provides the following guidance to the project:

- advises project staff on priority management and science issues for the near-term and future years
- facilitates on-site visits from NMFS and NOS staff to document needs and establish data sharing contacts
- reviews documents that define the science and management issues that can be addressed by GIS tools
- coordinates activities of the EcoGIS project with GIS activities in partner organizations

Appendix B - Meetings and Conferences

in reverse-chronological order, 2004-2007.

Coastal Zone '07, Portland, OR, July 24, 2007. Hosted by NOAA Coastal Services Center. Poster presentation by Moe Nelson, and informal demonstration of prototype tools, coordination with related efforts. Extended abstract published in proceedings, available online at <http://www.csc.noaa.gov/cz/index.html> .

The Coastal Manager's Toolkit for Ecosystem-Based Management – Training Session, July 21, 2007, at Coastal Zone '07, Portland, OR, hosted by NatureServe's EBM Tools Network. Live demonstration of EcoGIS Fishery Mapper by Moe Nelson. Primary contacts: Sarah Carr, Dan Dorfman.

Conference call with beta-testers, May 14, 2007, to get feedback on Fishery Mapper tool. Contacts: Brian Gervalis, Chris Orphanides, Brian Hooker, Dave Chevrier, Steve Fromm, Tobey Curtis.

Tenth Annual Chesapeake Bay Fisheries Science Symposium, Laurel MD, April 10-11, 2007. Poster presentation by Moe Nelson and coordination with related efforts.

Coastal GeoTools, Myrtle Beach, SC, March 6, 2007. Presentation by Moe Nelson and live demonstration of Fishery Mapper by Eric Finnen. Hosted by NOAA Coastal Services Center. Abstract published in proceedings, available online at <http://www.csc.noaa.gov/geotools/proceedings.htm> .

ESRI International Users Conference, San Diego CA, August 7-11, 2006. Presentation of paper by Tim Haverland, and live demonstration of Fishery Mapper Tool by Eric Finnen. Abstract and paper published in proceedings, available online at http://gis.esri.com/library/userconf/proc06/papers/papers/pap_1918.pdf .

EcoGIS Steering Committee Conference Call, Silver Spring MD, July 18, 2006. Review project results, demonstrate prototype tools, define the way forward. Entire project team and steering committee.

Mid-Atlantic Fishery Management Council, Dover DE, May 31, 2006. Demonstrate Fishery Mapper Tool, review and discuss Mid-Atlantic issues. Primary contacts: Tom Hoff, Jessica Coakley, Jim Armstrong.

NMFS Northeast Regional Office, Gloucester MA, April 12, 2006. Demonstrate Fishery Mapper Tool, review and discuss. Primary contacts: Brian Hooker, Ellen Keane, Bonnie Van Pelt, Peter Kelliher, Jay Hermsen, Tobey Curtis.

Conference on GIS in Fisheries, Boston MA, April 11, 2006. Hosted by MIT Sea Grant and NMFS Northeast Fisheries Science Center. Poster presentation and

informal demonstration of prototype tools, coordination with related efforts. Proceedings and abstracts available at <http://web.mit.edu/seagrant/GIS06/> .

Workshop on Tools for Ecosystem-Based Management, hosted by NatureServe, Arlington VA, March 23-24, 2006. Launch national network NGOs and resource managers developing GIS-based tools with applications to Ecosystem-Based Management (EBM). Primary contacts: Sarah Carr, Pat Halpin.

ArcIMS Workshop hosted by South Atlantic Fishery Management Council, hosted by Florida FWRI, St. Petersburg FL, March 7-8, 2006. Provide peer-review of SAFMC's ArcIMS project, and determine how to coordinate EcoGIS project for mutual benefit. Primary contacts: Roger Pugliese, Myra Brower, Tina Oudouj, Henry Norris.

South Atlantic Fishery Management Council - Ecosystems Committee, Jekyll Island GA, February 28, 2006. Presentation of project plans and progress by Moe Nelson, and demonstration of prototype Fishery Mapper Tool by Eric Finnen. Primary contact: Roger Pugliese.

New England Fishery Management Council, Newburyport MA, February 14, 2006. Demonstration of Fishery Mapper Tool for NEFMC and NMFS NERO staff, review and discussion. Primary contacts: Andy Applegate, Chad Demarest, David Stevenson, Brian Hooker, Ellen Keane.

Seminar on GIS Applied to Ecosystem Science. NMFS Northeast Fisheries Science Center, Woods Hole MA, February 13, 2006. Demonstration of Fishery Mapper Tool, critique, and discussion. Primary contacts: Joan Palmer, Dave Chevrier, Chris Orphanides, Mike Fogarty.

NMFS Office of Science and Technology, Silver Spring MD, January 30, 2006. In-house seminar to demonstrate project plans and progress, Fishery Mapper Tool, followed by review and discussion.

ESRI Federal Users Conference, Washington DC, January 31 - February 2, 2006. Oral presentation by Tim Haverland on EcoGIS and other NOAA GIS-related projects that support ecosystem-based fishery management.

Human Uses of Marine Environment Workshop, hosted by NOAA's MPA Center, Monterey CA, November 30 – December 1, 2005. Oral presentation by Moe Nelson of prototype tools to map fishing effort. Primary contact: Bryan Oles. Workshop summary available at <http://www.mpa.gov/pdf/helpful-resources/hupi-workshopreport-fdraft.pdf> .

Gulf of Mexico Fishery Management Council (Ecosystems Committee), Tampa FL, June 9-10, 2005. Oral presentation of project plans and progress, review of GMFMC's Ecosystem Pilot Project. Primary Contacts: Steve Atran, Joe Powers.

Video Conference with NMFS NEFSC, May 12, 2005. Review of project progress to date, plans for collaboration with NEFSC. Key contacts: entire project team, Joan Palmer, Dave Chevrier, Chad Demarest, Chad Keith, Heather Haas, Chris Rilling.

Coastal GeoTools Conference, Myrtle Beach SC, March 8-10, 2005. Hosted by NOAA's Coastal Services Center. Oral presentation of EcoGIS progress to date by Ken Buja.

EcoGIS Steering Committee Conference Call, February 10, 2005. Review project plan and website, refine scope and objectives. Entire project team and steering committee.

Mid-Atlantic Fishery Management Council – Ecosystems Committee, Wilmington DE, December 2004. Presentation on *Ecosystem Management and the role of GIS* by Ken Buja. Primary contact: Tom Hoff.

NMFS Howard Lab, Sandy Hook NJ, November 16, 2004. Review of project workplan and data sources. Primary contacts: Tom Noji, Steve Fromm, SueEllen Fromm.

Workshop on GIS Tools Supporting Ecosystem Approaches to Management, hosted by NOAA's Coastal Services Center, Charleston SC, September 8-10, 2004. Proceedings available at <http://www.st.nmfs.gov/ecogis/Workshop2004/> .

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