An Inventory of GIS-Based Decision-Support Tools for MPAs

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NATIONAL Marine Protected Areas CENTER

An Inventory of GIS-Based Decision-Support Tools for MPAs

Prepared by the National Marine Protected Areas Center
in cooperation with the
National Oceanic and Atmospheric Administration
Coastal Services Center

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NATIONAL MPA CENTER BACKGROUND

Executive Order No. 13158 on Marine Protected Areas (MPAs)

Signed in May of 2000, Executive Order No. 13158 calls upon federal, state, local, and tribal governments and the private sector to work together to strengthen the protection of U.S. ocean and coastal resources. The order directs the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA), working in partnership with the Department of the Interior (DOI), to establish a National Marine Protected Areas Center to provide the science, tools, and strategies to help build a national system of MPAs. Located in Silver Spring, Maryland, the National MPA Center will help build and support partnerships, fostering cooperation among and providing assistance to a range of governmental and nongovernmental entities working to develop, evaluate, and sustain a national MPA system.

In addition to the National MPA Center, two supporting institutes were formed to broaden both the technical expertise and the geographic representation of MPA efforts. The National MPA Center's Science Institute is located in Santa Cruz, California, and the National MPA Center's Training and Technical Assistance Institute (TTAI) is located at the NOAA Coastal Services Center in Charleston, South Carolina.

The TTAI provides resource managers with skills, products, and processes related to MPAs. Assistance may take the form of a customized technology tool, issue-based education modules, training in process skills (e.g., facilitation), or training in the use and application of geographic information systems (GIS) and remote sensing technologies. The institute provides direct training and technical assistance and operates as a referral service to connect managers and other stakeholders with a network of organizations and individuals that offer MPA-related assistance and expertise. Given the limited resources within many MPA programs, the TTAI seeks to develop products and services that can reduce duplicated effort and increase efficiencies across a broad array of sites.

DECISION-SUPPORT TOOL INVENTORY

Introduction

Many decision-support tools have been created over the past few years to address a variety of issues both within and around marine protected areas (MPAs). Because these tools are often site-specific or designed for a particular audience, secondary user groups may not be aware of their existence. This can lead to duplicated efforts to create similar products. In addition, some of these tools require only minor modifications to become useful to another group or for another purpose. This report is intended to document and publicize existing decision-support tools in order to raise their visibility within the MPA community, minimize duplicative efforts, and increase the use of decision-support tools.

For the purposes of this report, the term "decision-support tool" refers to an interactive, computer-based system that manipulates and presents spatial data to support informed, objective, and, in some cases, participatory decision making. Typically, these tools are used to evaluate a suite of proposed management actions or outcomes based on assigned criteria. This inventory is not intended to be a comprehensive list of geographic information system (GIS) applications to MPAs. Rather, it will focus specifically on customized GIS-based decision support tools that could be applied by marine protected areas (MPA) staff to support siting, zoning, monitoring, or MPA-related analyses (e.g., biodiversity or habitat suitability analyses). In addition, this inventory should be considered a living document that will be updated regularly as new tools and techniques become available.

Criteria for Inclusion

The goal of this report is to identify decision-support tools with a high utility for MPA processes; specifically, it identifies those that are GIS-based, MPA-related (i.e., those that support siting, zoning, monitoring, etc.), publicly available (i.e., low or no cost), and participatory or interactive. As a result, these four primary criteria were used to determine whether a tool was appropriate for inclusion. Certain tools or applications may not meet every one of the above criteria; however, they provide the general framework for evaluation. MPA Training and Technical Assistance Institute (TTAI) staff evaluated each tool to determine both its compatibility with the defined criteria and the level to which it may be extended for other purposes or geographic regions.

It is important to note that some of these tools may not have been created for or used by an MPA site; however, if the underlying analyses or decision processes implemented within the tool are appropriate for use within an MPA, it was included.

Content

The bulk of this inventory is in a list format with a descriptive summary of each tool explaining what the tool does, who developed it, what types of data are necessary to use it, if it is geographically specific, and how it may be useful to MPA activities. In addition to describing tools that are currently available for use, the inventory also lists tools that are under development or are the intended outcomes of current projects. The distinction will therefore be made in each summary as to the current or upcoming availability of the tool. The first section of the inventory covers marine-based decision-support tools. This section is followed by a more in-depth and detailed characterization of two of these tools and a discussion of their actual use and applicability to recent MPA issues or processes. The third section of the inventory is in the form of a short, annotated bibliography covering the more technical aspects of marine-related decision-support tools. Entries in this section provide references and summaries to documents on subjects such as the development of tools, their detailed underlying processes, and the creation of algorithms, models, and data layers.

This report focuses primarily on the U.S.; however, a limited number of international examples are presented as well. In response to an advertisement in MPA News, a few international sites contacted the project team to describe useful tools and processes for MPA siting and management applied within their respective countries. This document highlights one specific MPA siting example in the Great Barrier Reef Marine Park in Australia, given the applicability of the analyses and the potential for U.S. managers to consider similar strategies or applications in their regions.

Audience

The primary audience for this report is MPA managers since this group voiced the need for such an inventory. Also, managers are ultimately responsible for programmatic decisions regarding tool development or implementation. Nevertheless, it is the technical staff within these programs, as well as those within academic institutions and nongovernmental associations, that will be developing additional tools or determining the applicability of existing tools. As a result, these groups are also considered a prime audience for the report. In order to meet the requirements of both audiences, the report will include information that is general enough to spur interest within less technically focused staff, in addition to references to more detailed technical documents that will allow GIS and development staff to determine applicability for their regions or issues. Managers will be able to learn from the overall descriptions of existing tools or projects and generate ideas in terms of how to apply a similar strategy in their regions. Although manger-level staff may not be interested in the technical details, they are necessary to allow GIS staff to determine the suitability of the tool.

MARINE-BASED DECISION-SUPPORT TOOLS

This section includes a descriptive list of decision-support tools that could potentially support MPA management purposes. The following criteria were used to determine whether a tool was appropriate for inclusion: Marine-related, GIS-based, publicly available, and participatory or interactive. It should be noted that a tool does not have to fulfill all of the criteria to be included in this list, but it must have the potential to assist the MPA community in their management efforts. Included in this section are tools that are currently available, as well as tools that are likely forthcoming as a result of recent or ongoing projects. This distinction will be made clear in the tool summary.

Channel Islands - Spatial Support and Analysis Tool (CI-SSAT), NOAA Coastal Services Center. www.csc.noaa.gov/communities/agreement.html

CI-SSAT is a GIS-based tool developed by NOAA's Coastal Services Center to aid in the process of siting marine reserves around the Channel Islands National Marine Sanctuary. The tool was designed to help the various stakeholder groups involved reach consensus about the most appropriate place to site marine ecological reserves. The program uses ecological and socioeconomic data to do a preliminary assessment of the resources affected by a chosen site location. Users are able to weight criteria, in essence creating a numerical scale for their own perceived importance of the various factors. The user then has the ability to select or draw a proposed site and get a preliminary idea of what and how ecological or economic factors may be influenced. CI-SSAT uses a simple algorithm to compute suitability of site locations, and the processes could be adaptable to any location provided the appropriate site-specific data layers area available. CI-SSAT is not currently being distributed. For more information on CI-SSAT, please refer to the Web site above or contact NOAA Coastal Services Center at csc@csc.noaa.gov.

Ecopath with Ecosim, Ecopath. www.ecopath.org

Ecopath with Ecosim (EwE) is an ecological software package developed at the University of British Columbia's Fishery Centre with the help and sponsorship of partners from around the world. EwE can be used to examine the fishery resources in an ecosystem, explore specific management decisions, and assess impacts and issues related to an MPA siting. EwE consists of three main components (Ecopath, Ecosim, and Ecospace), each of which builds upon and adds functionality to the previous component. The first component, Ecopath, is used for mass-balance modeling of an ecosystem, and requires data which are usually available through fish stock assessments, ecological studies, or literature. Ecosim, the second module, adds a time component to the model based on the results from Ecopath and the policy in place. The final module, Ecospace, is a simulation tool that predicts the spatial pattern of various ecosystems' components. This spatial simulation combines the results of the Ecopath and Ecosim models with user-provided habitat preferences. EwE is freely available for download on the Ecopath website, and comes in both DOS and Windows versions. Utilizing EwE (version including Ecospace) allows for the exploration of various management options, including placement of MPAs, and the impacts these options would have on the ecosystem.

Evaluating Vessel Speed Restrictions to Mitigate Impacts to Marine Mammals in the Stellwagen Bank National Marine Sanctuary, NOAA Coastal Services Center. www.csc.noaa.gov/mpa/stellwagen.pdf

This project resulted in a stand-alone tool that evaluates of a suite of zoning alternatives based on the potential of each to reduce the risk of injury and mortality to cetaceans, while minimizing economic impact to the user community. The tool was designed for use by the sanctuary advisory committee and developed at the NOAA Coastal Service Center. The tool allows speed zones to be tested against any number of vessel routes, speeds, and operating costs and returns relative economic impact values that will, in turn, help the users design the most effective speed zone scheme with limited economic impact. The tool is highly adaptable to other locations and could be used to solve similar problems facing other marine protected areas. The tool runs on ArcGIS8.x and is available free of charge by request. Contact csc@csc.noaa.gov.

Geographic Information and Decision Support Tool – GiDSS, National Center for Caribbean Coral Reef Research.

The Geographic Information and Decision Support Tool – GiDSS is currently being developed at the National Center for Caribbean Coral Reef Research. This tool will be part of an interactive mapping site that includes hundreds of layers of marine and coastal data for the Florida Keys. Users will be able to specify their particular problem or issue, and the tool, using a herring-bone decision tree, will return suggested data layers related to the issue. The group is also working toward incorporating models into the system. An initial version of the tool should be publicly available by the end of the year. For more information on this tool, contact John McManus at 305-361-4814.

Habitat Suitability Modeling (HSM), NOAA's Biogeography Program, National Centers for Coastal Ocean Science. http://biogeo.nos.noaa.gov/products/apps/hsm/

Habitat Suitability Modeling (HSM) is a mapping tool used to estimate the habitat suitability of an area for a given species. The tool was developed by NOAA's Biogeography Program staff and ESRI (Environmental Systems Research Institute) in an effort to develop techniques for rapid assessment of coastal resources and to identify suitable habitat areas for coastal species. For HSM to generate its maps, the user must supply different environmental data layers as well as habitat suitability ratings for each environmental data type. HSM uses this information, along with standard or customized algorithms, to produce habitat suitability maps for certain fish and invertebrate species. HSM also has the ability to predict the effects of environmental change on different species. Using HSM to develop species and habitat distribution maps is potentially useful for MPA siting efforts, and its ability to assess the effects of planned changes to an area should make it helpful in evaluating different management and zoning options. As a basic suitability model, the tool can be used in any geographic area for which the user has appropriate data. HSM was designed to be used on a Windows NT computer with ArcView3.2 and requires the Spatial Analyst extension. At this time, distribution of the tool is on hold, but updating it to ArcGIS 8x or 9 is being considered. If this occurs, the tool will again become publicly available.

NOAA Technical Report: Integrated Spatial Data Model Tools for Auto-Classification and Delineation of Species-Specific Habitat Maps from High-Resolution, Digital Hydrographic Data. Rikk Kvitek, Pat Iampietro, and Erica Summers-Morris. 2003 http://seafloor.csumb.edu/publications/Kvitek_NA17OC2586_Rpt.pdf

This project set out to create a species-specific model for classifying habitat and assessing distribution and abundance of particular species through the use of high resolution multibeam data and ArcGIS functionality. The project was led by Rikk Kviteck at California State University Monterey Bay with the assistance of Pat Iampeitro and Erica Summers-Morris, among others. The intention was to create a tool that could identify sensitive fish habitats and predict the location of fish based on species-habitat associations, which would have obvious implications regarding the management of marine protected areas. To date, the methodology has not been packaged into an extension or tool. At this point, it is more a collection of methods, which must be conducted by hand. The model was created for use at a study site in Monterey Bay, California, but the methods could apply to other sites where high-resolution mutlibeam bathymetry data have been collected. Currently, the methodology as detailed within the above-mentioned NOAA Technical Report can be performed with any GIS software that has vector and GRID/raster analysis tools. The authors have future plans to package the methodologies into a tool or extension using ArcGIS as the platform. For additional information on this project, please contact Rikk Kvitek at rikk_kvitek@csumb.edu, or Pat Iampeitro at pat_iampietro@csumb.edu.

OCEAN – Ocean Communities 3E Analysis Network, EcoTrust. www.ecotrust.org/gis/ocean.html

OCEAN, the Ocean Communities 3E Analysis Network is a suite of tools developed by EcoTrust to meet the need of communities and managers in the Pacific Northwest for the ability to spatially integrate and analyze ecological, economic, and sociocultural data. (The three E's stand for equity, ecology, and economy.) The OCEAN framework consists of databases and tools that can be used to perform spatial queries and statistical analyses to better understand economic patterns of spatial behavior and marine management decisions. Many past applications of OCEAN have focused on fisheries management and its effects on adjacent coastal communities. A major strength of this tool is its participatory approach that incorporates local knowledge. The geographic coverage of the framework is the U.S. West Coast. The OCEAN framework itself is not available for distribution; rather, it is used for applications done through project-specific partnerships with EcoTrust, for which a consulting fee is required. For more information contact Charles Steinback - charles@ecotrust.org

The Oceanographic Analyst Extension, USGS, Alaska Biological Science Center. www.absc.usgs.gov/glba/gistools/index.htm#OCEANOGRAPHIC

The Oceanographic Analyst Extension (OAE) is an ArcView 3x extension developed by the U.S. Geological Survey (USGS). The extension allows users to bring a variety of oceanographic data into a GIS, thus integrating them with other spatial data sets. It specifically allows for the import, processing, and display of raw Sea-bird CTD (conductivity, temperature, and depth) data. The extension can be used to create 3-D views and contour plots of the cast data. OAE can also convert NOAA's National Climatic Data Center (NCDC) weather station data into a more standard and usable format. Other functionalities of the tool include calculating photic depth and integrating chlorophyll-a data, which can be used to help visualize plankton booms, mixing zones, and circulation patterns. OAE has no geographic limitations and has the potential to be useful in establishing the oceanographic base data necessary for the siting and monitoring of marine protected areas. OAE is to be used within ArcView 3x and requires the Spatial Analyst extension to function properly. OAE can be downloaded for free from the GIS tools section of the USGS Web site.

Sites, The Nature Conservancy. www.biogeog.ucsb.edu/projects/tnc/overview.html

The Nature Conservancy contracted with the University of California at Santa Barbara to develop Sites, an analytical toolbox for ecoregional conservation planning, as a reserve siting tool that incorporates spatial design criteria into the site-selection process. Sites allows users to address complex problems by sorting through large volumes of data and comparing alternative scenarios or portfolios. A region can be broken down into "planning units" (grids, watersheds, etc.) that are used as the building blocks to assemble different portfolios. The input files needed to run the system include the planning units, the elements within each unit, and the goals for each element (i.e., species). The system then uses algorithms to select the planning units that make up the most efficient portfolio for the goals entered. The user can set parameters related to the goals, cost assumptions, and spatial complexities. The toolbox interface (ArcView 3.x customization) gives the user a specialized menu and new buttons for running functions and displaying results. Users should view solutions selected by Sites as initial solutions, which may require additional review to incorporate local knowledge, judgement, and other factors not considered in the system. Sites has been used in a variety of planning studies in diverse locations, including a project to identify potential networks of marine reserves in the Florida Keys (see Leslie paper in annotated bibliography section). A Sites zip file, freely available for download from the above Web site, contains Sites 1.0 software, a manual, and an example. (The Site Selection Module included in Sites 1.0 was initially developed as SPEXAN by Ian Ball and Hugh Possingham at the University of Adelaide, Australia). Users will need a PC with at least 8 Mb of RAM and Windows to run the software, and ArcView 3.x to run the graphical interface.

DETAILED DESCRIPTIONS OF TWO PROCESSES USING DECISION-SUPPORT TOOLS

This section highlights two decision-support tools that have been used in actual MPA zoning and monitoring activities. The first example will detail MARXAN, a tool used by the Great Barrier Reef Marine Park Authority in recent efforts to zone existing MPAs. The second example describes OceanMap, a tool used by EcoTrust to incorporate local knowledge from fishermen and community input into MPA planning processes in California. These examples are highly applicable to MPAs and the streamlined integration of spatial technology with data gathering and analysis of these processes are especially interesting. Again, the tools detailed here are GIS-based, publicly available (i.e., low or no cost), and participatory or interactive.

I. Great Barrier Reef Marine Park's Representative Areas Program (RAP)

The Process

The Great Barrier Reef Marine Park is a multiple-use park, zoned to manage human activities and protect natural and other values. Originally 4 percent was zoned as no-take, and those areas were primarily protecting coral reef habitat. With increased awareness of the importance of an ecosystem approach and interconnected habitats, the Representative Areas Program (RAP) set out to develop a network of protected areas that would adequately represent the full range of habitats and communities within the marine park. The goal was to design a network to maximize the region's biodiversity protection while minimizing socioeconomic and cultural costs.

The Great Barrier Reef Marine Park Authority considered a variety of inputs when identifying potential sites, including expert option, stakeholder involvement, and analytical approaches. Throughout the process, the park authority used multiple geospatial technologies to help facilitate the development of each stage, which ultimately improved the overall effectiveness of the project. The application of spatial data and tools helped the park authority communicate with stakeholders, incorporate public comment, identify representative examples of the various habitats and communities within the park, consider connectivity among each, and build upon the existing network of protected areas.

During the initial phases of the program, interviews and research efforts led to the development of two sets of operating principles: biophysical principles and social, economic, and cultural principles. Biophysical principles included recommendations regarding the desired size, replication, and amount of different habitat types in protected areas. The social, economic, and cultural principles addressed placement issues to minimize potenital user conflicts and maximize public acceptance and ease of enforcement. Marine reserve design software, known as MARXAN, was adapted for use in the RAP. MARXAN uses an objective function to implement the operational principles, and simulated annealing to identify networks of areas that optimize the objective function.

By integrating GIS into each stage of the process, the park authority was able to increase the efficiency and timeliness with which data and information could be distributed to constituents. Within days of the data collection phase, maps were circulated to partners and stakeholders for discussion and feedback. Stakeholders were then asked to submit suggested areas based on the best available data. This inclusion instilled faith in the process, limited distrust among participants, and allowed all groups to have an equal standing in the process to ensure an impartial outcome. GIS allowed planners, stakeholder representatives, political authorities, and the public to visualize a broad range of data that supply a tangible and quantifiable characterization of the natural and human values of the Great Barrier Reef.

Based on these data, staff were able to use predefined reserve design criteria to generate potential boundary alternatives for comment. Participants were also permitted to use these maps to present additional boundary options for consideration. Because these discussions were in reference to real data and map displays, the group was quickly able to highlight preferred regions. The facilitated communication and data exchange was critical to the success of the zoning process, allowing the group to identify locations that preserve areas of high biodiversity while minimizing impact on the user communities. Also, once the sites were defined, the Great Barrier Reef Marine Park Authority was able to generate legal boundary descriptions for 672 areas directly from the spatial data, ensuring a more exact and defensible boundary (see www.reefed.edu.au/rap/ for these descriptions).

The Tool Applied

MARXAN

www.ecology.uq.edu.au/marxan.htm

MARXAN is a software tool that delivers decision support for reserve system design. The tool primarily uses a randomization method known as simulated annealing to find the most efficient solution to site selection. Based on defined criteria for biodiversity targets, the model calculates a "cost" for each potential solution and attempts to minimize this cost, while generating a near-optimal solution. Hundreds of different scenarios can be run and compared in order to evaluate a suite of outcomes and spatial patterns to determine the most critical areas for conservation. However, it is important to note that any model or decision-support tool is only as accurate or effective as the data available to it. For such a large geographic region as the Great Barrier Reef, it is difficult to collect sufficient information to feed these models. In addition, if the desire were to consider historical fishing grounds or known spawning locations, for example, this information is often not well documented and could be very time-consuming to generate.

Nevertheless, MARXAN was well received due to its inherent impartiality. There was less apprehension among the participants, a sense that decisions were based on "sound science," and an understanding that outputs truly addressed the defined criteria (e.g., for species, habitats, defined biodiversity targets, and boundary length). Although the stakeholders may not have understood the algorithms behind MARXAN, they were able to review the input parameters and visualize the output, which was generally an optimization of priority factors described in the Draft Zoning Plan. As a result, the initial response to the draft plan was very positive. Another important factor was that the participatory elements of the process allowed those involved to be actively engaged from the inception of the zoning process.

MARXAN is simply a "tool" to bring participants toward an acceptable outcome. Before using it, the group must have already considered which elements of reserve design are most critical to addressing priority issues for a given site. The two primary design parameters employed by Great Barrier Reef Marine Park Authority related to biophysical and social aspects of the region. For example, the reserve design criteria for a particular scenario may require that the site include a certain percentage of each defined bioregion and that it minimize socioeconomic impacts on the user community (www.reefed.edu.au/rap/overview/principles/). However, although these design principles remained constant, site selection was an iterative process in which proposed areas within the draft zoning plan changed as new information came to light during public consultation. This is not uncommon, given that local knowledge regarding historical fishing areas and other cultural areas is becoming more widely appreciated in these processes.

MARXAN was considered a critical element in the development of the Great Barrier Reef Marine Park zoning plan; however, it does have some limitations. In addition to the technical expertise required to operate the model, it is unable to ingest preferences for spatial configurations or specific reserve size. Due to these constraints, MARXAN was one of many tools and technologies applied throughout the process. Park authority technical staff also conducted additional (non-automated) spatial analyses to overcome such software constraints and ensure that the public was consulted during each zoning iteration.

MARXAN is a stand-alone application that was created as the marine version of the terrestrial reserve design software SPEXAN. Both are basic extensions of a FORTRAN 77 program SIMAN. To download the application, please go to the following Web site www.ecology.uq.edu.au/marxan.htm#get_download or contact Hugh Possingham at hpossingham@zen.uq.edu.au, University of Queensland, Australia. The developers of MARXAN are happy to make this software freely available, but they do ask that users remain in contact and inform them of subsequent applications and publications.

II. EcoTrust's Use of OceanMap

The Process

The California Marine Life Protection Act (MLPA) requires the California Department of Fish and Game (CDFG) to implement a network of MPAs in state waters. As part of this effort, it is required that profiles be compiled of fishing activities. One source of data for these profiles is fishermen. In order to accelerate the incorporation of this information, a pilot study was conducted to test the utility of geospatial analysis tools for eliciting and integrating fishermen's knowledge into MPA planning processes in California.

Environmental Defense and the Institute for Fisheries Research (IFR) collaborated on the pilot project to develop and test protocols for collecting, analyzing, and presenting locally relevant information. In addition to eliciting fishermen's knowledge, the project was designed to test ways to incorporate this information into the decision-making process, and to test spatially explicit methods for rapid socioeconomic assessments for MPA planning. EcoTrust worked with Environmental Defense to develop a GIS-based tool for the project, as well as conduct interviews.

The project focused on the north central region of California, where five main port areas were identified. Fishing representatives were involved in the design phase and helped develop the list of research questions to be asked of interviewees in each port. They also suggested other fishermen as potential interview participants based on the length of their fishing careers, their depth of knowledge, and their willingness to be interviewed. During semi-structured interviews, fishermen were asked questions related to four analytical areas: demographics, oceanographic information, biological information, and management. When appropriate, interviewees indicated on charts the locations and spatial extents of areas in response to questions. Interviewees' responses were then entered into a GIS mapping application called OceanMap, allowing the information gathered to be represented spatially and available for analysis. Other data layers in OceanMap, with which the local knowledge could be viewed and analyzed, included existing MPAs, habitat data, bathymetry, and nautical charts. After initial analysis, interview participants were invited to follow-up meetings to review the results, make any corrections or give additional input, and approve the maps for use in presentations and publications.

This project demonstrates a process for incorporating local knowledge into decision making, which adds an important participatory component for stakeholders and yields significant information. It may also help identify less contentious siting alternatives by looking at MPA siting with fishermen's socioeconomic concerns in mind early in the decision-making process. OceanMap aids this process by facilitating the spatial representation of local knowledge and its compatibility with other data sources.

Another EcoTrust project that utilized OceanMap was the Spatial Community Outreach Project (SCOOP). This collaborative effort between EcoTrust and the Pacific Marine Conservation Council (PMCC) gathered information from fishing communities on the impacts of rock fish conservation areas that were closed to fishing. EcoTrust and PMCC looked into the area closures and the impacts to adjacent communities and reported back to the Pacific Fisheries Management Council. In addition to gathering information on fishing behavior, target species, and incurred costs, the principle investigators were interested in hearing recommendations on alternative spatial management proposals for the future.

The Tool Applied

OceanMap

OceanMap was developed jointly by EcoTrust and Environmental Defense as part of the local knowledge project described above and carried out in support of the Marine Life Protection Act in the State of California. OceanMap is a collection of scripts within an ArcView project file that allows users to perform various spatial tasks. The tool also acts as an information gathering device for participatory research to help facilitate discussion and feedback through input dialogs, maps, and personal interviews.

OceanMap utilizes both scientific and socioeconomic data in its processes. The socioeconomic data, which many consider to be one of the data gaps in the MPA community, is a fundamental component to the OceanMap application. The socioeconomic data must first be gathered, which in the past has been done through group meetings, interception of interviewees in ports, and scheduled one-on-one interviews. The project partners found that the interviews worked best, and that the participants were very receptive when the process was framed correctly.

OceanMap can be used to find socioeconomic hotspots by species. Interviewees draw or indicate areas, by species, about the location of fishing grounds and rank the relative importance of each.

Users can also profile areas of socioeconomic importance, oceanographic processes, species diversity, and fishing effort. The data are then put into the OceanMap application for spatial analysis. The analyses range from simple overlap analyses to complex suitability analyses based on biological, physical, and socioeconomic databases. Once all of the socioeconomic data is aggregated, the data are overlayed with biological hotspots and unique or important natural and cultural features. The results will allow decision makers to make more informed decisions based upon sound science and economics.

While the tool was originally designed for California, it has since been customized to include Oregon as well. With the appropriate data sets it can be tailored for specific areas and uses, and it is easily replicated. It should be noted that the majority of the processes packaged within OceanMap are fairly simple operations and could be conducted easily by most GIS analysts. However, the customization of the interface to automate these analyses and tools makes it useful to MPA managers and staff who may not have in-depth geospatial analysis skills. OceanMap is to be used within ArcView3.x and requires the Spatial Analyst extension. This tool is publicly available and is distributed by Environmental Defense upon requested. For more information on OceanMap, please contact Peter Black at pblack@environmentaldefense.org.

ANNOTATED BIBLIOGRAPHY

This section of the inventory is an annotated bibliography covering the more technical aspects of marine related decision support tools. Entries in this section provide references and summaries to documents on subjects such as the development of tools, their detailed underlying processes, and the creation of algorithms, models, and data layers.

Adams, Christiaan Scott. **An interactive, on-line geographic information system (GIS) for stakeholder participation in environmental site selection.** MIT, Department of Civil and Environmental Engineering. January 16, 2004. http://dogfish.mit.edu/eSite/thesis/AdamsCS_Text.pdf

This thesis details an interactive, on-line geographic information system (GIS) that was developed to enhance the involvement of stakeholders in the public participation processes of site selection issues in the marine environment. Displaying educational material and interactive maps of relevant data, this tool allows users to input personal preferences for the criteria they value in the siting decision and produces a map showing the most and least suitable sites according to the user's weighting of the criteria. Other decision-making processes focus on finding an optimum solution from a number of alternatives using an objective analysis of the criteria, but they are often inaccessible to stakeholders and do not consider the fairness of the outcome. This tool is intended to educate stakeholders and enhance their involvement in the public decision-making process. To demonstrate the interactive, on-line GIS concept, a Web site called eSite was assembled (http://dogfish.mit.edu/eSite/), using as its case study the hypothetical issue of siting marine reserves within the Stellwagen Bank National Marine Sanctuary. The program behind eSite calculates a ranked suitability map of more and less suitable locations according to the user's preferences. eSite is built around an on-line GIS, using raster, or grid-based, data.

Ardron, Jeff. **A GIS recipe for determining benthic complexity: An indicator of species richness.** Draft #8. In Press, Marine Geography, 2002. www.livingoceans.org/files/complexity_draft8.pdf

This paper examines the development of GIS-based measurement for physical (benthic) complexity and describes the process steps used to conduct the modeling. The author discusses the fact that benthic complexity has proven very useful as an indicator of species richness, so in the absence of good comprehensive biological data, physical complexity could be used as a surrogate to direct marine planning and research activities.

Ardron, J., J. Lash, and D. Haggarty. 2002. **Modelling a network of marine protected areas for the central coast of British Columbia.** Ver. 3.1. Living Oceans Society. British Columbia, Canada. www.livingoceans.org/documents/LOS_MPA_model_v31_web.pdf

In this paper, the authors detail the modeling methodologies and results of the development and refinement of hypothetical marine protected areas for the central coast of British Columbia. The authors utilized various spatial modeling techniques within a GIS in the development of a classification scheme. The scheme, which accounts for both physical and biological factors, along with other inputs, was entered into MARXAN (v.1.2) software to produce the potential MPA networks. The model results were validated through stakeholder input, expert opinions, and review of previous studies. The paper includes a section on the assumptions and limitations of the approach used.

Beck, M.W., M.Odaya, J.J. Bachant, J. Bergan, B. Keller, R. Martin, R. Matthews, C. Porter, and G. Ramseur. 2000. **Identification of priority sites for conservation in the northern Gulf of Mexico: An ecoregional plan. The Nature Conservancy, Arlington, VA.** www.epa.gov/gmpo/habitat/NGoM_Final_allfigs.PDF

In this report, the authors detail the processes used to choose a set of high-priority sites for conservation in the northern Gulf of Mexico. The goal of the process was to identify sites that, if protected, would fully represent the biological diversity of the nearshore waters of the region. The two primary tools used to assemble the priority areas were: (i) a reserve selection algorithm, Sites v1.0, and (ii) expert interviews and an expert workshop. The requirements for the Sites program included information on the distribution and abundance of target habitats and species across bays, as well as a set of conservation goals. Based on the inputs, the program was used to establish the minimum number of sites meeting the targeted goals. The results were then used to spur discussion among experts, who were asked to evaluate the assumptions, data and results, and select their own priority sites. The final set of priority sites were assembled as a result of combining the Sites results with the comments from the experts. TNC has a number of similar projects in other regions around the United States.

Grober-Dunsmor, Rikki, Jason Hale, Jim Beets, Tom Frazer, Nick Funicelli, and Paul Zwick. **Applying landscape ecology principles to the design and management of marine reserves.** USGS. http://cars.er.usgs.gov/posters/Coral_and_Marine/Mngmt_of_Marine_Reserves/mngmt_of_marine_reserves.html

The authors explore the use of landscape-level metrics as a way to describe coral reefs and their associated habitats and explore the potential use of these metrics as predictors of reef fish assemblage structure. Landscape metrics (e.g., habitat diversity) were calculated for 10 coral reefs and their adjacent habitats around the island of St. John (USVI) to describe differences in the "reefscape." Two metrics, habitat diversity and total area of seagrass around the reef, were then correlated with various measures of reef fish abundance and species richness. The authors present this landscape approach as an aid to coral reef managers in their efforts to better design and manage marine reserves.

Leslie, H., M. Ruckelshaus, I.R. Ball, S. Andelman, and H.P. Possingham. 2003. **Using siting algorithms in the design of marine reserve networks.** Ecological Applications. www.sam.sdu.dk/fame/menu/pdfnov/leslie.pdf

The purpose of this paper is to describe how reserve-siting algorithms can be used to help identify marine reserve systems that comprehensively represent all habitat types in a sensible spatial arrangement. Using benthic habitat data from the Florida Keys, the authors investigated the relative influence of spatial information, planning-unit size, detail of habitat classification, and magnitude of the overall conservation goal on the resulting network scenarios. Using a flexible optimization tool (simulated annealing), they were able to identify many adequate reserve systems that met the conservation goals. The authors also discuss "irreplaceability analysis", a particular useful output of the algorithm that is a count of the number of times unique planning units were included in reserve design scenarios.

O'Donnell, V., Cronin, M. & Cummins, V. **Sustainable coastal habitats: GIS tools for effective decision support.** Coastal & Marine Resources Centre, Environmental Research Institute, University College Cork, Ireland. www.gisig.it/coastgis/papers/o%27donnell.pdf

This paper describes a project working to develop an efficient tool to aid in the management of protected areas, both marine and terrestrial, by calculating threats to environmentally sensitive coastal habitats. A GIS based Sensitivity Analysis Model will assess the various impacts of activities such as agriculture, burning, aquaculture, tourism etc on the protected species on sites that are protected in name but often not in planning and future management. The anticipated output from the tool will be a hierarchical list of designated sites, highlighting those most at risk from human and natural impacts. The project is ongoing and is hoped to eventually result in an output that will be a GIS, via the internet or an ArcView extension. For more information about this project, please contact Vicki O'Donnell at v.odonnell@ucc.ie.

Sala, E., O. Aburto-Oropeza, G. Paredes, I. Parra, J. C. Barrera, and P. K. Dayton. **A general model for designing networks of marine reserves. Science 298: 1991-1993. 2002.** www.cciforum.org/pdfs/Sala_Marine_Reserves.pdf

The authors describe a means of establishing marine reserve networks by using optimization algorithms and multiple levels of information on biodiversity, ecological processes (spawning, recruitment, and larval connectivity), and socioeconomic factors in the Gulf of California. The authors set out to design a network of marine reserves to protect biodiversity and complement fisheries management. They concluded that a network covering 40 percent of rocky reef habitat could fulfill many conservation goals while also reducing some social conflict. The authors assert that the quantitative approach used in this paper provides a powerful tool for decision makers tasked with siting marine reserves.

Sutherland, Michael, Sam Machari Ng'ang'a, and Sue Nichols. **In search of New Brunswick's marine administrative boundaries.** Symposium on Geospatial Theory, Processing and Applications. Ottawa, 2002. www.isprs.org/commission4/proceedings/pdfpapers/272.pdf

This paper describes New Brunswick's recent efforts to delineate the possible maximum spatial extent of its administrative boundaries. The purpose is to determine the spatial extent of the marine space over which New Brunswick exercises jurisdiction and administration in order to support provincial marine policies and good governance of its marine resources. The two GIS tools used to complete boundaries were CARIS GIS and CARIS LOTS (Law of the Sea). The paper outlines the process used, including various GIS tools and supporting legal research, in the creation of the marine boundary polygons. The technical and governance implications of the process and the product are also discussed.

Conclusion

The tools highlighted in this report provide functionality ranging from visualizing and integrating oceanographic data to site suitability modeling and incorporating stakeholder input. The references and specific project descriptions give additional technical background and illustrate how spatial tools can be used in conjunction with other mechanisms to facilitate MPA related management decisions. By documenting these summaries and examples, it is anticipated that MPA managers and staff will have the necessary initial information to determine the applicability of particular tools to their own management needs.

The intent of this inventory is to make the MPA community aware of existing GIS-based decision-support tools that may aid them in a variety of MPA-related activities (siting, zoning, monitoring, etc). Because new tools and techniques will invariably be developed and improved upon, it is the intent of MPA TTAI staff to maintain this inventory as a living document. As such, the inventory will be updated on a regular basis to reflect these changes and will be available in hard copy or online at www.mpa.gov. Members of the MPA community are encouraged to alert TTAI staff to any tools, projects, or papers that would be appropriate for future inclusion.

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