# Tools for Coastal-Marine Ecosystem-Based Management

## A Survey and Evaluation
## Of Utility, Sustainability, and Opportunities
## for Further Development

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# Introduction

In December of 2003, the board of David and Lucile Packard Foundation approved a new Science for Ecosystem-based Management Initiative focused on coastal-marine ecosystems. This was the culmination of a year-long process of merging our formerly separate Science and Conservation Programs. The initiative reflects Packard's firm commitment to marine conservation and belief in the importance of science in identifying solutions to the complex challenges we now face. Specifically, it responds to the growing number of scientists, practitioners, politicians, and environmentalists who believe that existing approaches to coastal-marine conservation are inadequate and who are calling for a new management approach that focuses on entire ecosystems, including the people and communities that live there. The ultimate goal of the initiative is to facilitate a shift to such management regimes.

Packard chose to focus on ecosystem-based management because of the great promise it holds for achieving this long-term goal. Ecosystem-based management (EBM) is a management approach designed to restore and sustain the health, productivity, and biological diversity of ecosystems and the quality of life for humans who depend on them. It is a science-based approach that:

- focuses on all of the organisms living in a given place as well as their interactions with each other and their physical environment, and is committed to understanding ecosystem processes and how ecosystems respond to environmental perturbations;
- integrates ecological, social, and economic goals and recognizes humans as key components of the ecosystem;
- defines the management regime based on ecological boundaries - not political boundaries, and the different spatial and temporal scales that accompany them;
- addresses the complexity of natural processes and social systems and uses an adaptive management approach in the face of resulting uncertainties;
- engages multiple stakeholders in a collaborative process to define problems and find solutions;
- is concerned with the ecological integrity and sustainability of the coupled human-ecological system, and;
- in coastal-marine systems, incorporates the dynamic interplay between terrestrial, marine, and freshwater systems.

EBM is as much a process as a science. Packard's working assumption is that to successfully establish a robust and durable ecosystem-based adaptive management regime in a particular region, stakeholders and decision-makers must be actively engaged in both understanding the consequences of their action (or inaction) and the process that leads to the adoption and implementation of a preferred management regime. Science and scientists are integral to this process, providing an understanding of the complex dynamics within a given system, helping answer "what if" questions, and identifying real conflicts based on differing values as opposed to perceived differences based on a limited knowledge, ideology, or historic conflicts between stakeholders.

A key strategy in Packard's Science for Ecosystem-based Management Initiative is the development of tools and methods that will help facilitate EBM processes in coastal marine systems. Tools in this case are process and analytical support tools such as software or well-documented and repeatable processes, not management tools such as marine-protected areas. Initial interviews have indicated that the most useful tools would help address four critical EBM functions:

- Provide a model – or at a minimum a plausible facsimile – of the ecosystem, in particular the interplay between ecological and economic factors and forces.
- Generate scenarios that illustrate the result of different management decisions on conservation and development.
- Encourage the meaningful and productive engagement of stakeholders with each other and with science and scientists.
- Lay the foundation for adaptive management.

In the spring of 2004, Packard began working with NatureServe to help develop a better understanding of the current status of such tools and methods, the short- and long-term needs for improving these tools, and possible ways a private foundation could help advance the field. Their research and report are intended as a first step to frame the issues and to help initiate dialogue with EBM scientists and practitioners working in coastal-marine environments. In this spirit, we welcome and encourage any and all comments or suggestions on every aspect of this work.

Scott Rehmus
Packard Foundation Program Officer

# Project Team

Denny Grossman: NatureServe Vice President for Science
Patrick Crist: NatureServe Science Applications Manager, project manager
Terri Kempton: NatureServe Intern, tools research and database development
Chris Madden: NatureServe coastal-marine consultant
Scott Rehmus: Packard Foundation Program Officer

# Acknowledgments

We thank the David and Lucile Packard Foundation for their support and enthusiastic participation in the project team, especially Scott Rehmus. We also thank and acknowledge the many participants in our workshop and report review who contributed their time and ideas. They are listed in Appendix 1.

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# Project Objectives

We had three primary objectives for this study:
1. Develop a hierarchical framework describing the functions of software tools needed to conduct coastal-marine ecosystem-based management (CMEBM).
2. Survey existing tools that may support CMEBM and annotate, in detail, a subset that appears especially relevant and promising.
3. Conduct workshops of scientists, CMEBM planners and managers, and software developers to evaluate our study and make recommendations to the Packard Foundation for funding priorities and strategies for supporting software tools.

# Tools Survey

We conducted a survey of available tools to assess their range and capabilities that could be useful for coastal marine ecosystem-based management.  This was a rapid assessment of tools relying primarily on web and limited consultations with practitioners.

## Sources for starting the search

We began the search by referencing previous surveys of tools.  Most helpful in providing leads on potentially useful tools were:
- The 2001 report from ABI (now NatureServe): Rapid Scan of Decision Support System Tools for Land-Use Related Decision Making by Johnson and Lachman (http://www.natureserve.org/library/toolsum.pdf).
- The National Commission on Science for Sustainable Forestry inventory of decision support systems (http://ncseonline.org/NCSSF/DSS/Documents/search/complete.cfm).
- The Coastal Information Focus Group (http://www.science.plym.ac.uk/DEPARTMENTS/GEOGRAPHY/research/groups/ALC/FinalDisk/review.htm#tools).
- NCEAS Working group on conservation planning software led by Bob Pressey in 2003 (draft report available from bob.pressey@npws.nsw.gov.au).

## Search methodology

The search-engine Google was employed to locate tools on the Internet.  We searched for specific tool names when available from the sources listed above.  We discovered additional tools by conducting Google searches with general terms (examples: ecological modeling, decision support system software, conservation planning, ecosystem-based management, land-use scenario software).  Once a tool was discovered, the web page was thoroughly explored for additional leads to other tools, applications, or development efforts.  Some web sites, such as the EUCC Coastal Guide (http://www.coastalguide.org/), serve as a clearinghouse of information and provided links to a number of potentially useful tools.  We supplemented this search with email inquiries with individuals at NOAA and conversations with the NatureServe and Packard staff, who in turn consulted their colleagues.

## Evaluation and Comparison

Our analysis had two objectives: first, to identify tools sufficiently applicable to CMEBM to list in our database, and second, to prioritize tools for more detailed analysis and description.  This

required a framework to evaluate tools against the needs of ecosystem-based management and compare tools that varied in their functional domains (e.g., ecological modeling, land-use planning, visualization, etc.). Our framework is a hierarchical list of objectives and functions (Appendix 2) for conducting CMEBM which could be further disaggregated. We used the framework functions to evaluate each tool's ability to address different aspects of ecosystem-based management, such as information gathering and goal setting, threat identification and mitigation, conservation area selection, and ecosystem management. The framework was developed using commonly accepted conservation planning and EBM processes. Additions were made to the framework in the workshop (described below) but as post hoc improvements, they are not reflected in our survey results.

Of the several hundred tools identified in web searches and previous surveys, we selected 67 tools for inclusion in our database (Appendix 3) based primarily on our perception of whether they addressed functions in our CMEBM framework. Each tool was then categorized using one of the following terms to produce a high-level understanding of their contribution to CMEBM:

- *Conservation*: tools that can identify or prioritize areas for conservation efforts and/or reserves using location maps and goals or criteria from the user.
- *Decision*: tools that facilitate multiple stakeholder negotiation and decision-making characterized by visualization and voting types of functions.
- *Growth*: tools dealing with smart growth and land-use planning that are capable of calculating effects of growth and/or prioritizing or finding suitable locations given multiple criteria. This category also includes urban growth models though we did not list those individually owing to the large population of such tools.
- *Interdisciplinary*: tools that combine more than one category (such as *growth + decision*).
- *Mapping*: non-analytical visualization and overlay of static map layers without the ability to conduct "what if" evaluations.
- *Model*: ecosystem modeling tools without prioritization or analysis capabilities that describe or predict a condition from various inputs.
- *Programming*: tools for building other software programs.
- *Resource*: tools for natural resource management to prioritize land use and model sustainable harvest levels given multiple criteria.

# Results

## What we know: generalizations of surveyed tools

Tools are not equally distributed among categories (Figure 1). Many tools are interdisciplinary but narrowly so, meaning they are focused on a single category of application but minimally bring in a function from another category. A few other categories stand out such as Conservation (reserve design) and Model (ecological modeling).
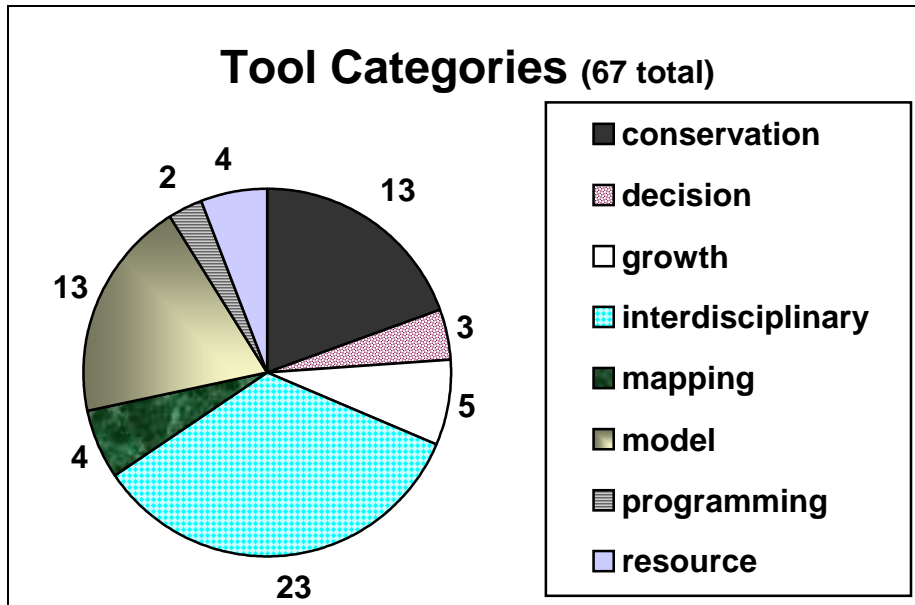
**Figure 1. Distribution of tool categories**

A majority of tools (42 of 67) are developed for the terrestrial realm (Figure 2). Nine of the tools are designed for freshwater applications. Fewer tools are developed for the marine realm, with 6 tools addressing coastal issues and 6 focused on marine applications.
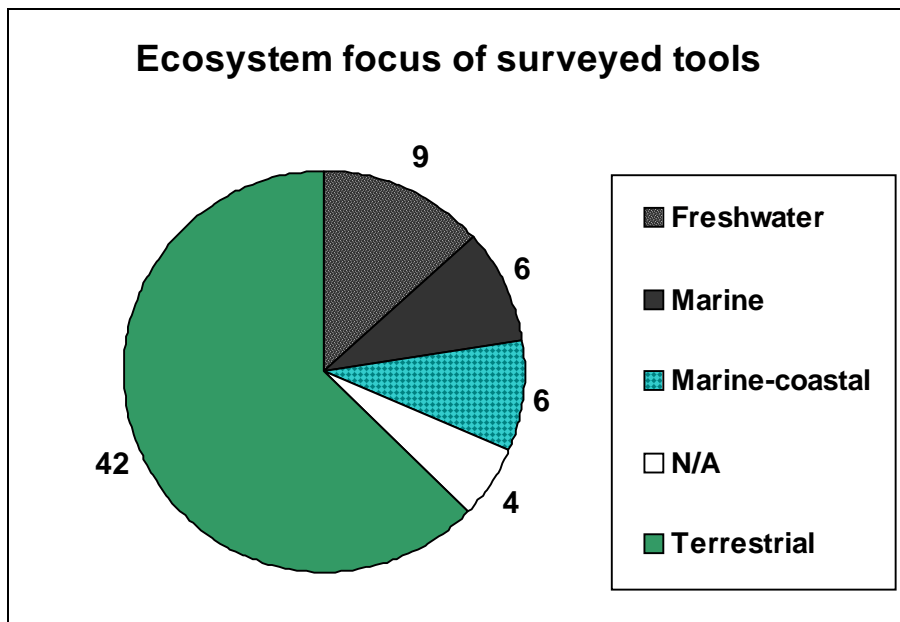


**Figure 2. Distribution of tools according to ecosystem focus**

## Summary of priority tools

One of our objectives was to prioritize a subset of tools for further description and evaluation of their utility for conducting CMEBM. We created 28 data fields (found in each of the

descriptions in Appendix 4) of desirable information about each tool's basic technological and accessibility information as well as which CMEBM functions it appeared to support.  We used the following criteria to prioritize all 67 tools as low, medium, and high priority:

- The number of functions and their specific fit to the CMEBM framework (Appendix 2) that the tool provided.
- History of applications to CMEBM projects.
- Technological and analytical sophistication: the degree that they are built with contemporary technological approaches on recent platforms and they perform actual analyses of data rather than static visualization or simple overlay.
- Perceived sustainability in terms of length of time the tool has been in existence, popularity for application, and institutional backing.

Eleven tools were rated high priority and are described in Appendix 4 and 21 were rated medium and are described in Appendix 5.  The remainder of this analysis discusses the 11 high priority tools.  These tools were created to meet a variety of goals; tools like CAPS and C-Plan were designed specifically for terrestrial biodiversity reserve identification, while EwE focuses on marine fisheries conservation and INDEX addresses land-use issues surrounding smart-growth decisions.  What they do have in common is their focus on land-use decisions that integrate conservation objectives.

## Coverage of CMEBM functions by high priority tools

Figure 3 identifies which tools support which functions of the CMEBM framework, the total number of priority tools addressing each function, and the number of functions addressed by each tool.  While there is fairly good coverage overall, we did not qualitatively evaluate how well the tools addressed each function and thus there is large uncertainty as to whether the tools would be deemed adequate in a field implementation.

### Information Gathering and Management

This functional category is fairly well covered by current tools but is particularly weak in the areas of ecosystem process models and inclusion of confidence information.  The most common functions of these tools were the ability of the user to identify elements (also known as features or targets) of interest and the ecological requirements of those elements.  There is great variability in the detail of element requirements that can be addressed and the flexibility of how they are expressed. Most tools only utilize presence of occurrence information; few incorporate spatial attributes of viability and confidence in presence.  Ecological modeling functions tend to be supported by separate tools that can incorporate a great deal of information about element reactions to temperature and chemical changes, and trophic interaction.  However, these single-purpose tools may be difficult to integrate with larger ecosystem planning tools utilizing coarser data.  Only two tools are inclusive of information regarding the confidence level of the data, a serious concern of decision makers.

### Goal Setting and Evaluation

All but one of the tools allow the user to set conservation goals, but only four of them are capable of setting any type of economic goals or limitations.  Stakeholder involvement in goal setting and evaluation is fairly well supported but few tools can allocate goals among separate jurisdictions within a larger ecosystem.

### Threat Identification and Impact Analysis

Many tools are able to identify or include information on threats to achieving ecological goals and viability. A few tools claim ability to identify threats to economic goals.

### Threat Mitigation Analysis

A single tool (NatureServe Vista) is capable of identifying land uses that are compatible with individual elements as opposed to generic compatibility of land-uses to conservation. Several tools can identify areas for restoration and an equal number can generate scenarios for conservation reserves.

### Conservation Area Selection

All tools allow some form of scenario comparison and a few conduct cost/benefit analysis and specifically support stakeholder involvement in the decision process. Functions that support plan implementation are covered partially by only two tools, Index and COSMO. Our colleagues suggest that no currently available tool is able to calculate an implementation budget that is sufficiently represents real world economic complexities or can support dynamic decision making and budgeting.

### Ecosystem Management

Very few tools are capable of the functions involved with ecosystem management, such as designating indicators for monitoring or creating a plan for monitoring and evaluation. Only one tool (EMDS) has the function of creating a monitoring plan or of supporting the implementation and monitoring of a land-use decision.

| Tool | category | Information gathering and management |  |  |  |  | Goal setting and evaluation |  |  |  | Threat ID and impact analysis |  |  | Threat mitigation analysis |  |  | Conservation area selection |  |  |  |  | Ecosystem Management |  |  |  | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | ID planning boundaries | Ecosystem process models | Element selection | Element requirements | Include confidence info | Set ecological goals | Set economic goals | Include multiple stakeholders | Allocate multiple goals | ID threats to eco goals | Impact analysis on eco viability | ID threats to econ goals | ID compatible land-use | ID restoration areas | Reserve areas | Scenario comparison | Cost/benefit analysis | Stakeholder involvement | Implementation plan support | Implementation budget calculation | ID EM indicators | Monitoring plan | Implementation and monitoring | Evaluation and adaptive mgt | Total functions |
| AQUATOX | model | x | x | x |  |  | x |  |  |  | x | x |  |  |  | x |  |  |  |  |  |  |  |  |  | 7 |
| CAPS | interdisc | x | x | x | x | x | x |  |  |  | x | x |  |  | x | x | x |  | x |  |  |  |  |  |  | 12 |
| Chesapeake | interdisc |  | x | x | x |  | x |  |  |  | x | x |  |  | x |  | x |  | x |  |  |  |  |  |  | 9 |
| CommunityViz | growth | x |  | x |  |  | x | x | x |  |  | x |  |  | x |  | x | x | x |  |  |  |  |  |  | 10 |
| COSMO | interdisc | x |  | x | x |  | x | x |  |  | x | x | x |  | x | x | x | x |  |  | x |  |  |  |  | 13 |
| C-Plan | conservation | x |  | x | x |  | x | x |  | x |  |  |  |  |  | x | x |  |  |  |  | x |  |  |  | 9 |
| EMDS | interdisc | x |  | x | x |  | x |  | x |  |  |  |  |  |  |  | x |  |  |  |  | x | x | x | x | 10 |
| EwE Ecopath | interdisc | x | x | x | x | x | x |  | x |  | x | x | x |  | x | x | x | x |  |  |  |  |  |  |  | 14 |
| INDEX | interdisc | x |  | x | x |  | x |  | x | x |  |  |  |  | x |  | x |  | x | x |  |  |  |  |  | 10 |
| MARXAN | conservation | x |  | x | x |  | x | x |  |  | x |  | x |  | x | x | x |  |  |  |  |  |  |  |  | 10 |
| Vista | interdisc | x |  | x | x | x | x |  | x |  | x | x |  | x |  |  | x |  | x |  |  |  |  |  |  | 11 |
| all tools: |  | 10 | 4 | 11 | 9 | 2 | 11 | 4 | 5 | 2 | 7 | 6 | 3 | 1 | 5 | 5 | 11 | 3 | 4 | 1 | 1 | 2 | 1 | 1 | 1 | |

Figure 3. Coverage of CMEBM functions by high-priority tools.  Note that the "Conservation area selection group has been renamed "EBM alternatives analysis, decision support, and implementation."

## Technology Platform

ESRI GIS software is the common platform for most tools, however, three tools run off of a Windows platform alone and one from a Linux platform without using GIS. Variability within the ESRI platform can still create integration and sustainability problems: four tools use ArcView 3.x, five use ArcGIS 8.x, one operates on an ArcMap 9 platform, and one uses an unspecified version of ArcMap.  Tools built on later ESRI platforms cannot work on earlier versions and it is impractical for users to run multiple versions of ESRI software on the same computers.

## Development Institutions

As expected most tools are developed by government (4) or academia (3) with fewer coming from private institutions.  For-profit software companies are essentially absent from the current DSS tools market. The market for these tools is usually very small, currently measured in the tens to hundreds with a potential in the tens of thousands.  The financial capability of the market is also small, consisting mostly of government and NGO projects with short term funding. Commercial DSS products for business and industry often cost tens of thousands of dollars per seat to be viable in similarly small markets, a cost that most conservation projects cannot support.

<u>Transferability Among Regions</u>

Most of these tools claim to be applicable at many scales and transferable among regions, limited only by data availability. There are, however, many useful models developed for specific projects that have not been automated into tools and would most likely require generalization.

A full annotation of the eleven priority tools can be found in Appendix 4.

## Limitations

Our survey was a rapid assessment of available tools utilizing knowledge readily gathered from the Internet and, in a few cases, interviews with developers. Undoubtedly we missed tools that should be in the database or those deserving of full description and misinterpreted available information in the characterization of tools. We seek to correct these limitations with the help of our participants and collaborators.

# Expert Workshop

The Foundation requested that an expert workshop be conducted to "ground truth" the results of our study and provide recommendations to the Foundation for tool support priorities and strategies. This workshop took place August 20, 2004 at NatureServe's office in Arlington, Virginia. Because of time limitations and the desire to focus on fewer issues, we chose to make this primarily a "needs" discussion among scientists and planners with the participation of some software developers. At this time, an additional workshop is being considered to focus on the technology strategy issues.

## Participant Roles

We sought to represent three roles among the participants:
- Scientists working in CMEBM who can describe the types of data, modeling, and process interactions that CMEBM requires and the degree of generalization and automation they believe could be accomplished versus location-specific custom analyses.
- Planners working in CMEBM who have been through the process, developed models, utilized software tools and have the practical sense of what tools can do, what is needed, transferability of tools and methodologies among ecosystems, and the priorities that would provide the most benefit in the near term.
- Tool developers who could provide insight into tool limitations and opportunities and ground the discussion of needs with their view of possibilities.

Participant candidates were identified by the Foundation and NatureServe Staff, and each contact was asked to make additional nominations. We identified around 70 individuals from some 40 institutions. The participants were selected based on the role they could play and their availability (see Appendix 1 for list of participants)

## Workshop Objectives

The specific objectives for the workshops were to:
- Review and critique our framework for CMEBM;
- Add important tools to the list for consideration for CMEBM;

- Add to or revise our list of priority tools for further description and consideration;
- Critique our assumptions and recommendations;
- Provide recommendations for needed tool functions and priority areas for the Foundation to consider supporting.

## Workshop Results

Results are presented relative to the objectives above. Recommendations from the participants are integrated with the Priorities and Opportunities section below. The participants spent considerable time discussing the process model for CMEBM and the major challenges in its implementation including sociopolitical challenges.

### Review the Framework for CMEBM

The participants confirmed that the framework is best considered a description of tool functions (the intended use) rather than as a general guide for performing CMEBM. They did recommend that a few significant new areas be added (now incorporated into Appendix 2). Because these functional areas were added after our survey, we cannot report on tool coverage of them. Additional recommendations regarding use of the framework as a tool for analyzing gaps and importance of existing tools are found in the Opportunities and Priorities section.

### Identifying additional tools for consideration

Few additional tools were identified and these tended to be case study examples of good processes that should be considered. New tools were added to the list in Appendix 3 but are currently unrated until they can be evaluated.

# Discussion

## Lessons Learned: Coverage of CMEBM by Software Tools

### Positive Findings

In our survey of available tools, we found that there are many good pieces to the overall puzzle of CMEBM tool functions. These include efficient group planning tools, sophisticated model and mapping tools, user-friendly smart growth software packages, and excellent reserve design tools. There are useful elements in each of the tools and specific functions may come together to create a useful CMEBM toolkit. Some CMEBM projects have begun this tool integration work such as the Chesapeake Bay Program Community Watershed Model that uses tools and/or models in one or more steps. Important lessons can be learned from such methodologies that accomplish many of the functions in the framework list.

### Challenges

- Looking across our CMEBM framework, few tools were designed specifically for coastal-marine applications. While a good deal of CMEBM planning and management activities take place in the terrestrial and freshwater systems, better linkage with and modeling within the marine system is needed.
- Within specific categories of CMEBM functions, the greatest shortage of tool capability is in ecosystem management and monitoring. These post-planning functions may be a

lower priority for immediate tool development and can be developed later as other functions are enhanced.

- Equally challenging to shortages in specific functions is the lack of interoperability among tools for a truly interdisciplinary approach. Many of the tools would need modification to integrate on a common technological framework and address the breadth of domains and attributes needed to link across the three ecosystem types.

## Lessons Learned: Quality and Viability of Existing Tools

Without obtaining the tools and "lifting up the hood" we can only offer conjecture about quality and viability based on published information. In this regard we offer recommendations under the "Next Steps" section below.

Positive Findings:
- Tool quality appears to be steadily improving as software programming tools make it easier to develop quality tools and developers focus around a smaller number of standardized platforms such as Windows and ArcGIS.
- Viability is being elevated as an issue among tool supporters in government and philanthropic organizations. After a decade of supporting numerous "proof-of-concept" initiatives, supporters are beginning to seriously consider how to make their investments viable for the long term.
- Interoperability is starting to be discussed among developers as a serious objective for future tool improvements.

Challenges:
- Most tool development is still conducted by government and academia which are not in the business of commercial software development and tend to build tools out of research interest, to make a particular practice more efficient, or to meet a specific need in one locality. There are exceptions to this generalization, with some organizations dedicated to long-term tool development, distribution, and training. However, tools from these organizations certainly have fewer resources than most commercial tools and may be more susceptible to resource fluctuations, political support, and changing missions.
- Funding and markets for these tools are very small, so long-term viability remains a tremendous challenge. The history of freely downloadable tools from government and academia have set expectations for tools (as with data) to remain free. When tools are successful, the original supporters are often overwhelmed by the real costs of not only maintaining the tools but providing technical support, training, and upgrades.
- Most tools tend not to be engineered to commercial standards or to be maintained with changing technology. For example, only one tool (NatureServe Vista) is currently operating on ArcGIS 9.0 (though some developers of other tools have indicated that they are planning an upgrade to ArcGIS9.0). This situation affects all aspects of viability from:
  - o the number of users that can access the tools because of changing platform;
  - o the usability of a tool as a commercial quality software that functions well and is supported;

o  the ability of tools to interoperate on a common platform to support CMEBM as an interdisciplinary suite.

# Opportunities and Priorities

## Leverage Emerging Approaches to Conservation

This is an important time of transition in the development of conservation and EBM tools. Much work has transpired in conservation algorithm and DSS development over the last 15 years, with large increases in capability because of technological and scientific advancements.  During the past 1-2 years however, the conservation community has begun to question the historic trend and real world applicability of tools that optimize set solutions for conservation reserves and to develop alternatives.  Recent approaches have started to include socioeconomics, opportunistic vs. strategic decision making, and dynamic planning and management approaches to better replicate real world decision environments.  Developers acknowledge that these approaches add considerable complexity to the problem which strains current technological capability.

This paradigm shift is both a challenge and opportunity for development of new tools for CMEBM.  The Packard Foundation can avoid investment in limited or outdated approaches and can leverage the emerging approaches which we believe are better suited to CMEBM implementation.  Following are more specific recommendations from the NatureServe project team and workshop participants about the leading priorities and opportunities for the Foundation to maximize its investments in tools for CMEBM.

## Develop EBM Framework Process and Integration Tools

### EBM Framework Process

Our presentation of our EBM framework for tools sparked considerable discussion about the state of development of EBM process description.  There was strong recommendation that the Foundation support development of a general process model for EBM drawing on previous and ongoing work and case studies of actual projects.

### An EBM Process Support Tool and Team

Building on our concept for an EBM framework tool, workshop participants suggested a tool simply to guide EBM practitioners through the process and that a dedicated team of EBM consultants be created to offer scientific and technical assistance to EBM projects.  The process tool would guide practitioners through the framework process above, referencing technological tools, models, and case studies at the appropriate places.  We interpret the tool to be a software tool that can more readily access other technological tools (as well as documented processes), rather than a manual.  The team would be supported by the Foundation to consult with project teams to more effectively conduct EBM.

### An EBM Framework Integration Tool

The conservation and ecosystem management disciplines have lacked "framework" software tools that integrate separate tools and functions.  ArcView has historically played, and continues

to informally play, this role as a frequent platform for spatial decision support tools. However, it lacks the power to integrate the high variability of spatial and non-spatial data across multiple disciplines. Changes in ESRI software have also tended to render many older tools, based on their ArcView 3.x platforms, obsolete. For this reason we believe that CMEBM will require a framework tool, not a "super tool" that performs all functions but a framework system for integration. This framework would also provide tool development standards for the community of developers, many of whom desire to remain in the R&D realm rather than become distributors and supporters of software.

## Infill EBM Tool Function Gaps

NatureServe and the workshop participants identified the following gaps that should be priorities for tool development, whether they are added to existing tools or developed as new tools. Spanning the categories below is the workshop participants' general recommendation that more emphasis should be put on tools that support change—education, involvement, decision support, and implementation support versus more analytical tools (except perhaps in the area of economics).

### Ecosystem process integration

Functions are needed that can integrate ecosystem processes from terrestrial actions to freshwater changes to coastal-marine ecosystem (e.g., estuary) impacts. This is one of the most important needs for timely decision making – to be able to propose scenarios of terrestrial (and freshwater) activities and predict impacts on marine conservation elements.

### Economics integration

Functions are needed that better integrate economics in ways that more realistically represent real-world situations of multiple trade-offs in values and multiple methods and funding sources for mitigating threats. This area was highlighted by the workshop participants as a major gap in existing tool capabilities.

### Uncertainty integration

Increase the ability of existing tools and ensure that new tools (where appropriate) include information on uncertainty and report uncertainty about results. This includes confidence information about input data, models, analytical assumptions and inputs, and the confidence in results of analytical processes. Tools should be able to communicate the information in ways that are understandable and useful to decision makers.

### Decision support and public involvement

Workshop participants highlighted the challenges of the political process in reaching decisions among alternatives and acting on them. There is a need for tool functions that integrate stakeholders and the public at multiple phases of EBM, from initial education about issues, to involvement in development and choosing among alternatives, to formally commenting on proposed alternatives. Tools could facilitate implementers working together rather than acting independently on the information. Workshop participants also suggested that tools could help identify multiple benefits from management actions (e.g., controlling

water pollution can help an estuary ecosystem as well as local drinking water quality) to help on the political side of decision making and funding allocation.

## Implementation support

Identifying appropriate actions and funding to carry them out is a constant challenge EBM and conservation. A key function for implementation support tools is to link elements of conservation/management focus with implementing institutions, compatible/beneficial practices, and funding sources available for such practices or targeted at those elements.

## Inventory and monitoring

Functions are needed that build inventory and monitoring into the plan development process such that monitoring and thresholds for plan revision can be automated.

## Standards for tool interoperability

Develop technology standards that can facilitate interoperability among tools. Investigating this issue should be a priority activity of a developers' workshop.

# Suggested Follow-on Activities to This Study

## Publishing and maintaining the tools database

We plan to publish the final version of this report and our tools inventory on the NatureServe website (www.natureserve.org). Expanding and maintaining the database is recommended as tool development is highly dynamic and the database can serve as a valuable resource for CMEBM practitioners. Workshop participants recommended further review of the literature and interviews with CMEBM practitioners to determine the extent of use of specific tools and do further work to weed out tools that are no longer used/usable/available, etc.

## Revising and maintaining the framework for CMEBM

The workshop participants recommended that Packard Foundation:
- Work with EBM scientists and planners to develop a general process model for EBM that can be used to guide the planning and management process as opposed to our narrow objective of describing potential functions for tools. The NCEAS project currently supported by the Foundation may be a good vehicle for doing this.
- Add/revise functional groups to the framework (incorporated into Appendix 2 and note the name change of the functional group Conservation Area Selection/Protection found in Figure 3 to EBM alternatives analysis, decision support, and implementation) .

## Evaluating priority tools for software design and sustainability

This project utilized information from tool websites and a small number of interviews and questionnaires from tool developers. NatureServe and workshop participants made the following recommendations to further investigate existing tools:
- Investigate high priority tools in terms of user experience, how CMEBM functions are addressed, future development plans, and sustainability of the tool technologically, institutionally, and financially.

- Match tools to the types of users that will need to apply them and evaluate usability against their capabilities.
- The need to improve existing tools and create new tools is often best evaluated during actual field trials. Given the Foundation's support of CMEBM field projects, we recommend that a project team integrate with tool developers to utilize relevant tools and evaluate their current ability to contribute to their tasks as well as opportunities to improve the tools. Workshop participants discussed the need to adequately test tools against the breadth of CMEBM activities and suggested that more than one project environment may be needed.

## Designing a sustainable strategy for the Foundation's tools support program

The history of most relevant tools to date has been freeware developed primarily by academia and government serving a global but rather close-knit community of high-end users in the applied research realm. Training and support was conducted informally by email exchanges with the developers or fellow users. CMEBM implementation, on the other hand, requires participation by dozens of agencies and organizations of varying scientific and technical capability, with heavy work demands that preclude experimenting with "research" software. These spatially and thematically disparate users will need tools that can compile, compare, and integrate their work across an ecosystem dynamically without a technical team placed at each planning jurisdiction. We believe that CMEBM will require tools that are integrated with similar interfaces, terminology, and standards to allow the degree of dynamic integration required. The Foundation has already identified a next step of hosting a workshop among tool developers, their supporting institutions, and other IT professionals to advise on technology and sustainability strategies. The Foundation also will need a strategy for integrating and cooperating with other tools programs, such as the NOAA Coastal Services Center.

# Appendix 1: Participants in the Project Workshops and Report Review

**Workshop 1 Participants**

| Last Name | First Name | Affiliation |
|---|---|---|
| Andelman | Sandy | NCEAS |
| Baker | Jim | Academy of Natural Sciences |
| Barker | Kristin | NatureServe |
| Brandt | Sara | Chesapeake Bay Program |
| Olson-Callahan | Alyssa | NOAA Coastal Services Center |
| Christensen | Villy | University of British Columbia |
| Colianni | Gregory | EPA |
| Cook | Terry | The Nature Conservancy |
| Crist | Patrick | NatureServe |
| Grossman | Denny | NatureServe |
| Linker | Lewis | Chesapeake Bay Program |
| Madden | Chris | NatureServe |
| Rehmus | Scott | Packard Foundation |
| Sanjayan | Muttulingam | The Nature Conservancy |
| Scavia | Don | University of Michigan |
| Sugarbaker | Larry | NatureServe |
| Walsh | Mike | Envision |
| Wright | Nancy | University of Idaho |

# Appendix 2: Coastal-Marine Ecosystem-Based Management Framework

This is a three-level hierarchical description of objectives and tasks for CMEBM. The intent of this framework is to identify primary objectives and tasks for CMEBM that can be matched to existing or proposed software tools to support the planning, analyses, and management requirements for CMEBM. It is intended to be roughly sequential as a planning and management process but with iterations and recycling of steps as needed for adaptive management. This is a draft description that is not yet peer-reviewed. It has been modified somewhat from the version used to characterize existing tools in this report. The format of the framework is as follows:

1. Objectives
   **1.1.** Task
      **1.1.1.** Subtask

1. **Context characterization** (this section added by workshop participants and is not analyzed in the report)
   **1.1.** Ecological context
   **1.2.** Socioeconomic context
   **1.3.** Political/regulatory context
      **1.3.1.** Understand the receptors of the information to be developed, who needs to act on it
      **1.3.2.** What are the constraints to involvement and action
2. **Education and public outreach** (this section added by workshop participants and is not analyzed in the report)
3. **Information gathering & management**
   3.1. Identification of planning region boundaries
      3.1.1. Delineate marine areas related to elements and processes of interest
      3.1.2. Delineate terrestrial watersheds affecting the coastal-marine area/elements/processes of interest
   3.2. Ecosystem process models
      3.2.1. Describe types and paths of interactions
      3.2.2. Formulate models to quantitatively describe interactions
   3.3. Element identification
      3.3.1. Identify elements as management/conservation objects or processes of interest such as species, habitats, watersheds, estuaries, etc. for which quantifiable goals can be set
   3.4. Element requirements info
      3.4.1. Describe element viability or integrity requirements that define when quantifiable goals are met e.g., minimum species habitat viable area, minimum water quality parameters, etc.
      3.4.2. Setting goals
   3.5. Determination of social values

3.5.1. Record and compare community values in conservation, economic, and social welfare objectives

3.6. Create high-level value-based goals and visions for what the public desires the ecosystem to look like in the future (this section added by workshop participants and is not analyzed in the report)

3.7. Creation of management goals

    3.7.1. Translate vision goals into quantitative management goals

        3.7.1.1. Enter 1 or more quantitative goals for elements that can be evaluated against current baseline and any predicted future state of the ecosystem

        3.7.1.2. Set economic goals for relevant systems such as sport and commercial fisheries, tourism, etc.

## 4. Threat identification and impact analysis

4.1. Assessment of threats to goals

    4.1.1. Map and characterize marine-based threats to elements

    4.1.2. Map and characterize terrestrial-based threats to elements

    4.1.3. Map and characterize freshwater-based threats to elements

    4.1.4. Identify other threats: atmospheric, global warming (new)

    4.1.5. Rank relative importance of multiple stressors (new)

4.2. Impact analysis on element viability/integrity

    4.2.1. Calculate effect on element goals

    4.2.2. Calculate changes in element viability

## 5. Threat mitigation analysis

5.1. Characterize compatibility between element viability and the use, management, or disturbance to their associated habitats or areas.

    5.1.1. Describe beneficial restoration activities and prioritize areas for restoration

5.2. Generate optional or optimal scenarios that mitigate threat and or restore impacted element viability

## 6. EBM alternatives analysis, decision support, and implementation

6.1. Scenario comparison

    6.1.1. Calculate differences among scenarios in goal achievement relative to cost

6.2. Stakeholder involvement

    6.2.1. Facilitate visualization and understanding of options to allow informed decision making by stakeholders

    6.2.2. Facilitate group communication and voting on alternatives

    6.2.3. Facilitate group development and comparison of alternatives in real time

6.3. Facilitate Public comment solicitation, gathering, analysis (this item was added by the workshop participants and thus was not analyzed in this report)

6.4. Implementation plan support

    6.4.1. Facilitate implementation via planning unit identification, compatible land uses, report and map generation, etc

    6.4.2. Implementation budget calculation: calculate cost of implementation and allocate to planning units

## 7. Ecosystem management: adaptive management of the plan implementation

7.1. Marine management

    7.1.1. Facilitate management plan development in marine ecosystems

7.2. Terrestrial management

7.2.1. Facilitate management plan development in terrestrial ecosystems

7.3. Freshwater management

    7.3.1. Facilitate management plan development in freshwater ecosystems

7.4. Indicators development

    7.4.1. Generate list of indicators from plan inputs and routinely updated data sources such as indicators of select element viability measures, water quality, land cover, etc.

7.5. Monitoring plan development

    7.5.1. Generate locations of indicators for monitoring based on random sampling, cost, and efficiency of data collection

    7.5.2. Identify frequency of indicator data collection (new)

7.6. Inventory and monitoring implementation

    7.6.1. Manage implementation of inventory and monitoring data collection and management

7.7. Evaluation and adaptive management

    7.7.1. Identify problems for plan areas and elements based on monitoring data and preset thresholds for adaptive management

    7.7.2. Indicate adaptive management actions to be taken, i.e., which step(s) of this framework should be cycled back to for re-analysis

## 8. Project management

8.1. Name and track project authorship

8.2. Track and save analytical processes

8.3. Facilitate ecosystem management

    8.3.1. Managing time-sensitive milestones

    8.3.2. Managing dependencies of management activities

    8.3.3. Incorporating inventory and monitoring with action thresholds for plan revision

## 9. Metadata and other documentation

9.1. Produce metadata

9.2. Allow documentation of other inputs/decisions

## 10. Reporting and visualization

10.1. Produce reports that can be exported to other word processing and tabular software tools

10.2. Automatically produce map graphic results of analyses

10.3. Allow customization of report and map result templates

# Appendix 3: List of tools identified for consideration in CMEBM

For complete definitions of the terms used in the Category field, please refer to page 5 in this document. Priorities were established for further investigating a tool. High priority tools were fully annotated in Appendix 4, and medium priority tools are summarized in Appendix 5.

| Category | Name | Priority | Ecotype |
|---|---|---|---|
| conservation | BMAS Biodiversity Management Area Selection | Low | Terrestrial |
| conservation | CODA Conservation Options and Decision Analysis | Medium | Terrestrial |
| conservation | C-Plan, the Conservation Planning System | High | Terrestrial |
| conservation | GIA Green Infrastructure Assessment (MD Greenprint) | Low | Terrestrial |
| conservation | HEP USGS Habitat Evaluation Procedures | Low | Terrestrial |
| conservation | MARXAN/SPEXAN | High | Terrestrial |
| conservation | RELM Regional Ecosystems and Land Management | Low | Terrestrial |
| conservation | ResNet GUI | Medium | Terrestrial |
| conservation | RESTORE | Low | Terrestrial |
| conservation | Sites: An Analytical Toolbox for Ecoregional Conservation Planning | Medium | Terrestrial |
| conservation | TAMARIN Toolbox for Analysis of Mata Atlântica Restoration Incentives | Low | Terrestrial |
| conservation | TARGET | Medium | Terrestrial |
| conservation | WorldMap | Medium | Terrestrial |
| decision | Expert Choice | Medium | N/A |
| decision | InfoHarvest | Low | N/A |
| decision | LIAM Legal Institutional Analysis Model | Low | N/A |
| growth | CITYgreen | Low | Terrestrial |
| growth | CommunityViz Scenario 360 | High | Terrestrial |
| growth | LandUse Analyst | Low | Terrestrial |
| growth | TRANSIMS Transportation Analysis and Simulation System | Low | Terrestrial |
| growth | UrbanSim Project | Low | Terrestrial |
| interdisciplinary | CAPS Conservation Assessment and Prioritization System | High | Terrestrial |
| interdisciplinary | Chesapeake Bay Program Community Watershed Model | High | Freshwater |
| interdisciplinary | CLAMS Coastal Landscape Analysis and Modeling Study | Low | Terrestrial |

| Category | Name | Priority | Ecotype |
|---|---|---|---|
| interdisciplinary | Cormas: Natural Resources and multi-agent simulations | Low | Terrestrial |
| interdisciplinary | COSMO Coastal Zone Simulation Model | High | Marine-coastal |
| interdisciplinary | DSS for Stormwater Management System Selection | Low | Freshwater |
| interdisciplinary | EMDS Ecosystem Management Decision Support (from USDA) | High | Terrestrial |
| interdisciplinary | EPA BASINS Better Assessment Science Integrating point & Nonpoint Sources | Medium | Freshwater |
| interdisciplinary | GeoChoice | Low | Terrestrial |
| interdisciplinary | INDEX Planning Support System | High | Terrestrial |
| interdisciplinary | LAMPS Landscape Management Policy Simulator (used in CLAMS) | Low | Terrestrial |
| interdisciplinary | Nobility EM | Medium | Terrestrial |
| interdisciplinary | PLACE3S | Medium | Terrestrial |
| interdisciplinary | PNCERS Pacific Northwest Coastal Ecosystems Regional Study | Medium | Marine-coastal |
| interdisciplinary | Quantm | Medium | Terrestrial |
| interdisciplinary | QUEST by Envision Sustainability Tools | Low | Terrestrial |
| interdisciplinary | RamCo Rapid Assessment Module Coastal Zone Management | Medium | Marine |
| interdisciplinary | SCREAM Southern California Riparian Ecosystem Assessment | Low | Terrestrial |
| interdisciplinary | SimCoast | Medium | Marine-coastal |
| interdisciplinary | Spectrum | Medium | Terrestrial |
| interdisciplinary | STREAM Spatial Tool for River basins, Environment and Analysis of Mgt options | Low | Freshwater |
| interdisciplinary | VISTA NatureServe | High | Terrestrial |
| interdisciplinary | WadBOS Wadden Sea spatial DSS | Low | Marine |
| mapping | EASy Mapping Solutions for Marine Resources | Medium | Marine |
| mapping | RangeView | Medium | Terrestrial |
| mapping | Regional SeaGrant mapping of NE coast | Low | Marine-coastal |
| mapping | SIMoN Sanctuary Integrated Monitoring Network | Low | Marine-coastal |
| model | Aqualand: The Massachusetts Aquatic Landscape Characterization Tool | Medium | Freshwater |
| model | DESIMA DEcision Support for Integrated coastal zone | Low | Marine- |

| Category | Name | Priority | Ecotype |
|---|---|---|---|
| | MAnagement | | coastal |
| model | EPA AQUATOX | High | Freshwater |
| model | ISAT Impervious Surface Analysis Tool | Medium | Terrestrial |
| model | LUCAS Land-Use Change and Analysis System | Low | Terrestrial |
| model | MMS Modular Modeling System | Medium | Terrestrial |
| model | POLCOMS Coastal Ocean Modeling System | Low | Marine |
| model | RiverWare | Low | Freshwater |
| model | SWAMP Spatial Wetland Assessment for Management and Planning | Medium | Freshwater |
| model | TELSA Tool for Exploratory Landscape Scenario Analyses | Low | Terrestrial |
| Model | The Nature Conservancy 5 S process | New | All |
| model | USGS GenScn - GENeration and analysis of model simulation SCeNarios | Low | Freshwater |
| model | UTOOLS | Low | Terrestrial |
| model | WMAD Watershed Management and Analysis Division (MD Greenprint) | Medium | Terrestrial |
| programming | EcoSim | Low | Terrestrial |
| programming | Geonamica DSS (parent of WadBOS) | Low | N/A |
| resource | ArcForest | Low | Terrestrial |
| resource | CRiSP Columbia River Salmon Passage Harvest Program | Low | Marine |
| Resource | EPlan | New | N/A |
| resource | EwE Ecopath with Ecosim | High | Marine |
| resource | MAGIS: A Multi- Resource Analysis and Geographic Information System | Low | Terrestrial |

# Appendix 4: Descriptions of High Priority Tools

# High Priority Tool Directory

The following page numbers are approximate depending on your computer settings

The following descriptions were generated from our Access database and reflect formatting limitations of exporting that data.

| Name | AQUATOX (EPA) |
|------|---------------|

| | |
|------|---------------|
| Category | model |
| URL | http://www.epa.gov/ost/models/aquatox/about.html#about |
| Status | released | Date of release |
| Contact | Marjorie Coombs Wellman |

Office of Science and Technology, U.S. EPA, 1200 Pennsylvania Ave., NW (4305T)

Washington, DC, 20460

telephone: 202-566-0407

wellman.marjorie@epa.gov, ncepimal@one.net,

Water Resources Center at 202-566-1729

Survey source      web

Summary      AQUATOX predicts the fate of various pollutants, such as nutrients and organic chemicals, and their effects on the ecosystem, including fish, invertebrates, and aquatic plants. AQUATOX is a valuable tool for ecologists, biologists, water quality modelers, and anyone involved in performing ecological risk assessments for aquatic ecosystems.Release 2 has enhanced scientific capabilities and analytical tools to more completely simulate and understand aquatic ecosystems.

      AQUATOX is a PC-based ecosystem model that predicts the fate of nutrients and organic chemicals in water bodies as well as their direct and indirect effects on the resident organisms. Most water quality models predict only concentrations of pollutants in water: they do not project effects of pollutants on organisms. AQUATOX simulates multiple environmental stressors (including nutrients, organic loadings and chemicals, and temperature) and their effects on the algal, macrophyte, invertebrate, and fish communities. Therefore, it can help identify and understand the cause and effect relationships between chemical water quality, the physical environment, and aquatic life. AQUATOX can represent a variety of aquatic ecosystems, including vertically stratified lakes, reservoirs and ponds, and rivers and streams.

      AQUATOX can be used in a myriad of ways to address water management issues (water quality criteria and standards, Total Maximum Daily Loads, and ecological risk assessment). AQUATOX should be considered when the user needs to understand the processes relating the chemical and physical environment to the biological community.  The model has been tested and validated for modeling nutrient loads in natural and constructed fresh water systems in Onondaga Lake, New York and the Coralville Reservoir in Iowa and it has been used to model the bioaccumulation of PCBs in Lake Ontario.

| | |
|------|---------------|
| Ecotype | freshwater |
| Scale | watersheds |
| Transferability | by watershed |
| Cost | free |
| Usability | GIS novice |

Platform                    ArcView 3.x

Source Code                 unavailable

Support/Training            Manual available for download

Info gathering and management    Includes identification of planning boundaries, ecosystem process modeling, and selection of elements

Goal setting & evaluation        Ability to set ecological goals

Threat ID & impact          Ability to identify threats to ecological goals and conduct impact analysis on ecological viability

Threat mitigation           Identification of restoration area and type

Conservation area           Not determined

Ecosystem Management        Not determined


Used for:       water quality risk assessment

Comment        This is a fate and ecological effects model showing biology/toxin interaction. It can be linked with BASINS GIS extension and watershed modeling system software (see this report).  It is unknown if the tool has been or can be used in marine environments.

Feedback       This is a simulation modeling tool for ecologists, biologists, and water quality modelers for performing ecological risk assessments in aquatic ecosystems.  Targets the fate and effects of nutrients and organic chemicals in aquatic systems, also includes ecological relationships and multiple stressor effects.

| Name | **CAPS Conservation Assessment and Prioritization System: An Interactive Decision-Support System** |
|---|---|
| Category | interdisciplinary |
| UR | http://www.umass.edu/landeco/research/caps/caps.html |
| Status | not released          Date of release expected December, 2004 |
| Contact | Dr. Kevin McGarigal, University of Massachusetts |
| | mcgarigalk@forwild.umass.edu |
| | 304 Holdsworth Natural Resources Center |
| | Box 34210 |
| | Amherst, MA 01003 |
| | Fax: (413) 545-4358 |
| | Phone: (413) 577-0655 |
| Survey source | Interview 8/20/04 |

Summary      CAPS is a computer software program designed to assess the biodiversity value of every location based on natural community-specific models, and (in combination with other relevant data), to prioritize lands for conservation action based on their assessed biodiversity value.  CAPS adopts a pragmatic focus on the maintenance of viable populations of all native species (from carnivores to soil bacteria) and communities found in their natural places, distributed and functioning within their natural range of variability.  The prototype development and pilot application of CAPS was done on the Housatonic River watershed in western MA.  The Housatonic Biodiversity Assessment Project is a community-based, coarse-filter approach— this system assumes that by conserving intact, biologically-defined natural communities, we can conserve most species and ecological processes.  The coarse filter is a first step in the process of targeting land for conservation.  CAPS and the related tool Aqualand do integrate assessments of fresh water resources into their capabilities, although they are not specifically designed to emphasize aquatic systems.  Both seem to be in their early developmental phases, with little application of the tools beyond MA.  The documentation does not refer to application in coastal or marine environments and the focus is on streamsheds and reservoirs in terrestrial contexts.

This approach to biodiversity valuation involves applying one or more "biodiversity filters" to each point and patch in the landscape.  The landscape is a map of predicted natural communities modeled from satellite imagery and terrain data.  Each filter consists of a model that applies community-specific criteria to the content, context, spatial character, or condition of a point or patch in the landscape to arrive at an index of biodiversity value.  Typically, several filters are applied to the landscape and then integrated in a weighted linear combination.  This process results in a final "biodiversity value" for each point in the landscape.  Intermediate results are saved to facilitate analysis—thus users can examine not only a map of the final biodiversity values, but maps of road intensity, natural community patch area, soil series diversity within forested areas, and so on.  Results from biodiversity filters are integrated in weighted linear combinations.  The user supplies weights to reflect the relative importance of each filter for each community.  Biodiversity values within each group are multiplied by their weights and added together.

CAPS was used recently in Massachusetts to evaluate different highway construction scenarios to calculate the impacts on biodiversity and quantify mitigation acreage. A freshwater version was developed by using different data and developing new filters to process that data. The developer speculated that a coastal version of the program would be possible by developing new filters and utilizing coastal ecology data.

Ecotype            Terrestrial, freshwater

Scale              not fixed
Transferability    transferable (very flexible)

Cost               free
Usability          expert user for current program
Platform           C++, requires ArcView spatial analyst or ArcGIS
Source Code        not available
Support/Training   documentation under development

Info gathering and management       Allows identification of planning boundaries; can benchmark values to obtain a relative value even outside of planning boundaries (such as patch size in boundary valued relative not only to boundary area but to entire state)

     Does not model ecosystem processes directly, but the filters implicitly incorporate ecosystem processes, such as the connectiveness filter.

     Includes ability to select elements and set element requirements at the natural community level.

     Although confidence information is not directly weighed, users can weight the filters based on their confidence that it is applicable/reflects accurate data.

Goal setting & evaluation          Allows setting of ecological goals
Threat ID & impact                 Identifies threats to ecological goals, calculates impact on ecological viability
Threat mitigation                  Identifies compatible land-use, restoration sites, and areas with reserve potential
Conservation area selection        Generates scenarios (limited only by time and resources). (A) Does not directly involve multiple stakeholders, but facilitates involvement by enabling each party to run a scenario for comparison using different priorities and filter weights.
Ecosystem Management               Not determined

Used for:      prioritize lands for conservation based on biodiversity

Comment      The strengths of this tool are in the objective visualization of conservation impacts and values, and fine resolution capabilities (down to 10 m units). With modification, it could be adapted to the marine environment.

     The weaknesses are that it's not end-user-friendly, and although the scenarios the tool generates are very inclusive and powerful, it is a cumbersome process, requiring a great deal of time and computer power. CAPS doesn't incorporate economics or socio-political aspects,

and there are no stakeholder meeting or negotiation functions.

Feedback        This is a pure conservation tool with no socio-economic aspects but several useful functions.

| Name | **Chesapeake Bay Program Community Watershed Model** |
|---|---|

| Category | interdisciplinary |
|---|---|
| URL | http://www.chesapeakebay.net/temporary/mdsc/community_model/ |
| Status | released                          Date of release |
| Contact | Chesapeake Bay Program Office, |

410 Severn Avenue, Suite 109,
Annapolis, MD 21403
(800) YOUR-BAY
Fax: (410) 267-5777

Survey source     web

Summary     The Chesapeake Bay Community Watershed Model was developed to empower state and local governments, academics, and other interested parties to run their own decision scenarios on the Chesapeake Bay Program's Watershed Model. Using this model, a group can determine the nutrient and sediment loads delivered to the Bay under various management strategies. By installing this model, supplying data on management practices, land use, and/or other relevant factors, and following the step to run the model, users can determine the loads that result.

The model system's use and application requires some knowledge of model simulation environments and procedures, the linux operating system, and the ability to manipulate input files (it is not transparent and there is not a user-friendly GUI).  The watershed model is connected to a sophisticated hydrodynamic model, also free and available but more complex and even less accessible to novices than the watershed model.  The system is made as transportable as possible, with online tutorials and training courses, but it is an extremely complex and powerful tool, not easily distilled into a simple package.  The circulation model is currently being modified and adapted for the Florida Bay estuary in support of the Comprehensive Everglades Restoration Plan.

The CBCWM combines this tool, along with significant investment in programs that involve local stakeholders, to create a community process.  Volunteers are involved in monitoring and restoration, adding a community and public aspect to the use of this tool.  Local stakeholder investment in the process has contributed to the model's success in action.

There is also a rough version of a Chesapeake Bay Hydrodynamic model available.

| Ecotype | Freshwater |
|---|---|
| Scale | fixed |
| Transferability | customization required |
| Cost | free |
| Usability | accessible to trained modelers- a community model system |
| Platform | The general system requirements are for a Linux operating system installed |

on a platform with at least a Pentium processor and a 4Gb Hard Drive.
Source Code        available
Support/Training    Two instruction files


Info gathering and management        Includes ecosystem process models and specification of
elements and element requirements.

Goal setting & evaluation        Undetermined
Threat ID & impact        Identifies threats to ecologic goals and conducts impact
analysis on ecosystem viability
Threat mitigation        Identifies optimal areas for restoration activities

Conservation area        Enables scenario comparisons and stakeholder involvement

Ecosystem Management        Undetermined

Used for:        impact of land use on Chesapeake Bay

Comment        This is a good example of a community making conservation/restoration decisions
with the help of an ecosystem-process model.  Although the actual model does not incorporate
all of the framework tasks, the process surrounding it with the Chesapeake Bay Program Office
and the local community complete almost all of them on the basis of the model.  Goals are set,
restoration scenario costs are calculated, and on-going monitoring and scenario generation
contribute to active and adaptive management.



Feedback        This tool contains a detailed evaluation and prediction of aquatic effects and
allows "what if" scenario evaluation.  The Linux operating system may be uncommon for the
types of users intended.  Although perhaps less integrated than other tools, the community aspect
of the process may allow each section of the process to develop more fully according to local
needs.

| Name | **CommunityViz Scenario 360** |
|---|---|

| | |
|---|---|
| Category | growth |
| URL | http://www.communityviz.com/ |
| Status | released       Date of release   April, 2004 |
| Contact | Bill Shouldice<br>1035 Pearl St, 5th Floor<br>Boulder, CO, US 80302<br>802.773.6336, 303.442.8800<br>hq@orton.org<br>Fax: 303.449.2487 |
| Survey source | web |

Summary    Scenario 360 is the second generation of GIS-based decision support software for planners and resource managers. It is an ArcGIS extension that adds interactive analysis tools and a decision-making framework to the ArcGIS platform. It allows the user to view, analyze and understand land-use alternatives and impacts. Scenario 360 makes land-use decisions more visual, more collaborative, and more effective. The user can:

- experiment with hypothetical scenarios
- measure economic, social, environmental, and visual considerations
- challenge assumptions on the fly
- view impacts of proposed changes
- make holistic, informed decisions

Scenario 360 takes advantage of ESRI's ArcGIS 8.3 capabilities, including scalable architecture, advanced editing tools, high-quality cartography, on-the-fly projection, and support for many different data formats.

Scenario 360 allows side-by-side viewing of alternative scenarios within the ArcMap environment. In addition, charts, maps and images can be tiled for comparison, presentation and review. Comparing alternatives in a visual manner can be a powerful way to educate stakeholders and make more informed and collaborative decisions.

Scenario 360 works with spatial data the way an Excel® spreadsheet works with numbers. Spatial information, table information and assumptions such as cost, count, density, etc., can be used to create formulas. These formulas dynamically calculate indicators of the designated impacts for alternative scenarios. As assumptions are changed or tables and shapefiles are edited, the formulas recalculate the indicators in real time, showing the updated changes in simple charts.

Scenario 360 uses dynamic attributes that can be automatically updated as changes are made to an analysis. This means that changes that are made to one aspect of the analysis drive recalculations and responsive changes throughout all related parts of the analysis. Formulas are associated with each dynamic attribute and they specify how the dynamic attribute is calculated. Dynamic attributes can be defined for any editable feature layer or database table layer. Users can quickly build 3D models and perform real-time exploration of photo-realistic site or landscape scale scenes. They can use over 350 models of houses, buildings, trees, and streetscapes from the exclusive CommunityViz Model Library that comes with our SiteBuilder

3D software, or create custom models using the optional ModelBuilder 3D application. Users are able to create a "fly-through" movie and share it as an AVI file, or share interactive 3D scenes via a free real-time viewer.

Although not specifically developed for aquatic situations, in its extensive nationwide usage, CommunityViz has been applied to freshwater systems such as in the Watershed Functional Rehabilitation Model for the Pasquotank River, NC, a water resource protection study in Black Earth Creek, WI, in developing the Resource Management Plan for the Lakeview District, OR, for a floodplain naturalization study in the Illinois River Valley, IL, and for a regional drinking water protection project in Laramie, WY.  No applications to coastal or marine systems have been noted.

The software includes many presentation features that assist in presenting information to various groups. People can ask "what if" questions and play out "if then" scenarios quickly and effectively. The result is an informed dialogue that leads to stronger consensus, better decisions, and far greater support for land-use plans.
     What if? is a complimentary product, an interactive GIS-based system which allows users quickly and easily to explore alternate local development scenarios and project future land use patterns and associated population, housing, and employment trends. The package is easy to use, customized to the user's GIS data and policy issues, and provides outputs in a variety of easy-to-understand maps and tables.
     As its name suggests, "What if?" is an explicitly policy-oriented planning tool for determining what would happen if public policy choices are made and assumptions about the future prove to be true. Policy choices that can be considered in the model include: (1) the expansion of public infrastructure such as major roads and sewer or water service; (2) the implementation of farmland or open space protection policies, or (3) the adoption of different land use plans, zoning ordinances, or other growth controls. Assumptions that can be incorporated into the model include future population and housing trends and the characteristics of future residential, industrial, and commercial development.
     What if? provides customized computational routines that are not available in any GIS product or any other commercially available package. The key functions performed by the software are:

- Conducting Suitability Analysis.
- Projecting Land Use Demand.
- Allocating Future Land Use Patterns


| | |
|---|---|
| Ecotype | Terrestrial |
| Scale | not fixed |
| Transferability | transferable |
| Cost | $2,500.00 for one seat, $250.00 for a lap-top add-on (allows you to use the software on a laptop in addition to your regular computer), includes 1 year of Technical Support & Maintenance. |
| Usability | GIS novice |
| Platform | ESRI ArcView 3.2/3.3 platform and ESRI ArcGIS 8.3 platform. |
| Source Code | undetermined |

Support/Training    First year included with cost of program.  Technical Support & Maintenance Plan $625 per seat per year, $750 for one seat plus lap-top add-on per year

Info gathering and management        Includes identification of planning boundaries and element selection

Goal setting & evaluation        Ability to set ecological goals, set economic goals, and include multiple stakeholders

Threat ID & impact                Not determined

Threat mitigation                Not determined

Conservation area                Scenario comparisons

Ecosystem Management                Not determined

Used for:        community planning, land-use proposal evaluation

| Name | **COSMO Coastal Zone Simulation Model** |
|---|---|

| Category | Interdisciplinary |
|---|---|
| URL | http://www.netcoast.nl/tools/cosmo.htm |
| Status | released          Date of release |
| Contact | Mr. H. Niesing |
| | telefax +31 70 3114380 |

Survey source          web

Summary          COSMO (Coastal Zone Simulation Model) is a component of a large suite of planning and modeling tools in the Integrated Coastal Zone Management (ICZM) package. ICZM tools are instruments to organize information and options about coastal zone planning and transfer that information. The design of the tool set reflects an enlightened philosophy that recognizes that coastal planning is an iterative cyclic process from problem recognition to planning to implementation to evaluation.

COSMO demonstrates the main steps in the design, analysis and evaluation of Coastal Zone Management plans. The program is an interactive tool that allows coastal zone managers to explore the impacts of development projects and environmental and coast protection measures. COSMO calculates various criteria, including long term effects of climate change, reflecting the use of the coastal zone. In the sample download of the program, simulation of the CZM problems takes place in the fictional territory of Catopia, a developing region situated along the waters of Catfish Bay. In the first round, one can explore a number of predefined cases. In the second round, the user is allowed to specify new development scenarios and combinations of measures.

Ecotype          coastal/marine

| Scale | not fixed |
|---|---|
| Transferability | transferable to any coastal/marine area |
| Cost | $150 |
| Usability | |
| Platform | Minimum hardware and software required are a PC with a 80386 |

processor, 3.5" disc drive, high density and MS Windows 3.1.

| Source Code | Unavailable |
|---|---|
| Support/Training | No training available |

Info gathering and management          Includes selection of elements and element requirements
Goal setting & evaluation          Ability to set ecological and economic goals
Threat ID & impact          Ability to identify threats to ecological goals, conduct impact analysis on ecological viability, and identify threats to economic goals
Threat mitigation          Identification of restoration area and type and creation of reserve scenarios
Conservation area selection          Allows scenario comparison, cost/benefit analysis, and budget calculation of implementation budget

Ecosystem Management                    Not determined

Used for:        Interactive simulations of coastal management plans

Comment        Tool for designing, analyzing and evaluating of CZM plans.  Interactive
framework for managers to explore impacts of development projects & environmental and
coast protection measures; good interface and excellent user accessibility; low requirements for
equipment and software.

Feedback                    Fairly complete interdisciplinary scenario evaluation, and can calculate
several environmental and socio-economic indices of impacts.  Although the visualization may
not be as sophisticated as CommunityViz and INDEX, it may be an easier communication
vehicle.  It can't "goal seek" scenarios.
        Though the web interface describes what looks to be a strong and well-developed tool set, it
also exhibits a lack of attention to detail as it is fraught with spelling errors.  There is obviously
an international focus to the package, increasing the applicability to global coastal issues.  It is
developed and maintained in an international venue (Netherlands), which would potentially
detract from the accessibility and interoperability of the toolset.  Another positive aspect of the
package is the explicit goal of biodiversity conservation and the direct application of the system
to coastal and estuarine ecosystems. Although COSMO is clearly intended to be used by coastal
zone managers in real world applications such as salt water intrustion and coastal land use, there
is not much evidence of the tool gaining traction.  The website is not informative and requires
contacting the European developers directly for further information.

Name                **C-Plan, the Conservation Planning System**

| | |
|---|---|
| Category | conservation |
| URL | http://members.ozemail.com.au/~cplan/ |
| Status | released                Date of release |
| Contact | cplan@ozemail.com.au, New South Wales National Parks & Wildlife Service |
| | 87 Faulkner Street (PO Box 402) |
| | Armidale NSW 2350 Australia |
| | Phone: + 61 2 6776 0040 |
| | Fax:    + 61 2 6772 2424 |
| Survey source | web |

Summary      C-Plan is a system designed to support conservation planning decisions.

C-Plan is a windows-based software package that when linked to a GIS can display the relative contribution (Irreplaceability and other measures) of land areas (sites) towards a predefined conservation goal. These contribution measures are derived from a biological database containing modeled species or forest distributions and/or actual survey results. The conservation goal takes the form of targets (goals) assigned to individual biological entities (features) within the landscape.

C-Plan is interactive in the sense that it can recalculate and redisplay these measures when one or more sites are earmarked for protection (by selecting sites in the GIS). All recalculations take any changes into account (sites that are selected or deselected for protection) and the result is mapped back onto the GIS to display a new pattern of options. The level of protection assigned to an area can be varied (note that this is still being developed to incorporate zoning for different land use zones).

C-Plan has the capability to include resource data such as timber yields. Using searches to identify sites with high conservation value, that also have a low timber production potential, it is possible to minimize the impact on timber reserves while still achieving conservation goals. Timber yield is just one example of a 'cost' associated with conservation, other costs might include total land area selected for protection or the acquisition cost of that land area.

For any site the biological database can be queried to return a list of features and their target status (percentage of target satisfied). It is also possible to identify sites that contain important features that remain under target.

All the information calculated by C-Plan (status of feature targets and sites) can be recorded in reports that can be dumped out at any stage to be read and manipulated in Excel. All site selection decisions can be fully documented in C-Plan. The selection log keeps a record of all selections and also enables the user to 'wind back' to earlier stages and resume the selection process from there.

The 'Minset' feature allows the user to build up a set of rules (an algorithm) to select one or more sites in an iterative search. Each time a site is selected, using the algorithm, C-Plan recalculates all site indices and selects the next site using the same algorithm and the updated site indices. Using this feature it is possible to minimize any predefined costs such as timber resource, land area selected or acquisition cost when selecting sites. It is also possible to enter a stopping condition that will stop site selection when the resource remaining in available sites

drops to a specified level. C-Plan will soon integrate with the popular Marxan (see this report) tool which conducts near-optimization of conservation solutions given a set of features and targets.

Ecotype          Terrestrial

Scale            not fixed

Transferability  trans

Cost             free

Usability

Platform          C-Plan operates in NT4 or Windows 95 operating systems. For the graphical interface C- Plan links in with the ESRI ArcView3.X GIS (ArcView version 2 is not compatible). An ArcGIS version is under development.  C-Plan produces reports in the form of comma delimited files that can be viewed in any spreadsheet program such as Microsoft Excel.

Source Code       undetermined

Support/Training   Downloaded manual includes tutorials for two sample data sets. Project support provided by the C-Plan R&D group within the National Parks and Wildlife Service. Training can be given to large groups in preparation for negotiations. GIS scripts and custom utilities for generating datasets and modifying data formats are available upon request.

Info gathering and management      Includes identification of planning boundaries, element selection, and specification of element requirements

Goal setting & evaluation          Ability to set ecological goals, set economic goals, and allocate goals

Threat ID & impact                 Compatible land use identification, reserve scenarios

Threat mitigation                  Not determined

Conservation area                  Scenario comparison

Ecosystem Management               Development of indicators

Used for:       Calculating the relative contribution of land to conservation goals

| Name | **EMDS Ecosystem Management Decision Support (USDA)** |
|------|------|

| Category | interdisciplinary |
|------|------|
| URL | http://www.fsl.orst.edu/emds/ |
| Status | released | Date of release version 3 released 11/1/2002 |
| Contact | Keith ReynoldsPhone: 541-750-7434 |
| | 603-853-2794 |
| | kreynolds@fs.fed.us |

Survey source      web

Summary      The Ecosystem Management Decision Support (EMDS) system is an application framework for knowledge-based decision support of ecological assessments at any geographic scale.   The system integrates state-of-the-art geographic information system (GIS) as well as knowledge-based reasoning and decision modeling technologies in the Microsoft Windows® (hereafter, Windows) environment to provide decision support for a substantial portion of the adaptive management process of ecosystem management.

The NetWeaver logic engine evaluates data against a knowledge base that provides a formal specification for the interpretation of data. A knowledge base can be thought of as a type of meta database. EMDS application developers use the NetWeaver Developer System (Rules of Thumb, Inc.) to design the knowledge bases used in EMDS. The logic engine allows partial evaluations of ecosystem states and processes based on available information, making it ideal for use in landscape evaluation where data are often incomplete. The NetWeaver engine was selected as the core logic processor of EMDS because its associated development system readily supports design of logic specifications for the types of large, complex, and abstract problems typically posed by ecosystem management.

A second key feature provided by the logic engine is the ability to evaluate the influence of missing information on the logical completeness of an assessment. The engine, in conjunction with the EMDS Project Environment and the Data Acquisition Manager, provides powerful diagnostic tools for determining which missing data are most valuable given currently available data and for determining how much priority to give to missing data given other logistical information.

Sophisticated geographic analyses often produce impressive looking maps. However, if the analytical system that produces a map cannot also explain the derivation of analysis results being portrayed in a relatively simple and straightforward way, then the system appears to observers as a black box. With the high level of public interest in natural resource management in these times, black box solutions are a political liability. The Hotlink Browser displays the evaluated state of a knowledge base. Users can navigate the networks of analysis topics to trace the logic of evaluations in an intuitive interface.   More importantly, the presentation of results in this graphic format is sufficiently intuitive that users of the system can use the Hotlink Browser as a powerful communication tool that effectively explains the basis of evaluation results to broad audiences.

The Priority Analyst (PA) is a planning component that assists with setting priorities for management activities in landscape elements of the assessment area given results of a landscape evaluation performed by the NetWeaver logic engine. Whereas the logic engine addresses questions about the current state of the assessment area, PA addresses questions about where to direct management for best effect. For most applications of evaluation and planning, maintaining this distinction is important because the landscape elements in poorest condition are not necessarily also the best candidates for management activities such as restoration for example. PA is a Multi-Criteria Decision Analysis (MCDA) component that assists resource managers in ranking landscape elements based on how well each rates against a set of decision criteria. Using output from a landscape evaluation and a decision model designed in Criterium DecisionPlus (InfoHarvest, Inc.), PA rates the landscape elements not only with respect to their condition, but also with respect to factors related to the feasibility and efficacy of management. PA implements two decision models: the Analytic Hierarchy Process (AHP) and the Simple Multi-Attribute Rating Technique (SMART).

The EMDS extension to ArcMap consists of the six components described in this section. For practical purposes, the EMDS Project Environment can be thought of as a supervisory component of the extension that manages the activities and interactions of the other components (see EMDS System Components) within the ArcMap environment. The EMDS Project Environment also is the primary component of the extension with which a user interacts to set up assessments, analyses, and scenarios, all of which are organized within a tree view of project structure.

ArcMap itself provides the resource manager with a powerful GIS environment in which to visualize, create, process, and display spatial information. It is in ArcMap where a user assembles all the necessary data layers to be processed by the NetWeaver logic engine, and ArcMap handles all EMDS spatial displays. More generally, however, because EMDS is implemented as an ArcMap extension, all the spatial processing power inherent to ArcMap, and any of its other available extensions, is available to the EMDS user.


Ecotype            Terrestrial

Scale              not fixed

Transferability    transferable

Cost               Free, but two commercial application development systems are required in conjunction with EMDS in order to create or edit logic models for landscape evaluation or decision models for planning: NetWeaver Developer and InfoHarvest's Criterium DecisionPlus.

Usability          GIS novice

Platform           ArcMap

Source Code        undetermined

Support/Training   download training manual and user guide

Info gathering and management    Includes identification of planning boundaries, element selection, and specification of element requirements

Goal setting & evaluation        Ability to set ecological goals and include multiple stakeholders

Threat ID & impact               Not determined

Threat mitigation                Not determined

Conservation area                    Not determined

Ecosystem Management        Development of indicators and monitoring plan, implementation of plan and monitoring, evaluation and adaptive management

Used for:        landscape evaluation and planning, primarily in public forest applications

Comment:        Developed for forested watersheds in the Pacific Northwest US, the tool has gained popularity and wide usage in many regions on several continents, though by far, with over 300 users, the greatest usage is in North America.   A pilot project is presented for the Chewaucan watershed.  Applications include evaluating ecosystem sustainability, landscape integrity, and salmon habitat suitability.  This product is in wide use and seems applicable and transportable to a variety of terrestrial systems and watersheds though some users report a very substantial effort upfront to populate the models.

Feedback        robust scientific modeling program, high detail

| Name | **EwE Ecopath with Ecosim** |
|---|---|

| Category | interdisciplinary resource |
|---|---|
| URL | http://www.ecopath.org/ |

| Status | released | Date of release | EcoPath – 1990, EwE - 1995 |
|---|---|---|---|
| Contact | Villy Christensen | | |
| | UBC Fisheries Centre | | |
| | 2259 Lower Mall | | |
| | Vancouver BC, V6T1Z4 | | |
| | (604) 822-5751 | | |
| | (604) 822-8934 | | |
| | v.christensen@fisheries.ubc.ca | | |

Survey source web and interview with Villy Christensen 7/21/04

Summary     EwE is an ecological software suite with more than 2000 registered users representing 120 countries. More than a hundred ecosystem models applying the software have been published.  EwE has three main components: Ecopath – a static, mass-balanced snapshot of the system; Ecosim – a time dynamic simulation module for policy exploration; and Ecospace – a spatial and temporal dynamic module primarily designed for exploring impact and placement of protected areas. The Ecopath software package can be used to

- Address ecological questions;
- Evaluate ecosystem effects of fishing;
- Explore management policy options;
- Evaluate impact and placement of marine protected areas;
- Evaluate effect of environmental changes.

     The foundation of the EwE suite is an Ecopath model (Christensen and Pauly 1992, Pauly *et al.* 2000), which creates a static mass-balanced snapshot of the resources in an ecosystem and their interactions, represented by trophically linked biomass 'pools'. The biomass pools consist of a single species, or species groups representing ecological guilds. Pools may be further split into ontogenetic (juvenile/adult) groups that can then be linked together in Ecosim. Ecopath data requirements are relatively simple, and generally already available.

     Ecosim provides a dynamic simulation capability at the ecosystem level, with key initial parameters inherited from the base Ecopath model. The key computational aspects are in summary form:
- Use of mass-balance results (from Ecopath) for parameter estimation;
- Variable speed splitting enables efficient modeling of the dynamics of both 'fast' (phytoplankton) and 'slow' groups (whales);
- Effects of micro-scale behaviors on macro-scale rates: top-down vs. bottom-up control incorporated explicitly.
- Includes biomass and size structure dynamics for key ecosystem groups, using a mix of differential and difference equations.

An FAO workshop was convened at UBC in July 2000 aimed at exploring 'The Use of Ecosystem Models to Investigate Multispecies Management Strategies for Capture Fisheries'. At the workshop around 40 scientists from throughout the world worked with 15-20 EwE models to investigate the impact of different multispecies harvesting strategies on the community structure and fishery yields with a view to identifying preferred harvesting strategies. A central aim of fisheries management is to regulate fishing mortality rates over time so as to achieve economic, social and ecological sustainability objectives. An important dynamic modeling and assessment objective is thus to provide insight about how high these mortality rates should be, and how they should be varied over time (at least during development or recovery from past overfishing). We cannot expect models to provide very precise estimates of optimum fishing mortality rates, but we should at least be able to define reasonable and prudent ranges for the rates.

The objective function can be thought of as a 'multi-criterion objective', represented as a weighted sum of the four objectives: economic, social, legal, and ecological. Assigning alternative weights to these components is a way to see how they conflict or tradeoff with one another in terms of policy choice. Even if we would not dream of incorporating the results into today's management without very thorough considerations of inherent risks and uncertainties, it is for now very rewarding to be able to participate in a process where the questions addressed are of the sort: "How do we want this ecosystem to look in the future, and what are the implications of our choices?"

The goal function for policy optimization is defined by the user in Ecosim, based on an evaluation of four weighted policy objectives:
1. Maximize fisheries rent;
2. Maximize social benefits;
3. Maximize mandated rebuilding of species;
4. Maximize ecosystem structure or 'health'.

EwE is being used for marine calculations in the global Millennium Ecosystem Assessment. EcoSpace adds a spatial component to the model that lends itself well to restoration targets and reserve locations.  Scenarios can be run with hypothetical marine protected areas to view their potential effects on the ecosystem and fisheries.

| | |
|---|---|
| Ecotype | Marine |
| Scale | not fixed |
| Transferability | transferability |
| Cost | Downloading, registration, user's guide and support is free of charge. |
| Usability | Used for graduate courses in a number of universities. Basic Ecopath modeling is not very difficult; mainly requires knowledge of the ecosystem to be modeled and reading the User's Guide. However, for advanced use in fisheries management it is as demanding as advanced single-species assessment tools. |
| Platform | Windows 98/2000/ME/NT4/XP |
| Source Code | Available upon request |
| Support/Training | User support is free |
| Info gathering and management | Includes identification of planning boundaries, ecosystem process modeling, selection of elements and requirements of those elements |
| Goal setting & evaluation | Ability to set ecological goals and incorporate multiple stakeholders |

Threat ID & impact                    Identifies threats to ecological goals, impact analysis on ecosystem viability, and threats to economic goals (expressed as cost to fisheries)

Threat mitigation                    Identifies potential restoration and reserve sites and allows user to run scenarios with hypothetical protected areas to identify most effective location

Conservation area                    Allows scenario comparison, and contains a basic fisheries cost/benefit equation

Ecosystem Management      Increasingly being incorporated in the management process, notably at NMFS laboratories

Used for:      dynamic simulation of large-scale marine ecosystems for investigating policy decisions

Comment:      EwE provides a common language for marine and fisheries managers and planners.  Although the tool does not explicitly include multiple stakeholders or conflict negotiation aspects, it does act as a powerful visualization for making complex decisions.  The inclusion of a basic fisheries economics equation minimally brings socio-political factors into the model that could potentially be expanded to include other factors or developed more fully to incorporate complex cost/benefit analysis. Ecopath/Ecosim are among the most widely used conservation planning tools in the discipline.  They have been around for several years and have undergone a number of upgrades and extensions.  Ecopath is part of a number of university curricula and has gained widespread mainstream use and application.  As of Nov. 2001 the registered userbase for Ecopath was 2700 in 126 countries on six continents.

| Name | **INDEX Planning Support System** | | |
|---|---|---|---|

| Category | interdisciplinary | | |
|---|---|---|---|
| URL | http://www.crit.com/ | | |
| Status | released | Date of release | March, 1994 |
| Contact | info@crit.com | | |

Phone: 503/224-8606
Fax: 503/224-8702,
725 NW Flanders Street, Suite 303
Portland, OR 97209-3539

Survey source       web and interview

Summary       INDEX is an interactive GIS-based planning support system that measures existing conditions, evaluates alternative plans, and supports implementation of adopted plans. The software is used to benchmark existing conditions, evaluate alternative courses of action, and monitor change over time. A strength of INDEX is its versatility for use in a wide variety of planning support roles.

- **Design** - Create land-use and transportation scenarios interactively with stakeholders at two geographic levels: parcels or larger user-defined areas.
- **Score** - Evaluate scenarios with a menu of 58 indicators that can be selected and weighted by stakeholders.
- **Compare** - Identify trade-offs between scenarios and gauge conformity with policies and goals.
- **Visualize** - Optionally visualize outcomes with photography, video, and 3D modeling.
- **Analyze** - Perform specialized evaluations, including travel, water, energy, air quality, stormwater runoff, and fiscal impact analyses.

At the heart of INDEX is a set of indicators that stakeholders use to measure conditions, inventory assets and liabilities, identify issues, evaluate alternative courses of action, and monitor change over time. INDEX has over 50 indicators available for community application. Their topical scope includes land-use, transportation, housing, employment, infrastructure, and the natural environment. New indicators are often designed in collaboration with local stakeholders during the customization process. Criteria to consider when selecting indicators include:

- Their connection to local priorities and values.
- The ability to measure them objectively.
- Their affordability to develop and maintain.
- Their relevance to typical decision-making.

PlanBuilder® includes the INDEX-exclusive "5D method" that estimates travel changes as a function of land-use and urban design changes. The tool also provides detailed measurements of

multi-modal accessibility conditions at the neighborhood level, such as pedestrian walking distances and route directness.  Other applications are Paint the Region, Paint the Town, and PlanWorks.

INDEX was introduced in 1994 and has been distributed to over 100 organizations in 35 states. Approximately half of these users are city and county planning departments, one-quarter are regional planning agencies, and the balance is divided among federal and state agencies, advocacy groups, and academic institutions.

Geographically, INDEX can be applied to single neighborhoods, entire communities, and multi-jurisdiction regions. Its indicator measurements can be calculated at either the parcel level or at a user-defined area level, such as census blocks or traffic analysis zones.

Data needs are determined by the scope and number of indicators in a given customization. Typically this includes parcel-level GIS coverages of land-use, housing, employment, transportation, infrastructure, natural environment, and related community data. Data availability is a key consideration in designing custom versions of INDEX to insure its compatibility with local conditions.

INDEX can import and export data files to create linkages to other models, e.g. fiscal impact, travel demand, stormwater runoff, etc.  It is applicable to ecosystem-based management in that some indicators measure open space, water resources, and pollution.


Ecotype              Terrestrial

Scale
Transferability

Cost                 The standardized PlanBuilder version of INDEX can be purchased for $3,900, including training and technical support.  Academic copies without training and support are $500.

Usability            INDEX is usable by anyone familiar with ESRI products and GIS modeling generally. User organizations will need a model steward with advanced GIS experience for certain installation and maintenance tasks.

Platform             ArcInfo 8.3/ArcEditor 8.3
Source Code          unavailable
Support/Training     Extensive tutorials, tech support and training are included with purchase.


Info gathering and management      Includes identification of planning boundaries, element selection, and element requirement information

Goal setting & evaluation          Enables setting ecological goals, involving multiple stakeholders, and goal allocation

Threat ID & impact                 Identifies land areas for restoration activities
Threat mitigation                  Not determined

Conservation area selection        Allows scenario comparison, stakeholder involvement, and implementation plan support
Ecosystem Management               Not determined

Used for:      community plans; creation, analysis, implementation

Comment      There is much similarity between Index and CommunityViz. Users with requirements met by these tools should thoroughly evaluate each for best fit.

Feedback      INDEX can calculate economic and environmental indicators. Introduced in 1994, Index has a decade-long history of application in 30 states in the US.  Example projects include San Antonio, TX, Tampa FL, and Dane Co., WI. The tool is focused on urban planning with capability of evaluating water use and resource availability, with little evidence of focused applicability on coastal issues.  However, the tool does appear applicable to coastal situations involving development planning.

Name          **MARXAN**

Category          Conservation
URL          http://www.ecology.uq.edu.au/marxan.htm
Status          released          Date of release
Contact          Hugh Possingham
          hpossingham@zen.uq.edu.au
     Director of The Ecology Centre
     Departments of Zoology and Mathematics
     The University of Queensland
     St Lucia, QLD 4072
     AUSTRALIA
     Tel: 61 7 3365 9766 (work)
     Fax: 61 7 3365 4828 (work)

Survey source          Web, NCFFS tool review

Summary          MARXAN is software that delivers decision support for reserve system design. MARXAN finds reasonably efficient solutions to the problem of selecting a system of spatially cohesive sites that meet a suite of biodiversity targets (goals). Given reasonably uniform data on species, habitats and/or other relevant biodiversity features and surrogates for a number of planning units (as many as 20,000) MARXAN minimizes the cost while meeting user-defined biodiversity targets.  The model calculates the portfolio cost for each potential solution and tries to minimize this cost while generating a near-optimal solution. Hundreds of different scenarios can be run and compared to look at different outcomes and patterns in the outcomes to determine which landscape elements are most critical to preserve.

     The optimisation algorithm that attempts to find good systems of sites is 'simulated annealing' (Kirkpatrick et al. 1983, Otten et al. 1989). The number of possible solutions is vast (for 200 planning units there are over 1.6 x 10^60 solutions) and because the problem is NP-complete there is no possible method for extracting an optimal solution in reasonable time for large problems. Because of this there is no real hope (or indeed incentive) to find *an* optimal solution: MARXAN will find good solutions using simulated annealing. The user can also invoke a variety of less sophisticated, but often faster, heuristic algorithms. We have found that one of the most useful outputs from the decision support software is the 'summed irreplaceability' output.  This output shows how often each planning unit is in one of the good systems. Planning units that are chosen more than 50% of the time can be thought of as being essential for efficiently meeting biodiversity goals. Sites that are rarely selected can be ignored.

     The Nature Conservancy (TNC) funded, through UC Santa Barbara, a project where Ian Ball integrated SPEXAN in to ARCVIEW (http://www.biogeog.ucsb.edu/projects/tnc/toolbox.html). Sandy Andelman, Frank Davis and David Stoms wrote a very useful tutorial for this new tool that is now extensively used by TNC. MARXAN was developed as a modified version of SPEXAN to meet the needs of the Great Barrier Reef Marine Planning Authority (GBRMPA) in their rezoning plans. GBRMPA provided partial support for the modification. MARXAN is currently being used by Adam Lewis and Suzanne Slegers to provide decision support for the GBR representative areas program. Along with the TNC ecoregional planning processes, these represent the largest applications of MARXAN/SPEXAN.  MARXAN is extensively used in marine and coastal planning

applications, including in the northern Gulf of Mexico coast of the US, the Florida Keys, the Gallapagos Is., British Columbia Canada, the Guld of California, the marine park in the Great Barrier Reef, and in the evaluation of reserve systems in southern Australia.


Ecotype                     Marine
Scale                       not fixed

Transferability             transferable

Cost                        free download
Usability
Platform                    A separate graphic user interface is provided for setting up input data and run options for the engine. MARXAN does not provide graphic display of design solutions, but its output data are easily imported into GIS applications such as ArcView 3.2 of ArcGIS 8.x.
Source Code                 Undetermined
Support/Training
Info gathering and management     Includes identification of planning boundaries, element selection, and specification of element requirements
Goal setting & evaluation         Ability to set ecological and economic goals
Threat ID & impact                Identifies threats to ecologic and economic goals
Threat mitigation                 Creates reserve scenarios
Conservation area                 Enables scenario comparison and economic cost/biodiversity benefit analysis.
Ecosystem Management              Not determined

Used for:       reserve system selection
Comment         under development by NMFS

Feedback        As it stands, there is no process modeling or scenario exploration.  There are only a few marine applications of the algorithm, two of which are in the Florida Keys and at the University of Queensland, Australia.  However, the developers are interested in a DSS framework (like Vista) to assist with the distribution and tech support aspects of the tool. MARXAN is the most common tool for designing reserve systems.  Several workshop attendees have worked on MARXAN and can contribute additional information.

| Name | **NatureServe VISTA** |
|------|------------------------|

| Category | interdisciplinary |
|----------|-------------------|

| URL | http://www.natureserve.org/prodServices/dss.jsp |
|-----|--------------------------------------------------|

Status    not released    Date of release    December, 2004

Contact    Kristin Barker
NatureServe
(703) 908-1818

Survey source    Interview with development team, 7/22/04

Summary    Vista is a conservation decision support system with three primary functions in its initial release. The first set of functions assist element experts in importing data and consolidating knowledge about conservation elements.  The second set of functions provide several alternatives to identify and understand areas of conservation priority based on the richness and characteristics of important elements.  Each element has an input on its distribution, relative weight of importance, the quality of the occurrence, and the confidence level of the data. The third set of functions support the assemblage of various map layers that describe baseline or alternative scenarios of current and potential land uses, management, and protection scenarios. These can be evaluated against the stated conservation goals for the conservation elements to maximize the effectiveness of management decisions.

All functions are supported by tabular and map reports, the ability to document all inputs and decisions, and to save, revise, update, and repeat any analyses. An accurate and repeatable decision-making process can facilitate the inclusion of conservation priorities in land-use decision-making.

Ecotype    Terrestrial
Scale    scale independent
Transferability    transferable
Cost    variable depending on training, number of seats, etc.
Usability    Variable depending on role.  Data preparation may require advanced GIS skills similar to other GIS natural resource projects; science expertise required to describe the elements. End users performing land-use analyses need no prior experience in GIS or science.
Platform    ArcMap 9 with Spatial Analyst
Source Code    unavailable
Support/Training    1 year included with purchase of program plus full documentation of software and non-software processes (e.g., data preparation instructions).

Info gathering and management    Includes identification of planning boundaries, element selection, specification of element requirements, and confidence information on element data

Goal setting & evaluation    Ability to set ecological goals and include multiple stakeholders by developing and storing alternative sets of goals and weights

Threat ID & impact    Identifies threats to ecological goals and ecological viability and integrity, based on three factors: 1. are the element's conservation goals met in terms of distribution and minimum patch size requirements? 2. is the element compatible with

co-occuring land use, management practices, disturbance features etc.; 3. is the policy mechanism on compatible land units deemed reliable by the user?

Threat mitigation                    Identifies compatible land use for each element and produces maps of richness of elements that have unmet goals and 1) have incompatible land use and 2) have compatible land use but unreliable policy mechanisms.  Identification of optimal restoration sites and the creation of reserve scenarios should be included in Version 2 of the tool but are currently available in other tools that can be used in tandem

Conservation area                    Enables scenario comparison in performance of element conservation goals and can allow multiple stakeholders to develop and evaluate scenarios and select the most desirable ones

Ecosystem Management                    Assists in documentation of process that can be viewed over time to assess changes in a landscape

Used for:        DSS for conservation-based land-use and management planning especially for ongoing dynamic planning and decision making

Feedback              NatureSeve Vista performs several functions currently unaddressed or under-served by existing land-use and conservation tools.  Specifically the assistance in entering spatial, tabular, and expert knowledge in a highly flexible system and evaluation of any type of scenario dynamically.  It also contains many aspects of a true decision support system lacking in many other tools such as the thorough documentation capabilities, ability to update and repeat analyses, and automated reporting functions. Vista is a newly developed application incorporating high-technology and GIS integration.  The first pilot application was for the Land Trust of Napa Valley, CA.  As it develops a wide userbase, Vista will demonstrate benefits from the extensive existing relationship with NatureServe Biotics 4 and the 50-state and multi-country Natural Heritage Programs and Conservation Data Centers.

# Appendix 5: Descriptions of Medium Priority Tools

Name            EPA BASINS Better Assessment Science Integrating point & Nonpoint Sources

Category      interdisciplinary
URL   http://www.epa.gov/waterscience/basins/basinsv3.htm
Status  released            Date of release  September, 1996. Version 3 released June 2001)

Ecotype          freshwater
Contact          Standards and Health Protection Division (4305T)
                 OST, Office of Water, US EPA
                 1200 Pennsylvania Avenue, NW, Washington, DC 20460
                 Email: basins@epa.gov,
Summary from website information: BASINS is a multipurpose environmental analysis system for use by regional, state, and local agencies in performing watershed and water quality based studies. This new software makes it possible to quickly assess large amounts of point source and nonpoint source data in a format that is easy to use and understand. Installed on a personal computer, BASINS allows the user to assess water quality at selected stream sites or throughout an entire watershed. It is an invaluable tool that integrates environmental data, analytical tools, and modeling tools to support development of cost-effective  approaches to environmental protection.
                      Originally released in September 1996, BASINS addresses three objectives: (1) to facilitate examination of environmental information, (2) to provide an integrated watershed and modeling framework, and (3) to support analysis of point and nonpoint source management alternatives.  BASINS supports the development of total maximum daily loads (TMDLs), which require a watershed-based approach that integrates both point and nonpoint sources. It can support the analysis of a variety of pollutants at multiple scales, using tools that range from simple to sophisticated.
         BASINS' databases and assessment tools are directly integrated within an ArcView GIS environment. By using GIS, a user can fully visualize, explore, and query to bring a watershed to life. The simulation models run in a Windows environment, using data input files generated in ArcView.
Scale:  Fixed to a single watershed
Transferability:            Transferable between watersheds
Cost:   free download
Platform:        ArcView 3.x
Source Code:  (multiple source codes for the various models;  available from model developers)
Support/Training:       contact for training
Used for:        watershed-level water quality and development of TMDLs
Comment: BASINS has become progressively more modularized in design, in order to allow more extensive and flexible linkages with models and utilities;  the modules are run as ArcView extensions.  Version 3.1 is scheduled to be released in fall 2004.  The process of migration to ArcInfo is underway for BASINS version 4.

Name        Spectrum
Category        interdisciplinary
URL    http://www.fs.fed.us/institute/planning_center/spec_update.html
Status  released        Date of release
Ecotype        Terrestrial
Contact        Bruce Meneghin,
               Phone: (970) 295-5725

Summary from website information: Spectrum is user-friendly software designed to help decision makers explore alternative resource management scenarios. It provides an integrating framework for multi-resource analysis, and capability to address NFMA requirements and ecosystem management issues. Model formulation is flexible, supporting simple to complex analysis.  Spectrum has a data entry system with on-line help, multiple model data set management, graphical data and solution display, relational data structure to store and query data and solutions, custom and default solution reports, and data and solution import/export.  Some sample applications are:
Forest Plan amendment and revision
Landscape/watershed scale analysis
Designing sustainable management strategies
Land and resource allocation
Finding pathways to desired future condition
Management activity scheduling
Environmental effects analysis
Economic analysis
Tradeoff analysis
Sensitivity analysis
Policy analysis
Cost:               free
Platform:           C-WHIZ
Support/Training:     online help
Used for:       ecosystem management dss
Feedback:        DSS for decision makers to explore alternative resource mgt scenarios; provides integrating framework for multi-resource analysis for addressing ecosystem mgt issues; user-friendly; no apparent connection to aquatic/coastal systems.

Name          SimCoast
Category      interdisciplinary
URL   http://www.ikzm-
d.de/addons/pdfs/SimCoast.pdf?PHPSESSID=c63d13cb14c7539342232a42ce6f49d3
Status  Date of release
Ecotype       coastal marine
Contact       Ann Hogart, Project Manager
              Fugro GEOS
              Phone: +44-1793-72 57 66
              Fax: +44-1793-70 66 04
              Jacqueline McGlade, Director
              CCMS – Centre for Coastal and Marine Science
              Phone: +44-1752-63 31 21
              Fax: +44-1752-26 90 11

Summary from website information:  SimCoast is a powerful tool in identifying the dominant
processes and issues that have a significant impact within an environment and draws together
expert knowledge from diverse fields of research. It takes into account not only the effects of
each activity on itself and others within the transect zone, but also the effect of activities taking
place outside the designated area. This results in defined weighting of impacts for different
activities, in terms of targets such as biodiversity and fisheries within the area of interest.
SimCoast indicates policy changes required with regard to specified activities within a coastal
community and the order of priority for those changes. Policy makers and planners during
development programs can then use the list of weighted impacts resulting from the interactions.
This ultimately leads to sustainable management of renewable and non-renewable resources
within the marine environment, while at the same time preserving its integrity for future
generations.

Used for:      DSS for coastal zone management
Feedback:      European Expert System for coastal management. Seems well developed,  but not
much available information about it on the website.  Alternate URL:
http://europa.eu.int/comm/development/body/publications/fish/099829.pdf

| Name | **RamCo** |
|---|---|
| Category | interdisciplinary |
| URL | http://www.netcoast.nl/tools/rikz/RAMCO.htm |
| Status | Date of release |
| Ecotype | Marine |
| Contact | Mr. Guy Engelen |
| | telefax: +31 43 3253155 |
| | guy@riks.nl |
| | Research Institute for Knowledge Systems (RIKS), |
| | P.P. Box 463 |
| | 6200 AL Maastricht |
| | the Netherlands |

Summary from website information:    The very heart of RamCo is formed by an integral model representing the physical, environmental, economic and social processes that typify the dynamics of the coastal zone. Policy makers face the difficult task of interfering in processes that are complex due to their interconnection and interrelation. RamCO offers a system model incorporating as much as possible of the essential linked processes and representing reality as faithfully as possible. The knowledge and model outline determine the nature and quality of the outcome of RamCo.

 Four aspects are prominent for policy makers: 1) intervention in complete systems (by means of integral models); 2) intervention in living systems (never at equilibrium); 3) intervention in spatial systems (neither evenly spread nor constant in time); and 4) dealing with uncertainty (making use of optimalisation). RamCo features model building blocks, has a library function and data can be easily exported to a GIS based environment. RamCo was initially developed by the National Institute for Coastal and Marine Management (RIKZ) and the Research Institute for Knowledge Systems (RIKS), where a demo version can be downloaded.

Used for:     integrative modeling of physical, environmental, economical, and social factors in marine systems
Comment:     download demo at: http://www.netcoast.nl/tools/ramco.htm
Feedback:     Integrated model representing physical, environmental, economic, social processes in coastal zone.  European.  GIS linkage; apparent features for ecological modeling but not available for inspection on publicity.

Name            GeoChoice
Category        Interdisciplinary
URL   http://www.geochoice.com/
Status  released                    Date of release
Ecotype          Terrestrial
Contact          info@greenchoice.com
                 Geo Choice Inc.
7817 235th Place NE
Redmond, Washington 98053
United States

Summary from website information: *ChoiceExplorer* is the decision modeling software module. If you have a problem that requires a choice to be made among various options, then *ChoiceExplorer* can help to make your decision easier. This software lets you use your data to select among criteria, assign valuations to the range of criteria data, weight the criteria, and then rank the options by a calculated score. The software is easy to use and provides an efficient, iterative environment to explore your options. The dynamic sensitivity analysis feature is a powerful tool that can tell you which options are consistently "good performers," no matter what set of perspectives you might choose.

The *ChoicePerspectives* software module helps groups work together on a problem of choice. This software can be used by someone who is facilitating the group decision process. The software provides various capabilities to collect and display voting results.

GeoVisual is the geographic extension that lets you easily review your background geographic data, your site attributes, and your decision modeling results with tables and maps in ArcView® GIS software (version 3.0a, 3.1 or 3.2). You can create rank and consensus maps to identify and further evaluate the most preferred site options (based on single and/or multiple perspectives).

Cost:   *GeoChoicePerspectives* software package is $895. There is a 30% discount for government agencies and not-for-profit organizations.
Platform:       ArcView 3.X
Used for:       evaluate habitat restoration sites & allocate funds
Feedback       Post-analysis decision-making; not dynamically linked to a spatial database. Most useful if linked to tools like Vista/CV.

Name          **Sites**
Category      Conservation
URL   http://www.biogeog.ucsb.edu/projects/tnc/toolbox.html
Status  released                    Date of release            1998
Ecotype       Terrestrial
Contact       Frank Davis
              fd@geog.ucsb.edu
      3017 Bren Hall

University of California, Santa Barbara

Santa Barbara, California 93106-5131

Lab Phone: 805.893.7044


Summary from website information:          Sites was developed in 1988 in a collaboration
between UCSB and TNC.  The goals were to:
Develop a new reserve siting tool for regional conservation analysis that explicitly incorporates
spatial design criteria into the site selection process.
Test and apply the new planning approach and performance measures in a structured decision
process involving local TNC staff to develop hypothetical conservation portfolios in two
different ecoregions.
Produce a web-based tutorial, including worked examples using TNC data and ecoregions; and
conduct a training workshop for TNC staff interested in learning and applying the regional
conservation planning tools to other TNC regions.
              Sites 1.0 is a customized ArcView project that facilitates designing and analyzing
alternative portfolios.  The software in Sites 1.0 to select regionally representative systems of
nature reserves for the conservation of biodiversity is called the Site Selection Module (SSM).  It
is a streamlined derivative of SPEXAN 3.0 (Spatially Explicit Annealing) that was developed by
Ian Ball and Hugh Possingham.  SPEXAN was originally developed as a stand-alone program
with no GIS interface for displaying portfolios and ancillary spatial data.  The model was applied
in two TNC ecoregions--the Idaho Batholith and the Northern Sierra Nevada.

Cost:         free
Platform:     ArcView 3.x
Used for:     Sites is a reserve-siting tool for regional conservation analysis that explicitly
incorporates spatial design criteria into the site selection process.

Name        TARGET
Category    Conservation
URL    http://www.amonline.net.au/systematics/staff_faith.htm
Status  Academic
Ecotype     Terrestrial
Contact     Dan Faith at the Australian Museum
            danf@austmus.gov.au

Summary from website information: TARGET builds on the trade-offs methods developed in Diversity-ED.  The motivation for TARGET arose from problems raised in the course of the Comprehensive Regional Assessments process in Australia - issues relating to setting of targets, surrogates for biodiversity, and whether or not trade-offs are incorporated at the level of priority setting (TARGET is based on the idea that they must be). TARGET also has served as a platform for exploring probability of persistence approaches, as a response to the perceived need to avoid the "all or nothing" view of protection and optionally allocate land uses that provide "partial protection" in addition to other ecosystem services.
The more recent development of TARGET has responded to the reality that few "whole" sets of areas from computer-based methods are ever implemented, so that the practical focus should be on scenarios and outputting of dynamic complementarity values for decision support and links to economic instruments.


Cost:          Available through research collaboration or other agreed provision, for free, for non-research applications.
Used for:      Creating an evaluation framework for balancing biodiversity conservation with competing values.
Feedback       Visualizations of some outputs is limited.  Some newer changes are not fully described in the current manual and workshop material