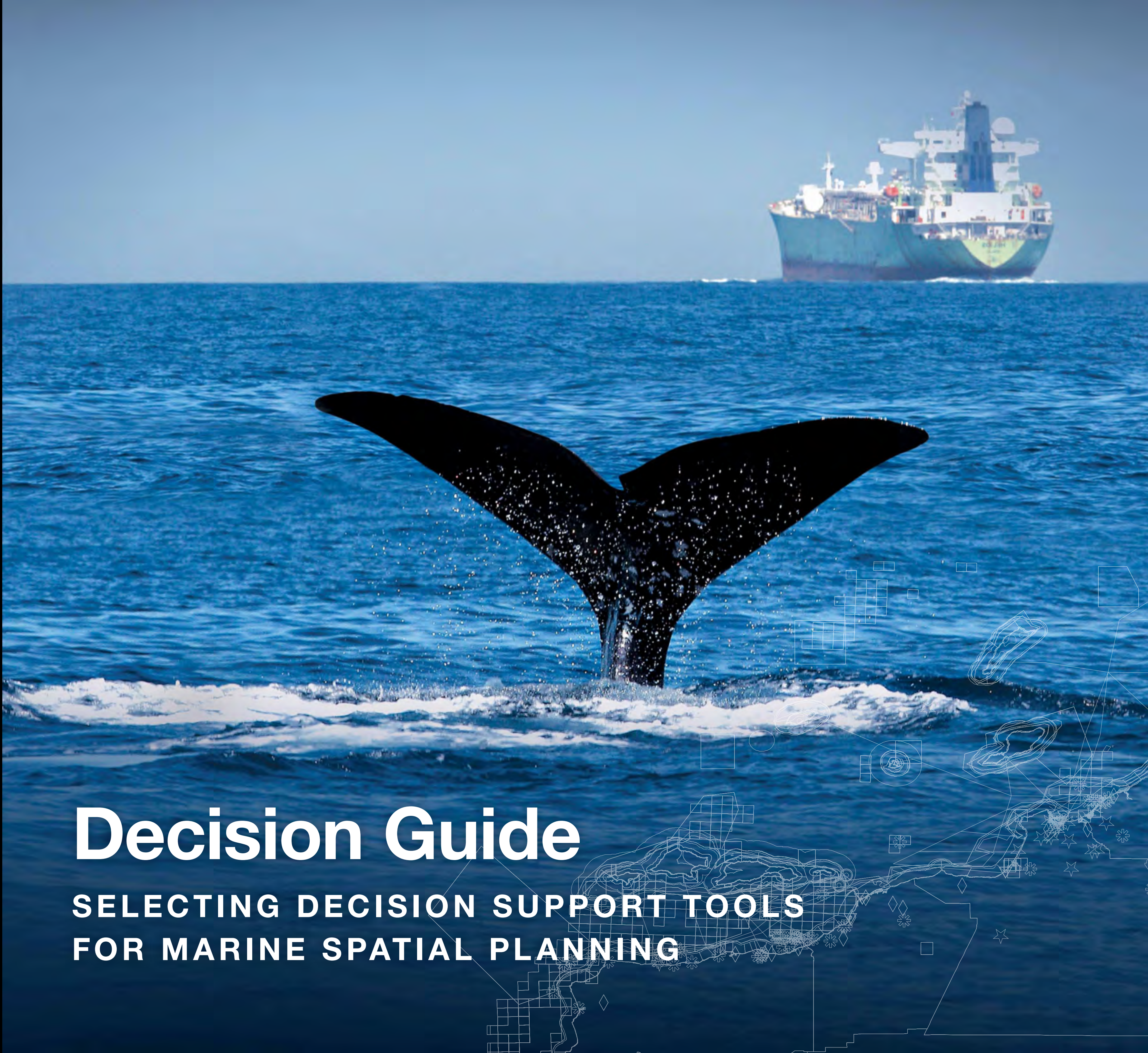

# Decision Guide

## SELECTING DECISION SUPPORT TOOLS FOR MARINE SPATIAL PLANNING

PacMARA
Pacific Marine Analysis
& Research Association

CENTER FOR
OCEAN
SOLUTIONS

Center for Ocean Solutions. 2011. Decision Guide: Selecting Decision Support Tools for Marine Spatial Planning. The Woods Institute for the Environment, Stanford University, California.

The Center for Ocean Solutions (www.centerforoceansolutions.org) is a collaboration between Stanford University (including Hopkins Marine Station), the Monterey Bay Aquarium, and the Monterey Bay Aquarium Research Institute. The Center for Ocean Solutions is administered by the Woods Institute for the Environment at Stanford University.

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Cover Photo: Sylvain Cordier/Getty Images

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Robert Stowe/Monterey Bay Aquarium


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# 1. Introduction

## THE ROLE OF DECISION SUPPORT TOOLS IN MARINE SPATIAL PLANNING

Spatially explicit approaches for planning human activities, resource use, and ecosystem integrity in marine areas are gaining traction around the world. Terms such as marine spatial planning, maritime spatial planning, coastal and marine spatial planning, integrated ocean management, and systematic conservation and marine use planning, all denote similar decisionmaking approaches that use scientific and geospatial information to address conflicts and organize human activities in the ocean, while maintaining ecosystem health, function, and services.

In this Decision Guide, the term marine spatial planning is used, but emphasis is placed on the *systematic* and *spatial* nature of these approaches rather than the name itself. The systematic component provides a framework for more comprehensive, flexible, well-governed, and science-based planning processes, while the spatial component adds a place-based focus to planning processes. The goals of these approaches are to promote efficient use of marine space and resources, while reducing use-use and use-ecosystem conflicts. To achieve these goals, resource planners and managers (hereafter referred to as *practitioners*) need spatially-explicit tools that can help (1) incorporate data from ecological, economic, and social systems; (2) transparently assess management alternatives and trade-offs; (3) involve stakeholders; and (4) evaluate progress towards management objectives. This Decision Guide, produced by the Center for Ocean Solutions (COS), is intended to assist practitioners in selecting appropriate decision support tools (DSTs) that can help them conduct marine spatial planning in their own jurisdictions.

Gustavo Hernandez/Marine Photobank

DSTs that use interactive software including maps, models, communication modules, and additional components can help solve problems that are too complex and multi-faceted to solve using human intuition or conventional approaches alone. Used properly, planning tools can:

- Save time, energy, and resources;
- Guide users through difficult steps of decisionmaking processes so they can quickly move from data analysis to final decisions;
- Repeat analyses with relative ease and reduce redundancy by leveraging the work of others;
- Reduce requirements for human expertise;
- Help users explore a wider range of alternatives;
- Document decisions about inputs and parameters; and
- Increase the understanding of planning requirements and limitations for multiple sectors in the planning process.

Effective marine spatial planning tools should be data-driven, efficient, explicit, transparent, and flexible, to meet ecosystem and resource use objectives, as well as identify existing gaps in current management designations. Although aspects of geographic information systems (GIS) analyses meet these criteria, DSTs often have additional features that provide complementary value (Box 1).

Several essential functions are necessary to facilitate systematic and spatial planning (Figure 1). A large number of tools with these functions currently exist, or are being developed, to facilitate planning processes. In this Guide, nine DSTs used to inform marine spatial planning processes around the world are profiled. The Guide highlights synergies between tools that could be used to create a DST “toolbox” (Chapter 3), how these DSTs could fit into a general marine spatial planning framework (Chapter 4), specific functions (Chapter 5) and features (Chapter 6), and case studies that provide a deeper look into how the nine featured DSTs have been used (Chapter 7). The Decision Support Tool Rubric (Chapter 5) integrates process steps, general tool functions, and individual DST capabilities to help practitioners identify and select appropriate tools. Finally, the Guide closes with a priority needs assessment to help tool developers and practitioners determine where future efforts and collaborations could best be allocated.

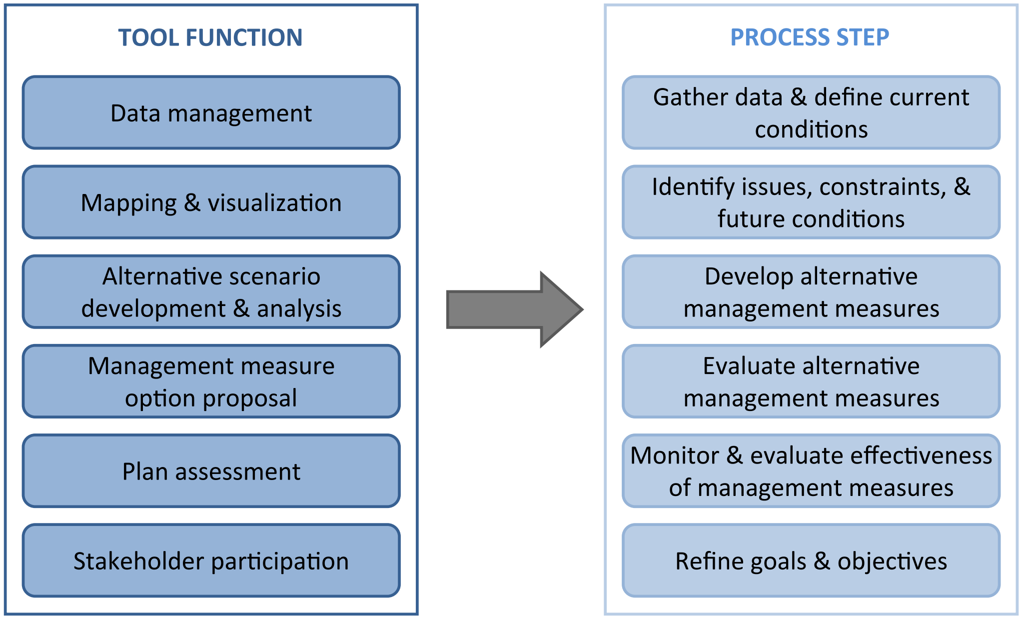

**Figure 1. Range of tool functions that can provide critical decision support throughout a planning process.**

**Box 1. Additional value provided by DSTs.**

DSTs provide additional value over standard GIS analysis. These additional capabilities fall into three overarching categories: data access and delivery, process design, and stakeholder engagement.

| DATA ACCESS AND DELIVERY | PROCESS DESIGN | STAKEHOLDER ENGAGEMENT |
|---|---|---|
| Provide frameworks for using data | Increase efficiency (reduce cost associated with planning) | Provide a common starting point |
| Help make data products publicly available | Facilitate transparency | Diffuse tension |
| Create decision space for data (context) | Allow for replication (geography/objectives) | Increase acceptance and accountability of decisions |
| Visualize the data | Facilitate adaptive management | Illustrate the scope of options |
| Provide authoritative outputs | Provide explicit criteria and decision rules | Facilitate collaboration between stakeholders and decision-makers |
| Identify gaps | Guide process creation | Improve consensus building |
| Facilitate data sharing | Value local knowledge | Increase spatial awareness |
| Demystify data | Apply directly to policy needs | Visualize complex options |
|  | Improve informed decisionmaking processes | Evaluate options |

The number of DSTs applicable to marine spatial planning is continually growing, and this Guide highlights only a limited selection. In addition, the application of the DSTs described here is not necessarily limited to marine spatial planning. The Ecosystem-Based Management (EBM) Tools Network (http://www.ebmtools.org/) is an excellent resource for broader coverage, with additional in-depth information on the tools highlighted in this Guide, along with many other tools.

The Process Matrix, Tool Function Matrix, and Tool Feature Matrix described in the Guide are static, providing a snapshot of existing functionality as of the date of this Guide's publication. However, these matrices are intended to be dynamic so that new DSTs can be incorporated as they become available and tool characterizations can be updated as developers improve existing DSTs. In partnership with the EBM Tools Network and NOAA Coastal Services Center, COS is currently developing a dynamic rubric that will be available online in fall 2011.

## RECOMMENDED READING

Ardron, J. 2010. Marine Planning: Tragedy of the Acronyms. Marine Ecosystems and Management: 4(2): 6.

Ardron, J., Ban, N., Field, J., Game, E., Pressey, R., Sørensen, T. and Vestergaard, O. [in review] 2011. Adaptive Marine Spatial Planning Paper 1: context and future directions. Technical report, United Nations Environment Programme, Nairobi, Kenya. 50 pages.

Ehler, C. and Douvere, F. 2009. Marine Spatial Planning: a step-by-step approach toward ecosystem-based management. Intergovernmental Oceanographic Commission and Man and the Biosphere Programme. IOC Manual and Guides No. 53, ICAM Dossier No. 6. Paris: UNESCO.

Margules, C.R. and Sarkar, S. 2007. Systematic Conservation Planning. New York: Cambridge University Press.

Randy Wilder/Monterey Bay Aquarium

# 2. The Workshops

This Decision Guide is the product of a series of workshops designed to build relationships among DST developers and practitioners, and to inform the development of next-generation DSTs for use in marine spatial planning. In October 2010, COS convened sixteen DST developers from nine DST development groups to discuss the features and functions of their respective DSTs and to identify synergies and complementarities between their DSTs. In February 2011, COS re-convened a subset of the DST developers, along with fourteen practitioners, in a second workshop designed to identify the DST features and functions that are most important for marine spatial planning. The practitioners communicated their needs to the tool developers, while the tool developers provided feedback regarding existing DST capabilities, as well as the feasibility of responding to practitioners' needs. The workshops, and this Guide, were timed to coincide with early stages of the Obama Administration's proposed timeline for coastal and marine spatial planning in the United States, but the process steps, and tool functions and features are broadly applicable across geographies and jurisdictions.

## TOOL DEVELOPER WORKSHOP (OCTOBER 4–5, 2010)

The first DST workshop featured nine existing DSTs with visualization, spatial analysis, and/or modeling components relevant to marine spatial planning. Through presentations and discussions, participants examined each others' DSTs, identified possible synergies between DSTs, and characterized how their DSTs could be applied in a marine spatial planning context. The objectives were to:

- Highlight the unique features and applications of the individual DSTs;
- Identify the scale, data, and model-specific assumptions behind tool applications;
- Explore technical capabilities and limitations of DSTs (e.g., data formats, mapping/visualization);
- Identify how DSTs could fit within a marine spatial planning process;
- Develop a "toolbox" of multiple DSTs to collectively address the steps of a marine spatial planning process, by identifying possible synergies among existing DSTs; and
- Develop a draft diagnostic rubric to aid practitioners in selecting DSTs for use in their own marine spatial planning processes.


Melissa Foley

**Developers working together at the tool developer workshop.**

## TOOL APPLICATION WORKSHOP (FEBRUARY 24–25, 2011)


Meg Caldwell

**One-on-one exchange between practitioners and tool developers at the tool application workshop.**

The second workshop convened practitioners alongside the tool developers to discuss (1) how DSTs are currently being used in marine spatial planning processes worldwide; (2) DST functions that help practitioners navigate the common steps of a planning process; and (3) additional DST features that are particularly important. The practitioners gave presentations demonstrating the use of GIS and/or DSTs in planning and management processes in their respective geographies. These efforts were followed by one-on-one exchanges between practitioners and tool developers to facilitate more detailed discussion regarding DST functionality and applications. In later sessions, the workshop participants: (1) refined the DST diagnostic rubric developed during the October workshop; (2) mapped tool functions to common planning process steps; and (3) reviewed and ranked the importance of DST features. Finally, workshop participants brainstormed a list of gaps and priority needs for future DST development and use (Chapter 8).

## DEVELOPMENT OF THE DECISION GUIDE

This Decision Guide, including the diagnostic rubric and priority needs assessment, was developed iteratively during and after the two workshops. These products were synthesized by COS and the Pacific Marine Analysis and Research Association (PacMARA) using content produced during the workshops and through additional communication with participants. This Guide is available in electronic format on the Center for Ocean Solutions website (http://www.centerforoceansolutions.org/) and the EBM Tools Network website (http://www.ebmtools.org/).

George L. Shillinger

# 3. Tools at a Glance

In this chapter, the nine DSTs represented in the workshops are profiled with an overview of their purpose, functionality, and application. In addition, the level of expertise required to use each DST is summarized in Box 2, while Figure 2 highlights the possible synergies between tools, which can aid practitioners in building a DST "toolbox." More in-depth information regarding how these DSTs have been applied, as well as the products that they generate, is presented in Chapter 7.

## ARTIFICIAL INTELLIGENCE FOR ECOSYSTEM SERVICES (ARIES)

**Developed by:** Basque Center for Climate Change (BC3), University of Vermont — Gund Institute for Ecological Economics, Conservation International, and Earth Economics

**Funded by:** National Science Foundation, United Nations Environment Programme

**Website:** www.ariesonline.org

**Purpose:** ARIES was designed to make land use policy and environmental decisions easier and more effective by helping users map and quantify environmental assets and the factors that influence their value. ARIES allows users to model and quantify the impacts of landscape feature changes on the provision of ecosystem services, thereby allowing the evaluation and comparison of alternative scenarios for climate change, land use, or land cover scenarios and policies for addressing them. Modeling the flow of ecosystem services from their source to use locations allows critical pathways (and their intersections) to be identified that are necessary for one or more services to travel across time and space. This information can be used to establish sensible and sustainable policies for governing land development, habitat protection, and ecosystem restoration efforts.

ARIES can be used in any geographical area to explicitly map the linkages between ecosystems that provide services and particular groups of human beneficiaries. Additionally, the ARIES platform fills a void in current methodologies for quantifying ecosystem services through its use of semantic modeling and the inclusion of Bayesian and artificial intelligence techniques.

**How it works:** ARIES is a web accessible analytical tool that uses a range of approaches, such as probabilistic Bayesian models, machine learning, and pattern recognition to assess the provision, use, and flow of ecosystem services on a user-identified landscape. These approaches allow users to evaluate and compare alternative policy and land-use scenarios in terms of their impact on the provision of crucial ecosystem services. ARIES is intended to be generally applicable to a variety of ecosystem services in any region in the world, yet comprehensive in its modeling approach, and designed so that users can create interfaces around specific workflows without knowledge of all the engine components. Moreover, its use of sophisticated statistical models provides a framework for tracking uncertainty and leveraging multi-scaled information in a fully transparent way.

**Applications:** ARIES has been used for projects involving carbon sequestration, flood and sediment regulation, water provision, aesthetics, recreation, subsistence fisheries, and coastal protection.

## ATLANTIS

**Developed by:** Commonwealth Scientific and Industrial Research Organisation (CSIRO) Marine and Atmospheric Research

**Funded by:** CSIRO, Gordon and Betty Moore Foundation, David and Lucile Packard Foundation, Pew Fellows Program, Australian Science Minister's Prize, and National Oceanic and Atmospheric Administration (NOAA)

**Website:** atlantis.cmar.csiro.au

**Purpose:** Current fishery management decisions are based on tactical models (short-term decisionmaking) that typically omit climate, oceanography, nutrient availability, food web interactions, and other aspects of ecology. Atlantis was developed as a full ecosystem simulation model that incorporates these factors in a spatially explicit way. The model is intended for use as a strategic planning tool (long-term decisionmaking) that can complement annual cycles of stock assessment and policy decisions by allowing users to test management policies and assessment methods against representations of complex ecosystems. Atlantis is primarily used in fishery applications where it allows users to identify trade-offs between and among species, fishing gear types, management goals, and the direct and indirect effects of different management policies. Atlantis can also address issues related to marine habitat, nutrients, and biodiversity.

**How it works:** Atlantis integrates physical, chemical, ecological, and fisheries dynamics in a three-dimensional, spatially explicit domain. In Atlantis, marine ecosystem dynamics are represented by spatially explicit sub-models that simulate hydrographic processes (current-, light- and temperature-driven fluxes of water and nutrients), biogeochemical factors driving primary production, food web relationships among functional groups, crude habitat interactions, and fishing fleet behavior. Atlantis uses a C++ code base that solves a series of differential equations across a three dimensional domain. Oceanography can be driven by state of the art hydrographic tools such as the regional ocean modeling system (ROMS). The ecological and fleet dynamics models are flexible, with many user choices for functional relationships.

**Applications:** Atlantis has been used for strategic evaluation of restructuring Southeastern Australia fishing fleets, the NOAA Integrated Ecosystem Assessment for the California Current, the Marine Stewardship Council Forage Fish Harvest Guidelines, and consideration of groundfish fleet impacts on protected marine mammals in the California Current.

## COASTAL RESILIENCE

**Developed by:** The Nature Conservancy, University of Southern Mississippi, and University of California, Santa Barbara

**Funded by:** David and Lucile Packard Foundation, Roslyn Savings Foundation, Arrow Electronics, and Long Island Sound Futures Fund

**Website:** lis.coastalresilience.org

**Purpose:** Adaptation to coastal hazards has traditionally been undertaken using shoreline hardening and engineered defenses. Alternative approaches to building infrastructure, such as ecosystem-based adaptation, are necessary as part of an overall strategy for creating resilient human communities in the face of climate change. Coastal Resilience was developed to help practitioners


Charles Seaborn/Monterey Bay Aquarium

and stakeholders understand how they can make informed decisions about marine and coastal conservation, land protection, and coastal development, and implement ecosystem-based adaptation strategies. Coastal Resilience helps users visualize future conditions so they can design, build, and discuss alternative future scenarios that address sea level rise, storm surge, social and ecological vulnerability, and conservation priorities.

**How it works:** The Coastal Resilience project delivers geospatial information on coastal ecosystems, socioeconomics, community vulnerability, and coastal hazards (including sea level rise and storm surge) via an internet mapping application that is a data viewer, data discovery tool, and a future scenario mapper. Coastal Resilience also includes a summary tool for calculating economic and ecological loss in specific geographies within the study area given different future scenarios. Coastal Resilience provides decision support to local decision-makers who are conducting their own comprehensive or post-storm redevelopment plans, and serves as an educational tool to inform stakeholders on the risks of sea level rise and storm surge.

**Applications:** Coastal Resilience has been used for data exploration with the New York State Emergency Management Office, and local towns and villages on Long Island and the Connecticut shores interested in including this information as part of their comprehensive plans.

## CUMULATIVE IMPACTS

**Developed by:** National Center for Ecological Analysis and Synthesis (NCEAS), University of California, Santa Barbara, and Stanford University

**Funded by:** NCEAS, David and Lucile Packard Foundation, Gordon and Betty Moore Foundation, and Massachusetts Ocean Partnership

**Website:** www.nceas.ucsb.edu/globalmarine

**Purpose:** Recent policy emphasis on comprehensive spatial management of the ocean suggests an urgent need for high-resolution maps of human activities and their ecological impacts. Past approaches to evaluating the distribution and ecological impacts of human activities are almost all tailor-made to specific ecosystem types or management questions. Cumulative Impacts uses a new framework for modeling, mapping, and evaluating the cumulative impacts of human activities that is adaptable to a variety of management scenarios and scales, and amenable to a variety of analyses and applications.

Cumulative Impacts was developed to support marine spatial planning and ecosystem-based management efforts by helping practitioners assess the most vulnerable locations, identify priority stressors to mitigate specific areas, identify compatible and incompatible ocean uses based on ecosystem vulnerability, map the most and least impacted areas within a planning region, and assess the relative contribution of stressors or suites of stressors to overall ecosystem condition. The Cumulative Impacts interactive map allows users to visualize how impacts are distributed throughout a region, identify the stressors that are contributing most to the impact score, and assess possible avenues for mitigating cumulative impacts.

**How it works:** The Cumulative Impacts model uses spatial data and weighted expert opinion to predict a cumulative impact score for each unit (i.e. pixel) of the study region. This impact score for each unit is based on the type and intensity of anthropogenic drivers, the type of ecosystems present, and the assigned impact weight for each anthropogenic driver on a particular ecosystem. The model assumes that the presence of an anthropogenic driver has a negative impact on an ecosystem and that those impacts accumulate in an additive fashion.

**Applications:** Cumulative Impacts has primarily been used to set conservation and management priorities and assess the most vulnerable locations in an area. It has also been used by state agencies as a foundation for an environmental impact assessment.

## INVEST

**Developed by:** The Natural Capital Project — Stanford University, World Wildlife Fund, The Nature Conservancy, and the University of Minnesota

**Funded by:** Gordon and Betty Moore Foundation, Google Inc. Charitable Giving Fund of Tides Foundation, National Science Foundation, NOAA, John D. And Catherine T. MacArthur Foundation, David and Lucile Packard Foundation, and University of Minnesota

**Website:** www.naturalcapitalproject.org/InVEST.html


Melissa Foley

**Purpose:** Ecosystems provide a number of important benefits and services to humans. Despite their importance, services are poorly understood, scarcely monitored, and often only appreciated after they are lost. Recognizing, mapping, and valuing these ecosystem services can enable diverse stakeholders to find common ground and allow the true costs and benefits of natural resources to be incorporated into decisionmaking processes.

InVEST was developed to use the conceptual framework of ecosystem services to inform management of terrestrial, freshwater, and marine ecosystems. InVEST identifies where ecosystem services are provided, where they are consumed, and how resource management decisions will affect multiple aspects of the economy, human well-being, and the environment. InVEST also shows where trade-offs and synergies may occur between and among different ecosystem services and biodiversity.

InVEST can inform marine spatial planning and prioritization, permit allocation and mitigation, climate adaptation, food security planning, ecosystem-based management processes, and design of payments for ecosystem services or conservation agreements by helping users assess the current and potential status of ecosystem services under alternative, spatially explicit future scenarios.

**How it works:** InVEST is composed of a number of models for different ecosystem services including, but not limited to, carbon storage, wave energy, recreation, fishery production, erosion control, habitat quality, water quality, crop pollination, and timber production. InVEST is designed to be flexible, such that users can choose models of interest, apply them at relevant spatial scales, populate them with available data, and choose outputs that are biophysical (e.g., meters of shoreline eroded) or socioeconomic (e.g., monetary values or number of people affected).  The structure and composition of the InVEST models can and should be developed in collaboration with decision-makers or stakeholders to reflect their priority objectives, ecosystem services of interest, and available data. InVEST is a toolbox in ArcGIS and runs on both spatial and non-spatial physical, biological and economic data and information. The models are generally process-based and allow users to estimate how changes in ecosystem structure and function (due to management actions and climate change) influence the delivery and value of ecosystem services.

**Applications:** InVEST has been used in a wide variety of applications, including: spatial planning on land (e.g., Colombia, Hawai'i), marine and coastal systems (e.g., Canada, Belize), climate adaptation evaluation (e.g., Monterey Bay), payment for ecosystem services (e.g., Ecuador), return on restoration investments (e.g., Gulf of Mexico), permit allocation and mitigation (e.g., Colombia), and land-sea connections (e.g., Puget Sound, Chesapeake Bay).

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## MARINEMAP

**Developed by:** MarineMap Consortium — University of California, Santa Barbara, The Nature Conservancy, and EcoTrust

**Funded by:** Resources Legacy Fund Foundation, The Nature Conservancy, and Ecotrust

**Website:** www.marinemap.org

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**Purpose:** The California Marine Life Protection Act (MLPA) of 1999 mandated the state of California to design and implement a network of marine protected areas (MPAs) while using the best readily available science. The state was required to meet multiple objectives, including: (1) protecting marine life, habitat, ecosystems, and natural heritage; (2) improving recreational, educational, and research opportunities provided by marine ecosystems; and (3) minimizing the economic impact to local commercial and recreational fisheries and coastal communities.

California established the MLPA Initiative as a highly participatory public process in which representatives of various stakeholder groups could propose their own designs for the state's MPA networks. Working with the MLPA Initiative, the MarineMap Consortium developed the MarineMap decision support tool to allow stakeholders to access large amounts of authoritative geospatial information and to delineate boundaries of MPAs that met the objectives of the law. The stakeholder-generated MPAs were ultimately evaluated against scientific guidelines (e.g., size, distance to other MPAs, and amounts of habitat represented).

**How it works:** MarineMap decision support tool was developed in response to the specific needs of average, non-technical stakeholders as they collaboratively designed MPAs and MPA networks. It is an open source, modular web-based application that can easily be adopted for use in other spatial planning processes. The latest version of MarineMap has a core set of extendable functions that includes: (1) a spatial data viewer; (2) design tools that allow users to draw shapes; (3) group management software that allows users to share their proposals with others either privately or publicly; and (4) analytical tools that allow users to evaluate their proposals

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against goals defined in the course of any planning process.

**Applications:** MarineMap has been used for the California MLPA Initiative and the Oregon Territorial Sea Planning process.

## MARXAN WITH ZONES

**Developed by:** University of Queensland

**Funded by:** Environment Australia, The Nature Conservancy, Great Barrier Reef Marine Park Authority, United States National Marine Fisheries Service, NCEAS, University of California, Santa Barbara, and University of Queensland

**Website:** www.uq.edu.au/marxan

**Purpose:** Marxan delivers decision support for spatial planning, particularly protected areas. It was originally developed to identify a network of locations for conservation management that meet biodiversity targets and are relatively socially and economically cost-effective. The program answers the reserve design issue known as the “minimum set problem,” where the goal is to achieve some minimum representation of biodiversity features for the smallest possible “cost” (which usually represents socioeconomic costs). Marxan with Zones was developed to further incorporate multiple zone types, the contributions of zones to different management targets, the costs of implementing different zones types in different locations, and interactions between zones. Marxan with Zones was also designed to generate spatial alternatives that meet the spatial objectives of the planning process (e.g., preference for zones that are spatially compact).

Marxan can be used to explore and propose possible network configurations, facilitate collaborative network design, or guide decisions for land acquisition or marine zoning. Marxan with Zones can provide decision support for any problem that requires identifying a combination of sites to achieve targets for different zones simultaneously. The program has mostly been used for spatial planning to indicate potential locations for different types of activity or conservation management.

**How it works:** Marxan uses a stepwise algorithm to identify combinations of sites that meet targets set for biodiversity or other features, while minimizing the sum of costs for protecting each of those areas. Costs to protection include user-supplied socioeconomic values, a weighting value for biodiversity features, and a boundary length modifier value to account for the “clumpiness” of a reserve. When penalties are too high, the spatial solution changes by replacing “high-cost” solutions with “lower-cost” solutions. Marxan was originally developed based on the principle of complementarity, such that sites that are most similar to other sites in their composition of features, such as species, are selected together. Marxan with Zones essentially operates as a multi-layered version of Marxan.

**Applications:** Marxan is typically used to recommend sets of locations that constitute a network. However, the program has also been used to conduct gap analyses and recommend areas that should be zoned for a purpose other than conservation, such as fishing. Marxan with Zones has mostly been used to inform spatial planning processes (e.g., marine reserves, area zoning), and identify broad areas of interest for conservation.

**Box 2. Level of technical expertise required of users to effectively use each DST. Tools that are listed in multiple columns may have capabilities that require varying levels of expertise.**

| Minimal training or technical expertise | Minimal training and expertise but process objectives must be set in advance | Expert users |
|---|---|---|
| InVEST | ARIES | ARIES |
| MarineMap | Coastal Resilience | Atlantis |
| Multipurpose Marine Cadastre | Cumulative Impacts | InVEST |
| | Marxan with Zones | Marxan with Zones |
| | MIMES | MIMES |

## MULTI-SCALE INTEGRATED MODELS OF ECOSYSTEM SERVICES (MIMES)

**Developed by:** AFORDable Futures

**Funded by:** Gordon and Betty Moore Foundation and United States Environmental Protection Agency

**Website:** www.uvm.edu/giee/mimes/

**Purpose:** MIMES helps practitioners develop arguments for approaching the conservation of ecosystems as a form of economic development, thus facilitating quantitative measures of ecosystem service effects on human well-being. MIMES is a modeling tool that can incorporate stakeholder input and a wide array of datasets for valuation and complex trade-offs analyses among ecosystem services. This multi-scale, integrated suite of models can help users assess the true value of ecosystem services by quantitatively linking the dynamics of ecosystem services to aspects of human welfare, and illustrating how the function and value of ecosystem services could change under various management scenarios. MIMES facilitates understanding of the context of spatial patterns of land use, the dynamics of value, and the spatial and temporal scales at which information is available for estimating ecosystem service production and delivery.

**How it works:** MIMES simulates ecosystems and socio-economic systems in space by modeling systems over time, and the interactions between systems, and calculates specific values of ecosystem services through marginal cost pricing. The tool provides estimates of ecosystem service values for land use decisionmaking and marine spatial planning through scenario analyses, and considers the production of an array of ecosystem services.

**Applications:** MIMES is being used by the Massachusetts Ocean Partnership to examine the trade-offs between different sectors in spatial planning, and to model ecosystem service values at multiple scales.

## MULTIPURPOSE MARINE CADASTRE (MMC)

**Developed by:** Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE; formerly Minerals Management Service) and NOAA Coastal Services Center

**Funded by:** BOEMRE and NOAA

**Website:** www.marinecadastre.gov

**Purpose:** The MMC was originally designed to support the needs of developers and regulators of offshore energy projects, and to meet the requirements of the United States Energy Policy Act of 2005, to create a mapping initiative to support alternative energy projects in the outer continental shelf. At its core, the MMC contains authoritative marine cadastral data, which encompasses the spatial extent, usage, rights, restrictions, and responsibilities of marine areas, as well as other regionally-specific data needed to support planning, management, and conservation of submerged lands and marine spaces. MMC can help users visualize where uses occur and areas of potential conflict, particularly for renewable energy development. The combination of marine cadastral and regionally-specific data provides users with the spatial context needed to address issues, such as alternative energy siting and comprehensive coastal and marine spatial planning.

**How it works:** Using ArcServer and Adobe Flex widgets, MMC is a web-based geospatial data viewer containing over 80 data layers from a variety of sources. Each layer can be turned on or off or queried one at a time. It has three possible background tiled services. Users can use preset windows, or zoom in and out on their own. Flex widgets include the ability to draw lines, polygons, and circles, measure distances or areas, create buffers, draw areas based on known coordinates, download data, create and print PDFs of a selected map creation, and share maps via a specialized, shareable URL. The MMC also serves as a data portal that provides direct links to the authoritative data presented through the viewer.

**Applications:** MMC is used for permit review, map creation for demonstration or decisionmaking purposes, and demonstration of location of entities within specific regions during planning meetings.

Gerick Bergsma 2009/Marine Photobank

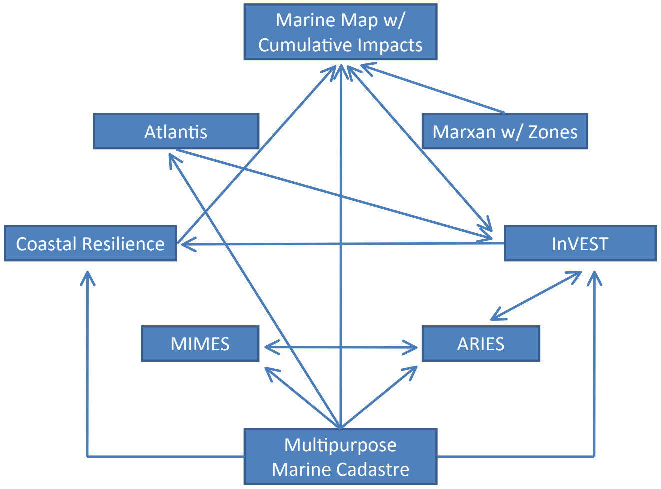
## TECHNICAL EXPERTISE REQUIRED BY USERS

The DSTs profiled above were built for a variety of processes and users. One key consideration in selecting a tool or combination of tools is the level of sophistication necessary to use the tool(s) (Box 2).

## POTENTIAL SYNERGIES BETWEEN EXISTING DSTS

As practitioners consider their needs for decision support, they may find that no single tool has been built exactly for their purposes. Instead, it may be best to create a "toolbox" of several DSTs that could be used during a planning process (Figure 2). For an example of DST "toolbox" construction, refer to Chapter 6.

**Figure 2. Possible synergies between existing DSTs that participated in the workshops. Arrows indicate where data, model outputs, or final products could be ported from one DST to another.**



## RECOMMENDED READING

**ARIES**

Dragisic, C., et al. 2011. Tools and methodologies to support more sustainable biofuel feedstock production. Journal of Industrial Microbiology & Biotechnology 38: 371–374.

**Atlantis**

Brown, J.A., et al. 2010. The Application Of Observing System Data In California Current Ecosystem Assessments. Marine Sanctuaries Conservation Series NMSP-ONMS-10-01. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 112 pp.

Fulton, E.A., et al. 2004. Ecological indicators of the ecosystem effects of fishing: final report. Australian Fisheries Management Authority Report R99/1546, pp. 116.

**Coastal Resilience**

Ferdaña, Z. et al. 2010. Adapting to Climate Change — Coastal Resilience Long Island. In: Andrade Pérez, A., Herrera Fernandez, B., Cazzolla Gatti, R. (eds.) Building Resilience to Climate Change: Ecosystem-based adaptation and lessons from the field. Gland, Switzerland: IUCN: 72–87.

**Cumulative Impacts**

Halpern, B.S. et al. 2008. A Global Map of Human Impact on Marine Ecosystems. Science 319: 948–952.

Selkoe, K.A., et al. 2009. A map of human impacts to a "pristine" coral reef ecosystem, the Papahanaumokuakea Marine National Monument. Coral Reefs 28: 635–650.

**InVEST**

Nelson, E., et al. 2009. Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales. Frontiers in Ecology and the Environment 7: 4–11.

**MarineMap**

Fox, E. et al. 2010. Information Flow in Coastal and Marine Spatial Planning: A Conceptual Framework to Inform Technological Choices to Meet Planning Needs. http://marinemap.org/framework

**Marxan with Zones**

Grantham, H.S., et al. (In Prep) Zoning marine protected areas for biodiversity conservation, sustainable fisheries and secure access to fisheries: case study from Raja Ampat, West Papua.

Watts, M.E, et al. 2009. Marxan with Zones: software for optimal conservation based land- and sea-use zoning, Environmental Modelling & Software 24: 1513–1521.

**MIMES / MIDAS**

Boumans, R. and Costanza, R. 2007. The multiscale integrated Earth Systems model (MIMES): the dynamics, modeling and valuation of ecosystem services. In: van Bers, C., Petry, D., Pahl-Wostl, D. (eds.) Global Assessments: Bridging Scales and Linking to Policy. Issues in Global Water System Research: 104–107.

Patel, H., et al. 2011. MIDAS: A Spatial Decision Support System for Monitoring Marine Management Areas. International Regional Science Review 34: 191–214.

**Multipurpose Marine Cadastre**

Fowler, C., et al. 2010. Building a Marine Spatial Data Infrastructure to Support Marine Spatial Planning in U.S. Waters. Geographic Technologies Applied to Marine Spatial Planning and Integrated Coastal Zone Management. H. Calado and A. Gil, Universidade Dos Acores: 46–52.

Nelson, D.M., et al. 2010. Assessing of existing information on Atlantic coastal fish habitats: development of a web-based spatial bibliography, query tools, and data summaries. NOAA Technical Memorandum NOS NCCOS 103: 1–59.

Christine Shillinger

# 4. Marine Spatial Planning Process Steps

Although marine spatial planning processes have been described in many different ways, these descriptions share common elements and process steps (refer to Box 3). This chapter examines how DSTs meet practitioners' needs based on eight common process elements that are described below and in Figure 3. At the end of the chapter, the Process Matrix is presented, which matches relevant tool functions (described in more detail in Chapter 5) to each process step.

**Common planning process steps:**

1. **Define goals and objectives**
2. **Gather data and define current conditions**
3. **Identify issues, constraints, and future conditions**
4. **Develop alternative management measures**
5. **Evaluate alternative management measures**
6. **Implement the plan**
7. **Monitor and evaluate management measures**
8. **Refine goals and objectives**

**Box 3: Other examples of planning steps for systematic and spatial planning processes.**

Systematic Conservation Planning Steps (adapted from Margules and Sarkar 2007):

1. Identify stakeholders for the planning region
2. Compile, assess, and refine biodiversity and socioeconomic data for the region
3. Identify biodiversity surrogates (indicators) for the region
4. Establish conservation goals, objectives, and targets
5. Review the existing conservation network (gaps analysis)
6. Prioritize new areas for potential conservation action
7. Assess prognosis for biodiversity within each newly selected area
8. Refine networks of areas selected for conservation action
9. Examine feasibility using multi-criteria analysis
10. Implement a conservation plan
11. Periodically reassess network

Marine Spatial Planning Steps (adapted from Ehler & Douvere 2009):

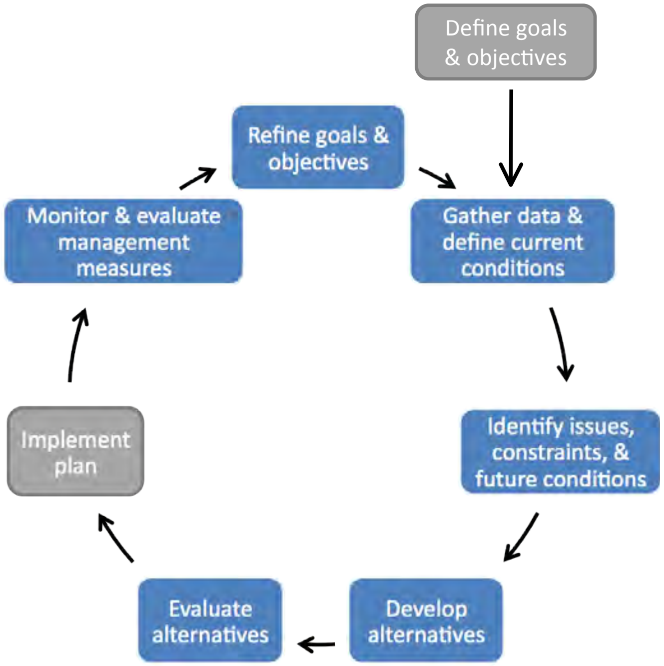
1. Identify need and establish authority
2. Obtain financial support
3. Organize stakeholder participation
4. Organize the process through pre-planning
5. Define and analyze existing conditions
6. Define and analyze future conditions
7. Prepare and approve the spatial management plan
8. Implement and enforce the spatial management plan measures
9. Monitor and evaluate performance
10. Adapt the spatial management process

Randy Wilder/Monterey Bay Aquarium

## DEFINE GOALS AND OBJECTIVES AND IMPLEMENT THE PLAN

Two of the most difficult and contentious steps in the planning process are “developing goals and objectives” and “implementing the plan.” While these are important and necessary components, they are not a focus of this Guide because these steps should not rely heavily on DSTs. Rather, practitioners should operationalize conceptual objectives and choose feasible, implementable planning options. In addition, involving stakeholders is important throughout the planning process, and thus it is not listed as a single step here. Finally, since planning processes are often iterative rather than strictly sequential, a practitioner may revisit the first few steps after an evaluation phase or as new information becomes available.

**Figure 3. General marine spatial planning process steps. Steps shown in blue boxes indicate steps that can benefit most from the use of DSTs. Steps in gray boxes should not rely heavily on the current functioning of DSTs.**



## GATHER DATA AND DEFINE CURRENT CONDITIONS

In order to develop a plan that meets the planning goals and objectives, practitioners will need to gather appropriate data and define current conditions — including ecological, social, and economic conditions — in the planning area. Practitioners can use DSTs in this process step to develop, provision, and manage data. They can also use DSTs to map and visualize current conditions in the planning area including the spatial distribution of resources, activities, ecosystems, and jurisdictions, as well as to provide non-spatial reports and graphics depicting current states and trends. In addition, practitioners can use DSTs to engage stakeholders and gather local and traditional knowledge.

## IDENTIFY ISSUES, CONSTRAINTS, AND FUTURE CONDITIONS

After gathering data and defining current conditions, practitioners need to identify the management issues, constraints, and future conditions that will be most relevant to their ability to meet planning objectives, and start to narrow the list of potential management measures. Practitioners can use DSTs with mapping and visualization functions at this stage to determine where conflicts among users or between users and ecosystems currently exist or are likely to occur in the future. Practitioners can also use tools to solicit stakeholders’ local and traditional knowledge to help identify issues and constraints, identify proposals that are “non-starters” for stakeholders, and assess the impact of future conditions (driven by natural and/or anthropogenic events) on ecosystems and stakeholders.

## DEVELOP ALTERNATIVE MANAGEMENT MEASURES

Developing management measures to achieve planning objectives is an important step in the planning process. In many cases, practitioners must identify multiple alternative means of reaching those objectives and ensure that decision-makers and the public understand the potential ramifications of each alternative. Practitioners can use DSTs to develop alternatives and to explore and visualize what each alternative might look like from the perspectives of multiple decision-makers and stakeholders. These alternatives may be generated based on ecosystem service values, trade-offs between ecological, social, and economic systems, or optimizing the degree to which the planning objectives are met.

## EVALUATE ALTERNATIVE MANAGEMENT MEASURES

After alternative management measures have been developed and are understood by decision-makers and stakeholders, it is important to evaluate alternatives based on the goals and objectives of the process. Practitioners can evaluate alternatives by using DSTs to produce maps, visualizations, and reports that communicate how plan objectives are met under each scenario. DSTs show considerable promise in making the trade-offs associated with any management action more transparent to stakeholders, practitioners, and decision-makers.

## MONITOR AND EVALUATE MANAGEMENT MEASURES

Marine spatial planning is not meant to generate management measures that remain static and unresponsive to change. As such, monitoring and evaluation of the effectiveness of management measures towards attaining plan objectives is an important step following plan implementation. Monitoring and evaluation can help hold planning and implementing agencies accountable for their actions and signal that course corrections are required. Practitioners can use maps and visualizations produced by DSTs to compare conditions prior to plan adoption with post-adoption conditions. They can also use DSTs to provide forums for stakeholder engagement in the form of information contributions and comments. Finally, practitioners can use some DSTs to view and analyze monitoring data directly in order to assess the effectiveness of the plan and associated management measures, ground-truth the assumptions that were made in the initial model development phase, and assess progress towards objectives.


Melissa Foley

## REFINE GOALS AND OBJECTIVES

The planning process is often iterative, requiring practitioners to revisit earlier steps following evaluation or as new information becomes available. For example, goals and/or objectives may need to be revised over time in response to monitoring or evaluation results or to address unforeseen constraints. DSTs with mapping and visualization functions may prove useful in gathering stakeholder input to facilitate this process.

Nancy Boucha, www.scubasystems.org 2005/ Marine Photobank

## PROCESS MATRIX

This Process Matrix shows the generic steps of a marine spatial planning process and the DST functions (detailed in Chapter 5) that can add value to each of the steps.

| | PROCESS STEP | | | | | |
|---|---|---|---|---|---|---|
| **TOOL FUNCTION** | Gather data and define current conditions | Identify issues, constraints, and future conditions | Develop alternatives | Evaluate alternatives | Monitor and evaluate management measures | Refine goals and objectives |
| Data management | ✓ | | | | | |
| Mapping and Visualization | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Alternative scenario development and analysis | | ✓ | ✓ | ✓ | | |
| Management measure option proposal | | | ✓ | ✓ | | |
| Stakeholder participation and collaboration, and community outreach and engagement | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Adaptive management and assessment of achieving objectives | | | | ✓ | ✓ | ✓ |

Charles Seaborn/Monterey Bay Aquarium

## RECOMMENDED READING

Ardron, J., et al. [in review] 2011. Adaptive Marine Spatial Planning Paper 1: context and future directions. Technical report, United Nations Environment Programme, Nairobi, Kenya. 50 pages.

Ardron, J.A., et al. (eds) 2008. Marxan Good Practices Handbook. External review version; 17 May, 2008. Pacific Marine Analysis and Research Association, Vancouver, BC, Canada. 155 pages.

Environmental Law Institute. 2009. Ocean and Coastal Ecosystem-Based Management: Implementation Handbook.

Beck, M.W., et al. 2009. Best Practices for Marine Spatial Planning. The Nature Conservancy, Arlington, Virginia.

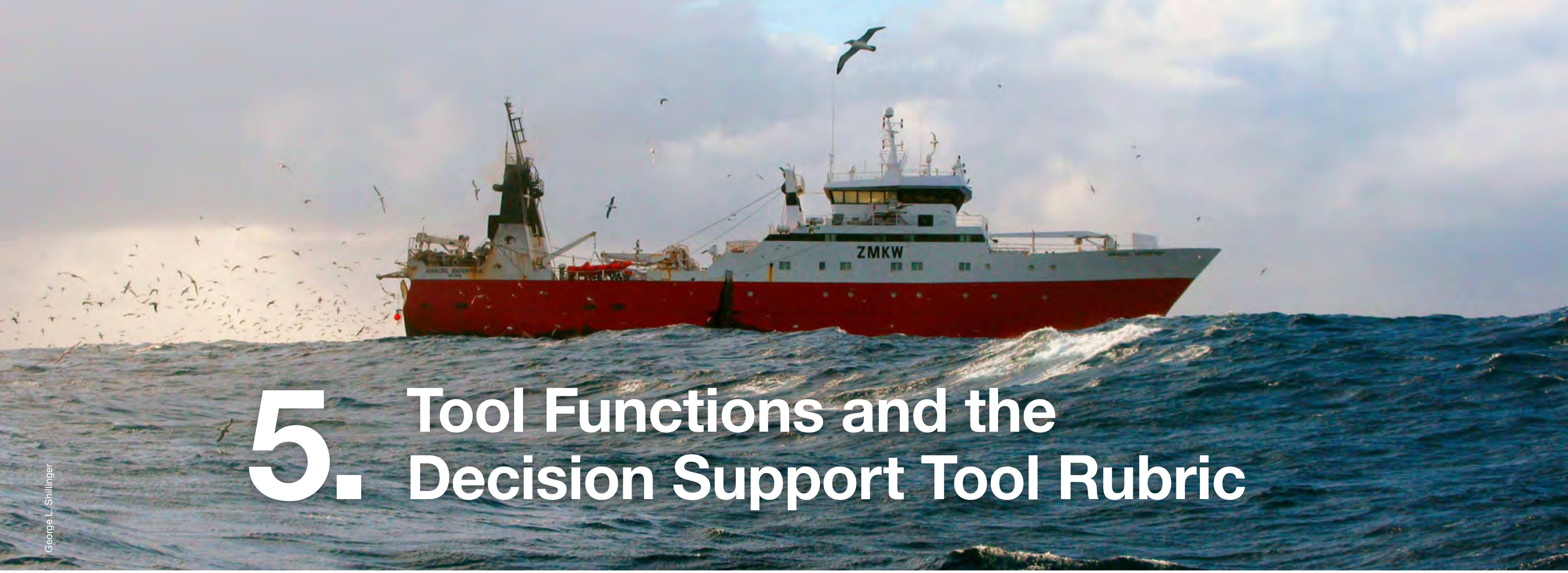
Ehler, C. and Douvere, F. 2009. Marine Spatial Planning: a step-by-step approach toward ecosystem-based management. Intergovernmental Oceanographic Commission and Man and the Biosphere Programme. IOC Manual and Guides No. 53, ICAM Dossier No. 6. Paris: UNESCO.

Gilliland, P.M and Laffoley, D. 2008. Key elements and steps in the process of developing ecosystem-based marine spatial planning. Marine Policy 32: 787–796.

Margules, C.R. and Pressey, R.L. 2000. Systematic conservation planning. Nature 405: 243–253.

Margules, C.R. and Sarkar, S. 2007. Systematic Conservation Planning. New York: Cambridge University Press.

U.S. Interagency Ocean Policy Task Force, led by the White House Council on Environmental Quality. 2010. Final Recommendations of the Interagency Ocean Policy Task Force.


George L. Shillinger

# 5. Tool Functions and the Decision Support Tool Rubric

The Process Matrix in Chapter 4 provides a visual representation of the steps in any marine spatial planning process that can benefit from the use of decision support tools, along with the tool functions that are most appropriate for each step. In this chapter, tool functions are described in more detail and are mapped to the nine DSTs in the Tool Function Matrix (pages 24–25). Finally, the Process Matrix and Tool Function Matrix were combined to form the Decision Support Tool Rubric (page 26), which provides a snapshot of each participating DST's core functions and potential roles in a planning process.

## DESCRIPTION OF TOOL FUNCTIONS

The tool functions described below were identified by the workshop participants as critical functional elements of DSTs that enable practitioners to make well-informed decisions at each process step. These functions can also be used to determine which DSTs are best suited for the specific needs of a process. The tool functions can be divided into six categories, including:

1. Data management
2. Mapping and visualization
3. Alternative scenario development and analysis
4. Management measure option proposal
5. Stakeholder participation and collaboration, and community outreach and engagement
6. Adaptive management and assessment of achieving objectives

These six categories are expanded in the Tool Function Matrix (pages 24–25) to include more specific functions that may be important for addressing particular planning objectives. The broad tool function categories are defined in more detail below with reference to specific tool functions in bold type and the process steps that are best supported by these functions in italics (tool function categories and process steps are also summarized in the Decision Support Tool Rubric).

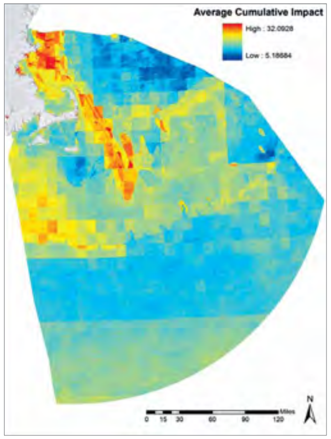
**1. Data Management** refers to tools that improve efficiency of data gathering and management and help to *Gather Data & Define Current Conditions*. Within this category, practitioners indicated that they might be particularly interested in tools that can provide data (**data provisioning**), assess the quality of available data (**data quality assessment**), upload and archive data (**data upload and archival**), and set standards and protocols for data compilation and inter-calibration (**data development**).

Geology and Seafloor

| Title | Source | Last Update | Download |
|---|---|---|---|
| California Bathymetry Contours (10m Intervals) | California Department of Fish and Game | 3/1/2004 | |
| Offshore Surficial Sediment | U.S. Geological Survey | 7/3/2007 | |
| Seafloor Geology | U.S. Geological Survey | 11/13/2009 | |
| Outer Continental Shelf Sand and Gravel Borrow Areas | Bureau of Ocean Energy Management, Regulation and Enforcement | 11/25/2008 | |
| New Jersey Bathymetry Contours (10ft Intervals) | New Jersey Department of Environmental Protection | 3/1/2006 | |
| Northeast Bathymetry Contours (10m Intervals) | U.S. Geological Survey | 9/27/2002 | |
| Northwest Bathymetry Contours (10m Intervals) | U.S. Geological Survey | 7/20/2004 | |
| Southeast Bathymetry Contours (2m Intervals) | NOAA Coastal Services Center | 1/1/2000 | |
| Undersea Feature Placenames | National Geospatial-Intelligence Agency | 2/4/2009 | |
| Offshore Wind Energy Potential | National Renewable Energy Laboratory | 4/14/2011 | |

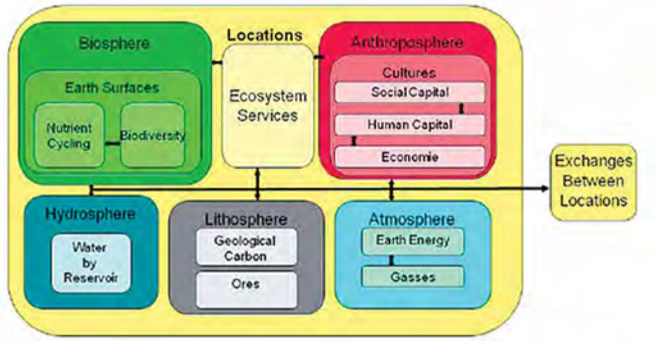
**Data download ability in the Multipurpose Marine Cadastre.**

**2. Mapping and visualization** functionality is important throughout the process from *Defining Current Conditions to Refining Goals and Objectives*. Within this broad category, tool developers and practitioners distinguished between spatial and non-spatial data. **Spatial** data can be mapped or visualized to provide information about the following attributes: the physical characteristics of an area, from base maps to bathymetry, depth, temperature, and persistent oceanographic features (**basemaps/physical**); biological information, including distributions of relevant species and habitats (**habitats/species**); the location of ecosystem service provision or pathway of service flow (**ecosystem services**); temporal features of an area, including seasonal species distribution, oceanographic conditions, and time series data (**temporal features**); vulnerability of ecosystems to future changes, including new uses, cumulative impacts, and climate change (**vulnerability**); existing or proposed human uses or activities, including the footprint of activities and the value of those uses (**uses**); incompatible activities, impacts to ecosystems, natural resources, or particular uses (**incompatibility and impacts**); and legal and jurisdictional information, including existing management measures such as marine protected areas, essential fish habitat, or shipping safety measures (**jurisdictions**).



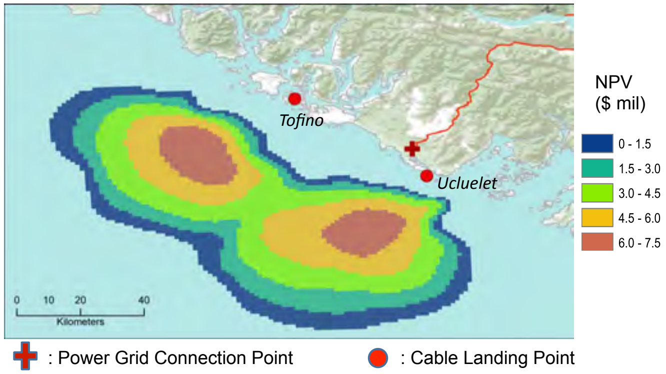
**Example of how cumulative impact data can be mapped and displayed visually using the Cumulative Impacts model.**

**Non-spatial** data can be visualized to provide the following outputs: graphical displays of analyses, including, for example, the percentage of planning area with overlapping uses, threat values for activities, amount of planning area vulnerable to sea level rise, emoticons, and thumbs-up or thumbs-down status (**graphical display**); and text-based displays of analyses, including, for example, lists of uses, species, or habitats that occur within a planning area, the amount of overlap of uses, or the area of incompatibility (**reports**).

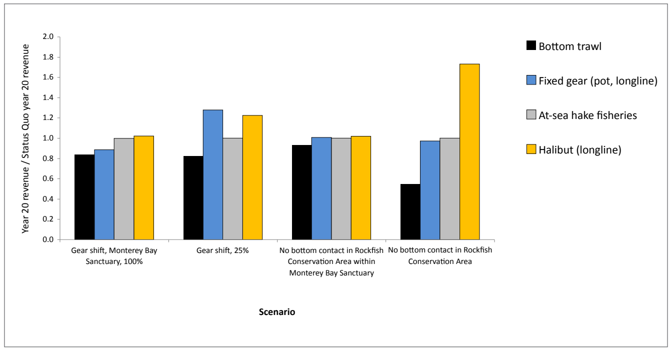


**Conceptual framework for MIMES that illustrates how systems are connected and how ecosystem services flow through the ecosystem. This graphical framework display can help practitioners determine the types of data and information that are necessary to build a dynamic spatial model that accounts for the linkages between systems and models where ecosystem services are provided to human communities.**

**3. Alternative scenario development and analysis** is a major function provided by DSTs that can aid in *Identifying Issues, Constraints, and Future Conditions; Developing Alternative Management Measures*; and *Evaluating Alternative Management Measures*. Alternative scenarios can be developed for a number of specific categories that practitioners might find useful, including tools that: assign value to the amount and type of ecosystem services delivered under different management scenarios (**ecosystem service valuation**); assess trade-offs across multiple sectors and management objectives (**trade-off assessment**); assess impacts of individual and multiple activities to ecosystems (**impact assessment**); provide visual context for different planning options to help stakeholders understand the array of possible planning scenarios (**planning option context**); allow users to calculate the best returns for defined planning objectives (**optimization**); provide reports, maps, or other forms of information that show users whether a proposal meets one or more plan objectives (**planning objective assessment**); model future scenarios, for example, based on implementation of specific management measures or due to climate change predictions (**forecasting**); give users a sense of the risk and uncertainty associated with each scenario (**uncertainty tracking**); and assess the sensitivity of models, including to the amount and scale of data (**sensitivity assessment**).

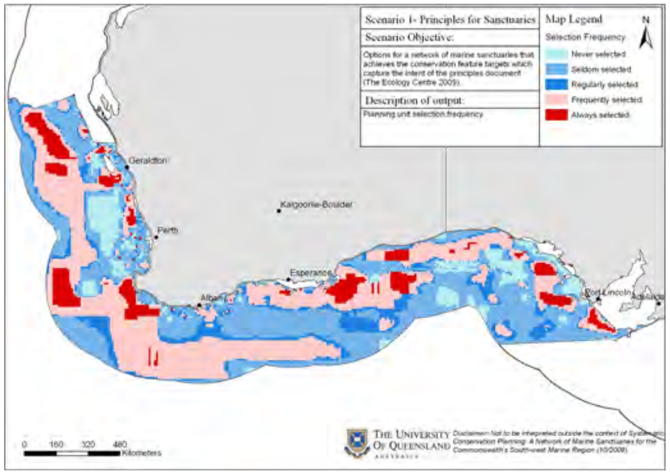


**InVEST visualization of the net present value (millions of $) of captured wave energy over a 25-year life span. This visualization can help users develop and analyze alternative scenarios based on the differential value of siting wave arrays in various locations along the west coast of Vancouver Island.**



**Example report generated by Atlantis showing the revenue of four fishing fleets based on different management scenarios.**

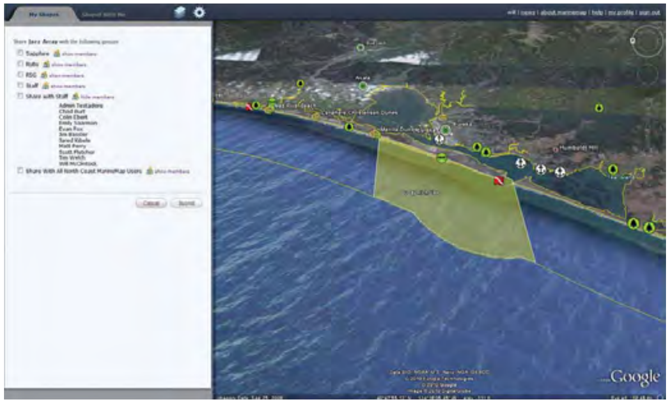
**4. Management measure option proposal** is an important tool function that can aid in *Developing Alternative Management Measures* and *Evaluating Alternative Management Measures*. Specific tool functions may include: proposing or analyzing siting locations, permit conditions, or mitigation measures for specific projects (**siting conditions**); and tools that propose or analyze area-based management measures that apply to a suite of activities taking place in specified areas based on compatibility with other uses and the ecosystem (**zoning proposals**).



**Marxan with Zones optimizes a spatial solution for Southwestern Australia by calculating the best locations for defined planning objectives.**

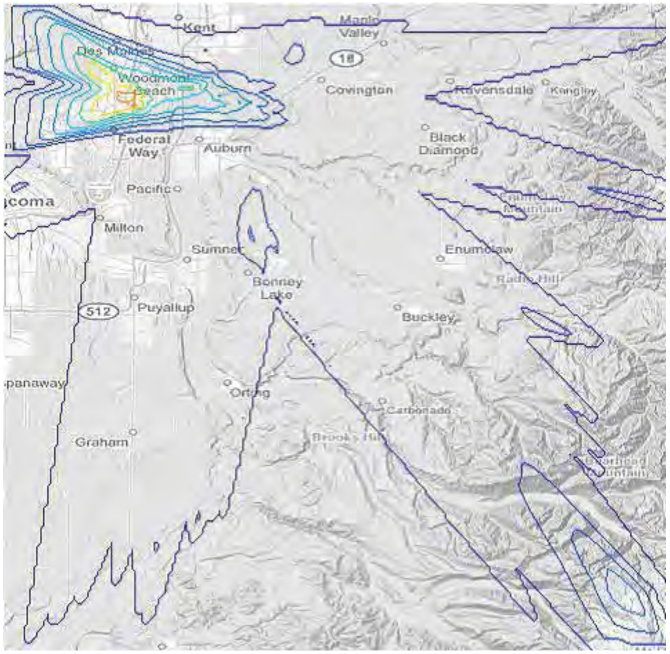
**Example of how the Coastal Resilience DST can be used to inform management options by forecasting inundation based on future sea level rise and storm water surge scenarios, which could result in infrastructure loss, increased community vulnerability, and loss of biodiversity.**

**5.** Tool functions that support **stakeholder participation and collaboration, and community outreach and engagement** are important throughout all steps of the planning process. DSTs can involve stakeholders by allowing users to: discover information through data queries and map layers (**exploratory**); interact with the tool on their own (web-based) or during meetings (desk-based) (**participatory interface**); incorporate local and traditional knowledge about the location of uses or resources (**incorporates local and traditional knowledge**); help shape the format and type of outputs based on iterative feedback to the tool developers (**iterative**); share proposals with other stakeholders (**user collaboration**); and write and share comments about specific aspects of plans or planning information (**comment and communication**).



**MarineMap was created principally to involve stakeholders in California's effort to designate a statewide network of marine protected areas. Stakeholders were able to create networks of MPAs by drawing proposals on a map (as in this example), evaluating and comparing alternative networks for achievement of design guidelines, and sharing ideas with other stakeholders.**

**6.** Finally, DSTs that incorporate **adaptive management and assessment of achieving objectives** functionality into their tools are important for *Evaluating Alternative Management Measures, Monitoring and Evaluating Management Measures*, and *Refining Goals and Objectives*. Specific tool functions in this category include: comparing initial conditions, plan information, and original goals to post-monitoring conditions to assess plan effectiveness (**use monitoring data to assess plan effectiveness**); testing the assumptions in original scenarios and changing model parameters as needed if management measures are not achieving the objectives as predicted (**ground-truth assumptions in scenarios**); and generating reports, graphs, and maps to illustrate progress toward objectives, and reevaluating models where progress is not being made (**assess progress toward objectives**).



**Ecosystem service provision maps developed by ARIES help decision-makers visualize where critical areas are located in order for ecosystem services to reach intended beneficiaries. These critical contour flow maps and the underlying model can be revisited following plan implementation if objectives are not being reached.**

## TOOL FUNCTION MATRIX

The Tool Function Matrix on the following pages documents the current core competency of each DST that participated in the workshops. In tandem with the Process Matrix (Chapter 4), the Tool Function Matrix should help practitioners determine which DSTs could benefit each step of the process based on the specific tool functions.

A single tool listed in the Tool Function Matrix may not include all the tool functions needed during a planning process. However, this matrix can help practitioners identify multiple tools that they may need in their “toolbox” to meet the requirements and objectives of a planning process.

| | DECISION SUPPORT TOOLS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| TOOL FUNCTION | ARIES | Atlantis | Coastal Resilience | Cumulative Impacts | InVEST | MarineMap | Marxan with Zones | MIMES | Multipurpose Marine Cadastre |
| **DATA MANAGEMENT** | | | | | | | | | |
| Data provisioning | ✓ | | ✓ | ✓ | ✓ | | | ✓ | ✓ |
| Data quality assessment | ✓ | | | | | | | | |
| Data upload & archival | ✓ | | ✓ | ✓ | | | | ✓ | ✓ |
| Data development | | | ✓ | | | | | ✓ | ✓ |
| **MAPPING & VISUALIZATION** | | | | | | | | | |
| **Spatial** | | | | | | | | | |
| Basemaps/Physical | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Habitats/species | ✓ | | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ |
| Ecosystem services | ✓ | | | | ✓ | | | ✓ | |
| Temporal features | ✓ | | ✓ | | ✓ | ✓ | | ✓ | |
| Vulnerability | ✓ | | ✓ | ✓ | ✓ | | | ✓ | |
| Uses | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Incompatibility & impacts | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Jurisdictions | ✓ | | ✓ | ✓ | | ✓ | | | ✓ |
| **Non-spatial** | | | | | | | | | |
| Graphical display | ✓ | | | | ✓ | ✓ | | ✓ | |
| Reports | ✓ | | | | | ✓ | | ✓ | |

| TOOL FUNCTION | DECISION SUPPORT TOOLS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | ARIES | Atlantis | Coastal Resilience | Cumulative Impacts | InVEST | MarineMap | Marxan with Zones | MIMES | Multipurpose Marine Cadastre |
| **ALTERNATIVE SCENARIO DEVELOPMENT & ANALYSIS** | | | | | | | | | |
| Ecosystem service valuation | ✓ | | | | ✓ | | | | |
| Trade-off assessment | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ | |
| Impact assessment | ✓ | | ✓ | ✓ | ✓ | ✓ | | ✓ | |
| Planning option context | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Optimization | | | | | | | ✓ | ✓ | |
| Planning objectives assessment | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Forecasting | ✓ | ✓ | ✓ | | ✓ | | | ✓ | |
| Uncertainty tracking | ✓ | | ✓ | | ✓ | | | | |
| Sensitivity assessment | | | | | | | | ✓ | |
| **MANAGEMENT MEASURE OPTION PROPOSAL** | | | | | | | | | |
| Siting conditions | ✓ | | | ✓ | ✓ | | | ✓ | ✓ |
| Zoning proposals | | | | ✓ | ✓ | ✓ | ✓ | ✓ | |
| **STAKEHOLDER PARTICIPATION AND COLLABORATION, AND COMMUNITY OUTREACH AND ENGAGEMENT** | | | | | | | | | |
| Exploratory | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Participatory interface | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ |
| Incorporates local & traditional knowledge | ✓ | | | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Iterative | ✓ | | ✓ | | ✓ | ✓ | ✓ | ✓ | |
| User collaboration | ✓ | | | | | ✓ | ✓ | | |
| Comment & communication | | | | | ✓ | ✓ | | | |
| **ADAPTIVE MANAGEMENT & ASSESSMENT OF ACHIEVING OBJECTIVES** | | | | | | | | | |
| Use monitoring data to assess plan effectiveness | ✓ | | | | ✓ | | | ✓ | |
| Ground-truth assumptions in scenarios | | | | | | | | ✓ | |
| Assess progress towards objectives | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | | |

## THE DECISION SUPPORT TOOL RUBRIC

The following matrix combines the Process Matrix from Chapter 4 with the Tool Function Matrix on the previous pages into one Decision Support Tool Rubric. This Rubric highlights the generic steps in a planning process, couples the tool function categories that are likely to be important for those steps, and highlights the DSTs that currently fill such a role. This Rubric should be reviewed alongside the Tool Function Matrix to ensure that the tools selected include the specific tool functions required in a process.

| PROCESS STEP | Gather data & define current conditions | | | Identify issues, constraints, and future conditions | | | Develop alternative management measures | | | | Evaluate alternative scenarios | | | | | Monitor and evaluate management measures | | | Refine goals and objectives | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOOL FUNCTION | Data Management | Mapping & Visualization | Stakeholder Participation | Mapping & Visualization | Alternative Scenarios | Stakeholder Participation | Mapping & Visualization | Alternative Scenarios | Management Measures | Stakeholder Participation | Mapping & Visualization | Alternative Scenarios | Management Measures | Stakeholder Participation | Adaptive Management | Mapping & Visualization | Stakeholder Participation | Adaptive Management | Mapping & Visualization | Stakeholder Participation | Adaptive Management |
| DECISION SUPPORT TOOL | | | | | | | | | | | | | | | | | | | | | |
| ARIES | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Atlantis | | | | | ✓ | | | ✓ | | | | ✓ | | | ✓ | | | ✓ | | | ✓ |
| Coastal Resilience | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | | ✓ | ✓ | |
| Cumulative Impacts | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| InVEST | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| MarineMap | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Marxan with Zones | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| MIMES | ✓ | ✓ | ✓ | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Multipurpose Marine Cadastre | ✓ | ✓ | ✓ | | | | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ | |

# 6. Decision Support Tool Features

Thomas Hallermann/Marine Photobank

While the Decision Support Tool Rubric (refer to Chapter 5) highlights the core functions of each tool, additional features contribute to the overall look, feel, and functioning of each DST. The features themselves do not always fit within one of the general tool function categories; nor do they individually guide practitioners through a specific process step. Many of these features, however, form the basis of the models, visualizations, and scenario analysis functions that are important for any marine spatial planning process. In addition, some of these features determine how stakeholders and practitioners interact with DSTs, the time and resources needed to effectively use DSTs, and their transferability to other geographies.

In this chapter, tool features are described in more detail and are mapped to the nine DSTs in a Tool Feature Matrix (pages 30–31). Also provided is an example of how this Tool Feature Matrix can help practitioners assemble the most appropriate “toolbox” of DSTs for their planning process (Box 4).

Melissa Foley

## DESCRIPTION OF TOOL FEATURES

During the October workshop, DST developers identified important features of individual tools and grouped these features into categories. During the February workshop, tool developers and practitioners worked in small groups to rank the list of tool features in order of importance to them. The list below and the Tool Feature Matrix include 16 categories of tool features; each category is expanded into a set of specific features to help practitioners match their decision support needs to the appropriate DSTs.

**Priority tool objective:** the primary planning objective for which the DST can provide support.

- **Conservation:** identifying areas and methods most appropriate to provide protection of ecosystems, species, habitats, and ecological function.
- **Emerging uses:** locating new human uses in a planning area.
- **Managing trade-offs:** understanding the costs and benefits of alternative management actions and structuring trade-off decisions.
- **Education and awareness:** helping a range of stakeholders understand issues, alternatives, and potential effects of management actions throughout a planning process.
- **Scenario analysis:** analyzing the feasibility and/or desirability of alternative management actions.
- **Socio-economic:** considering human concerns and impacts.

**Data demands and needs:** the amount, type, and resolution of data necessary to use a particular DST.

- **Specific data needed to use the DST:** the tool requires a specific type of data.
- **Incorporates multiple types of data:** the tool can incorporate many types of data.
- **Resolution of required data is flexible:** the tool will run using data of varying resolutions.
- **Minimum threshold of data required:** a certain amount of data must be available for the tool to function.

**Output type:** the DST product type.

- **Maps**
- **Models**
- **Valuation**
- **Spatially-explicit**
- **Reports**
- **Movies**

**Validation/peer-review:** whether various aspects of the DST have been validated through a peer review process.

- **Data**
- **Code/model**
- **Application**

**Transferability:** whether the DST models or approaches are transferable to other regions or must be customized for each use.

- **Transferable**
- **Customized**

**Transparency:** whether the assumptions underlying the tool are apparent to users, whether the DST operates as a "black box," and whether the tool can incorporate assumptions provided by the users.

- **Working assumptions are stated clearly upfront**
- **Working assumptions are expressed in modeling equations or software code**
- **Working assumptions are understandable by all users**
- **Assumptions can be supplied by users**

**Intended audience:** the primary user group(s) for whom the DST was designed.

- **Public stakeholders**
- **Policy makers**
- **Public agency resource managers**
- **Scientists**
- **Communities**
- **Education/schools**
- **Businesses**
- **Project applicants**
- **Technical staff**

**Support for users:** whether assistance is available to users. Assistance might take the form of written, virtual, or in-person training and good practice resources, real-time technical advice, or DST user/developer forums, including workshops and conferences.

- **Yes**
- **No**

**Objectives:** the number of planning objectives for which the DST is designed to provide support.

- **Single:** planning for only a single objective (e.g., identifying areas appropriate for conservation).
- **Dual:** planning for two objectives (e.g., identifying areas appropriate for conservation and minimizing impacts to fishing industries).
- **Multiple:** planning for more than two objectives (e.g., identifying areas appropriate for conservation and siting renewable energy facilities, while minimizing the impacts to fishing industries and shipping).

**Run-time/performance:** whether users can expect outputs of the DST in real-time or after a significant delay.

- **Real-time:** DST is appropriate for use during planning meetings.
- **Delay:** DST should be used to prepare for planning meetings.

**Delivery mechanism for tool/model outputs:** how the DST outputs are made available to users.

- **Web-based:** outputs available through online DST interface.
- **Desktop:** outputs generated via desktop application.
- **Gaming:** outputs presented and simulated via gaming approaches.
- **Summary:** outputs available as summaries, statistics, or graphs.
- **Workshops:** outputs delivered to stakeholders during a workshop.
- **Mobile application:** outputs available on mobile devices.

**User access:** whether there are cost or control limitations to DST access.

- **Free access:** there is no monetary cost to use the DST.
- **Fee to access:** the DST developer charges a monetary fee to access the tool. This includes tools that run on fee-based platforms like many ESRI products.
- **Controlled access:** the DST administrator can provide differing levels of access to different users or user-groups, which allows confidential sharing of plan proposals.
- **No access for non-expert users:** the DST is too technical for non-expert users.

**Software:** whether the software is proprietary or open-source.

- **Proprietary:** a license is required to use the software and certain uses are restricted.
- **Open-source:** the software's source-code is available free of charge to the public to use, copy, modify, and/or redistribute.

**User collaboration:** whether DST users are currently able to work together to create, share, and edit planning proposals or whether the developer is considering adding collaborative use features in the future.

- **Existing**
- **Future potential**

**Synergies with other tools:** whether the DST is currently able to work with another DST or if developers are working to make tools compatible in the future.

- **Current**
- **Future**

**Model type:** underlying assumptions and construction of models included in DSTs.

- **Probabilistic:** models are based on stochastic variables, which allow users to generate a set of outcomes based on the probability of occurrence.
- **Deterministic:** the end points of the models are predetermined through known relationships among states or events.
- **Dynamic:** models account for the element of time.
- **Empirically based:** models are based on data.

Boltron, flickr.com/photos/boltron/3118728210/

## TOOL FEATURE MATRIX

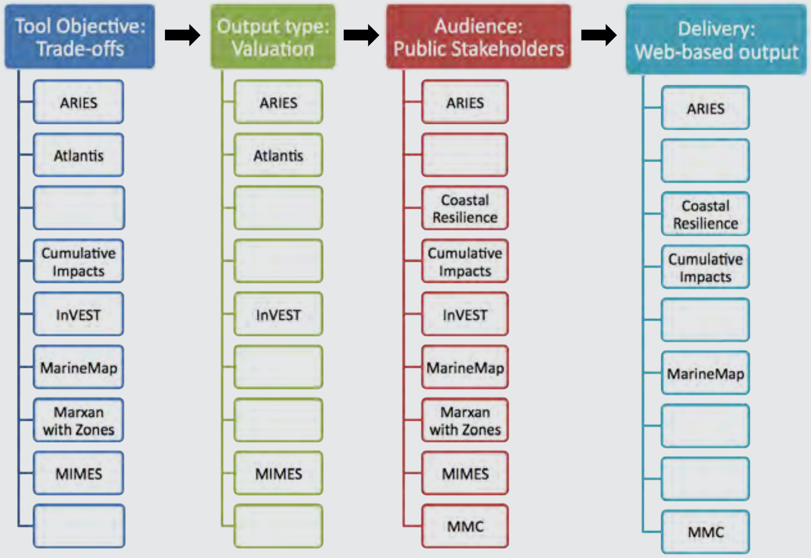
The Tool Feature Matrix on the following pages highlights the general and specific features of the nine DSTs that participated in the workshops. Feature categories are listed in order of importance to the workshop participants, particularly practitioners.

| FEATURE CATEGORY | SPECIFIC FEATURE | ARIES | Atlantis | Coastal Resilience | Cumulative Impacts | InVEST | Marine-Map | Marxan with Zones | MIMES | Multi-purpose Marine Cadastre |
|---|---|---|---|---|---|---|---|---|---|---|
| Priority tool objective | Conservation | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Emerging uses | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Managing trade-offs | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Education & awareness | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Scenario analysis | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Socio-economic | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ |
| Data demands & needs | Specific data types needed to use DST | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | |
| | Incorporates multiple types of data | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Resolution of required data is flexible | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Minimum amount of data required | ✓ | ✓ | | | ✓ | | ✓ | ✓ | |
| Output type | Maps | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ |
| | Models | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | |
| | Valuation | ✓ | ✓ | | | ✓ | | | ✓ | |
| | Spatially-explicit | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Reports | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Movies | | ✓ | ✓ | | | | | ✓ | |
| Validation/peer-review | Data | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ |
| | Code/model | ✓ | | | ✓ | ✓ | | | ✓ | |
| | Application | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Transferability | Transferable | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Customized | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | |
| Transparency | Working assumptions are stated clearly upfront | ✓ | | ✓ | ✓ | ✓ | ✓ | | ✓ | |
| | Working assumptions are expressed in modeling equations or software code | ✓ | ✓ | ✓ | | | | | ✓ | |
| | Working assumptions are understandable by all users | | | | | | ✓ | | ✓ | |
| | Assumptions can be supplied by users | ✓ | | | | ✓ | | | ✓ | |
| Intended audience | Public stakeholders | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Policy makers | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Public agency resource managers | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Scientists | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Communities | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Education/schools | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Businesses | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Project applicants | ✓ | | | ✓ | ✓ | ✓ | ✓ | | ✓ |
| | Technical staff | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | ✓ |

| FEATURE CATEGORY | SPECIFIC FEATURE | ARIES | Atlantis | Coastal Resilience | Cumulative Impacts | InVEST | Marine-Map | Marxan with Zones | MIMES | Multi-purpose Marine Cadastre |
|---|---|---|---|---|---|---|---|---|---|---|
| Support for users | Yes |  | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |  |
|  | No | ✓ |  |  |  |  |  |  |  | ✓ |
| Objectives | Single | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
|  | Dual | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
|  | Multiple | ✓ | ✓ |  | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Run-time/performance | Real-time | ✓ |  |  | ✓ | ✓ | ✓ |  | ✓ | ✓ |
|  | Delay |  | ✓ | ✓ |  |  |  | ✓ |  |  |
| Delivery mechanism for tool/model outputs | Web-based | ✓ |  | ✓ | ✓ |  | ✓ |  |  | ✓ |
|  | Desktop | ✓ | ✓ |  |  | ✓ |  | ✓ | ✓ | ✓ |
|  | Gaming |  |  |  |  |  |  |  |  |  |
|  | Summary | ✓ |  | ✓ | ✓ | ✓ | ✓ | ✓ |  |  |
|  | Workshops | ✓ |  | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |  |
|  | Mobile application |  |  |  |  |  |  |  |  |  |
| User access | Free access | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |  | ✓ | ✓ |
|  | Fee to access |  |  |  |  |  |  | ✓ |  |  |
|  | Controlled access | ✓ | ✓ |  | ✓ |  | ✓ |  | ✓ |  |
|  | No access for non-expert users |  |  |  |  |  |  |  |  |  |
| Software | Proprietary |  | ✓ | ✓ |  |  |  | ✓ | ✓ |  |
|  | Open-source | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |  |  | ✓ |
| User collaboration | Existing | ✓ | ✓ | ✓ |  | ✓ | ✓ |  | ✓ |  |
|  | Future potential | ✓ |  |  | ✓ |  | ✓ |  | ✓ | ✓ |
| Synergies w/ other tools | Current |  |  |  | ✓ |  | ✓ |  |  |  |
|  | Future | ✓ | ✓ | ✓ |  | ✓ |  | ✓ | ✓ | ✓ |
| Model type | Probabilistic | ✓ |  | ✓ |  | ✓ |  |  |  |  |
|  | Deterministic | ✓ |  |  |  | ✓ |  |  | ✓ |  |
|  | Dynamic | ✓ | ✓ |  |  | ✓ |  |  | ✓ |  |
|  | Empirically based | ✓ |  | ✓ | ✓ | ✓ |  |  |  |  |

Mike Baird, flickr.bairdphotos.com

## Box 4. Using the Tool Feature Matrix



This schematic illustrates how practitioners can use the Tool Feature Matrix to build their DST "toolbox." In this example, the four boxes across the top show the DST features that practitioners often request — in order of priority from left to right. First, the practitioner needs a DST that incorporates trade-off analysis features; there are seven DSTs in the above matrix that fit this need. Second, the practitioner needs the DST to generate outputs of the trade-off analyses in the form of valuations; there are four DSTs that fit this need. Third, the practitioner needs to ensure that public stakeholders can use the DST, a feature that eight DSTs can fill. Finally, in this case the practitioner would like the delivery of materials to be available through a web-based application; five DSTs currently provide this service.

In this example one DST, ARIES, might fulfill all of the practitioner's priority needs. ARIES also has core functioning in each of the general process categories, indicating that a one-tool approach may be feasible. However, there may be other solutions involving multiple DSTs for the provision of different desired outputs. For example, it is possible that the trade-offs the practitioner needs to analyze are based on the impacts of different activities rather than on the relative values of ecosystem services. In this case, the Cumulative Impacts DST may be better suited to the process. Cumulative Impacts does not provide output in terms of valuation metrics, but it may be possible for the results from the Cumulative Impacts analysis to be incorporated into one of the four DSTs that does provide valuation output, such as Marine InVEST. Both the Marine InVEST and Cumulative Impacts DSTs allow public stakeholders to interact with the outputs, but only Cumulative Impacts has the ability to deliver web-based products through its partnership with MarineMap. So in this example, three tools in the "toolbox" — Cumulative Impacts, InVEST, and MarineMap — may be necessary to address the practitioner's priority needs.

# 7. Tool Case Studies

© Aquamarine Power, photo by Mike Brookes Roper

In this chapter, one or two case studies of each DST are showcased to provide an in-depth look at the processes for which these tools are currently being used, including their goals or objectives, the products generated, the data and technical skills required to use them effectively, and lessons learned.

# ARtificial Intelligence for Ecosystem Services (ARIES)

## Case Study — Coast of Madagascar

**Planning agency:**

- United Nations Environment Programme's World Conservation Monitoring Center

**Ultimate decision-maker:**

- No planning process has been initiated to date

**Goals or objectives of the planning process:**

- Develop proof of concept for marine ecosystem service models for subsistence fisheries and coastal storm protection
- Inform potential decision-makers of the connections between the subsistence use of coastal fisheries and coastal populations and poverty; and between the presence of humans and infrastructure on the coast, the threat to lives and property from tropical storms, and the attenuation of storm impacts by natural features
- Provide a mechanism for analyzing the effects of policy and/or land use changes on coastal protection and the subsistence use of coastal fisheries

**What data themes were used for the process?**

- Fisheries — commercially important fish species, habitat description, species abundance, harvesting methods, historical catch data
- Demographics — population density, poverty
- Physical — bathymetry and topography
- Tropical storm tracks — wind speed and atmospheric pressure
- Artificial coastal protection structures — jetties, sea walls, etc.
- Natural features — coral reefs, mangroves, seagrass, sand dunes, and terrestrial vegetation

**Were multiple scenarios or management options generated? If so, how were they evaluated?**

ARIES users presented one scenario for subsistence fisheries, but presented three alternative coastal protection scenarios based on historical tropical storm tracks in the region. For each scenario, users evaluated storm impacts on coastal assets and the loss of life.

**Product(s) generated by ARIES for this planning process:**

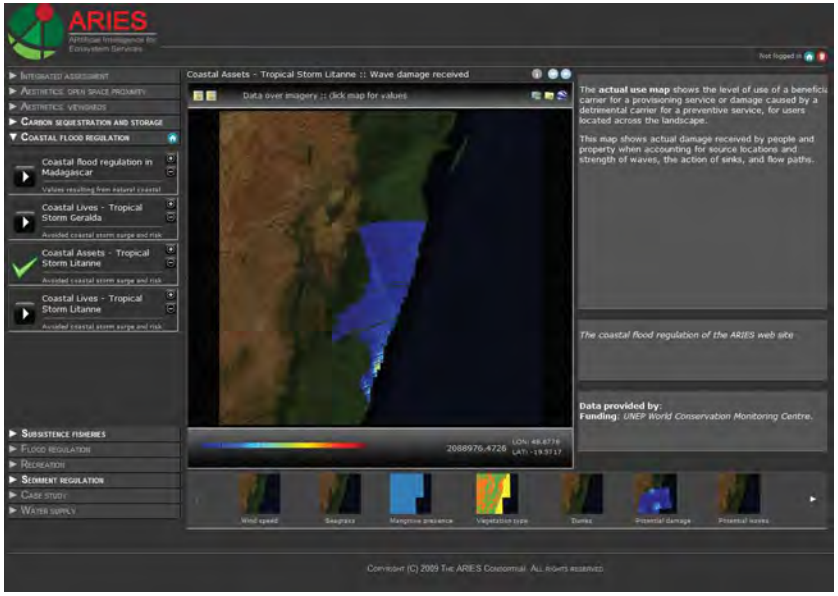
- Maps of input data and modeled outputs that can be exported as image files or spatial data and imported into desktop GIS applications for further analysis
- A report detailing data sources and model assumptions
- An interactive internet interface that allows users to run the model over a specified geography and under alternative assumptions

### What level of technical skill is needed to use ARIES?

ARIES is intended for use by interested stakeholders of varying technical proficiency. Model development activities (including data collection and processing, source code and interface development, and model documentation) are conducted by the tool developers. Once the model has been developed and customized to reflect the relevant social and environmental contexts, experienced GIS staff can use the outputs to generate products (e.g., maps, graphics and tables) that are useful for policy deliberation. Upon development and deployment of the model to the ARIES website, the model is accessible to a broad public audience — from unskilled web surfers to technically trained users such as spatial analysts — enabling the browsing of input data and modeled outputs, the alteration of data for custom designed scenarios, and the production of maps and graphics to facilitate discourse and improve understanding of the interface between human development and subsistence use of coastal resources.

### Were there any significant barriers in helping users and/or practitioners use ARIES? What lessons were learned?

The ARIES modeling platform is a complex DST with multiple potentially significant barriers to implementation. One strategy employed by the ARIES team is to work directly with decision-makers, interested stakeholders, and others to define a research or policy question, translate that need into a model based on available data and expert opinion, and prepare the model and data documentation along with an explanation of the results. Completed models are included in an online interface that includes a description of the model purpose and application, full accounting of model input data, and multiple alternatives for viewing model outputs, including pre-formatted images, spatial data, and a storyline representation of model inputs and outputs that defines the linkages between human beneficiaries and the particular ecosystem service of interest.



The **actual use map** shows the level of use of a beneficia carrier for a provisioning service or damage caused by a detrimental carrier for a preventive service, for users located across the landscape.

This map shows actual damage received by people and property when accounting for source locations and strength of waves, the action of sinks, and flow paths.

*The coastal flood regulation of the ARIES web site*

**Data provided by:**
**Funding:** *UNEP World Conservation Monitoring Centre.*

**ARIES web interface showing the spatial extent of damage to people and property along the east coast of Madagascar, following a tropical storm.**

# Atlantis

## Case Study #1 — Southeastern Australian continental shelf, slope, and open ocean

**Planning agency:**

- Australian Fisheries Management Authority and the Commonwealth Scientific and Industrial Research Organisation (CSIRO)

**Ultimate decision-maker:**

- Australia Fisheries Management Authority

**Goals or objectives of the planning process:**

- Give strategic insights into the consequences and potential trade-offs associated with a range of fisheries management strategies for Southeastern Australian waters

**What data themes were used for the process?**

- Biological — abundance and spatial distribution of vertebrates and invertebrates
- Fisheries — catch by fleet, bycatch, and discards
- Oceanographic — hydrodynamic models
- Economic — costs and profits for different fishing fleets
- Social — jobs per fishery and impacts on coastal communities

**Were multiple scenarios or management options generated? If so, how were they evaluated?**

Stakeholders and scientists generated five main scenarios, and many variants, for fisheries management. These scenarios included spatial closures for certain fishing fleets, catch quotas, gear restrictions, fleet buyouts, and other options. A spatial ecosystem model was used to evaluate the predicted future effect of each scenario. The outcomes were also scored on the basis of ecological metrics, biodiversity, fishery yield (tons), economic performance (dollars), and management and monitoring costs.

**Product(s) generated by Altantis for this process:**

- Report to management authorities
- Maps of the biological and economic outcomes for each fishery management action

**What level of technical skill is needed to use Atlantis?**

The Atlantis ecosystem model was applied by experienced scientists at CSIRO. Stakeholders did not run the model, but instead gave input on scenario development and fishery management options to test.

**Were there any significant barriers in helping users and/or practitioners use Atlantis? What lessons were learned?**

The model itself requires significant experience to run, calibrate, and interpret. The complexity of the model necessitates considerable effort to simplify the outputs and communicate results.

## Case Study #2 — California Current Integrated Ecosystem Assessment

**Planning agency:**

- National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS), and National Marine Sanctuaries

**Ultimate decision-maker:**

- This case study was a scoping exercise; no specific management decisions were made

**Goals or objectives of the planning process:**

- Explore the potential influence of a broad array of fisheries management options on groundfish and the marine ecosystem
- Examine status quo management
- Explore the consequences of several gear switching and spatial management scenarios

**What data themes were used for the process?**

- Biological — abundance and spatial distribution of vertebrates and invertebrates
- Fisheries — current and historical catch by fleet, bycatch, and discards
- Oceanographic — hydrodynamic models
- Economic — revenue per fleet

**Were multiple scenarios or management options generated? If so, how were they evaluated?**

A series of interviews with ten fishery managers and scientists led to the creation of 80 different scenarios and variations related to fisheries management and global change. Of these, 18 scenarios were selected as most relevant to the themes of NOAA's 2010 Integrated Ecosystem Assessment and most appropriate for testing using the Atlantis ecosystem model of the California Current. The outcomes were also scored on the basis of ecological metrics of ecosystem health, metrics of abundance and condition of groundfish, fishery yield (tons), and economic performance (dollars).

**Product(s) generated by Atlantis for this process:**

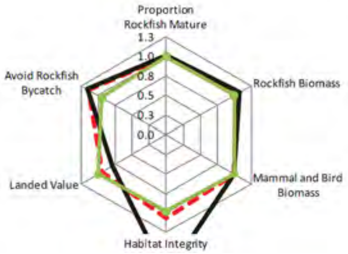
- Portion of NOAA's 2010 Integrated Ecosystem Assessment of the California Current
- Maps of the biological and economic outcomes

**What level of technical skill is needed to use Atlantis?**

The Atlantis ecosystem model was applied by experienced scientists at NMFS, while fishery managers and scientists at the National Marine Sanctuaries gave input on scenario development and fishery management options to test.

**Were there any significant barriers in helping users and/or practitioners use Atlantis? What lessons were learned?**

The model itself requires significant experience to run, calibrate, and interpret. The complexity of the model necessitates considerable effort to simplify the outputs and communicate results.



**A schematic generated by Atlantis for the California Current Large Marine Ecosystem, illustrating three alternative fisheries management scenarios and their impacts on the fishery, ecosystem components, and economic gains. (Refer to Chapter 5 for an additional example of graphical output from Atlantis.)**

# Coastal Resilience

## Case Study — Long Island Sound (New York and Connecticut shores)

**Planning agency:**

- Local coastal development and conservation programs

**Ultimate decision-maker:**

- Regulatory authorities on coastal development

**Goals or objectives of the planning process:**

- Build a spatial database and interactive web mapping application that provides decision support for meeting both biodiversity conservation and coastal hazard mitigation objectives
- Construct a website that explains the approach, methods, and strategies for ecosystem-based adaptation to climate change
- Identify reasonable and viable alternatives that reduce losses and vulnerability of coastal communities for people and ecosystems

**What data themes were used for the process?**

- Biological — coastal wetlands, dune, piping plover, and other species of concern
- Physical — storm surge, sea level rise, elevation, tide height
- Socioeconomic — land use, land cover, population census, economic
- Indices developed — human community vulnerability, potential economic loss, potential protective capacity, viability of coastal wetlands through marsh migration

**Were multiple scenarios or management options generated? If so, how were they evaluated?**

The Long Island Sound web mapping application can generate multiple sea level rise and storm surge inundation scenarios that help users identify potential vulnerabilities of ecological and human communities. It also provides insight into strategies for maintaining the health of natural coastal systems (e.g., via marsh migration) so that human communities remain resilient in the face of future storm surge and sea level rise. For example, stakeholders can evaluate multiple management options by viewing different marsh migration scenarios in concert with social and infrastructure vulnerability data and land use information (e.g. zoning/parcel data). This feature can help identify management solutions that jointly achieve hazard mitigation and biodiversity conservation.

**Product(s) generated by Coastal Resilience for this process:**

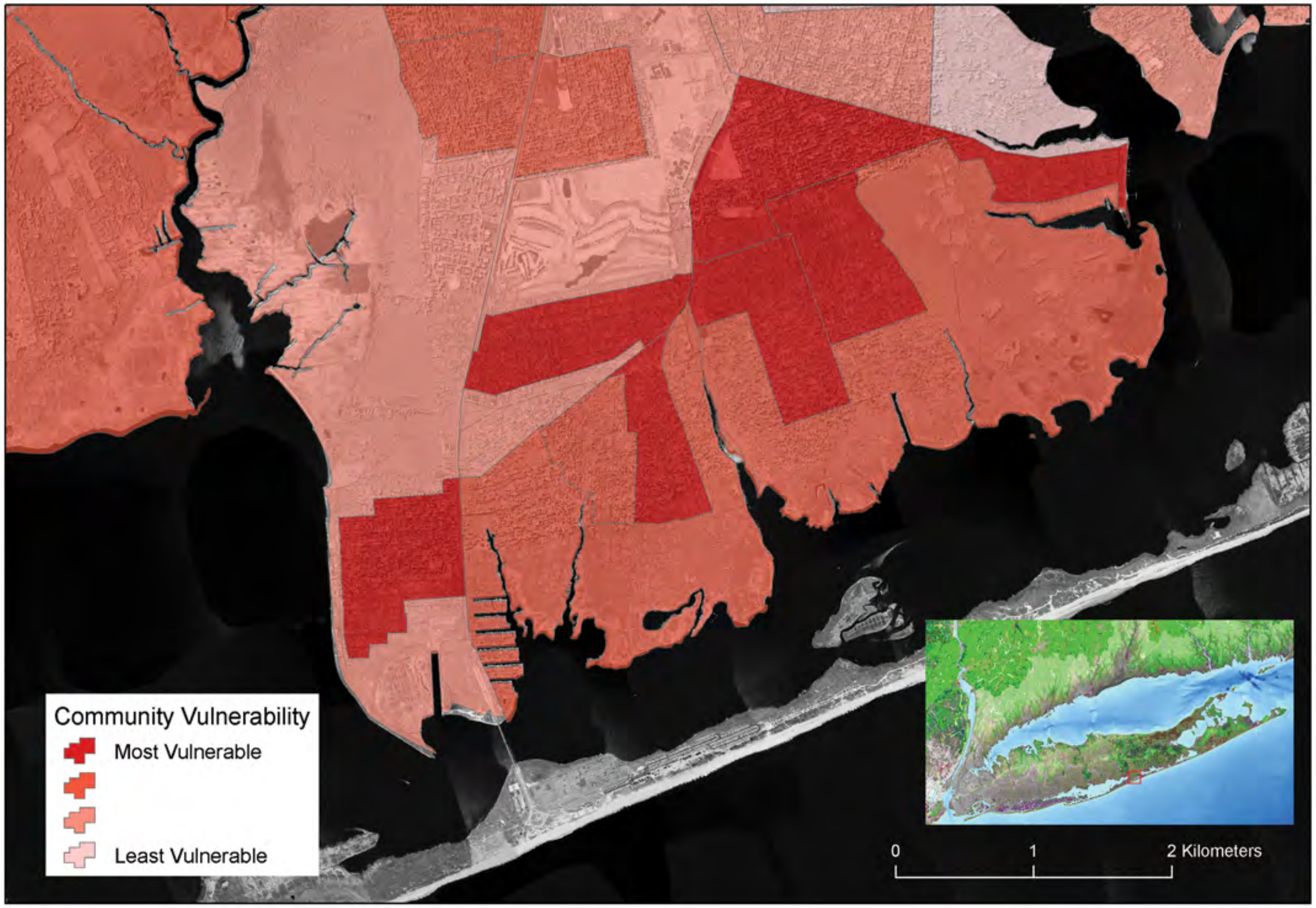
- Multiple map types — inundation risk, vulnerability, marsh migration and protective capacity

**What level of technical skill is needed to use Coastal Resilience?**

Coastal Resilience does not require any prior training or experience with GIS. However, in this case, trainings were conducted to determine usability and how to make the application more user-friendly.

**Were there any significant barriers in helping users and/or practitioners use Coastal Resilience? What lessons were learned?**

Many local elected officials do not believe that sea level rise poses a threat, and thus do not think that it should be a major consideration in planning. The state agency participants have somewhat more flexibility to promote planning for sea level rise, but since most land use planning is accomplished by local governments, state agencies generally need a local partner to engage in sea level rise or coastal hazards projects. Because local leaders are rarely cognizant of the risks to their communities by future changes — and the adaptation options to plan for these changes — Coastal Resilience allows agencies to collaborate with communities that are conducting planning processes to integrate sea level rise issues and potential ecosystem based adaptation strategies into their plans. Coastal Resilience is transferring lessons learned from Long Island Sound to other communities.



**Community vulnerability index generated by Coastal Resilience for communities in Long Island Sound, based on future projections of storm surge and sea level rise. (Refer to Chapter 5 for another example of how Coastal Resilience maps future scenarios based on projected sea level rise and storm water surge.)**

# Cumulative Impacts

## Case Study #1 — Papahānaumokuākea Marine National Monument, Northwestern Hawaiian Islands

**Planning agency:**

- Papahānaumokuākea Marine National Monument, with scientists from the Hawai‘i Institute of Marine Biology

**Ultimate decision-maker:**

- Papahānaumokuākea Marine National Monument

**Goals or objectives of the planning process:**

- Map all anthropogenic threats to the region with habitat-specific analysis

**What data themes were used?**

- Biological — habitat, species impact
- Human use — all human activities
- Physical — water depth

**Were multiple scenarios or management options generated? If so, how were they evaluated?**

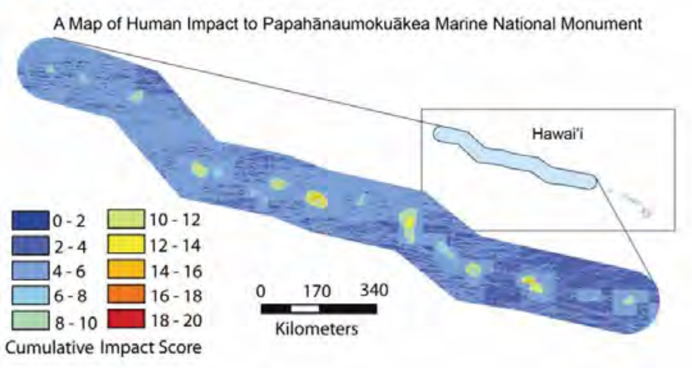
Subsets of cumulative impact maps were generated to isolate climate change and non-climate change impacts.

**Product(s) generated by Cumulative Impacts for this process:**

- Maps
- Reports
- Press release

**What level of technical skill is needed to use Cumulative Impacts?**

The output maps can be viewed with no technical skill. To manipulate (e.g., zoom in or turn layers on/off) the maps, basic GIS knowledge is required.



**Map of cumulative impacts in the Northwestern Hawaiian Islands generated by the Cumulative Impacts tool.**

## Case Study #2 — Massachusetts state and adjacent federal waters

**Planning agency:**

- Commonwealth of Massachusetts in partnership with the Massachusetts Ocean Partnership

**Ultimate Decision-maker:**

- Massachusetts Executive Office of Energy and Environmental Affairs

**Goals or objectives of the planning process:**

- Manage development in state waters
- Balance natural resource preservation with traditional and new uses, including renewable energy

**What data themes were used for the process?**

- Biological — habitat distribution
- Human use — human activities and associated stressors
- Ecosystem vulnerability based on expert judgment

**Were multiple scenarios or management options generated? If so, how were they evaluated?**

Multiple scenarios were not generated. However, results of the cumulative impact of different subsets of stressors were presented for purposes of edification.

**Product(s) generated by Cumulative Impacts for the process:**

- Maps (refer to Chapter 5 for a map of cumulative impact scores in Massachusetts state and adjacent federal waters)
- Results report
- Matrices of incompatible uses
- Database of spatial data and associated metadata

**What level of technical skill is needed to use Cumulative Impacts?**

The version of the tool used in Massachusetts requires GIS analytical skill and developer support throughout the project. As part of the project, an Arc Model Builder version of the tool was created so that anyone with limited GIS skills can implement the tool.

**Were there any significant barriers in helping users and/or practitioners use Cumulative Impacts? What lessons were learned?**

Educating users on the different types of data that needed to be included and how best to find, develop, or derive them was a time-intensive process.

# InVEST

## Case Study #1 — West Coast of Vancouver Island, British Columbia, Canada

**Planning agency:**

- West Coast Aquatic Management Board

**Ultimate decision-maker:**

- West Coast Aquatic Management Board and government agencies at the federal, provincial, and First Nations levels

**Goals or objectives of the planning process:**

- Facilitate the development and implementation of a strategy for the integrated management of aquatic ecosystems on the west coast of Vancouver Island

**What data themes were used for the process?**

Coastal Protection model:

- Biophysical — bathymetry, wind, wave, topography, distribution of biogenic habitats, tidal data
- Valuation — coastal property values, population density, infrastructure value, beach nourishment costs

Finfish Aquaculture model:

- Biophysical — water temperature, farm locations
- Valuation — operating costs, market prices of salmon, farm revenues

**Were multiple scenarios or management options generated? If so, how were they evaluated?**

Multiple scenarios and management options were developed in this case study. Ecological and social outcomes were evaluated based on ecosystem service production, measured either in biophysical or economic terms, and how well the results of each scenario met the stated objectives of the process.

**Product(s) generated by InVEST for this process:**

- Maps of ecosystem service production in biophysical and economic terms (refer to Chapter 5 for a map showing the predicted net present value over a 25-year lifespan of three wave energy conversion facilities for the west coast of Vancouver Island)
- Trade-off balance sheets showing which services increase and decrease under various management scenarios

**What level of technical skill is needed to use InVEST?**

InVEST is designed to be used by trained planning or stakeholder staff. The Natural Capital Project facilitates training sessions for planners with some GIS expertise to learn how to use InVEST. Because the west coast of Vancouver Island was the first site application of InVEST in a marine context, Natural Capital Project staff were substantially involved in gathering the data and running the models. InVEST developers are working to improve the user-friendliness of the tool so that it can be used with minimal training.

**Were there any significant barriers in helping users and/or practitioners use InVEST? What lessons were learned?**

One of the most challenging issues was to help the West Coast Aquatic Management Board develop input scenarios. Scenario development can be difficult if users and stakeholders are not familiar with the suitability of areas within their planning region for various human uses. To help overcome this barrier, Natural Capital staff prepared basic ‘suitability maps’ that show site suitability for various human activities based on biophysical attributes. In addition, Natural Capital staff are working to develop a separate scenario development tool that will incorporate basic biophysical attributes, known conflicts and compatibilities among human ocean uses, and planning visions to generate potential scenarios to help facilitate the early stages of a decisionmaking process.

## Case study #2 — North Shore of Oʻahu, Hawaiʻi

**Planning agency:**

- Kamehameha Schools, the largest private landowner in the state of Hawaiʻi

**Ultimate decision-maker:**

- Kamehameha Schools

**Goals or objectives of the planning process:**

- Design and implement a land-use plan that fulfilled Kamehameha Schools' mission to balance environmental, economic, cultural, educational, and community values

**What data themes were used for the process?**

- Biophysical — precipitation, soil type, digital elevation maps
- Human-use — land-use, land cover
- Economic — returns from land leases

**Were multiple scenarios or management options generated? If so, how were they evaluated?**

The InVEST and Kamehameha Schools team developed three alternative land-use scenarios including agriculture transition for biofuel feedstock, diversified agriculture and forestry, and residential development. The scenarios quantified changes in the delivery of services and financial return from the land, while changes in cultural services were modeled qualitatively. The alternative scenarios were then compared based on the delivery of a broad suite of services.

**Product(s) generated by InVEST for the process**

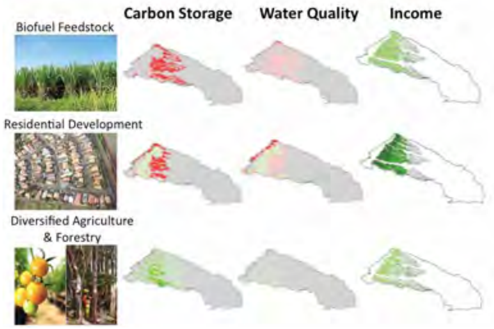
- Maps
- Biophysical and economic change in the delivery of ecosystem services
- Explicit trade-offs between services

**What level of technical skill is needed to use InVEST?**

The InVEST team worked with decision-makers to turn various planning alternatives into model inputs, ran the models, and then worked with the decision-makers to iterate and revise.

**Were there any significant barriers in helping users and/or practitioners use InVEST? What lessons were learned?**

InVEST requires a substantial amount of input data, which is challenging to collect and prepare. In data-poor areas, the InVEST team attempts to provide as much globally available data as possible.



**Maps showing the model results for the three Kamehameha Schools planning scenarios. Carbon storage and water quality show enhancements (green color) or reductions (red color) in ecosystem service provision for the scenario relative to the current landscape; gray color denotes no change. The income maps show projected land rental rates (biofuel feedstock, diversified agriculture, and forestry scenarios) or sale price (residential development), with darker green colors representing greater values.**

# MarineMap

## Case Study — California's Marine Life Protection Act, South Coast and North Coast planning regions

**Planning agency:**

- California Department of Fish and Game

**Ultimate decision-maker:**

- California Fish and Game Commission

**Goals or objectives of the planning process:**

- Increase the coherence and effectiveness of California's marine protected area (MPA) network in protecting the state's marine life and habitats, marine ecosystems, and marine natural heritage
- Improve recreational, educational and study opportunities provided by marine ecosystems subject to minimal human disturbance

**What data themes were used for the process?**

- MPA designs — draft marine protected area proposal boundaries
- Biological — species distributions
- Existing management areas — essential fish habitat, fishery management boundaries, etc.
- Cultural — cities, coastal access points, shipwrecks
- Physical — bathymetry, hydrography, canyons, pinnacles
- Habitat — predicted substrate, eelgrass, kelp, etc.
- Consumptive uses — fisheries surveys
- Non-consumptive uses — kayaking, tide pooling, whale watching sites, etc.

**Were multiple scenarios or management options generated? If so, how were they evaluated?**

Stakeholders generated multiple management scenarios on their own (e.g., at home or with constituents) and in collaboration with other stakeholders at public meetings. MarineMap provided analytical feedback to help stakeholders prepare proposals that complied with the scientific guidelines for MPA placement. Proposals were further evaluated by the Marine Life Protection Act Initiative staff and the Science Advisory Team. Proposals were ultimately considered by the California Fish and Game Commission.

**Product(s) generated by MarineMap for this process:**

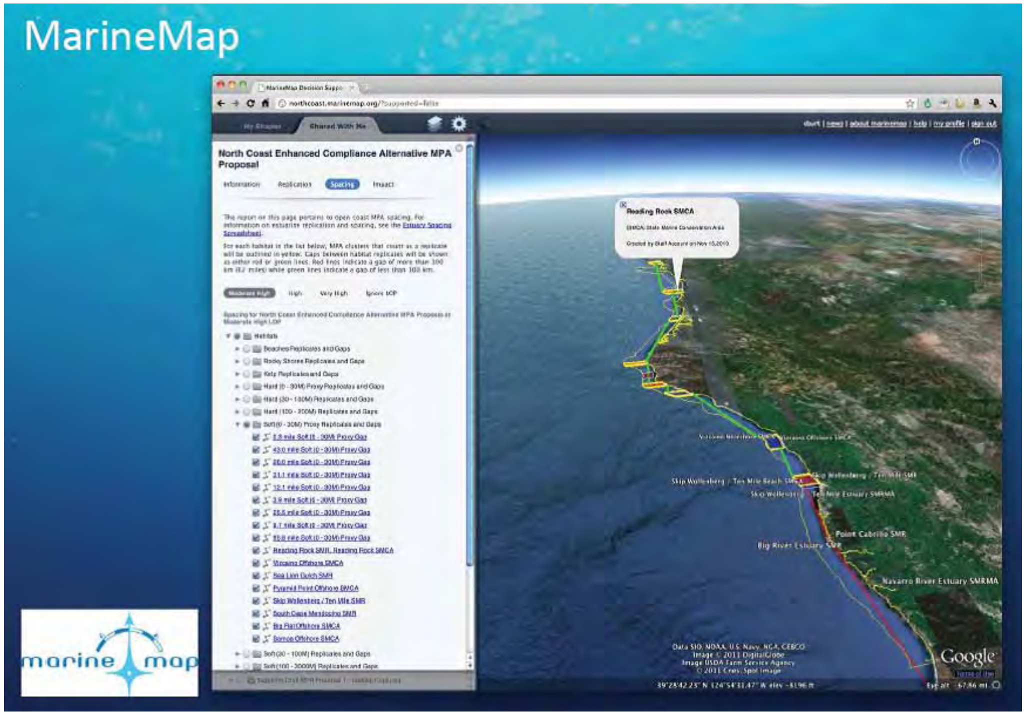
- Maps and reports that could be exported to third party formats
- Report of the attributes of each MPA (e.g., designation, allowed uses, regulated activities, goals and objectives, design considerations, boundary description, geometry) in digital format (KML files)
- Report of the attributes of each MPA network (e.g., description, supporting files) in digital format (KML files)
- Analytical reports for individual MPAs, including size, habitat representation, and potential economic impact to fisheries
- Analytical reports for each regional MPA network, including the number, size, and percent of the study region covered by each MPA type along with the level of protection, habitat replication, spacing, and economic impact to fisheries

**What level of technical skill is needed to use MarineMap?**

MarineMap was designed to be used by anyone with a web browser and an internet connection.

**Were there any significant barriers in helping users and/or practitioners use MarineMap? What lessons were learned?**

MarineMap was used by stakeholders from a variety of backgrounds who had little to no experience with traditional GIS software. For this reason, a great deal of attention was paid to the usability and responsiveness of the application. Investments were made in developing a purpose-built user interface that borrowed many conventions, lessons learned, and technologies from consumer mapping applications such as Google Earth. Additionally, developers were involved in the entire planning process, allowing them to customize and refine the application as the planning process evolved and feedback was gathered from stakeholders.



**MarineMap visualization for the West Coast Enhanced Compliance Alternative MPA Proposal, a stakeholder-derived network proposal. (Refer to Chapter 5 for an additional example of the maps generated by MarineMap.)**

# Marxan with Zones

## Case Study #1 — Raja Ampat, West Papau, Indonesia

**Planning agency:**

- Non-governmental organizations

**Ultimate decision-maker:**

- District government

**Goals or objectives of the planning process:**

- Design criteria included biodiversity, fisheries and social goals

**What data themes were used for the process?**

- Biological - ecosystem types, habitat condition, species of conservation concern, important life history areas
- Human use — community fishing grounds, fishing structures (e.g., huts, drying racks), and mariculture sites

**Were multiple scenarios or management options generated? If so, how were they evaluated?**

Multiple iterations of outputs were generated based on stakeholder evaluation.

**Product(s) generated by Marxan with Zones for this process:**

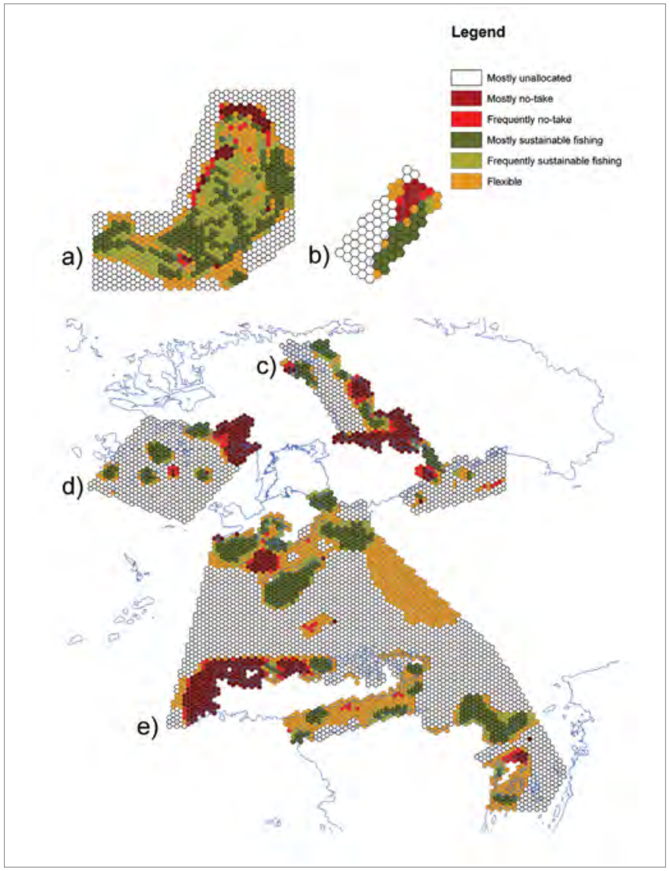
- Maps
- Geodatabase
- Reports — technical, public, two-page summary, and scientific publications

**What level of technical skill is needed to use Marxan with Zones?**

A high level of technical skill is needed to use Marxan with Zones. While stakeholders did not use the actual program directly, they were included in the planning process. Stakeholder involvement ensured that their input shaped the application of Marxan with Zones, and that stakeholders maintained some ownership of the process. Marxan with Zones is highly technical, and this was one of the few projects in the world to have used it to date.

**Were there any significant barriers in helping users and/or practitioners use Marxan with Zones? What lessons were learned?**

The complexity of the tool requires expert users to explain the results to non-experts. To facilitate dialogue with users that possess a range of knowledge levels, the complexity of outputs varied (e.g., technical reports for those with some knowledge, two page summary for others).



**In Raja Ampat, Indonesia, each planning unit was classified into the zone that it was most frequently selected for in the analysis.**

## Case Study #2 — Southwestern marine region, Australia

### Planning agency:

- Australian federal government, non-governmental organizations, and consultants

### Ultimate decision-maker:

- Australian federal government

### Goals or objectives of the planning process:

- Include the full range of ecosystems recognized at an appropriate scale within and across bioregions
- Reserve adequate area to ensure the ecological viability and integrity of populations, species and communities
- Marine areas selected for inclusion in MPAs should reasonably reflect the biotic diversity of the marine ecosystems from which they derive

### What data themes were used in the process?

- Biodiversity — ecosystems, species, ecological processes (1894 data layers)
- Industry — fisheries, defense, petroleum, mining, population, shipping (46 data layers)

### Were multiple scenarios or management options generated? If so, how were they evaluated?

Multiple scenarios were developed based on varying parameters in the results. They were evaluated based on the socio-economic impacts to different sectors.

### Product(s) generated by Marxan with Zones for this process:

- Technical report
- Maps (refer to Chapter 5 for the scenario map generated for this process)

### What level of technical skill is needed to use Marxan with Zones?

A fairly high level of technical skill is required.

# Multi-scale Integrated Models of Ecosystem Services (MIMES)

## Case Study — Coastal Massachusetts and Stellwagen Bank

**Planning agency:**

- Commonwealth of Massachusetts in collaboration with the Massachusetts Ocean Partnership

**Ultimate decision-maker:**

- Massachusetts Executive Office of Energy and Environmental Affairs

**Goals or objectives of the planning process:**

- Manage development in state waters
- Balance natural resource preservation with traditional and new uses, including renewable energy

**What data themes were used in the process?**

- Species — pelagic, benthic, migrants, residents (40 species)
- Human use — otter trawling, pot gear, gill nets, wind, LNG, shipping, and conservation (13 activities)
- Economics — coastal income distribution

**Were multiple scenarios or management options generated? If so, how were they evaluated?**

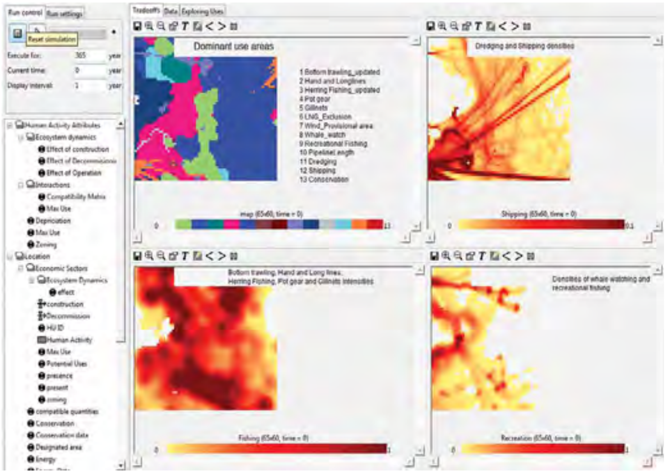
Scenarios are being developed that illustrate the trade-offs between different sectors (e.g., fishing, energy, and conservation) in spatial planning. These scenarios will be evaluated both by their impacts on species distribution and overall biomass, as well as the impacts on different economic sectors.

**Product(s) generated by MIMES for this process:**

- Spatially explicit trade-off maps
- Non-spatial models

**What level of technical skill is needed to use MIMES?**

MIMES requires specially trained staff to build and run the models. The Marine Integrated Decision Analysis System (MIDAS) visualization platform, which relies on MIMES models, is intended to be used by non-technical users with no prior training via the internet or at workshops.


Execute for: 365 year
Current time: 0 year
Display interval: 1 year

**Screenshot of some of the components of the MIMES model being used to evaluate trade-offs between different uses in Massachusetts state waters.**

# Multipurpose Marine Cadastre (MMC)

## Case Study — Northern California

**Planning agency:**

- NOAA National Marine Fisheries Service Habitat Conservation Division

**Ultimate decision-maker:**

- Federal agencies including NOAA, NMFS, National Marine Sanctuaries, and the U.S. Coast Guard

**Goals or objectives of the planning process:**

- Evaluate the ecological impacts of proposed ocean energy projects, including designated essential fish habitat and threatened and endangered species habitat

**What data themes were used in the process?**

- Jurisdictional boundaries and limits — Territorial Sea, federal/state boundary, outer continental shelf lease blocks
- Navigation and marine infrastructure — traffic lanes, shipping safety fairways, anchorage areas
- Human use — proposed California hydrokinetic projects
- Marine habitat and biodiversity — NMFS Habitat Areas of Particular Concern, Essential Fish Habitat, gray whale migration routes
- Physical — seafloor geology, bathymetric contours

**Were multiple scenarios or management options generated? If so, how were they evaluated?**

Although no alternative scenarios or management options were generated using the MMC, maps were distributed to multiple divisions within NOAA for comment and recommendations using the "URL Link" tool in the application, which allowed staff to quickly create, share and discuss proposed areas.

**Product(s) generated by MMC for this process:**

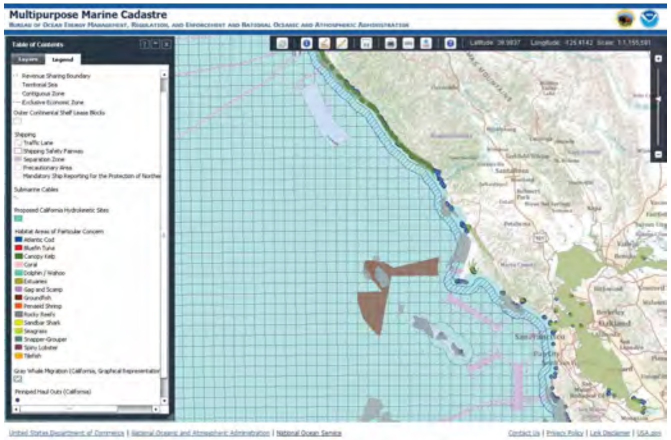
- Maps

**What level of technical skill is needed to use the MMC?**

The MMC was designed to serve a wide variety of users and stakeholders with varied technical experience and knowledge. A Quick Start Guide was created to orient new users to various functions, from online mapping applications to the mapping interface and custom tools.

**Were there any significant barriers in helping users and/or practitioners use MMC? What lessons were learned?**

No technical or other significant barriers were encountered in assisting the NMFS Habitat Conservation Division staff utilize this tool for reviewing an ocean energy project.



**Map of the Northern California coast generated by MMC to help facilitate discussions of siting renewable energy hydrokinetic projects in federal waters.**


Jiangang Luo/Marine Photobank

# 8. Conclusion

Decision support tools provide powerful and effective methods of helping practitioners and stakeholders understand, operationalize, and implement marine spatial planning approaches. This Decision Guide was designed to aid practitioners in their efforts to select and use DSTs, and to help tool developers identify where future development efforts should be directed.

DST developers are expanding the scope and functioning of existing DSTs, while new data modeling and visualization technologies will stimulate the development of increasingly sophisticated DSTs. These developments should increase the utility of DSTs and open up new applications for their use. However, work remains to further clarify the role of DSTs in planning processes, and to make the tools more accessible to users. Box 5 summarizes the strengths of existing DSTs, potential improvements that could be made, areas for development, and priority next steps for DST developers.

The stewardship of a community of practice of tool developers, practitioners, and other stakeholders is one way to advance communication and collaboration. We hope that this Guide will catalyze more extensive dialogue within the community of DST developers and practitioners, and that this dialogue will continue to inform and improve marine spatial planning efforts, thereby contributing to our greater goal of sustaining healthy ocean ecosystems and the services that they provide.

**Box 5. Strengths, gaps, and priority needs for future DST development.**

**Strengths of existing DSTs**

- Mapping and visualization
- Informing decisionmaking processes with scientific and spatial data
- Developing alternative scenarios
- Clarifying available knowledge and data/information gaps
- Promoting systematic rigor in planning processes
- Providing single sites for sharing a variety of data

**Potential improvements to existing DST functions and features**

- Representing data quality and sources in simple ways
- Communicating complex data and information to stakeholders
- Supporting multi-objective planning
- Building stakeholder participation and collaboration
- Providing more tool-specific training for practitioners
- Identifying and prioritizing likely areas of conflict
- Representing uncertainty in models and maps
- Improving efficiency and coordination of data management
- Creating better feedback loops between DST developers and users

**DST functions and features for future development**

- Reporting within and across data layers
- Developing new ways to incorporate data (e.g., time series)
- Capturing social and cultural values
- Developing novel ways to view output data (e.g., 3D)
- Developing user-friendly manuals, best practices, and training opportunities
- Incorporating cumulative impact and climate change impact assessments
- Verifying models, support prediction, and validation
- Improving data sharing and functional interoperability
- Building mechanisms to elicit user feedback

**Next steps for DST developers**

- Researching geospatial data formats that facilitate better visualization and communication
- Researching ways to accept and display data in multiple formats
- Conducting outreach, enhancing marketing, improving documentation of tool capabilities
- Collaborating to develop new approaches
- Working with data managers to communicate problems
- Providing a marketplace for DST developers and users to interface and communicate capabilities and needs
- Developing standards for tool interoperability
- Continuing to foster a community of practice with tool developers, practitioners, and stakeholders

# Acknowledgments

We thank the participants in the decision support tool workshops listed below. We particularly thank The David and Lucile Packard Foundation for providing financial support for the decision support tool workshops and this Decision Guide.

## DST WORKSHOP PARTICIPANTS

### Workshop #1 — October 2010

| NAME | ORGANIZATION | TOOL GROUP |
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| Brian Voigt | University of Vermont | ARIES |
| Miroslav Honzak | Conservation International | ARIES |
| Isaac Kaplan | NOAA Northwest Fisheries Science Center | Atlantis |
| Colin Ebert | University of California, Santa Barbara | Coastal Resilience & Cumulative Impacts |
| Zach Ferdaña | The Nature Conservancy | Coastal Resilience |
| George Raber | University of Southern Mississippi | Coastal Resilience |
| Katie Arkema | Natural Capital Project | InVEST |
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| Chad Burt | University of California, Santa Barbara | MarineMap |
| Matt Merrifield | The Nature Conservancy | MarineMap |
| Heather Coleman | Pacific Marine Analysis & Research Association | Marxan with Zones |
| Hedley Grantham | Conservation International | Marxan with Zones |
| Roelof Boumans | University of Vermont | MIMES |
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## Workshop #2 — February 2011

| NAME | ORGANIZATION | TOOL GROUP/PLANNING PROCESS |
|---|---|---|
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| Mike Beck | The Nature Conservancy | Coastal Resilience/Gulf of Mexico |
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| Steve Diggon | Coastal First Nations, British Columbia | Pacific North Coast Integrated Management Area |
| Tim Doherty | San Francisco Bay Conservation and Development Commission | San Francisco Bay project siting and permitting |
| Laura Engeman | California Ocean Protection Council | California Marine Renewable Energy Working Group |
| Rebecca Gentry | California Ocean Science Trust | |
| Paul Gilliland | Marine Management Organization | United Kingdom Marine Planning |
| Mary Gleason | The Nature Conservancy | California's Marine Life Protection Act |
| CK Kim | Natural Capital Project | InVEST |
| Phil Levin | NOAA Northwest Fisheries Science Center | Atlantis/Integrated Ecosystem Assessments |
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| John Rozum | EBM Tools Network | |
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| Cassidy Teufel | California Coastal Commission | Coastal Zone Management Act |
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Ed Babb/Marine Photobank

The **Center for Ocean Solutions** is a nonpartisan organization that crafts interdisciplinary solutions to the challenges facing the world's oceans. In addition to developing new knowledge to solve ocean challenges, COS researchers and staff reach out to decision-makers from government, business and the nonprofit sectors to translate the results of marine science and policy research into action. COS also educates current and future leaders by offering enhanced graduate-level educational and research opportunities.

**PacMARA** acts as a catalyst for collaboration and provides non-partisan, outcome-driven, evidence-based decision-making related to marine planning, conservation and resource use in British Columbia. PacMARA facilitates the development of cooperative and collaborative research and analysis initiatives between First Nations, provincial and federal governments, non-government organizations, academics, and community and commercial interests.

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