Marine Integrated Decision Analysis System (MIDAS)
User Guide
Version July 2010: Belize

MIDAS Belize Team:

Graduate Students:
Chris Holden
Valerie Pasquarella
Hrishi Patel
Marta Ribera
Burton Shank
Evan Walters

Professors:
Suchi Gopal and Les Kaufman

Contributing Organizations:
Conservation International
Southern Environmental Association (SEA) Belize
Healthy Reefs for Healthy People
Belize Fisheries Department
University of Belize

Marine Integrated Decision Analysis System (MIDAS)
User Guide
Version 5.4: Belize

Table of Contents

1. Introduction

Despite the recent increase in the use of Marine Management Areas (MMAs) for marine resource management, we still know little about how different types of MMAs (e.g., fully protected vs. various levels of partial protection) perform under different circumstances, nor do we have a comprehensive understanding of how ecological, socioeconomic and governance factors interact to influence MMA performance. To address this need, Conservation International is conducting a MMAs Global Management Effectiveness Study to examine ecological, socioeconomic and governance in 15 global sites. The main objectives of this study are to:

1. Specify the socioeconomic, governance and ecological ***effects*** (outcomes) of MMAs;
2. Determine the ***critical factors*** (ecological, socioeconomic and governance) that influence MMA effects, as well as the impact of the ***timing*** of those factors;
3. Provide management tools for ***predicting*** MMA effects based on ecological, socioeconomic and governance variables, as well as outputs showing results of various management actions.

The Marine Integrated Decision Analysis System (MIDAS) is a software tool that addresses the third objective. It was developed to assist the MMA users and managers in understanding the critical factors that influence MMA effects so that they can plan accordingly, to estimate likely MMA effects based on the ecological, socioeconomic and governance conditions, and finally, to advise management plan revisions that will result in optimization of outcomes and outputs. MIDAS will help conservationists demonstrate the likely effects of a new MMA, and will enable conservationists working in existing MMAs to determine the likely effects of alternative strategies and therefore, where they should most effectively focus resources. User groups (such as fishers, tourism operators) and the general public can use MIDAS to understand how and why various ecological, socioeconomic and governance conditions are so critical for positive outcomes. Users and policy makers are encouraged to use the tool in an exploratory way to identify interactions of variables and potential outcomes. MIDAS could also be used as a diagnostic tool to identify specific problems in MMAs that could be further addressed or examined.

MIDAS is not designed to replace the decision-making process, but to provide an interface to perform a series of thought experiments or game play. MIDAS does not provide a categorical single answer to a given question, nor does it provide a single solution to a problem. MIDAS provides an intuitive graphic interface that displays key outputs and outcomes. This enables the potential outcomes of different levels of key factors to be compared. For example, the user can visualize the likely impact of fishing and coastal development on ecological sustainability.

In addition, MIDAS includes spatial analysis features. Relevant information layers, such as MMA boundaries, key habitat types and land cover, are visualized using simple overlay functions. MIDAS can also produce risk overlay maps based on user perceptions of conditions in, within and around MMA boundaries.

Source of Data: MIDAS is based on the primary and secondary data gathered by Bob Pomeroy and Tammy Campson (University of Connecticut), Burton Shank (Boston University) and Craig Dahlgren (Perry Institute of Marine Science). A number workshop delegates from Belize helped to develop, improve and enhance the MIDAS-Belize. We would like to acknowledge the following:

Virginia Burns (Wildlife Conservation Society)
Diane Haylock (Belize ISIS Enterprises)
Djocelyn RaeFinch (FON/TASTE/SEA)
Jack Nightangle (TASTE/SEA)
Juan Chub (Belize Fisheries Dept)
Kirah Forman (Belize Fisheries Dept, HolChan)
Miguel Alamilla (Belize Fisheries Dept, HolChan)
Melanie McField (Healthy Reefs Smithsonian)
Lauretta Burke (WRI)
Yvette Alonzo (APAMO)
Robin Coleman (Wildlife Conservation Society)
Leandra Cho-Ricketts (Univ of Belize)
Saul Cruz (Forestry Dept)
Renata Ferrari (TIDE)
Adele Catzum-Sanchez (Belize ISIS)
Lindsay Garbutt (CI Belize)

In addition, we would like to thank Giselle Samonte Tan, Leah Karrer, and John Tschirky at Conservation International.

2. Technical Specifications

MIDAS is platform independent since it is written in Java and requires less than 5 megabytes (mb) to run. The Java Runtime Environment (JRE) must be installed on your computer in order to run MIDAS. The earliest version of the JRE supported is Java 6 update 10. You may download the most up to date Java Runtime Environment at:

http://www.java.com/getjava/

The Java Runtime Environment requires approximately 100 megabytes (mb) of space on your computer

2.1 Java Installation

Windows Users: Download the Java Runtime Environment, run the application, and follow the instructions in order to install it. The default installation location should work properly. If you think you already have Java installed, check which version of Java you have and to ensure that a compatible version is installed. From the Start menu, select Settings, then Control Panel to open the Windows Control Panel. Open the Java Control Panel (the launcher in the Windows Control Panel should have the Java Coffee Cup logo). To view which version of Java you have, click the About button on the General tab. To update Java, go to the Update tab and click Update Now.

Macintosh Users: Mac's come with Java preinstalled. In order to get the most up to date version of the Java Runtime Environment, click on the Apple symbol at the top left of the taskbar and select "Software Update…". If no update for the Java Runtime Environment is available, you have a working version of the JRE. You can check your Java settings by opening Finder and navigating to /Applications/Utilities/. Next, open the "Java Preferences.app" application. In the General tab, make sure that a version of Java SE 6 (either 32-bit or 64-bit is fine) is the preferred version of Java to launch Java Applications with. You can do this by dragging a Java SE 6 version to the top of the list under "Java Applications".

Linux Users: Depending on your Linux distribution, a working version of the JRE should be available through the packaging system used by your distribution. Because MIDAS is developed for a wide range of computer specifications, any JRE in the depository from your distribution will most likely work, although the commercial version from Oracle (previously Sun) is preferred. If not, you can visit Oracle's website mentioned above and select an appropriate version and install it through your packaging system (e.g. .deb, .rpm, etc.).

2.2 Running MIDAS

MIDAS is designed as an executable JAR file. To open MIDAS, double click on MIDAS.jar. Please ensure that a compatible version of Java (Java 6 update 10) is installed and is the version of Java your computer is running before opening MIDAS.

3. MIDAS Menu

3.1 File Menu

3.1.1 Save Current Settings

This menu item will allow the user to save their input values for all Critical Determining Factors (CDF), their weights for the outcome equations, and their input for the MIDAS risk model for all MMAs. MIDAS saves these values in a comma separated value file (CSV) that has the file extension ".midas" to identify it as a MIDAS save file.

3.1.2 Load Custom Values

This menu item allows the user to restore his or her inputs for all CDFs, custom weight values for outcomes, and risk model values for all MMAs. Users must first have a saved ".midas" file created in a previous session.

3.1.3 Print Report

The Print Report menu item allows the user to input his or her name and organization and then select the parts of MIDAS that he or she would like to be printed for the current MMA selected. A header on each page of the user's name, organization, and the date of the report is included. Leaving the name or organization fields blank will result in MIDAS ignoring these fields when printing the report.

Options for printing include the names and values of all CDFs, the five CDF outcomes, and the four portions of the spatial view of MIDAS.

3.1.4 Export Report to Image

Selecting this menu item will bring up a screen where users can select an outcome or spatial view to save as an image file on their computers. Selectable options include all five CDF outcomes as well as the four components of the MIDAS spatial view.

Users can select to save one of these choices in the following supported formats: JPG, JPEG, GIF, and PNG.

3.1.5 Exit MIDAS

This menu item closes MIDAS.

3.2 Select MMA Menu

Choosing this menu will allow the user to switch between MMAs.

3.3 Switch view Menu

Choosing this menu will allow the user to switch between the CDF and the Spatial views.

3.4 About MIDAS

3.4.1 View user guide

Choosing this menu item will bring up a distilled version of the MIDAS user guide for convenient access. In order to view a topic, please click on the desired topic. For example, for explanations about the Governance Index, please click on the words "Governance Index" within the popup window.

3.4.2 Acknowledgments

This option will bring up a window displaying some of the people that the MIDAS team would like to acknowledge for their advice and constructive criticism through emails, conferences, or workshops throughout the development stages of MIDAS.

3.4.3 Show Welcome Screen

This menu option will bring up the Welcome Screen originally displayed when a user runs MIDAS. If a user decides to hide the Welcome Screen by deselecting "Show this window at startup" on the Welcome Screen window, this menu option is a way of restoring the window.

3.5 Advanced

3.5.1 Adjust MIDAS Weights (Advanced Users)

Choosing this menu item will display a window where the user can change the weighting system for the CDF outcomes. In tabs at the top of this window are the choices for the MMAs. To begin, change tabs to the desired MMA you wish to change the weights for.

Below are the three outcomes the user can change the weights for: the Governance Index, Socioeconomic Index, and the Ecological Index. Under each index, on the left hand column the letters and numbers (as well as colors) indicate which CDF the text field to the right corresponds to. For example, G1 corresponds to the first governance CDF – "Stakeholder Involvement".

The weights are multipliers to the values of each CDF assigned by the user. Each CDF has five possible values, corresponding to 1 through 5. A very low choice, such as Very Low (slider all the way to the left) for the Governance CDF "Stakeholder Involvement" corresponds to a 1 while a high value (slider all the way to the right), such as Very High corresponds to a 5.

If a CDF has a weight of 0, then that CDF is not included in the outcome because of the multiplicative effect of the weighting scheme. Similarly, a weight of 1 would mean that it is included in the calculation with a weight of 1. By default, MIDAS weights all input CDFs equally so all weights default to a 1 if the CDF is included in an outcome by default. However, if I changed a weight for a CDF to 3, this would mean that the given CDF is three times more weighted relative to the other CDFs.

Before closing the window, please press Apply Changes to save and implement the weighting scheme chosen.

3.5.2 Adjust MIDAS Weights (Advanced Users)

This menu item controls whether or not the user can see the Expert Opinions for the Governance Outcome, Socioeconomic Outcome, and Ecological Outcome.

4. Quick Start Guide

Welcome to MIDAS (Marine Integrated Decision Analysis System)! This quick start guide is intended to familiarize you with the general layout and functionality of the MIDAS interface. More detailed descriptions of MIDAS inputs and features are available in later sections of this guide.

After initiating your MIDAS session:

1. **Select Language:** The MIDAS program may be viewed in either English or Spanish. To switch the interface language, go the *File* pull-down menu (located at the top left of the screen) and select *Language/Idioma* to choose a language. MIDAS will automatically restart using the language selected during your previous session.

2. **Select MMA:** Use the *Select MMA* pull-down menu (located to the right of the File menu) to select an MMA.

3. **Changing Views:** The MIDAS interface contains two views: (1) the Critical Determining factor (CDF) view, which allows you to input values for factors affecting MMA success and generate outcome graphs based on these inputs, and (2) the Spatial view, which allows you to map the MMA and nearby habitats and to map ecosystem risk (Figure 1). When MIDAS is started, the CDF view is shown by default, but you may change to the Spatial view at any time during the session by using the *Switch View* pull-down menu (near the top left of the screen) or by right clicking and selecting Switch View.

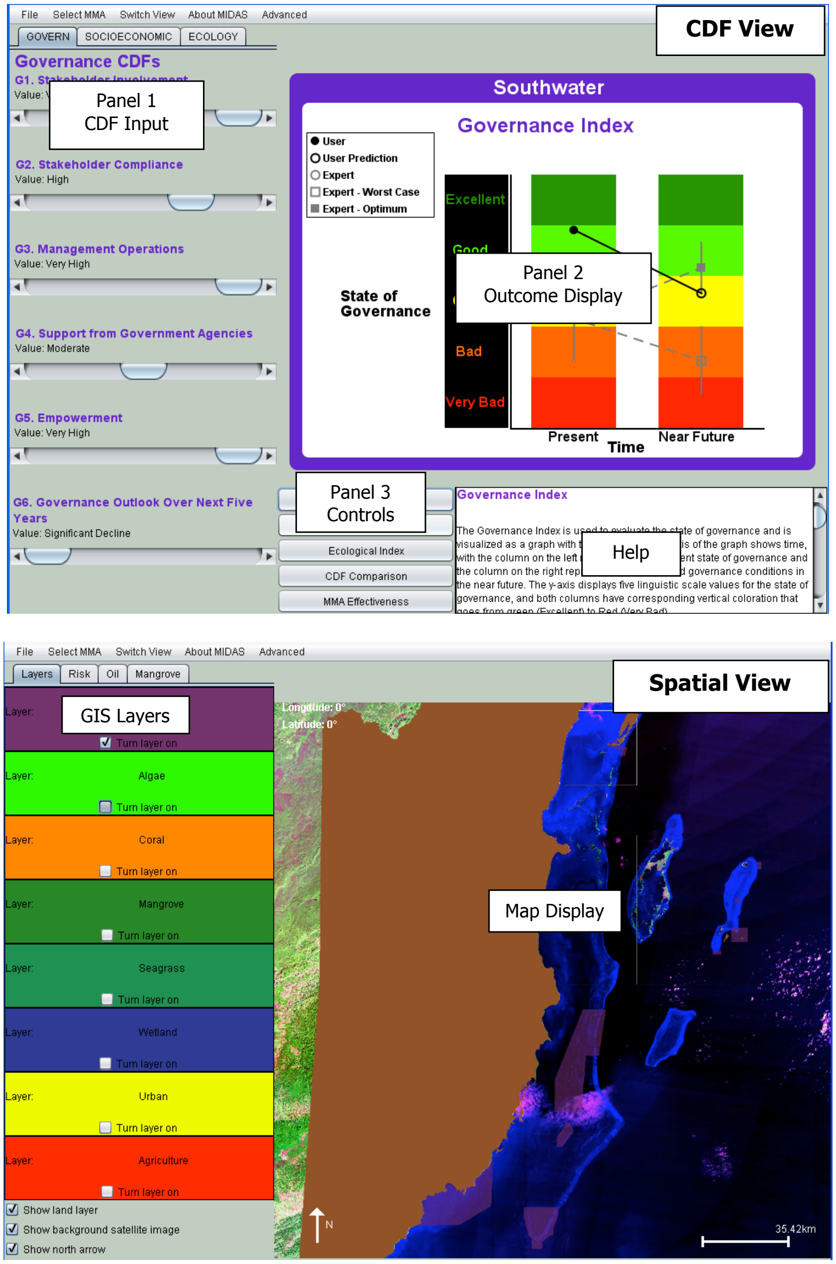


Figure 1: MIDAS Views

4. **CDF View:**
    a. **Input Values for 18 CDFs:** MIDAS generates outcomes based on user inputs for 18 CDFs. The CDF Input panel is located along the left-hand side of the CDF View interface. CDFs are divided into three categories—governance, socioeconomic and governance. The panel displays the CDFs in only one category at a time. You must click the GOVERN, SOCIOECONOMIC, and ECOLOGY tabs at the top of the panel to view CDFs in other categories. Below each CDF name, its current value is displayed. This value is adjusted using the corresponding slider bar. You must select an input for each CDF by moving the slider until the desired value is displayed. When choosing your inputs, keep in mind the MMA you selected in Step 2 and nearby coastal communities. See page 15 for complete CDF descriptions.

    b. **Display Outcomes:** After values have been selected for all 18 CDFs, you may begin displaying outcomes. MIDAS contains five outcomes: three index outcomes (Governance, Socioeconomic, and Ecological) and two mixed applet outcomes (CDF Comparison and MMA Effectiveness). Buttons corresponding to these outcomes are contained in the Outcome Selection panel. When you click an outcome button, the Outcome Display panel is updated to show that outcome. The Outcome Display is also updated automatically when CDF values are changed, allowing you to visualize the effect of changing inputs on outcomes. See page 26 for complete outcome descriptions.

    c. **Compare Your Index Outcomes with Expert Opinion**: If you want to compare any of the three Index outcomes to an expert opinion (gathered from our prior workshop in Belize in January 2010), you can select the Show Expert Opinion option in the Advanced menu on the toolbar. This will give you the Figure 2 visualization for the governance index at Southwater. In this figure, the user selected a significant decline in the near future for governance and hence the black line is dipping down from the present condition shown on the left histogram. The expert opinion shown in gray dotted lines shows a large variation in expert outlook for the near future scenario. Similarly, the user can display their own and expert outcomes for socioeconomic and ecological index outcomes.

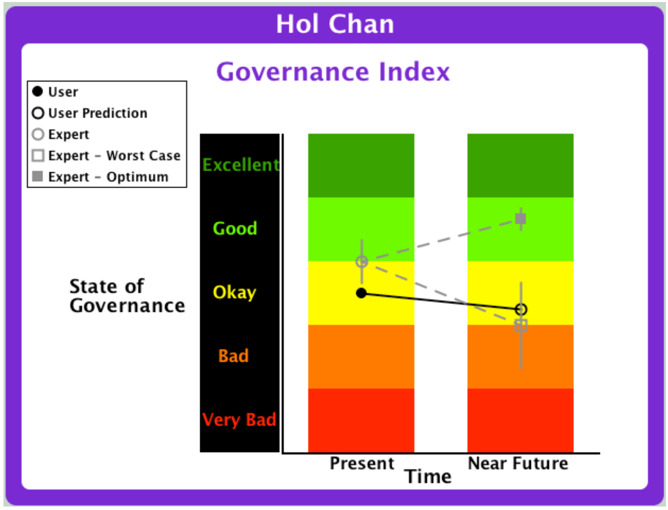
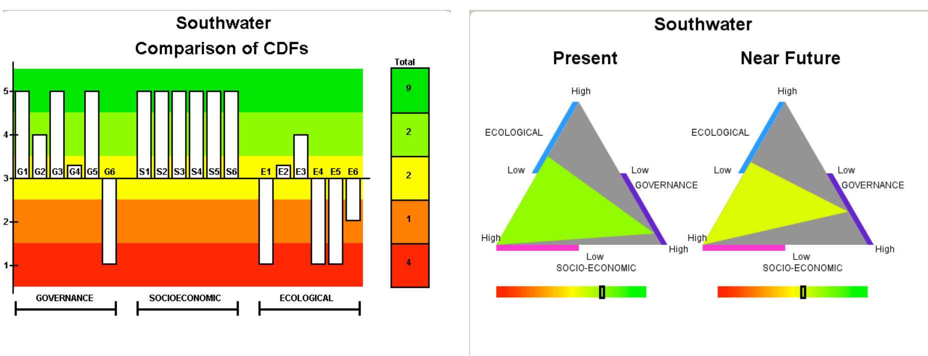


Figure 2: The MIDAS Governance Outcome

d. Display Overall MMA Effectiveness: Once you have completed your CDF selection, you can display overall results using the last visualization schemes. The CDF comparison shows the user selected values (Figure 3a) while the MMA effectiveness shows two triangles representing the present and near future scenarios for overall effectiveness (Figure 3b). The ratio of the size of the inner and outer gray triangle results in an index shown below in color ranging from red (high risk) to green (excellent).

Figure 3: The MIDAS Outcome- 3a- Histogram of User Selected CDFs; 3b – MIDAS MMA Effectiveness Present and Near Future.



5. Spatial View: When you press switch view button, and choose spatial view, you can see a maps of each MMA with several map layers. Layers are selected by checking the corresponding box, labeled 'Turn layer on'. The satellite image view can be turned on or off by pressing the appropriate button below. This enables user to access important GIS layers for this MMA.

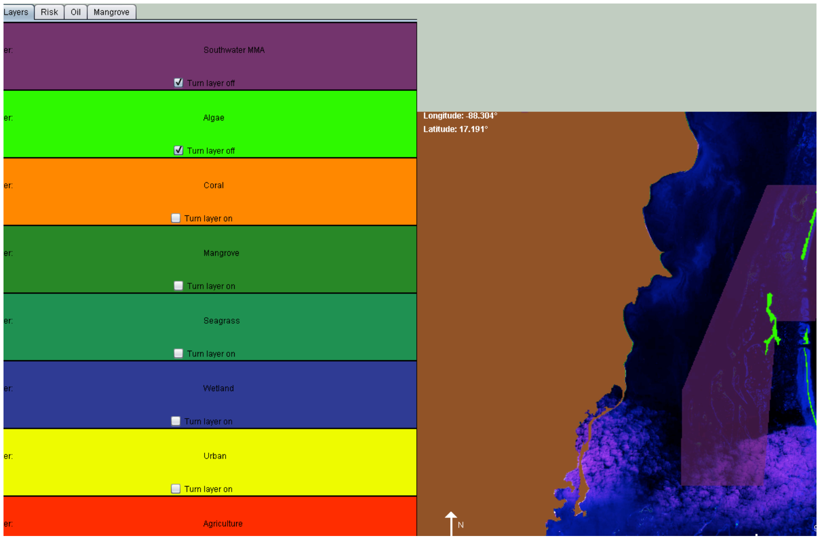


Figure 4: The MIDAS Spatial View (South Water Cayes)

a. **MIDAS Spatial Risk Model:** You can input your own values for health and threat of each map layer, algae, mangrove, coral, seagrass and wetland ranging from bad to excellent by dragging the button across each variable. This action will result in the risk map for South Water shown.

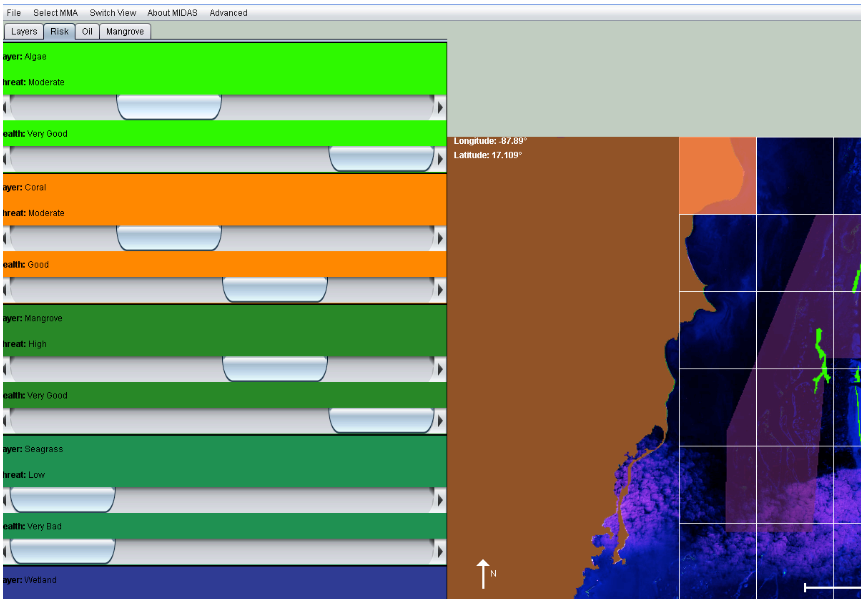


Figure 5: The MIDAS Spatial Risk Model (South Water Cayes)

b. MIDAS Oil Model: The oil model in MIDAS is an exploratory tool that is based on a very simple oil model. We ask users to accept the agreement since the model is not a predictive tool and we do not have access to all data and a complex realistic oil modeling is beyond the scope of this project. This oil spill model based off of the Lehr-Fay equations for oil spreading and moving on the sea. You are requested to input the following:

- Enter the month desired. The average of 5 years of current and surface wind data from satellite are used for each month.
- Enter the type of oil. This accounts for the density of oil. The American Petroleum Index (API) numbers are shown for reference.
- Enter the volume of the point spill in barrels. (For reference, the Exxon-Valdez spill in 1989 released approximately 250,000 barrels.
- Enter the time since spill in minutes. For reasons of accuracy, we have not attempted to model beyond 5 hours.
- To begin, click on the map. You can continue the spill by increasing the time using the time selection slider.
- To erase the spill, right click the map.
- NOTE: This model is complex and takes a while to run. Please be patient

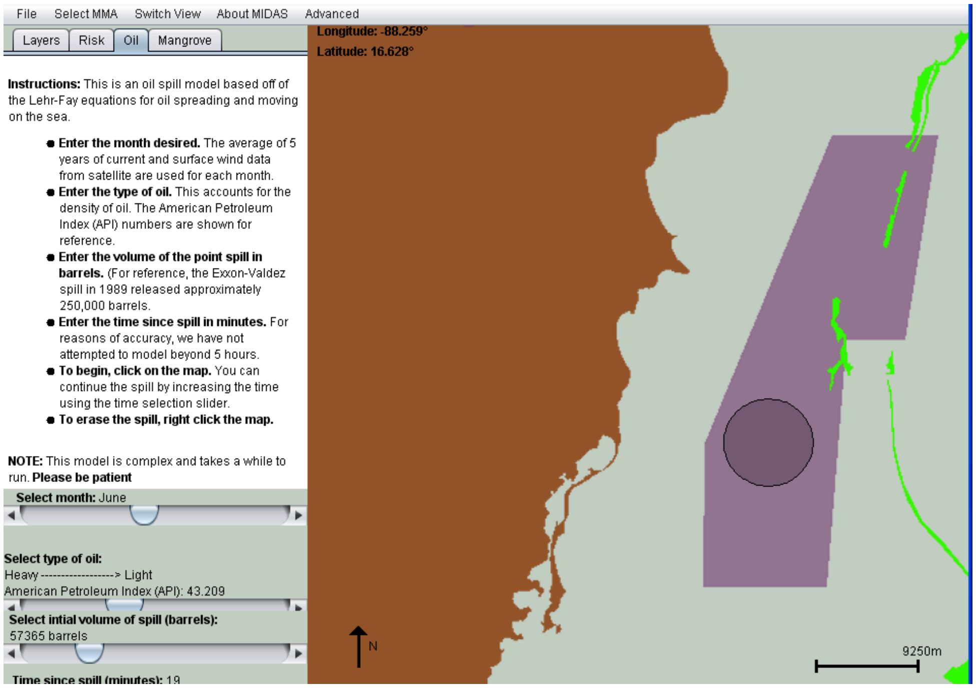


Figure 6: The MIDAS Oil Spill Model (South Water Cayes)

c. **Mangrove Model:** Detailed economic valuation of individual mangrove stands would be data-intensive and very costly and hence the MIDAS Mangrove Assessment Model estimates the relative likelihood of mangrove stands contributing to several key ecosystem services where relative models were assigned based on spatial relationships using empirical literature.

This model option allows you to display risk associated with loss of ecosystem services resulting from cutting mangrove in any MMA. You can choose an area of mangrove to cut by displaying mangrove layer on the map (green) and using your mouse to start at an initial point on this mangrove and outline an area by dragging across (Figure 7). This cutting zone is displayed now in pink while the impact on tourism, nursery, protection and total score is displayed in the panel on the left.

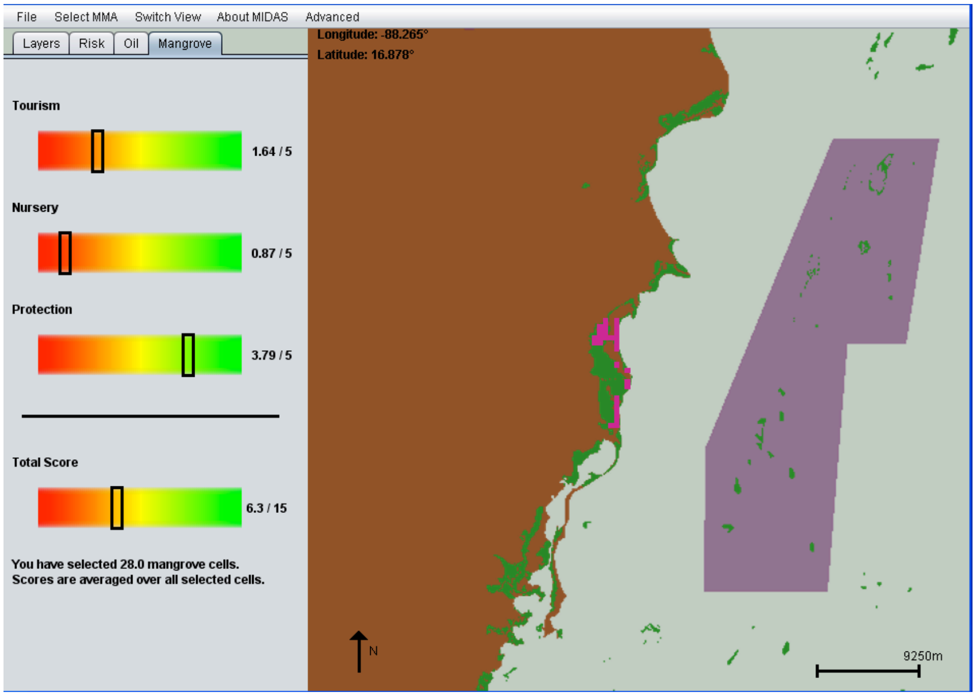


Figure 7: MIDAS Mangrove Model(South Water Cayes)

6. Help and User Guide: You may view this Quick Start Guide at any time during a MIDAS session by clicking the user guide under About MIDAS option in the top drop down menu.

5. The MIDAS CDF View

The MIDAS interface is designed for use with a 1280 x 800 pixel screen resolution. At smaller resolutions, the user may have to scroll left to right or top to bottom. When MIDAS is launched, the user is presented with a three-panel interface screen. This is the CDF view.

Panel 1 – **CDF Input**: enables the user to enter values relating to a set of eighteen governance, socio-economic, and ecological variables. These inputs are used to generate outcomes which are displayed in Panel 2.
Panel 2 – **Outcomes**: display can be changed using outcome buttons in Panel 3.
Panel 3 – **Controls**: contains the buttons to change to other outcome indices or displays. Also, on the right corner, the user can read the MIDAS help.

The user can change to the spatial view using the top menu "Switch view"

5.1 Panel 1 – CDF Input

Panel 1 (CDF Input) is a graphic interface written in JAVA code that allows the user to change outcome model parameters or conditions as a thought experiment; this part of the model is called MIDAS-JIM (Java Interface for Managers). The CDF Input Panel displays a list of eighteen CDFs that influence MMA effects, each accompanied by a scaled set of linguistic input options for that CDF. MIDAS categorizes CDF inputs as governance, socioeconomic, and ecological, and there are six CDFs for each of these categories. The six governance CDFs, shown in purple, include: (G1) stakeholder involvement, (G2) stakeholder compliance with rules and regulations, (G3) management operations, (G4) support from government agencies, (G5) empowerment (e.g., training, education), and (G6) Governance outlook over the next five years. The six socioeconomic *CDFs*, shown in blue, include: (S1) Perceived threat due to development, (S2) Perception of local extractive resources, (S3) non-extractive alternative livelihoods, (S4) socioeconomic benefits from establishment of MMAs, (S5) Perception of local seafood availability, and (S6) expected change in livelihoods over five years. The six ecological *CDFs*, shown in green, include: (E1) level of fishing effort, (E2) relative change in habitat extent, (E3) habitat quality, (E4) herbivory, (E5) focal species abundance, and (E6) Expected change in ecosystem health over the next five years.

At the start of a MIDAS session, the user must select a value for each CDF. The default condition is set at the medium level. To select a value, the user points the mouse to the variable level (marked with a down arrow) and clicks to see the other options as a pull-down menu. Definitions of CDFs and extended value scale descriptions are included in Section 5.1 of this guide.

5.2 Panel 2 – Outcome Display

Panel 2 (Outcomes) is subdivided into two sections, allowing the user to display two outcomes simultaneously. The outcome display shows one of five Java applets representing the outcomes of interactions between the variable states input by the user in Panel 1. As the CDF inputs are varied, the applets dynamically change, giving the user instant feedback on how key outcomes are influenced. By running a number of simulations, the user can investigate the relationship between governance, socioeconomic, and ecological CDFs and the state of the MMA system. Of the five applet outcomes that can be visualized with MIDAS, three are index outcomes corresponding to the three categories of CDF inputs: (O1) governance index, (O2) livelihoods index, and (O3) ecosystem health index. Outcome (04) is a CDF comparison that shows the user selected values for each CDF during the current session. The remaining applet is a mixed outcome model that assesses (O5) MMA effectiveness.

Gopal 6/21/10 5:41 AM
Deleted: O4

5.3 Panel 3 – Controls

Panel 3 (Controls) includes a series of buttons to change the outcome displayed in Panel 2 and the help panel.

The outcome selection portion of Panel 3 contains four buttons corresponding to the available outcome applets. The user can toggle to display other outcomes by clicking the name of the outcome they wish to view. To change the outcome displayed in the top section of Panel 2, the user must left click on the name of the desired outcome.

Any time a new outcome is displayed, the help panel will show all the information about the selected outcome. Moreover, the user can click on each CDF to read its definition and possible values on the same help panel.

6. MIDAS Model Assumptions, Structure and Functionality

This section describes the model structure and functionality of MIDAS. The definitions of the three CDF categories and 18 CDFs, as well as detailed explanations of the linguistic scales representing available input values are included in Section 5.1. Section 5.2 covers how key outcomes are determined, including parameters and select underlying equations.

6.1 Determining CDF Inputs

Based on discussions held during GME workshops and meetings, 18 CDFs relevant across all MMA sites were selected for use in MIDAS. There are six CDFs for each of the following categories: governance, socioeconomic and ecological. The user must input a value for each CDF with the slider bar available for each CDF. This section of the User Guide contains definitions of the CDF categories, as well as of the CDFs themselves. Detailed descriptions of the linguistic scale inputs associated with each CDF are also included; these descriptions can be accessed at any time during a MIDAS session by clicking the CDF name.

6.1.1 Governance CDFs

Governance is the complex of ways by which individuals and institutions, both public and private, manage their common concerns. In the context of MMAs, governance refers to the structures and processes used to govern behavior, both public and private, in the coastal area and the resources and activities it contains. In a MMA, there is a need to create a governance system capable of managing multiple uses in an integrated way through the cooperation and coordination of government agencies at different levels of authority and of different economic sectors.

There are six governance CDFs (Figure 8):

G1. Stakeholder involvement
G2. Stakeholder compliance with rules and regulations
G3. Management operations
G4. Support from government agencies
G5. Empowerment
G6. Governance outlook over next five years

Figure 8: Governance CDF Input panel

G1. Stakeholder Involvement

The level of stakeholder participation in the management of the MMA is a measure of the amount of active involvement of people in making MMA management decisions or participating in management activities. Stakeholders are individuals, groups, or organizations who are interested, involved or affected (positively or negatively) by the MMA. Their actions can support or sustain an MMA, being potential partners or threats in managing the marine reserve. Therefore, the active participation of coastal resource stakeholders in the planning and management of an MMA can improve its success.

Levels of Stakeholder Involvement:

- Very Low: The level of participation is almost non-existent.
- Low: Low level of participation may lead to negative impacts.
- Moderate: Moderate stakeholder participation levels resulting in a slightly higher positive impact for the MMA.
- High: Involves high level of involvement from a relatively large proportion of stakeholders.
- Very High: Almost all stakeholders actively participate in management decisions and/or activities.

G2. Stakeholder Compliance with Rules and Regulations

This variable defines the level of compliance by the community or people to the rules enforced by federal government or agencies. Rules and regulations define specifically what acts are required, permitted and forbidden by stakeholders and government agencies within the protected area. Lack of compliance to these rules is not only detrimental to the resources, but to gaining stakeholder support. It is widely perceived that if users are not complying with the regulations, it will be difficult to gain anyone's trust, support or participation. However, stakeholders may violate rules and regulations if these are not well understood or if they don't make sense to stakeholders. Therefore, to ensure a greater success of the MMA, stakeholders need to learn its rules, regulations and enforcement arrangements through training or educations programs.

Levels of Stakeholder Compliance:

- Very Low: The community doesn't at all comply with the rules and regulations.
- Low: There is some level of compliance, but not high enough to have any positive impact.
- Moderate: Moderate level of compliance creates some positive impact on the MMA management.
- High: High compliance results in positive relationship between the government and the community.
- Very High: Very high levels of compliance make marine management highly effective thus increasing the pace for marine conservation and the room for implementation of newer policies.

G3. Management Operations

This variable includes:

a) Existence of a management plan

The Management Plan sets out the strategic directions for the MMA management program. It states the overall goals and objectives to be achieved in the MMA, the institutional structure of the management system, and a portfolio of management measures and whether the plan is enforceable. The effective management of the MMA is based on the achievement of goals and objectives through the use of appropriate management measures. The existence and adoption of a management plan means that there are strategic directions and actions for the implementation of the MMA.

b) Clearly defined enforcement procedures
Enforcement is a crucial step in the MMA management system. Clearly defined enforcement procedures allow both MMA enforcement staff to more effectively undertake their duties and MMA resource users to be aware of consequences of non-compliance. Having clear systems for enforcement and engaging the community in enforcement and monitoring may help the MMA to achieve its objectives with minimal levels of conflict and costs. However, properly carrying out enforcement activities (surveillance, constructing guardhouses, installing marker buoys, etc.) has a financial cost. For this reason, the MMA management needs to have adequate financial resources available to ensure project's success.

c) Conflict management
If resource users are to follow the rules, a mechanism for discussing and resolving conflicts and infractions is necessary. The term 'conflict' can be taken to mean just about any situation in which there is a clash of interests or ideas. In the context of an MMA, it usually means that there is a group or groups whose interests are in opposition to those of the MMA. Conflicts involving MMAs are inevitable. For example, when a MMA is taken out of production new rights and rules for use of marine resources are implemented and individual and group interests in the marine resources are affected. The MMA staff face the challenge of trying to respond to these conflicts so that unproductive consequences can be avoided while human well-being and the natural environment are protected.

Levels of Management operations:

- Very low: There is very little management operation.
- Low: There is some level of management operation.
- Moderate: Moderate level of operation creates some positive impact on the MMA management and effectiveness.
- High: High level of operation ensures effective stakeholder participation and representation.
- Very High: Very high levels of operation make marine management highly effective thus increasing the pace for marine conservation and the room for implementation of newer policies.

G4. Support from Government Agencies
This variable defines the level of input or feedback from the Legislative body (Government) in support of the MMA. This may come in the form of enacted legislation, supporting existing policies or creating new ones resulting in a positive impact on the MMA. A strong two-way relationship between the Federal Government and the Community is vital for good long-term results.

This variable includes:
a) Existence and adequacy of enabling legislation
It is a measure of formal legislation in place to provide the MMA with a sound legal foundation so that its goals and objectives can be recognized, explained, respected, accomplished and enforced. The establishment of a MMA more often than not requires the drafting and adoption of appropriate supportive legislation and in some cases the recognition of traditional laws. This variable ensures that the management plan is supported by adequate legislation to implement its successful implementation.

b) Long-term support of local government
Supportive local leadership is a contributing factor to the success of marine management projects.

Levels of Support from Government Agencies:

- Very Low: Government has no input mechanism in place to support the MMA.
- Low: Government gives low level of input to local community groups or the local government in support of the MMA.
- Moderate: Moderate level of input from the federal government is still not that effective but better than none at all.
- High: High level of input improves the relationship with the community thus affecting compliance and community involvement.
- Very High: Government has aggressive campaigns in support of the MMA. Strong and effective input and/or policies are in place for the better management of the MMA.

G5. Empowerment

This variable includes:

a) Level of education of the community

This refers to the overall education and skill levels of the communities. A community with a generally high education level will be more willing to participate in conservation efforts.

b) Level of information about the environment

In order for people to take action to protect and manage the environment, they need to understand how the natural ecosystem works. Those with higher levels of knowledge of natural history tend to be more receptive to management initiatives, such as MMAs, and provide more support to its management operations. This knowledge can come either from scientific research or from stakeholder observations, experiences, beliefs and perceptions of cause and effect.

c) Capacity-building training

To participate effectively in MMA management, stakeholders need to be empowered to have greater awareness about why a MMA is needed and what are its functions. Stakeholders need to be equipped with knowledge, skills and attitudes to prepare them to carry out new tasks and meet future challenges. Capacity-building must address not only technical and managerial dimensions but also attitudes and behavioral patterns. Capacity building may be carried out by the MMA staff or by another organization such as a non-governmental organization (NGO).

Levels of Empowerment:

- Very Low: Low empowerment leads to lack of community participation and, ultimately, the failure of a MMA.
- Low: Low empowerment of local community groups results in lack of support of the MMA.
- Moderate: Moderate level of empowerment is still not that effective but better than none at all.
- High: High-level community empowerment affects compliance and community involvement.
- Very High: Very high empowerment is desirable since it ensures the continued success of a MMA.

G6. Governance Outlook over Next Five Years

This variable is designed to predict the state of governance in the near future.

Levels of Governance Outlook over Next Five Years:

- Significant Decline: User believes that the values for 3 or more of the other governance CDFs will decrease in the next five years.
- Slight Decline: User believes that the values for 1 or 2 of the other governance CDFs will decrease in the next five years.
- No Change: User believes that values for the other governance CDFs will not change in the next five years.
- Some Improvement: User believes that the values for 1 or 2 of the other governance CDFs will increase in the next five years.
- Significant Improvement: User believes that the values for 3 or more of the other governance CDFs will increase in the next five years.

6.1.2 Socioeconomic CDFs

The goals and objectives of many MMAs include socio-economic considerations such as food security, livelihood opportunities, monetary and non-monetary benefits, equitable distribution of benefits, compatibility with local culture and environmental awareness and knowledge. Understanding the socio-economic context of stakeholders involved with or influenced by the MMA (individuals, households, groups, communities, organizations) is essential for assessing, predicting and managing marine resources.

The use of socio-economic indicators allows MMA managers to a) incorporate and monitor stakeholder group concerns and interests into the management process; b) determine the impacts of management decisions on the stakeholders; and c) demonstrate the value of the MMA to the public and decision-makers.

There are six socio-economic CDFs in MIDAS (Figure 9):

S1. Perceived threat due to development
S2. Perception of local extractive resources
S3. Non-extractive alternative livelihoods
S4. Socio-Economic benefits from establishment of MMA
S5. Perception of seafood availability
S6. Expected Change in livelihoods over next five years

Figure 9: Socioeconomic CDF panel

S1. Perceived Threat Due to Development

This variable defines the level of development including urban expansion, pollution, hotels, cruise ships, and other tourism activities near the MMA. Other major concerns include coral damage due to boat anchors, physical contact by divers with the corals and waste generated via development. Various land use activities can affect the success of a MMA. For example, coastal construction can negatively impact the environment. Sedimentation both from logging and urban development can smother coral. In addition, industrial and domestic wastes are frequently discharged directly into waterways, generating an additional threat. The number (and density) of people living near the MMA has been proven to affect both environmental and social/governance conditions of the protected area. Social science-based studies show that population density is negatively correlated with the success of a MMA.

Levels of Perceived Threat Due to Development:

- Very Low: A very low level of development has a positive impact on the MMA since it has led to increased job and employment opportunities for the local community.
- Low: Low level of development along coast can have a positive impact on the MMA.
- Moderate: Moderate development level with best practices creates a positive impact on the MMA.
- High: Higher level of development activities is a bigger threat to coastal and marine ecosystems.
- Very High: Higher development levels have an adverse impact on the MMA.

S2. Perception of Local Extractive Resources

This variable is a measure of what the users of extractive marine resources think about the availability of target fish species, seashells, mangrove trees, wood, and other extractive resources, and their perceptions on changes in availability of these target species. This indicator is useful for determining if the MMA management is achieving its objective of increasing harvests of seafood and other extractive resources and consequently increasing the availability of local caught species. If the perceptions are a positive increase, then the users may be more receptive to MMA management. If the perceptions are negative, then the users may be less receptive to MMA management and changes in management operations may be necessary. The indicator is also a useful measure of resource abundance, availability and size and species composition.

Levels of Perception of Local Extractive Resources:

- Very low: Current use of local marine resources poses a very low threat to MMA.
- Low: Current use of local marine resources poses a low threat to MMA.
- Moderate: Current use poses moderate level of threat.
- High: High level of threat is perceived given the aggressive marine resource pattern.
- Very High: Very High level of threat is perceived given the aggressive marine resource patterns.

S3. Non-Extractive Alternative Livelihoods

This variable measures the availability of productive activities (occupation, sources of income, both monetary and non-monetary) across households and social groups in the community that do not involve extracting resources from the environment (i.e. seafood, mangrove wood). Some examples of alternative livelihoods include tourist guides, hotel staff, researchers, park management staff, transport industry or food services. Alternative income-generating activities are considered necessary to provide substitute and supplementing income sources for fishing communities in MMAs. This variable will allow for a measure of the dependence of households on coastal extractive resources for livelihood, and changes over time on that dependence. Consequently, this variable will result in a measure of the impact of the MMA on the household occupational structure in the community.

Levels of Non-extractive Alternative Livelihoods:

- Very low: There are no other jobs and people are dissatisfied; needs to be addressed immediately.
- Low: Some jobs are available but not sufficient enough to serve the needs of the whole community.
- Moderate: Alternative jobs such as tour guides and hospitality service jobs are moderately available.
- High: Jobs are abundant, local needs are served.
- Very High: Many alternative jobs for both men and women satisfy and provide livelihoods leading to better MMA management and local participation.

S4. Socio-Economic Benefits from Establishment of MMA

Socioeconomic benefits from the establishment of MMAs include food security and income generating activities. This results in general nutrition and health, quality of life and relative wealth for people in the community. This is an important indicator that helps to check if the MMA is providing improvements. The incentive structure facing individuals in a community will directly impact their support for an MMA. Community members are more likely to feel positively about an MMA and therefore support it voluntarily if the costs of participating and/or complying with the regulations (i.e. traveling further to get to new fishing grounds, restricting lucrative but destructive activities) do not exceed the benefits (such as any personal enjoyment from conservation or the positive MMA outcomes identified above).

Levels of Socio-Economic Benefits:

- Very Low: Very poor conditions reflect comparative lack of wealth and poor quality of life in the community.
- Low: Low socioeconomic benefits from the establishment of the MMA.
- Moderate: Medium level indicates a minimum access and distribution of basic resources.
- High: High Socio-economic benefits resulting from the establishment of the protected area.
- Very High: Very high level leads to better quality of life as well as human development.

S5. Perception of Seafood Availability

Perception of seafood availability is a measure of what the primary food purchaser/preparer in the household thinks about the local availability of seafood for their own consumption. This indicator is important for understanding the contribution of the MMA to food security in the local community. The Food and Agriculture Organization (FAO) defines household food security as “that state of affairs where all people at all times have physical and economic access to adequate, safe and nutritious food for all household members, without undue risk of losing such access”.

Levels of Perception of Seafood Availability:

- Very Low: Seafood is insufficient and unavailable to the local community (for most of the days of the week) and needs to be addressed immediately.
- Low: Seafood is available in small quantities and is not enough to serve the needs of the whole community.
- Moderate: Seafood is moderately available.
- High: Seafood is abundant. Local needs are served.
- Very High: Very High availability of seafood in the local markets completely satisfies the local demand and provides adequate sustenance.

S6. Expected Change in Livelihoods over Next Five Years
This variable is designed to predict the condition of livelihoods in the near future.

Levels of Expected Change in Livelihoods over Next Five Years:

- Significant Decline: User believes that the values for 3 or more of the other socioeconomic CDFs will decrease in the next five years.
- Slight Decline: User believes that the values for 1 or 2 of the other socioeconomic CDFs will decrease in the next five years.
- No Change: User believes that values for the other socioeconomic CDFs will not change in the next five years.
- Some Improvement: User believes that the values for 1 or 2 of the other socioeconomic CDFs will increase in the next five years.
- Significant Improvement: User believes that the values for 3 or more of the other socioeconomic CDFs will increase in the next five years.

6.1.3 Ecological CDFs

Regardless of their many social benefits and aims, MMAs are ultimately a tool for conserving the biophysical conditions of our oceans and coasts. In most cases, the link between the biological state of the marine environment and the livelihoods, income and food security of the people who use and depend upon the resource is explicit and intimate. Therefore, beyond characterizing natural systems, the measurement of ecological indicators can also be useful when viewed in the context of socio-economic and governance conditions that operate in and around the MMA.

There are six ecological CDFs in MIDAS (Figure 4):

E1. Level of fishing effort
E2. Relative change in habitat extent
E3. Habitat quality
E4. Herbivory
E5. Focal species abundance
E6. Expected change in ecosystem health over next five years

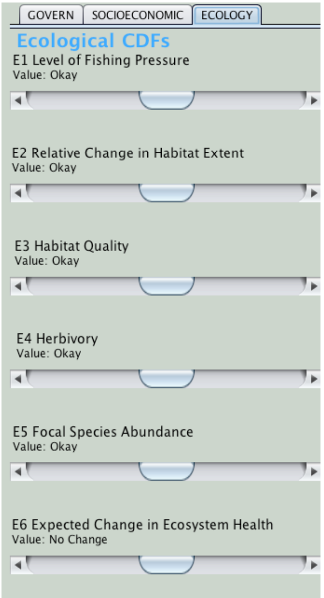


Figure 4: Ecological CDF panel

E1. Level of Fishing Effort

Fishing effort refers to the economic resources devoted to catching fish. This includes capital goods (e.g., boats and gear), labor (captains and deckhands), and materials and energy. A significant issue for fisheries is to ensure the ecological sustainability of wild fish stocks in the long term so that ecosystems that are being fished remain diverse and healthy. Often MMAs are established explicitly because of the large impact that fisheries' extraction has in sustaining human societies. Increased fishery yields and improved livelihoods are therefore common and important objectives of MMA use throughout much of the world. This variable is a direct attempt to quantify and track trends in fisheries yields, technological uses, and livelihood opportunities through time.

The maximum biological yield that the fishery is capable of producing is called the Maximum Sustained Yield (MSY). MSY is often regarded as the best target to aim for exploiting resources such as fishery. Fishing at MSY means catching the maximum proportion of fish stock that can safely be removed while, at the same time, maintaining its capacity to produce maximum sustainable returns in the long term. Fishing over MSY levels leads to dangerous depletion of spawning biomass below optimum levels. On the other hand, the Optimum Yield (OY) is the amount of fish harvested that will provide the greatest overall benefit to the nation, with particular reference to food production and recreational opportunities. OY is based on MSY as modified by economic, social or ecological factors.

Levels of Fishing Effort:

- Extremely Underfished: The amount of effort used during fishing is very low.
- Moderately Underfished: Fish stock that has the potential to sustain catches higher than those currently taken.
- Medium / sustainable: Fishing at Optimum Yields (OY).
- Moderately overfished: Fishing at maximum sustainable yield (MSY).
- Extremely overfished: Fishing over MSY leads to dangerous depletion of spawning biomass below optimum levels.

E2. Relative Change in Habitat Extent

This variable refers to relative changes (both positive and negative) in reef, mangrove and seagrass habitats inside and outside the MMA after it is established. Habitat is defined as the living space of an organism, population or community, and it is characterized by both its biotic and physical properties. Habitat types are distinguished from each other by both biotic and abiotic composition and structure. Total area (in km^2), configuration and physical location are important in describing extent. Disturbance events in the community, whether anthropogenic or natural, can lead to changes in habitat extent, structure and complexity. MMAs are used to prevent or reduce the frequency and intensity of man-made disturbances in an area so as to prevent major changes in the habitat within.

Levels of relative change in habitat extent:

- Significant decrease: Great reduction of habitat extent of coral, sea grass and mangrove.
- Moderate decrease: Reduction in coral, sea grass and mangrove is moderate.
- No change: No observable change in the habitat.
- Moderate Increase: Increase in coral, sea grass and mangrove is moderate.
- Significant increase: Great increase in habitat extent of coral, sea grass and mangrove.

E3. Habitat Quality

Communities of organisms are dependent on the presence of adequate living space within which to exist and reproduce. Disturbance events in the community, whether natural or man-made, can lead to changes in habitat structure and declines in complexity. Such changes may in turn cause reductions in target species abundance and changes in population structure and community composition. It is not surprising that the maintenance of ecosystem 'health' is considered a critical measure of success in many MMAs, particularly in large-scale ecosystem-level MMAs that are representative of multiple habitats.
This variable includes:

a) Coverage (distribution)
The habitat distribution within a specified area or ecosystem is the structural and spatial characterization of all habitat types represented based on their (1) Physical location; (2) configuration (e.g. placement next to one another); and (3) extent in terms of total area (km^2).

b) Rugosity
Rugosity is a measure of the habitat's structural complexity. The habitat complexity is defined by the extent (area in Km^2) and diversity (number) of habitat types and distinct zones found within a specified area.
Higher habitat complexity does not necessarily indicate a 'better' or healthier ecosystem; the 'right' level of complexity depends on what would occur naturally in the absence of human impacts.

c) Habitat Maturity/Integrity
Habitat integrity can be defined as the likelihood that the distribution and complexity of living space in an area will persist through time. A 'healthy' habitat is therefore one that is considered to have strong integrity and is resilient to pronounced change.

d) Aesthetics
Environmental aesthetics can be defined broadly as the interaction between an individual and the environment in relation to beauty. Non-aesthetic values such as ecological or economic values are usually considered most important. However, the aesthetic experience is significant to the value we place on the natural environments, and preserving the aesthetic characteristics of an ecosystem improves its overall value.

Levels of Habitat Quality:

- Pristine: Intact system with near reef habitats such as mangroves and sea grass.
- Good: Reef, mangrove and seagrass systems with little natural or anthropogenic disturbances
- Moderate: Reef and other habitats present, but their function has been compromised (e.g. loss of living coral on reef, poor water quality, heavily silted seagrass, fragmented mangrove creek systems, etc.)
- Poor: Habitats limited in species diversity and/or abundance, extensive areas of disturbances (e.g. coral disease/death from bleaching, algal overgrowth on reefs and seagrass, sedimentation, etc.)
- Unrecognizable: Worst condition signaling major impacts

E4. Herbivory

Herbivory measures the level and abundance of both invertebrate herbivores (including urchins, crabs, limpets) and vertebrate herbivores (including reef fishes, sea turtles, dugongs). Herbivore species (animals that only consume plant matter) are extremely important to the health of coral reefs. They maintain the balance between corals and macroalgae, which potentially out compete the corals. Thus, they increase coral coverage on reefs, promote resilience to disturbances and increase benthic diversity.

Levels of Herbivory:

- Very Low: Large herbivores and urchins absent, no evidence of herbivory keeping algae in check.
- Low: Large herbivores and urchins rare, microherbivores present
- Moderate: Moderate herbivory, missing one or two key species
- High: Large herbivores present, but in low abundance
- Very High: Very high abundance of large herbivores, like large parrotfish and sea turtles. Sea urchins also abundant

E5. Focal Species Abundance

Species abundance is the number of individuals of a particular species found to occur within or outside the MMA. It is a commonly used proxy for population size and it is thought to reflect the status of a species' population within a specific location. Species abundance is one of the most widely used biological 'success' measures of management effectiveness. A focal species is an organism of ecological and/or human value whose management through the MMA is of high priority. Examples of focal species are conch, lobster, shark, and commercial fish species such as snappers and groupers. The protection, enhancement and/or maintenance of populations of focal species are among the most common reasons for using MMAs. Improved and sustained numbers of focal species in the MMA through time is widely seen to indicate effective MMA use.

Levels of Focal Species Abundance:

- Very Low: Focal species rarely seen if ever. No viable population exists. It will have major impacts in ecosystem health and/or fisheries
- Low: Focal species rare, few mature adults in population, populations rely on emigration from elsewhere for persistence and not capable of supporting fishery.
- Moderate: Focal species present, but at low abundance and/or small sizes; population sustainable
- High: Focal species at medium abundance/biomass
- Very High: High abundance/density of focal species, large individuals, high biomass

E6: Expected Change in Ecosystem Health over Next Five Years

This variable is used to predict the change in ecosystem health in the near future.

Levels of Expected Change in Ecosystem Health over Next Five Years:

- Significant Decline: User believes that the values for 3 or more of the other ecolgical CDFs will decrease in the next five years.
- Slight Decline: User believes that the values for 1 or 2 of the other ecological CDFs will decrease in the next five years.
- No Change: User believes that values for the other ecological CDFs will not change in the next five years.
- Some Improvement: User believes that the values for 1 or 2 of the other ecological CDFs will increase in the next five years.
- Significant Improvement: User believes that the values for 3 or more of the other ecological CDFs will increase in the next five years.

6.2 Modeled Outcomes and Interpretation

MIDAS includes visualizations for five different outcomes. Three of these outcomes are index outcomes corresponding to the three CDF categories (governance, socioeconomic, and ecological). The fourth outcome, CDF comparison, shows all the CDFs in one simple graph. The final outcome, MMA Effectiveness, is a mixed applet outcome that allows the user to compare results of the three index outcomes.

The Outcome Selection panel is shown in Figure 10.

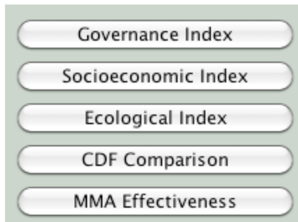


Figure 10: MIDAS outcomes

6.2.1 MIDAS Index Outcomes

All three MIDAS index outcomes include a time-series component that allows the user to visualize both the present state of the system and a prediction of how the state of the system will change in the near future. The expert present and near future (optimum and worst case) values for each index have been pre-determined through literature review, expert evaluation, and analysis of survey data. These values provide an accurate baseline for change assessment.

The user present and near future values for each index are calculated based on a simple additive multi-attribute model, determined by Equations 1 and 2 shown below (see Keeney and Raiffa, 1993). This model allows each CDF value (attribute) to be weighted to reflect its importance relative to the values of other CDFs. A specific subset of CDFs is used to calculate each of the three index outcomes, and weights have been assigned based on existing literature and consultation with experts. As the user changes CDF inputs, the index outcomes dynamically change. This allows the user to visualize how each CDF affects the present and the near future state of the governance, livelihoods, and ecosystem health.

Equation 1

$$\mathbf{V(x_i)} = \sum_{j=1}^{n} w_j v_j (x_{ij})$$

Where V is the overall value, $0 \le V \le 1$,
X_i is the vector of attribute values x_{i1}, x_{i2}, …x_{in}
$v_j(x_{ij})$ is a single attribute function $0 \le v_j(x_{ij}) \le 1$,
w_{ij} are weights reflecting the relative importance of the range of values of attributes j

Equation 2

$$\sum_{j=1}^{n} wj = 1$$

All three indexes are visualized as two separate columns, each with a coloration that goes from green (Excellent) to Red (Very Bad). The column on the left of the screen represents the present situation and the column on the right shows the conditions for the near future. . Within each column are one point representing the user value, calculated from the equations above using a specific set of CDFs and weights, and one or two points representing pre-determined expert values. Two expert values are given for the near future to show both the range between best and worst-case scenarios as determined by experts.

O1. Governance Index

The Governance Index is used to evaluate the state of governance. The following CDFs are used to calculate the present Governance Index:

G1. Stakeholder involvement
G2. Stakeholder compliance with rules and regulations
G3. Management operations
G4. Support from government agencies
G5. Empowerment
S3. Non-extractive alternative livelihoods
S4. Socio-Economic benefits from establishment of MMA
E5. Focal species abundance

G6. Governance outlook over next five years is included in the equations to calculate the near future state of governance,.

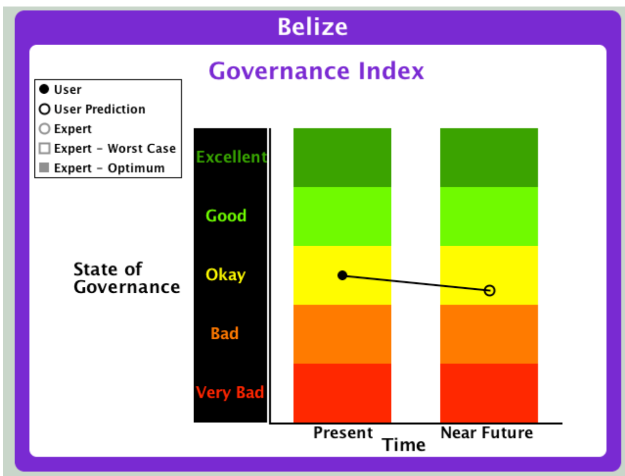


Figure 11: Governance Index

O2. Socioeconomic Index

The Livelihoods Index is used to evaluate the state of human wellbeing. The following CDFs are used to determine the present Socioeconomic Index:

S1. Perceived threat due to development
S2. Perception of local extractive resources
S3. Non-extractive alternative livelihoods
S4. Socio-Economic benefits from establishment of MMA
S5. Perception of seafood availability
E1. Level of fishing effort
E3. Habitat quality
E5. Focal species abundance
G1. Stakeholder involvement
G5. Empowerment
S6. Expected change in livelihoods over five years is included in the equations to calculate near future livelihoods.

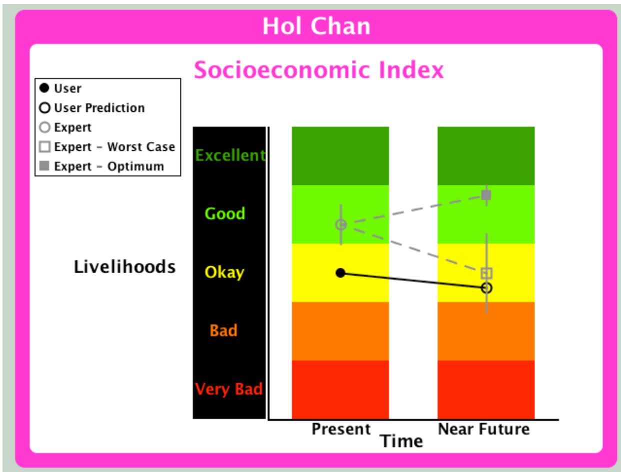


Figure 12: Socioeconmic Index

O3. Ecological Index

The Ecological Index provides a measure of the health and resilience of natural ecosystems found in the coastal regions of the site country. The following CDFs are used to determine the present Ecological Index:

E1. Level of fishing effort
E2. Relative change in habitat extent
E3. Habitat quality
E4. Herbivory
E5. Focal species abundance
G2. Stakeholder compliance with rules and regulations
G4. Support from government agencies
G5. Empowerment
E6. Expected change in ecosystem health over five years is included in the equations to calculate near future ecosystem heath.

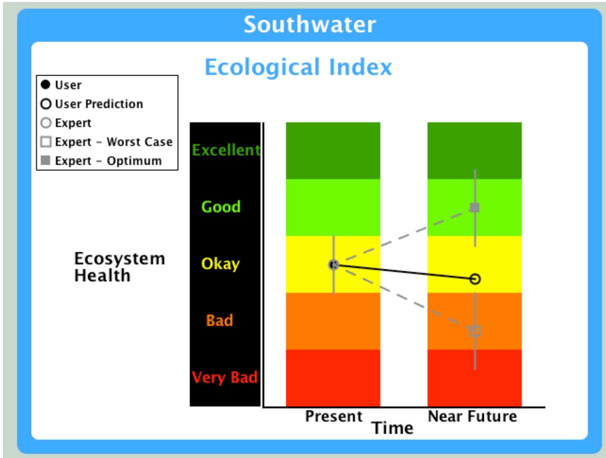


Figure 13: Ecological Index

6.2.2 MIDAS Mixed Outcome Applets

O4. CDF Comparison Tool

The CDF comparison tool shows the values for all 18 CDFs in one graph. With this visualization tool, the user will be able to perceive trends in their inputs and come to general conclusions.

Each CDF is represented as one white bar on the graph. The bar labels refer to letter/number combination assigned to each CDF as shown in the CDF Input panel. As the user changes the CDF sliders, the corresponding bars in the graph move from the Excellent category (green) to the Very Bad (red) category. On the right side of the screen, a column of total boxes displays the total number of CDFs falling into each category.

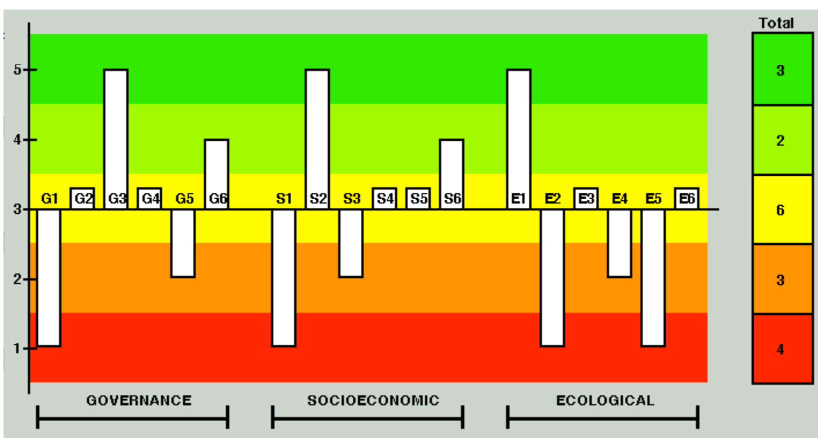


Figure 14: CDF Comparison tool

O5. MMA Effectiveness

The MMA effectiveness mixed outcome applet is visualized as a triangle whose three sides correspond to the three previously described index outcomes, scaled from low to high. The size of this triangle will change depending on how close to the extremes the user-defined value for each index falls. When all index outcomes are near the high values, the size of triangle will be large (Figure 10a). When all index outcomes are near the low values, the size of the inner triangle will be small (Figure 10b).

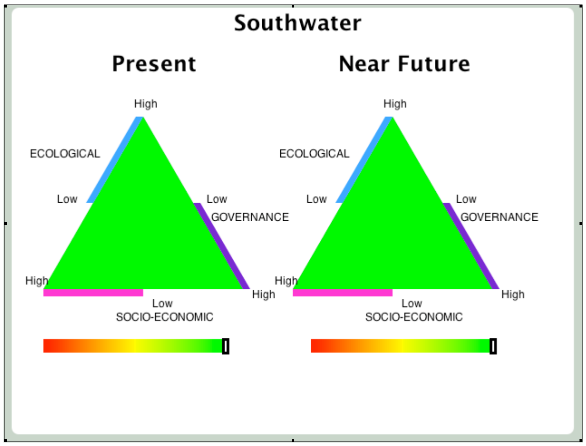


Figure 15a: MMA Effectiveness (HIGH values for all indices)

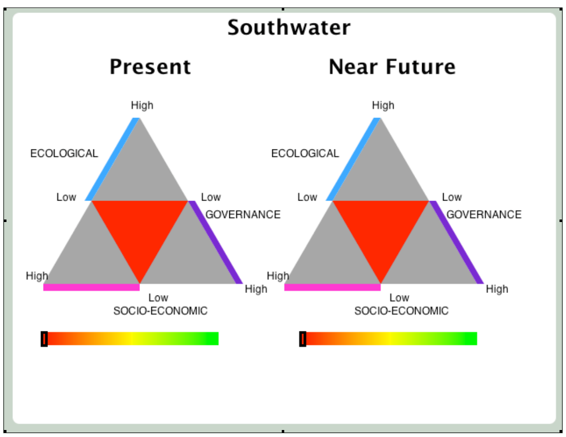


Figure 15b: MMA Effectiveness (HIGH values for all indices)

6.3 MIDAS Spatial View

In designing MIDAS, we integrated two approaches, spatial decision support system (SDSS), and Ecosystem-Based Management (EBM). A SDSS includes an easy-to-use interface that allows users to explore possible options, as well as analytical functions that generate feasible solutions based on user-specified criteria and preferences. Users can change their criteria and preferences and repeat the analysis process many times with SDSS. The MIDAS user has the ability to vary the inputs to get a variety of contexts of risks.

Layers are selected by checking the corresponding box, labeled 'Turn layer on'. The satellite image view can be turned on or off by pressing the appropriate button below. This enables user to access important GIS layers for this MMA (see Figure 16).

This spatial view also includes 3 specific models for Belize: The spatial risk model, the Oil model and the Mangrove model.

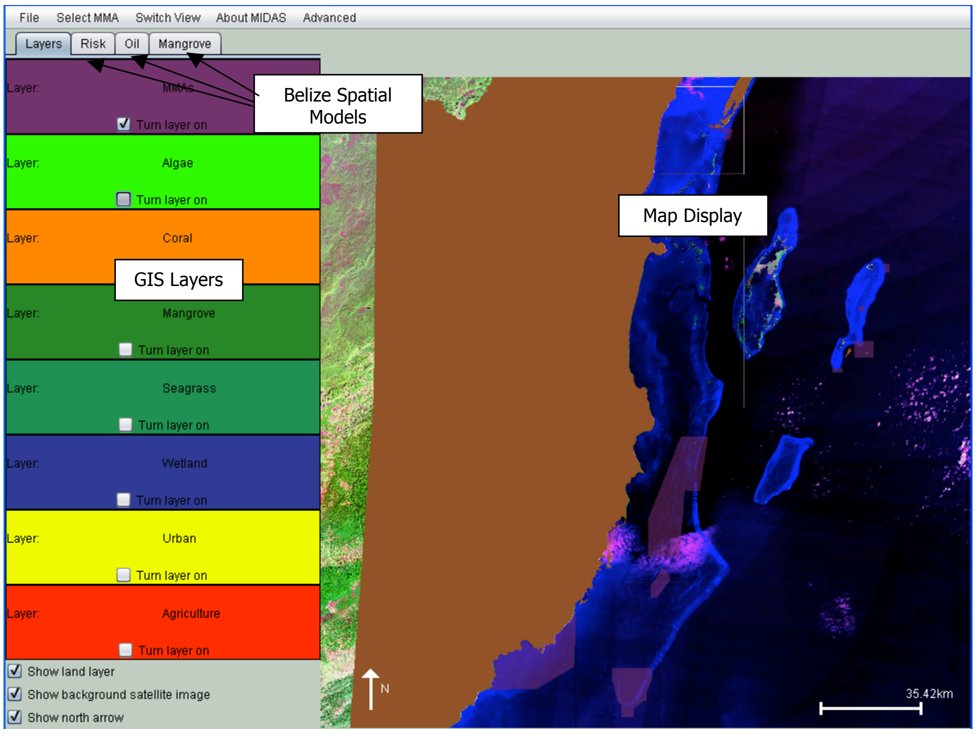


Figure 16: MIDAS Spatial View (Satellite image on the right)

6.3.1 MIDAS Spatial Risk Model

The declining health of marine ecosystems around the world is of great concern. There is a need for ecosystem-based marine spatial planning in order to maintain healthy coastal and ocean ecosystems and sustain human uses of the ocean. Informing stakeholders and managers of MMAs about the spatial distribution of health and risk is critical to overall MMA effectiveness. One proposed solution to this problem is to highlight perceptions concerning the health and threat to coral, mangrove, seagrass, and algae in spatial decision making using a simple additive model through map overlay. All threats in each cell are added to compute overall risk in each cell of the MMA.

6.3.2 MIDAS Oil model

The ongoing Gulf of Mexico oil spill demonstrates the complexity of making a confident prediction of what the impact scenario is in terms of space and time. Good review papers (Reed et al., 1999; Chao et al., 2001) indicate that the state-of-the-art oil spill models seek to describe the key physical and chemical processes that transport and weather the oil on and in the sea. These models have addressed processes such as advection, spreading, evaporation, dispersion, emulsification, and interactions with ice and shorelines. Some existing models have utilized the relationship between oil properties, and oil weathering and fate, and the evaluation of oil spill response strategies. Early oil spill models were typically two-dimensional surface models; they used constant or variable parameters to link wind and current velocities to the velocity of the surface oil slick (Reed et al., 1999).

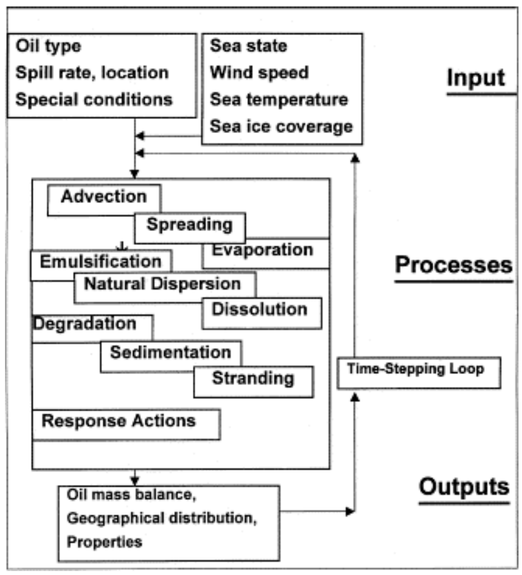


Figure 17: Oil Modeling (Source: Reed et al., 1999)

The oil model in MIDAS is an exploratory tool that is based on a very simple oil model. We ask users to accept the agreement since the model is not a predictive tool and we do not have access to all data and a complex realistic oil modeling is beyond the scope of this project. This oil spill model based off of the Lehr-Fay equations for oil spreading and moving on the sea based on equations in Cho et al (2001).

Users are requested to input the following:

- Enter the month desired. The average of 5 years of current and surface wind data from satellite are used for each month.
- Enter the type of oil. This accounts for the density of oil. The American Petroleum Index (API) numbers are shown for reference.
- Enter the volume of the point spill in barrels. (For reference, the Exxon-Valdez spill in 1989 released approximately 250,000 barrels.
- Enter the time since spill in minutes. For reasons of accuracy, we have not attempted to model beyond 5 hours.
- To begin, click on the map. You can continue the spill by increasing the time using the time selection slider.
- To erase the spill, right click the map.
- NOTE: This model is complex and takes a while to run. Please be patient

According to Professor Les Kaufman "*MIDAS almost certainly CONSIDERABLY UNDERESTIMATES the magnitude of the impacts that would result from a serious oil spill in Belizean shelf waters. Most likely the plume would spread way south of where it does now, almost wherever you might place it. It would probably then exit at the Sapodilla Cayes, enter the cycle of westward-trending gyres that move across the Honduran Shelf, and lap up against the reef, over and over again, as far north at least as Glovers Atoll. The proposed exploration track for Belize look like a dense spider web was lain over the entire reef and much of inland Belize, covering all the protected and World Heritage areas."*

6.3.3 MIDAS Mangrove Assessment Model

Unlike many countries in the tropics, Belize has retained large areas of mangrove forest 386 km coastline fringed by an almost continuous mangrove belt. Large-scale preservation was possible largely due to historically low population and development pressure. However, rapid coastal development and associated deforestation has increased threat to intact mangrove stands in recent years.

The Forest (Protection of Mangroves) Regulations of Belize (1989, revised 2003) states it is "desirable in the national interest to establish rules and regulations to protect mangrove communities. No person shall alter, allow, or cause to be altered any mangrove [black mangrove (Avicennia germinans), red mangrove (Rhizophora mangle) and white mangrove (Laguncularia racernosa)] in jurisdictional water without first obtaining a permit from the Department [of Forestry]" on any "privately owned and public lands". Several ecosystem functions are included as factors considered when determining if a project is "in the public interest despite environmental damage". In order to minimize ecosystem service losses, permits should be issued such that mangrove stands with the least ecosystem service value are preferentially selected for deforestation over stands with greater value.

Detailed economic valuation of individual mangrove stands would be data-intensive and very costly and hence the MIDAS Mangrove Assessment Model estimates the relative likelihood of mangrove stands contributing to several key ecosystem services where relative models were assigned based on spatial relationships using empirical literature. Hence MIDAS uses relative values assigned based on existing valuation data or simple spatial relationships itemized below.

1.Tourism value

- Increases if adjacent to a protected area or park (mainland)
- Increases if backed by rainforest (mainland)
- Increases if within 5km of development on the barrier (islands)
- Increases if land is above water (islands)

2. Storm buffering

- Based on valuation data presented in WRI's Costal Capital Belize working paper (Cooper 2009, data provided by Lauretta Burke at WRI)

3. Fishery value

- Increases if adjacent to seagrass beds (differentiated by type)
- Increases if within 500m of a reef

The MIDAS mangrove model option allows the display of risk associated with loss of ecosystem services resulting from cutting mangrove stands. The user can choose an area of mangrove to cut by displaying mangrove layer on the map (green) and using the computer mouse to start at an initial point on this mangrove and outline an area by dragging across. This cutting zone, consisting of 500m mangrove forest grid cells, is displayed in pink on the map, and while impact on tourism, nursery, protection and total score is displayed in the panel on the left. If a single cell is selected, the values for that cell will be displayed; when multiple cells are selected, ecosystem service values are averaged over all selected cells.

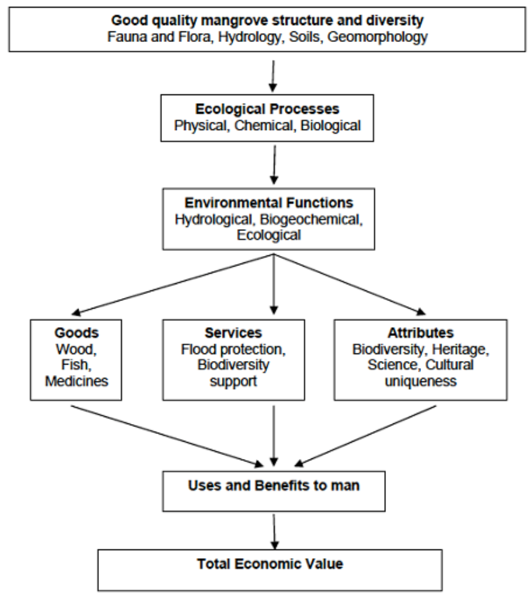


Figure 18 Mangrove Valuation (Macintosh 2002)

In Figure 19, the impact of cutting 28 mangrove cells on tourism is around 1.64 (out of 5) and 0.87 (out of 5), both in the red risk zone. Protection valuation is somewhat better around 4 (out of 5) placing it in the green zone. The total score is around orange (6.3 out of 15).

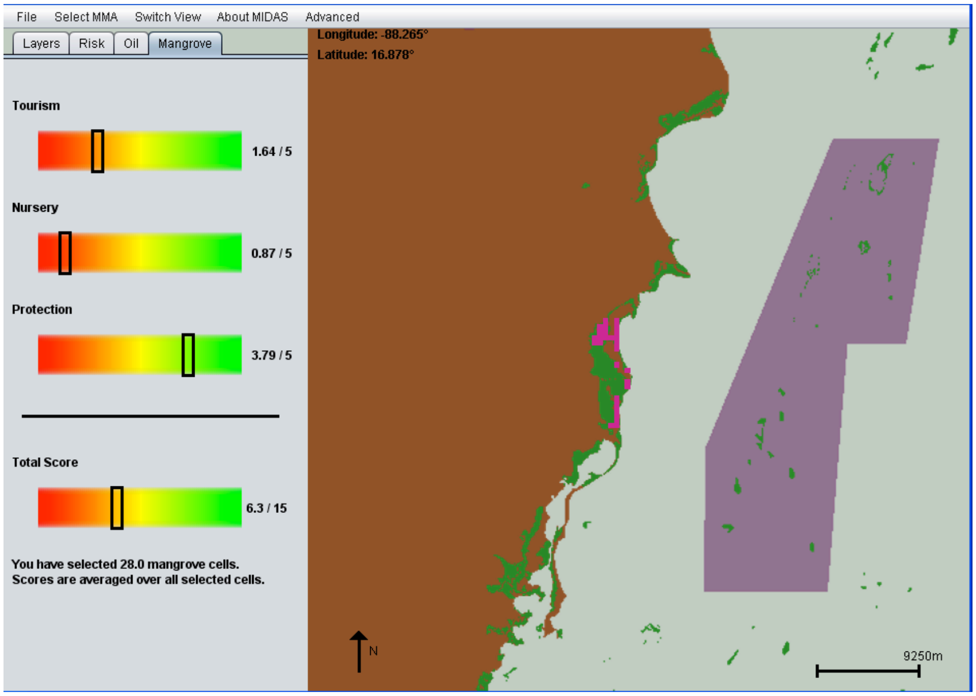


Figure 19 – MIDAS Mangrove Valuation in South Water Cayes

References

Beger, M, Harborne, A. R., Dacles, T. P., et al. (2004). *A framework of lessons learned from community-based marine reserves and its effectiveness in guiding a new coastal management initiative in the Philippines*. Environmental Management, (6), 786-801.

Belize, Government of. (2003) *Forests (Protection of Mangroves) (Amendment) Regulations*. S.I. No. 86 of 1992.

Berkelmans, R. (2002). *Time-integrated thermal bleaching thresholds of reefs and their variation on the Great Barrier Reef.* Mar Ecol Prog Ser 229: 73–82.

Bunce, L., Townsley, P., Pomeroy, R., Pollnac, R. (2000). *Socioeconomic manual for coral reef management*. Townsville, Queensland, Australia: Australian Institute of Marine Science.

Cesar, Herman S. J. (2000). *Coral Reefs: Their Functions, Threats and Economic Value. Published in Collected Essays on the Economics of Coral Reefs*. H. Cesar ed. Kalmar University, Kalmar, Sweden: CORDIO.

Cinner, J., Sutton, S.G., and Bond, T. (2007). *Socioeconomic Thresholds That Affect Use of Customary Fisheries Management Tools.* Conservation Biology, 21(6), 1603-1611.

Cho, L. (2005). *Marine protected areas: a tool for integrated coastal management in Belize.* Ocean & Coastal Management, 48, (11-12), 932-947.

Chao, X., Jothi Shankar, N., Cheong, H.T. (2001). Two- and three-dimensional oil spill model for coastal waters, Ocean Engineering, 28(12), 1557-1573.

Cooper, E., L. Burke, and N. Bood. (2009). Coastal capital: Belize. The economic contribution of Belize's coral reefs and mangroves. *WRI Working Paper*. World Resources Institute: Washington DC. 53pp.

Ehler, Charles N. (2003). *Indicators to measure governance performance in integrated coastal management*. *Ocean & Coastal Management* 46, pp. 335-45.

Field, Barry C. (2005). *Natural Resource Economics: An Introduction*. Waveland Pr Inc Publishers.

Gibson, J. Carter (2003). *The reefs of Belize*. Published in Latin American Coral Reefs, J. Cortés ed. Pages 171-202

ICLARM, (1998). *Analysis of Co-Management Arrangements in Fisheries and related Coastal Resources: A Research Framework*. International Centre for Living Aquatic Resources Management (ICLARM).

Macintosh, D.J. and E.C. Ashton. (2002). A review of mangrove biodiversity conservation and management. *Center for Tropical Ecosystems Research*.

Mora, Camillo. (2008*). A clear human footprint in the coral reefs of the Caribbean.* Proceedings of the Royal Society, 275:1636, pp. 776-73.

Pollnac, Richard B., Brian R. Crawford, Maharlina L.G. Gorospe. (2001). *Discovering factors that influence the success of community-based marine protected areas in the Visayas, Philippines*. Ocean & Coastal Management 44, pp. 683-710.

Pomeroy, R., Pollnac R, Katon B, Predo C. (1997). *Evaluating factors contributing to the success of community-based coastal resource management: the Central Visayas Regional Project-1, Philippines*. Ocean & Coastal Management 36, pp. 97-120.

Pomeroy, Robert S., Brenda M. Katon, and Ingvild Harkes (2001). *Conditions affecting the success of fisheries co-management: lessons from Asia*. Marine Policy, 25:3, pp. 197-208.

Pomeroy, R.S., Parks, J.E. and Watson, L.M. (2004). *How is your MPA doing? A guidebook of Natural and Social Indicators for Evaluating Marine Protected Area Management Effectiveness*. IUCN. Gland, Switzerland and Cambridge, UK.

Reed, M., Johansen, O., et al. (1999). Oil Spill Modeling towards the Close of the 20th Century: Overview of the State of the Art. *Spill Science & Technology Bulletin*, 5 (1), 3-16.

Wilkinson,C. (2002). *Coral bleaching and mortality – the 1998 Event 4 years later and bleaching to 2002*. Published in Status of Coral Reefs of the World, pp.33–44. C.Wilkinson editor. Global Coral Reef Monitoring Network and Australian Institute of Marine Science, Townsville,Australia,2002.

World Resources Institute. (1998). *Reefs at Risk: A Map-Based Indicator of Threats to the World's Coral Reefs*. World Resources Institute. 1998. http://reefsatrisk.wri.org/