Technical Final Report

Inter-American Biodiversity Information Network (IABIN)

COMPONENT 3: Development of Value-Added Tools for Decision-Making

Internet-Based GIS Ecosystem Assessment and Reporting Tool for Conservation Decision-Making

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1. Executive Summary

It is of utmost importance to IABIN that useful biodiversity information is readily available to decision-makers in both the public and private sectors. The tool developed for this project responds directly to that need and demonstrates how data from the Ecosystems and Protected Area Thematic Networks can be effectively integrated and used in the decision making process to guide and enhance environmental management decisions. The principal outcome of this project was the development of an Internet-based Geographic Information System (GIS) Ecosystem Assessment and Reporting (EAR) Tool for conservation decision-making. The tool can be accessed either through an internet browser or executed on a local machine using GIS software, providing a user-friendly "manager's dashboard" approach for querying current spatial information on ecosystem condition, socioeconomic threat to these ecosystem, and protected area management status. By integrating biodiversity, socioeconomic and protected area datasets, the Ecosystem Assessment and Reporting Tool provides a simple, but powerful interface designed to answer questions such as "Which ecosystems are least protected?" "Of these ecosystems, where and how do we need to improve management?" and "Where are the opportunities to most efficiently reduce threats to these ecosystems?" This decision-support tool takes advantage of powerful new internet-based GIS technologies that go beyond traditional desktop GIS functionality, and have been designed using open advanced analysis techniques in a dynamic and easy-to-use web interface. By integrating data from the Ecosystems and Protected Area Thematic Networks that have been assigned biodiversity, threat, and management status, conservation decision-makers are able to cross-query ecosystems/species with protected area information, then report back spatial and tabular results formatted using user-defined categories on the condition and vulnerability of selected ecosystems. This information can then be used by conservation decision-makers to develop focused and prioritized strategies, effectively allocating resources and activities to the most appropriate places in order to achieve maximum results.

2. Introduction

The demand for strategic conservation action is increasing and conservation decision-makers are often faced to make urgent decisions in an atmosphere of uncertainty and, sometimes, without a complete understanding of the different factors that can affect the environment. This is particularly true in developing countries where data are often limited and of poor quality, being outdated and/or inaccurate. Consequently, there is a tremendous need for developing decision-support tools that are able to easily access and integrate available data in a quick and efficient manner. Such tools help to minimize risk and anticipate the second- and third-order effects that may result from a decision. The ability to make informed decisions which consider unforeseen circumstances is a fundamental and powerful way to achieve efficient and effective environmental management, conservation of biodiversity, and sustainable development.

The objective of this project was to design and develop both an internet-based and stand-alone version decision-support tool, using the latest GIS technology that integrates data from IABIN's Ecosystem and Protected Area Thematic Networks. The tool resulting from the efforts of this work is called the **Ecosystem Assessment and Reporting (EAR) Tool** and has been designed around The Nature Conservancy's (TNC) approach for calculating "*Effective Conservation*" (Higgins et al, 2007). This approach is a way of measuring progress (i.e. gauging the raising of the needle) towards achieving established conservation goals for ecosystems. An ecosystem achieves *effective conservation* when the biodiversity of an ecosystem is expected to persist as a result of conservation actions. The framework for calculating the level of *effective conservation* uses three measures in combination (see Figure 1):

- *Viability Status* - the biological potential for a given ecosystem to persist (*e.g.* ecosystem size, condition, and landscape context).
- *Threats Status* - the degree of anticipated negative impact (*i.e.* socio-economic activity) to a given ecosystem (*e.g.* severity, scope of threat).
- *Conservation Management Status* - the likelihood that management activities will secure biodiversity and allow it to persist within a protected area (*e.g.* intent, tenure, and effective management potential).

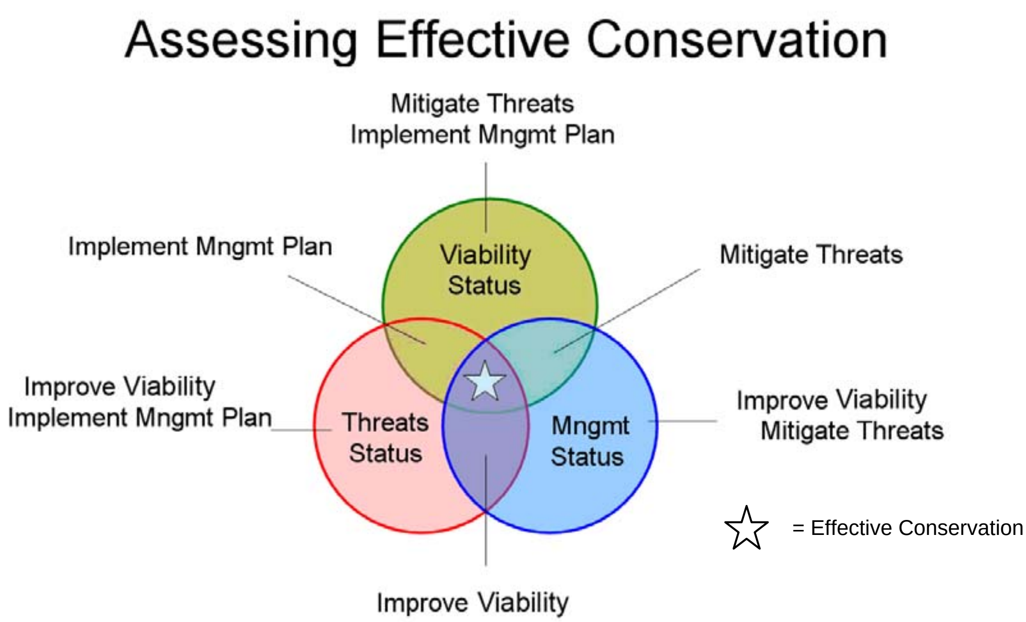


Figure 1. *Effective conservation* of an ecosystem is achieved when acceptable levels are reached for all three measures: viability, threat, and conservation management status. Knowing the status of each measure for each ecosystem will help decision-makers to know when and where to prioritize and guide *effective conservation* actions (Higgins et al, 2007).

The calculation of *effective conservation* for ecosystems requires that viability information, anticipated threat, and on-going conservation management be calculated for each ecosystem patch. Each of these measures is calculated using several indicators which are later combined to develop a final rating for each ecosystem patch. It is up to the decision-maker to decide at what level each of the measures are acceptable or unacceptable in terms of conservation objectives (e.g. Are viability levels sufficient? Are threats being abated? Is adequate management in place?) These patch level indicators can then be rolled up and compared across scales and to other ecosystems. However, the EAR tool does not require users to employ a particular method (i.e. TNC's method) for calculating viability, threat, and management measures and their associated levels of acceptability. The tool is flexible to accommodate the most simple or the most sophisticated methods for calculating these measures. What is required is that the user calculates the measures, adds the attribute fields, and assigns a rating (e.g. Very Good, Good, Fair, and Poor) within each of the GIS input files (i.e. ecosystems, species, protected areas). In order to comply with the data model used in the tool, a decision must be made at what level each measure is determined to be acceptable in terms of the conservation objectives. The example data included with the EAR tool contains pre-determined acceptability classes for each of the measures fields within the GIS ecosystem and protected area data. The measure classes were derived from TNC's ecoregional assessments which include detailed viability, threat, and conservation management information. This type of information is being completed in phases across all of Latin America and the Caribbean and efforts are currently underway to crosswalk these ecosystems to the IABIN ETN standard format.

Conservation decision-makers need to be able to map and visualize all categories of ecosystem condition (i.e. the resulting class combinations based on the intersection of the viability, threat, and conservation management status) and generate reports to determine what types of strategies are required to bring additional hectares of ecosystems towards acceptable levels of *effective conservation*. Only when acceptable levels are attained for all three measures is when biodiversity is reasonably expected to persist and *effective conservation* is achieved (see Figure 1). This approach provides critical insight into the current status of each ecosystem patch, identifying restoration needs, threat abatement, and protection improvements that are needed. These types of analyses can be used to communicate the results of the tool to a broad range of partners, stakeholders and policy makers. For additional information on methods for calculating measures of effective conservation, please refer to Higgins et al (2007).

3. Results of the planned products and impact of the project

The EAR tool specifically responds to several IABIN objectives—namely providing: a) access to scientifically credible biodiversity status information in the Americas; b) developing tools necessary to draw knowledge from that wealth of resources, which in turn will support sound decision-making concerning the conservation of biodiversity; and c) a mechanism to exchange information relevant to conservation and sustainable use of biological diversity. As both public and private sectors are routinely required to make decisions in an atmosphere of uncertainty and limited resources, the EAR tool helps to maximize resources and prioritize actions needed across the conservation landscape.

The primary impacts of this tool include:

1. **Integration of data from Ecosystems and Protected Area Thematic Network databases.**
   The integration of ecosystem and protected area data is increasingly recognized as vital to scientific research and societal decision-making related to a wide range of pressing environmental and biodiversity issues (IABIN, 2004). A primary gap in this process has been the lack of integration with these types of GIS databases to determine ecosystems at risk and corresponding management effectiveness needs. Consequently, the EAR tool helps to address this need by integrating ecosystem, threat, and protected area data and providing an interactive and user-friendly approach to identify conservation gaps, prioritizing conservation actions. In addition, the tool has been specifically designed to integrate and take advantage of TNC's ecoregional datasets and methods for measuring effective conservation. To date, TNC has completed over 140 freshwater, marine, and terrestrial ecoregional assessments and new assessments are continually being completed. These ecoregional assessments provide a range of useful data that can be used in the EAR tool. These data include viability, threat, and protected area investigations based on spatially explicit representations of ecosystems, point locations for communities and species, and maps of portfolio areas (Higgins et al, 2007).

2. **Tools for visualization and analysis of Ecosystem and Protected Area TN data and information.**
   Having been built using new Internet-based GIS technology (i.e. Environmental Systems Research Institute (ESRI) ArcGIS Server™), the EAR tool can be linked to existing GIS datasets, designed with flexibility, scalability, and diversification in mind. By integrating existing TNC ecoregional data with IABIN's Ecosystems and Protected Area Thematic Networks datasets, the tool maximizes the utility of these data by providing users with advanced query and visualization functions. Users are able to visualize the current status of each ecosystem patch by combining the three measures, obtaining spatial and tabular answers to questions such as:

   - What is the current protection status of each ecosystem?
   - How close are we to meeting conservation goals, what percentage has been achieved?
   - If I need additional hectares to reach my goal, where are the most suitable areas to implement a protection strategy?

For added visualization functionality, model results can be exported as KMZ files and viewed in Google Earth. Using ESRI's ArcGIS Server™ technology, users are able to query large distributed GIS databases, execute advanced GIS functions, and view model results via an internet browser or other thin clients (e.g. ArcExplorer). Executing the tool via a server is often ideal since all model processing is performed on the server, minimizing the use of local resources. The web-based version of the tool is available using an internet browser and has been designed so that non-GIS users can utilize the power of GIS without extensive training. For users who do not have internet access, the EAR tool is also available as a stand-alone version ArcToolbox, requiring the use of ESRI's ArcGIS™ desktop software. ESRI software was chosen as the application for the tool since ESRI is a strong supporter of TNC's mission and provides a grant agreement in which conservation partners can freely obtain their software for conservation-related work. In addition, the EAR tool can be used with model output from existing IABIN tools such as the Protected Area Tools (PAT) for ArcGIS, a tool that was developed as part of the Development Grant Facility (DGF) as has been updated continually with ongoing support and maintenance from TNC. The PAT tools are available for free download in multiple versions of ArcGIS along with a detailed user manual and corresponding tutorial data (*http://www.gispatools.org*).

3. **Utilize tool output to develop scenarios and plans of conservation action for decision makers**

   Effective conservation decisions often require up-to-date information on the viability of an ecosystem, the level of socio-economic threat to that ecosystem, and the actual protected area management that is being implemented on the ground. These types of information are often used to help policy and environmental managers set conservation priorities, respond to critical needs in an effective manner, and distribute limited resources efficiently. The EAR tool provides decision-makers crucial direction by providing spatial information on the most appropriate places to do conservation work and indicate what actions are needed to improve biodiversity conservation for each ecosystem by explicitly addressing the following questions:

   1. Where is biodiversity reasonably secure and expected to persist?
   2. What are the gaps in biodiversity protection and threat abatement?
   3. Where are there opportunities to expand and enhance biodiversity protection?
   4. What progress are we making as a result of conservation actions, and what biodiversity has been lost?

4. Methodology employed and activities carried out to achieve the planned products

With ongoing development of IABIN's Ecosystem and Protected Area TN databases, there exists tremendous opportunities to leverage these databases with TNC's ecoregional assessment databases to further advance biodiversity protection. The EAR tool takes advantage of new and powerful Internet-based GIS technology that integrates viability, threat, and conservation management status, providing integration results in easily digestible maps and reports. These maps and reports can be generated dynamically from the tool, providing a current conservation action prioritization for a given area or ecosystem.

In summary, key activities carried out during this project include:

a. **Design of data model** - Design of a data model that integrates TNC's ecoregional assessment products with the ecosystem and protected area standard format databases into a suitable and efficient framework for internet-based GIS analysis and reporting. The data model integrates and combines the three basic measures (viability, threat, and management status) to produce the desired output products and reports. All GIS methods that are used in the tool are based on the design of the data model.
b. **Implementation and testing of data model** – The project team has worked to ensure that the adopted data model produces the desired output based on the integration of the Ecosystem and Protected Areas TN databases. Several terrestrial and marine ecoregional datasets throughout Mesoamerica and the Caribbean have been chosen to prototype and test the data model.
c. **Hardware setup and loading of supporting database** - Consolidation of database onto a robust server with high-speed internet connection and access to IABIN's existing distributed databases. The tool and databases were loaded and tested at one of TNC's partner servers located at the University of Southern Mississippi's Department of Geography and Geology.
d. **Design of tool and output products** - Design of an ArcGIS Server-based tool and method for creating output products compatible with the data model and useful for decision-makers. The tool has been designed primarily for use by non-GIS people who have little GIS technology training. When using GIS data from the Ecosystems and Protected Area TNC databases, users can perform complex spatial queries and receive back maps and reports indicating model results. When using the internet version of the tool, execution of the geoprocessing services occurs on the remote server, where the data is located. Users have the option of visualizing model results using an Internet browser, Google Earth, or ArcGIS Explorer, a free viewer which offers direct connection to geodatabases, to open source Web Map Services (WMS).

e. **Implementation and testing of tool** - Implementation and testing of the tool has been conducted using centralized and distributed databases within a variety of clients (*e.g.* Internet browser, Google Earth, ArcGIS Explorer).

f. **Delivery of final report and tool with accompanying user manual** – This final report has been written and delivered with the implementation of the tool and accompanying user manual. All supporting tool documents are available in English and will be translated into Spanish.

4.1 Data model used in the tool

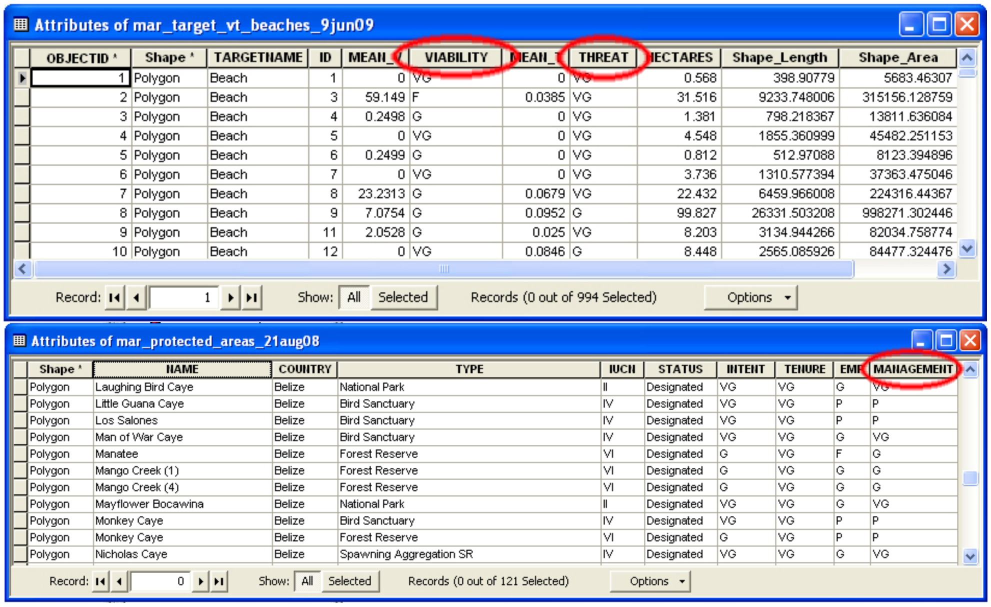
The data model used in the tool has been designed so that the user must choose at what level each of the *effective conservation* measures (*e.g.* viability, threat, and conservation management status) is acceptable or unacceptable with regards to the conservation objectives. In other words, at what cut-off level is the condition of that particular ecosystem patch considered acceptable in terms of its viability, threat, and management status. Based on the combination of these measures, an effective conservation action class is accordingly assigned to each ecosystem patch; each patch being assigned one of eight possible classes (Table 1). The assignment of these scores is based on the spatial intersection of the three measures attributes contained with the ecosystem and protected area data. An example of what the attribute tables look like for both the ecosystems and the protected areas layers are shown in Figure 2.

Table 1. Data model showing how the different combinations (acceptable= 0 and unacceptable= 0) of effective conservation measures (*e.g.* viability, threat, and management status) result in the assignment of one of eight conservation action classes and corresponding proposed ecosystem conservation action.

Viability Status	Threat Status	Conservation Management Status	Effective Management Class	Proposed Ecosystem Conservation Action Class
1	1	1	1	Maintain *Effective Conservation*
0	1	1	2	Improve Viability
1	0	1	3	Abate Threats
1	1	0	4	Implement Better Management
0	0	1	5	Improve Viability and Abate Threats
1	0	0	6	Abate Threats and Implement Better Management
0	1	0	7	Improve Viability and Implement Better Management
0	0	0	8	No Status (No acceptable levels on any of the 3 measures)

The ecosystems data layer must have a VIABILITY and THREAT attribute field that has been calculated to one of four levels (e.g. Very Good (*VG*), Good (*G*), Fair (*F*), Poor (*P*)). In addition, the protected areas data layer must also have a MANAGEMENT field assigned and calculated accordingly. Prior to executing the tool, the user must decide at what level each measure is considered acceptable with respect to the conservation objectives. For example, are the viability categories of "Good" and "Very Good" considered acceptable levels of viability for the conservation objectives? The default values the tool uses are "Good" and "Very Good" as the level of acceptability, but the user can change these categories if desired. If users have multiple ecosystem and protected area shapefiles or feature datasets, it is recommended that these files be merged prior to tool execution;

however it is important that each file follow the same status measure field requirements for each layer.


Attributes of mar_target_vt_beaches_9jun09

OBJECTID *	Shape *	TARGETNAME	ID	MEAN_V	VIABILITY	MEAN_T	THREAT	HECTARES	Shape_Length	Shape_Area
1	Polygon	Beach	1	0	VG	0	VG	0.568	398.90779	5683.46307
2	Polygon	Beach	3	59.149	F	0.0385	VG	31.516	9233.748006	315156.128759
3	Polygon	Beach	4	0.2498	G	0	VG	1.381	798.218367	13811.636084
4	Polygon	Beach	5	0	VG	0	VG	4.548	1855.360999	45482.251153
5	Polygon	Beach	6	0.2499	G	0	VG	0.812	512.97088	8123.394896
6	Polygon	Beach	7	0	VG	0	VG	3.736	1310.577394	37363.475046
7	Polygon	Beach	8	23.2313	G	0.0679	VG	22.432	6459.966008	224316.44367
8	Polygon	Beach	9	7.0754	G	0.0952	G	99.827	26331.503208	998271.302446
9	Polygon	Beach	11	2.0528	G	0.025	VG	8.203	3134.944266	82034.758774
10	Polygon	Beach	12	0	VG	0.0846	G	8.448	2565.085926	84477.324476

Record: 1 Show: All Selected Records (0 out of 994 Selected) Options

Attributes of mar_protected_areas_21aug08

Shape *	NAME	COUNTRY	TYPE	IUCN	STATUS	INTENT	TENURE	EMP	MANAGEMENT
Polygon	Laughing Bird Caye	Belize	National Park	II	Designated	VG	VG	G	VG
Polygon	Little Guana Caye	Belize	Bird Sanctuary	IV	Designated	VG	VG	P	P
Polygon	Los Salones	Belize	Bird Sanctuary	IV	Designated	VG	VG	P	P
Polygon	Man of War Caye	Belize	Bird Sanctuary	IV	Designated	VG	VG	G	VG
Polygon	Manatee	Belize	Forest Reserve	VI	Designated	G	VG	F	G
Polygon	Mango Creek (1)	Belize	Forest Reserve	VI	Designated	G	VG	G	G
Polygon	Mango Creek (4)	Belize	Forest Reserve	VI	Designated	G	VG	G	G
Polygon	Mayflower Bocawina	Belize	National Park	II	Designated	VG	VG	G	VG
Polygon	Monkey Caye	Belize	Bird Sanctuary	IV	Designated	VG	VG	P	P
Polygon	Monkey Caye	Belize	Forest Reserve	VI	Designated	G	VG	P	P
Polygon	Nicholas Caye	Belize	Spawning Aggregation SR	IV	Designated	VG	VG	G	VG

Record: 0 Show: All Selected Records (0 out of 121 Selected) Options

Figure 2. Sample GIS attribute tables for ecosystems (top) and protected areas (bottom) data layers showing the required fields (VIABILITY, THREAT, MANAGEMENT) needed in the GIS files prior to running the Ecosystem Assessment and Reporting (EAR) tool. Additional information about creating and calculating these fields is found in the User Manual.

As explained, the EAR tool uses three measures in combination to estimate effective conservation which are assigned at the habitat patch level. The following is a brief description of each measure and examples of how estimates for each measure can be derived and assigned to the ecosystems and protected areas data. Additional information can be found in Higgins et al, (2007).

Viability Status – Defined as the biological potential for a given population, community or ecosystem to persist (independent of future threats and current protection or management). One of the sample datasets that accompanies the tool comes from the ecoregional assessment of the Mesoamerican Reef, where spatial-based statistics from the underlying environmental risk surfaces were used to calculate viability status. These surfaces involve the combination of multiple socio-economic features that imply

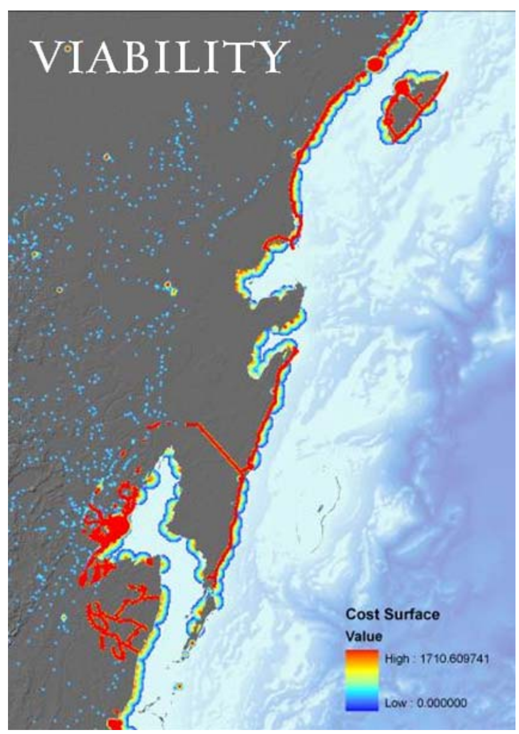


Figure 3. An example of a viability model for a portion of the Mesoamerican Reef. Shades of red indicate areas of poorer viability based on the underlying socioeconomic activities.

impacts to viability to habitats (e.g. coastal development, land and sea-based pollution, sedimentation, etc). Acceptable viability levels for ecosystem patches were selected as either in the "Good" or "Very Good" category. All other patches containing "Fair" or "Poor" were considered unacceptable. Figure 3 shows graphic showing an example of a viability model for marine ecosystems in a portion of the Mesoamerican Reef. Shades of red indicate areas of poor viability based on the underlying socioeconomic activities that were used to create the environmental risk model. Table 2 lists each viability score and a corresponding description of what each score means.

Table 2. Listing and description of the Viability status measure scores (adapted from Higgins et al,2007).

Viability Status Measure	Description An assessment of the potential for an ecosystem to persist given current intrinsic characteristics of size and condition, and the extrinsic characteristic of landscape context.
Very Good	The ecosystem patch exhibits characteristics necessary to thrive for the long term (e.g., 100 years).
Good	The ecosystem patch exhibits characteristics necessary to persist for the long term (e.g., 100 years), but its viability/integrity may decrease with time.
Fair	The ecosystem patch exhibits compromised characteristics and is unlikely to persist for the long term (e.g., 100 years) unless managed appropriately.
Poor	The ecosystem patch will likely not persist over the next 25 years.

A rapid approach to define ecosystem viability and ecological system integrity uses a single or a combination of indicators (depending on available data) of size, condition and landscape context (Stein and Davis 2000):

- ***Size*****:** The abundance/density of a population, or the area of a population or ecological system.
- ***Condition*****:** The quality of biotic and abiotic factors, structures and processes within a population or ecological system occurrence, such as age structure, species composition, ecological processes and physical/chemical factors.
- ***Landscape context*****:** The quality of structures, processes and biotic/abiotic factors of the landscape immediately surrounding a population or ecological system, including degrees of connectivity and isolation to adjacent habitats, populations and ecological systems.

Threats Status – Defined as the degree of anticipated negative impact to a given population, community or ecosystem in the future. Threats pose tangible risks to degrading the current viability status of ecosystems. When calculating threats to ecosystems, it is important to clearly separate current (ongoing) impacts to viability taking place on the landscape from threats that have not yet been manifested (Higgins et al, 2007). Current impacts are evaluated and reported in the Viability Status measure and are usually incorporated in the assessment of condition and/or landscape context. Near-term threats that are anticipated to be manifested and affect biodiversity in the next 10 years should be considered in this measure of Threat

Status. This distinction guides conservation actions more explicitly then combining current impacts and future threats in one measure. Table 3 lists descriptions of the four different threat categories.

Distinctions between impacts and threats of different time frames are provided below (Higgins et al, 2007):

- ***Current Impacts:*** Those factors that are negatively impacting biodiversity at the present time. Impacts should be, in the best case scenario, included in the Viability Status measure indicators. For example, an existing road corridor impacts the condition of an occurrence by changing disturbance patterns, and affects its landscape context via isolation.
- ***Near-term Threats:*** Sources of potential impact to the biodiversity target occurrences that will likely be manifested within the next 10 years. In general, there is higher reliability when rating near-term threats than long-term threats. For example, the anticipated degradation or conversion of land along a road corridor.
- ***Long-Term Threats:*** Sources of potential impacts that are likely to manifest themselves on a time frame longer than 10 years. These threat sources are generally assessed with lower reliability than near-term threats. Examples would include invasive species expanding from a new road corridor, climate change impacts, or long-term plans for development along coasts.

Table 3. Listing and description of the threat status measure scores (adapted from Higgins et al, 2007).

Threat Status Measure	**Description** The degree of anticipated negative impact to biodiversity in the future.
Low/None:	There is no threat, or the threats identified will have little to no influence on the integrity of the ecosystems.
Moderate:	Single or multiple threats have been identified that together pose a risk of decreasing the integrity of an ecosystem.
High:	Single or multiple threats have been identified that together pose a risk of significantly decreasing the integrity of ecosystems resulting in a change to poor Viability Status.
Very High:	Single or multiple threats have been identified that together will destroy or lead to the extirpation of ecosystems.

For this measure we calculated long-term threats using climate change variables including sea-level rise (SLR) risk and areas of reef resilience based on previous investigation. The intent was to forecast future negative impacts on ecosystems. Figure 4 shows the two inputs for the threat model, including anticipated sea-level rise (based on 30-meter Shuttle Radar Topography Mission (SRTM) data) and reef resilience based on a previous study of 325 reef dive locations (Healthy Reef Initiative, 2008). By combining both the SLR and reef resilience models, future threat forecasted based on the models. Spatial statistics were then used to assign average threat value to each ecosystem patch. Using Jenk's Natural Breaks, the average threat values by ecosystem patch were then used as the basis for assigning a threat score and corresponding threat category.

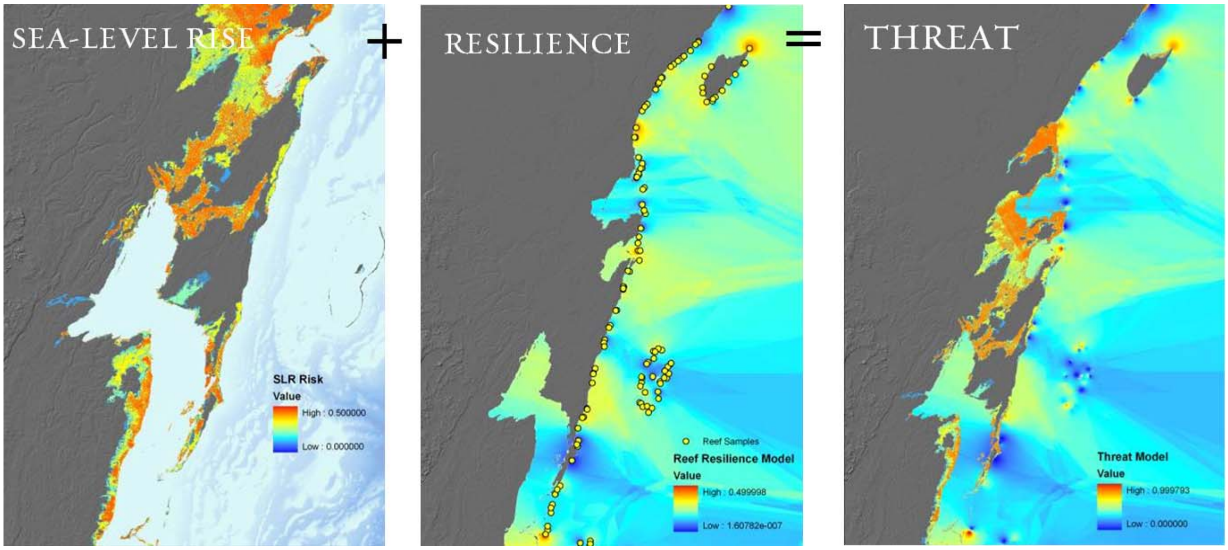


Figure 4. The calculation of threat value based on a combination of predicted sea-level rise (SLR) and reef resilience models. The SLR models were based on 30m SRTM data and the reef resilience model was based on a Healthy Reef Initiative (2008) reef study.

Conservation Management Status – Defined as the likelihood that protection and/or management activities will secure biodiversity and allows it to persist. Typically this measure is calculated using three protected area indicators: *intent* of the protected area (IUCN category), the *duration of the protected area* (level of time the area is expected to remain protected), and the potential for the protected area to be *managed effectively*. Each of these indicators can be defined as:

- *Intent*: The relative degree to which stated protection and/or management objectives of activities are intended to secure biodiversity. Usually based on an IUCN category.
- *Duration*: The tenure of the commitment to the protection and/or management activities. This is usually based on official government protected area declarations.
- *Effective Management Potential (EMP)*: The potential for an entity to be effective in implementing activities to achieve stated protection and/or management objectives. This is usually based on available resources, governance, and planning framework for a particular protected area.

In the Mesoamerican Reef example, the Intent indicator was assigned using the IUCN protected area category in the following way:

I, II, IV = Very Good (VG)
V, VI = Good (G)
III = Fair (F)
Non-designated = Good (G) - based on assumption that these areas are rich in marine habitats and most likely set up for a sustainable conservation focus.

For the Duration indicator, all government declared protected areas were assigned a Very Good (VG), while non-declared protected areas were assigned Poor (P) for no commitment.

For calculating the EMP indicator, we used PAME (Protected Area Management Effectiveness) surveys, such as the PROARCA surveys that have been collected for protected areas throughout the Mesoamerican reef in recent years. These surveys were integrated with existing protected area management workshop information to calculate each of the protected area's resources, governance, and planning framework. Since there are so many different kinds of management survey methods, often times this indicator has to be calculated using a crosswalk, assigning survey questions to each of the resource, governance, and planning categories. The combination of these three categories results in an EMP scoring for each protected area. Each score was chosen based on a "Majority Rules" criterion, where if at least two of the three categories share the same rating, then the ecosystem patch receives that rating. The final Conservation Status Measure (CMS) was assigned using the

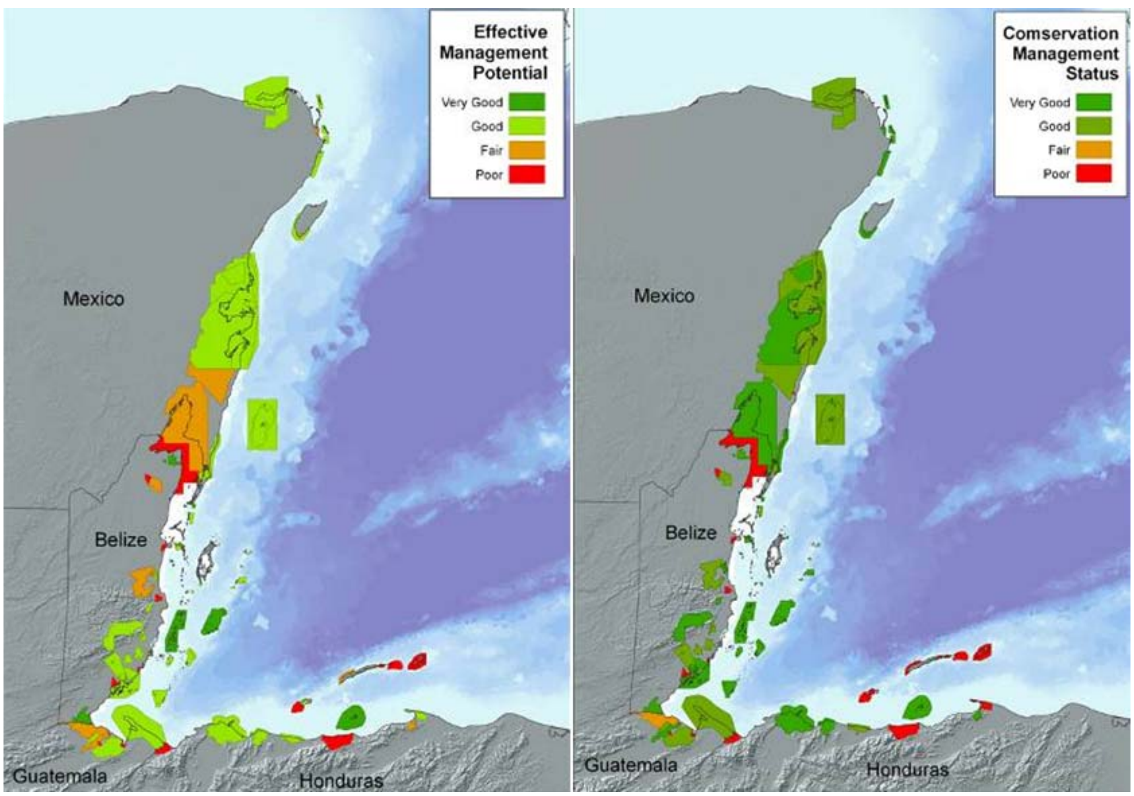


Figure 5. The Conservation Status Measure (CMS) assigned to the protected areas of the Mesoamerican Reef. The map on the left shows the calculation of each protected area's *Effective Management Potential*, or the combination of available resources, governance, and planning framework. The map on the right shows the final CMS score based on the total combination of *Intent, Duration, and Effective Management Potential* indicators. Threshold levels for viability were all ecosystem patches with a Good or Very Good category.

same Majority Rules criterion, only based on the combination of the final *Intent, Duration, and EMP* indicators. Below is a graphic showing the output of the model based on the assimilation of indicators assigned to each protected area for both the *EMP* and overall *Conservation Management Status* (CMS). Table 4 lists categories and corresponding descriptions for each of the Conservation Management Status measure scores. Additional information can be found in Higgins et al (2007).

Table 4. Listing and description of the Conservation Management Status measure scores (adapted from Higgins et al (2007).

Conservation Management Status Measure	**Description** A measure of the likelihood to which activities will secure biodiversity and allow it to persist.
Very Good (Sound)	Activities have a high likelihood to secure biodiversity and allow it to persist.
Good (Sufficient)	Activities have a moderate likelihood to secure biodiversity and allow it to persist.
Fair (Limited)	Activities have a low likelihood to secure biodiversity and allow it to persist.
Poor (Inadequate)	Activities do not have the likelihood to secure biodiversity and allow it to persist.
Unknown	Activities have unknown characteristics.

4.2 Tool output and implementation

Having assigned the status measure fields to the ecosystems and protected areas data layers and merging input files where necessary, the EAR tool can now be used to create the GIS output files and reports describing ecosystem condition at the patch level based on the intersection of the viability, threat, and management status. For example, if a user wants to calculate the current protected status for a suite of forest ecosystems, the user chooses these data and selects the corresponding fields of interest (*e.g.* protected area management attributes). Upon execution, the layers are intersected and resulting output files and tables are calculated and made available for viewing. The user is then able to visually assess the condition and protected status for each forest ecosystem patch and examine the cross-tabular reports with corresponding hectare totals for each conservation action class. The EAR tool provides the framework to calculate a variety of useful summary statistics and maps which will facilitate a more informed and effective implementation of conservation strategies. Users can also download any of the outputs including the reports, GIS and KML files, and export internet-served maps to JPG or PDF format.

Designed for user flexibility in mind, the EAR tool can be accessed in two ways: a) internet version; and b) stand-alone ArcToolbox version for ArcGIS 9.3. Users that have internet access, but lack GIS software, can access the tool over the internet using an internet browser directed at http://gg.usm.edu/EAR (Figure 7). For users with limited internet access, but have ArcGIS 9.3 software on their computer, the tool can be downloaded at the same website and launched as a stand-alone version in ArcToolbox

(Figure 8). These tools have been written in Python code and operate using the pre-defined data model that uses the viability, threat, and management classes added in the input GIS files attribute tables. Also available for download at the same URL is the User Manual that guides the use and implementation of these tools.

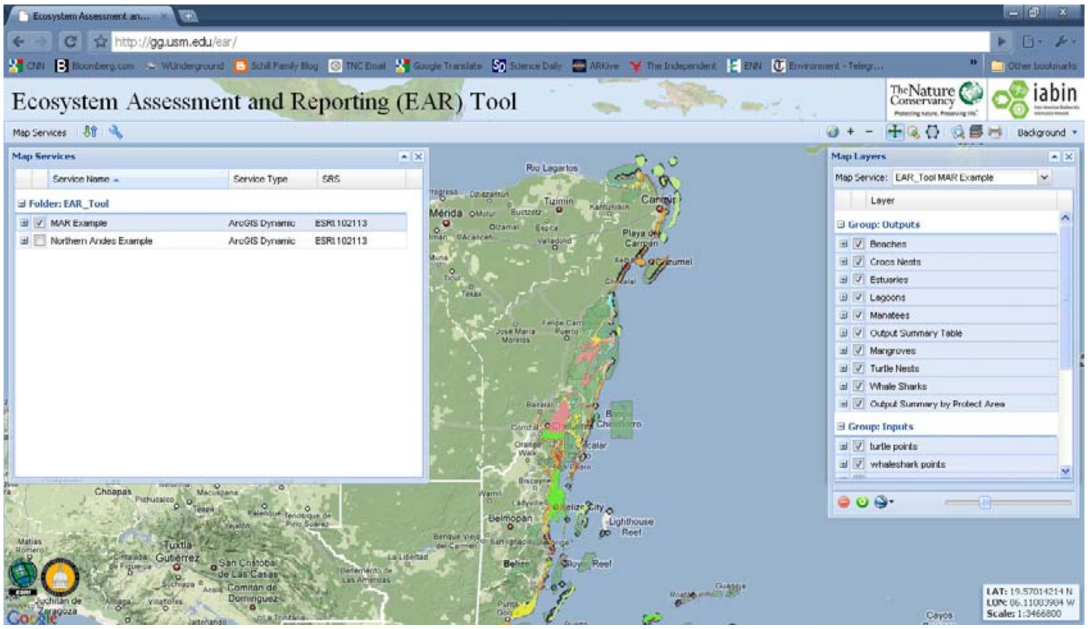


Figure 7. The user-interface of the internet version of the EAR tool. Users can select existing map services, or upload their files to perform the calculation of the conservation action classes. Users also have access to advanced graphing and reporting functions that cross-query ecosystems and protected areas attributes (see Figures 9 and 10).

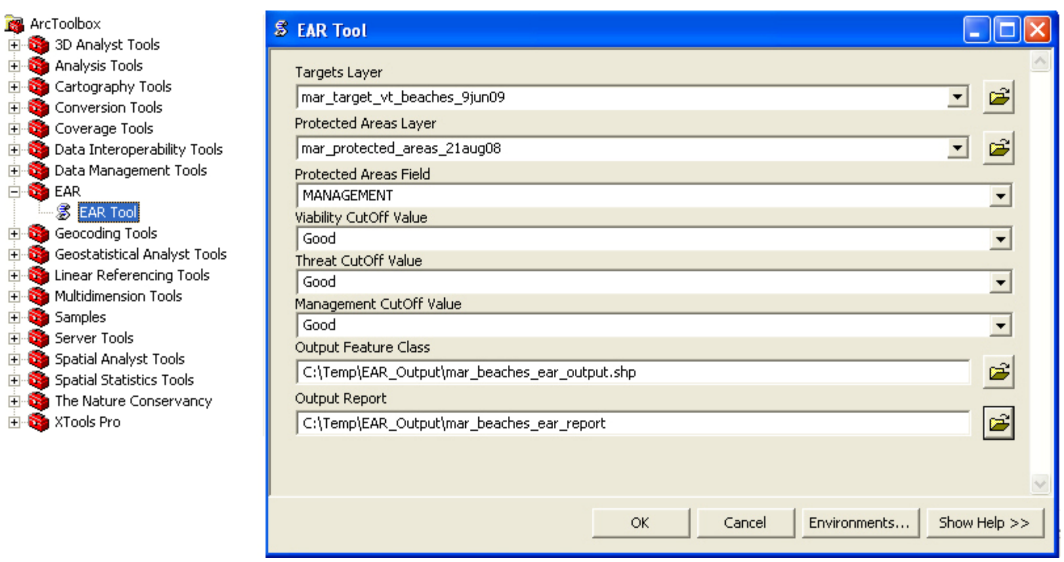


Figure 8. The user-interface of the stand-alone version of the EAR tool. The tool is added to the ArcToolbox window and when launched, the user specifies the ecosystem and protected area input layers, the cut-off values for each of the measures, and the GIS and report output filenames.

Once the user specifies the input files and executes the tool, three output GIS files (shapefiles or feature datasets depending on user's format choice) are created:

1. **Raw Output File** – This file is based on user-specified <output_filename> and assigned each ecosystem patch to a conservation action class along with a variety of percentage calculations. Below is an example of the attribute table and description of relevant fields:

Attributes of mar_beaches_ear_output

VA	TA	MA	EMC_VALUE	EMC_TEXT	AMOUNT	AMOUNTT_PA	AMOUNT_TAR	PERC_T_PA	PERC_TAR	PERC_PA	PERC_SA_T	PERC_SA
0	1	0	7	Improve Biodiversity and Implement Better Management	16.124739	16.124739	13216.981121	100	0.12	0.12	41.95	41.95
0	0	1	5	Improve Biodiversity and Abate Threats	176.956175	1859.584378	13216.981121	9.52	1.34	14.07	8.19	8.19
0	1	1	2	Improve Biodiversity	950.221874	1859.584378	13216.981121	51.1	7.19	14.07	11.89	11.89
1	0	1	3	Abate Threats	127.359559	1859.584378	13216.981121	6.85	0.96	14.07	1.76	1.76
1	1	1	1	Maintain Effective Conservation	605.04677	1859.584378	13216.981121	32.54	4.58	14.07	7.69	7.69
0	0	0	8	No Status	41.021231	389.096992	13216.981121	10.54	0.31	2.94	11.36	11.36
0	1	0	7	Improve Biodiversity and Implement Better Management	132.960577	389.096992	13216.981121	34.17	1.01	2.94	41.95	41.95
1	0	0	6	Abate Threats and Implement Better Management	54.293201	389.096992	13216.981121	13.95	0.41	2.94	6.69	6.69
1	1	0	4	Implement Better Management	160.821983	389.096992	13216.981121	41.33	1.22	2.94	10.47	10.47
0	0	1	5	Improve Biodiversity and Abate Threats	906.131171	2044.284517	13216.981121	44.33	6.86	15.47	8.19	8.19
0	1	1	2	Improve Biodiversity	621.068848	2044.284517	13216.981121	30.38	4.7	15.47	11.89	11.89
1	0	1	3	Abate Threats	105.712373	2044.284517	13216.981121	5.17	0.8	15.47	1.76	1.76
1	1	1	1	Maintain Effective Conservation	411.372126	2044.284517	13216.981121	20.12	3.11	15.47	7.69	7.69

Record: 1 Show: All Selected Records (0 out of 17 Selected) Options

EMC_TEXT: Name of the computed conservation action class (out of eight total classes in Table 1) assigned to each ecosystem patch.

AMOUNT: Total hectare of the ecosystem patch (i.e. each spatial record)

AMOUNT_PA: Total hectare within a protected area boundary

AMOUNT_TAR: Total number of hectares for a particular type of ecosystem (i.e. total hectares of all patches combined)

PERC_T_PA: Of all the ecosystems in this Protected Area, this percentage has the same conservation action class as this record. For example, if for a hypothetical record the protected area name was "Deep River" and the ecosystem name was "mangroves" and the conservation action class (EMC_TEXT field) was "Maintain Effective Conservation" and the value in this field were "10" you would read the explanation this way: 10 percent of the mangroves in the "Deep River" protected area have the conservation action class "Maintain Effective Conservation."

PERC_TAR: Based on the entire study area, this percentage is the percent of each ecosystem that falls within this protected area and has the same conservation action class. For example, if for a hypothetical record the protected area name was "Deep River" and the ecosystem name was "mangroves" and the conservation action class (EMC_TEXT field) was “Maintain Effective Conservation” and the value in this field were “10,” you would read the explanation this way: 10 percent of the mangroves in the study area fall within the “Deep River” protected area and have the conservation action class “Maintain Effective Conservation.”

PERC_PA: This is the percentage of this ecosystem within this protected area to the total amount of this ecosystem within the study area. For example, if for a hypothetical record the protected area name was “Deep River” and the ecosystem name was “mangroves” and the conservation action class (EMC_TEXT field) was “Maintain Effective Conservation” and the value in this field were “10” you would read the explanation this way: 10 percent of all mangroves in the study area are within the “Deep River” Protected area.

PERC_SA: This is the percentage of all ecosystems in the input data layers that have the same conservation action class as this record. For example, if for a hypothetical record the protected area name was “Deep River” and the ecosystem name was “mangroves” and the conservation action class (EMC_TEXT field) was “Maintain Effective Conservation” and the value in this field were “10,” you would read the explanation this way: 10 percent of all the ecosystems in the input data layer in the study area have the conservation action class “Maintain Effective Conservation.” Note that if you input your ecosystems as separate data layers (for example not merged or you are using the batch tool), this statistic will have less meaning, and may have the same value as the PERC_SA_T value below (i.e. if every input data had only one ecosystem per ecosystem input).

PERC_SA_T: This is the total percentage of each ecosystem contained within each conservation action class. For example, for a hypothetical record the protected area name was “Deep River” and the ecosystem name was “mangroves” and the conservation action class (EMC_TEXT field) was “Maintain Effective Conservation” and the value in this field were “10” you would read the explanation this way: 10 percent of the mangroves in the study area have the conservation action class “Maintain Effective Conservation.”

2. **Output Summary File** – This file is a dissolved version of the raw output file (i.e. using the ecosystem field as the dissolve item), summarizing the total amounts of

Attributes of mar_beaches_ear_output_Summary

FID	Shape *	TARGETNAME	EMC_VALUE	EMC_TEXT	SUM_AMOUNT	PERC_SA_T
0	Polygon	Beach	1	Maintain Effective Conservation	1016.418896	7.690249
1	Polygon	Beach	2	Improve Biodiversity	1571.290722	11.888423
2	Polygon	Beach	3	Abate Threats	233.071932	1.763428
3	Polygon	Beach	4	Implement Better Management	1383.432227	10.467081
4	Polygon	Beach	5	Improve Biodiversity and Abate Threats	1083.087346	8.194664
5	Polygon	Beach	6	Abate Threats and Implement Better Management	883.742494	6.686416
6	Polygon	Beach	7	Improve Biodiversity and Implement Better Management	5543.936117	41.945551
7	Polygon	Beach	8	No Status	1502.002721	11.364188

Record: 1 Show: All Selected Records (0 out of 8 Selected) Options

SUM_AMOUNT: The total hectares of the conservation action class for that particular ecosystem.

PERC_SA_T: This is the total percentage of each ecosystem contained within each conservation action class (same field as in the raw output file).

3. **Output Summary by Protected Area Management Score** – This output file contains summary information for each ecosystem and the total hectares and percentages by management score (e.g. VG, G, F, P) that fall within each conservation action class. Below is an example of the attribute table and description of relevant fields:

Attributes of merge_test_Summary_by_PA

TARGETNAME	MANAGEMENT	AMOUNT	PERC_PA	C1	C1_PERC	C2	C2_PERC	C3	C3_PERC	C4	C4_PERC	C5	C5_PERC	C6	C6_PERC	C7	C7_PERC	C8	C8_PERC
Beach		8907.891828	67.4	0	0	0	0	0	0	1222.6	13.73	0	0	829.449	9.31	5394.8	60.56	1460.9	16.4
Beach	F	16.124739	0.12	0	0	0	0	0	0	0	0	0	0	0	0	16.124	100	0	0
Beach	G	1859.584378	14.07	605.04	32.54	950.22	51.1	127.35	6.85	0	0	176.95	9.52	0	0	0	0	0	0
Beach	P	389.096992	2.94	0	0	0	0	0	0	160.82	41.33	0	0	54.2932	13.95	132.96	34.17	41.021	10.54
Beach	VG	2044.284517	15.47	411.37	20.12	621.06	30.38	105.71	5.17	0	0	906.13	44.33	0	0	0	0	0	0
Bird Nest		8846.279563	48.16	0	0	0	0	0	0	2491.1	28.16	0	0	1501.06	16.97	3911.6	44.22	1431.3	16.18
Bird Nest	G	2519.553078	13.72	788.78	31.31	1243.6	49.36	191.56	7.6	0	0	314.11	12.47	0	0	0	0	0	0
Bird Nest	P	1302.148838	7.09	0	0	0	0	0	0	628.23	48.25	0	0	0	0	673.91	51.75	0	0

Record: 1 Show: All Selected Records (0 out of 18 Selected) Options

AMOUNT: Total hectares for each ecosystem by protected area management score

PERC_PA: Percentage for each ecosystem that lies within each protected area management score

C1: Total hectares of the ecosystem for each management score that lies within the conservation action class: Maintain Effective Conservation

C1_PERC: Percentage of the ecosystem for each management score that lies within the conservation action class: Maintain Effective Conservation

The remaining fields follow each of the conservation action classes in the following order, reporting hectare totals and percentages by ecosystem for each of the four protected area management scores:

C2 Improve Viability
C3 Abate Threats
C4 Implement Better Management
C5 Improve Viability and Abate Threats
C6 Abate Threats and Implement Better Management
C7 Improve Viability and Implement Better Management
C8 No Status (No acceptable levels on any of the 3 measures)

An example of the kind of output the tool can produce using data from the Mesoamerican Reef, can be seen in Figure 6 where mangrove ecosystem and the protected area data have been used as inputs. The EAR tool computes eight conservation action classes based on the intersection of the ecosystem and protected area data and their corresponding viability, threat, and management scores (see Table 1). For each of the three measures, scores of "Good" and "Very Good" were chosen as the acceptable threshold. Using these types of output, conservation decision-makers can visually assess the eight conservation action classes for mangroves and tabulate the total number of hectares that are "effectively conserved," or in other words, mangrove patches that have acceptable levels of viability and management and low levels of threats. This type of information can be used to determine the most cost-effective actions to add additional hectares into the effective conservation action class. If a decision-maker's goal is to have 10% of all mangroves *effectively conserved*, and there are only 8% currently in that class, an additional 2% must be identified that can most efficiently be brought into the effective conservation action class. A manager may decide that investing in improving protected area management may be the most cost-effective method to gain the additional 2%, so efforts may be directed at the mangrove hectares that exhibit adequate viability, low threats, but poor management. Conversely, if a manager wants to invest in abating threats, he/she may direct efforts towards mangrove hectares that have good viability, adequate management, but unacceptable threat levels.

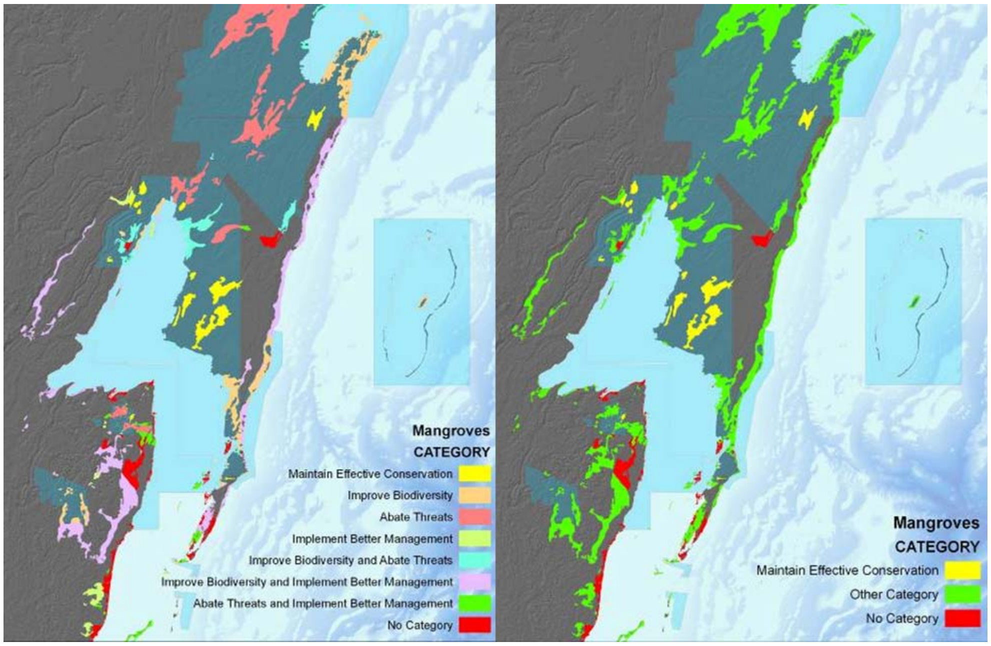


Figure 6. EAR tool output of Mangrove ecosystems and the protected area data for the Mesoamerican Reef. The tool was used to compute the eight conservation action classes based on the intersection of the ecosystem and protected area data and their corresponding viability, threat, and management scores (see Table 1). The right map shows collapsed categories of the same data.

4.2.1 Graphs and Reporting

In addition to the three output GIS files, the EAR tool produces a series of graphs and reports that provide further insight and support to conservation decision-makers. These graphs and reports provide in-depth ecosystem comparisons between conservation action classes and protected area management scores. Figure 7 shows an example of the types of graph that can be produced for each of the ecosystems. The pie chart shows the breakdown of each conservation action class by ecosystem. The user can toggle between ecosystems charts and hover above each pie slice to view the total hectares and percentages by class.

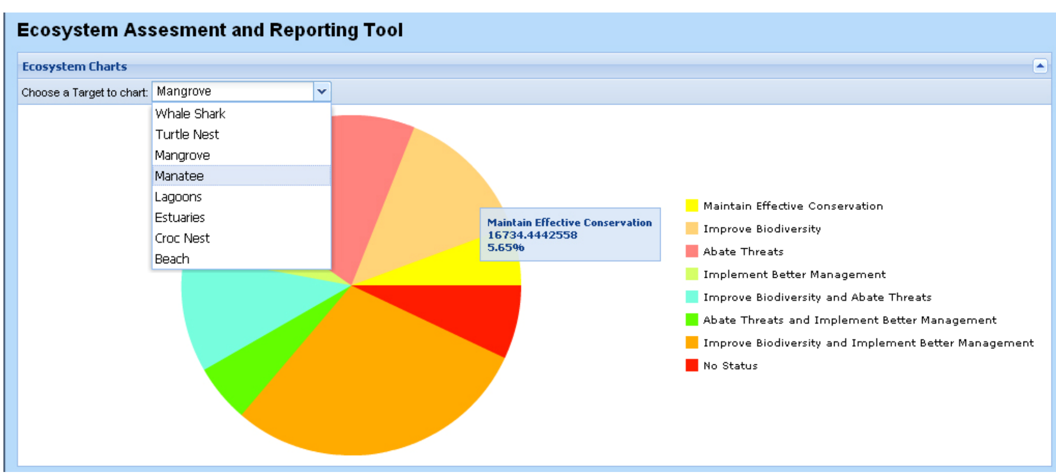


Figure 7. Ecosystem pie chart showing conservation action class percentages.

In addition to the graphs, users can create and print out a variety of reports that cross tabulate a variety of indicators that serve multiple functions. The types of reports include:

1. Ecosystem Report (Figure 8) – this report lists each ecosystem that was included in the analysis along with the breakdown of each conservation action class hectares and percentage by protected area listing. The report includes the following headers, each listing is grouped by ecosystem:

Protected Area:	Name of the protected area as listed in the protected area
Amount:	Total hectares by protected area
Percentage:	Percentage of the ecosystem within the protected area
EC:	Total hectares of the ecosystem within the protected area that are in the conservation action class "Maintain Effective Conservation"
EC%:	Percentage of the ecosystem within the protected area that are in the conservation action class "Maintain Effective Conservation"

Ecosystem Report

Protected Area	Amount	Perc...	EC	EC%	C1	C1%	C2	C2%	C3	C3%	C4	C4%	C5	C5%	C6	C6%	C7	C7%
Mangrove																		
Arrecife de Puerto Morelos	400.0	0.1	0.0	0.0 %	400.0	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Arrecifes de Sian Ka'An	0.0	0.0	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Bahia de Santo Tomas	686.2	0.2	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	686.2	100....	0.0	0.0 %
Barras de Cuero y Salado	1679.8	0.4	774.7	46.1 %	905.1	53.9 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Block 127	101.4	0.0	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	101.4	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Cerro San Gil	274.9	0.1	0.0	0.0 %	274.9	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Cerros Maya	0.6	0.0	0.0	0.0 %	0.0	0.0 %	0.6	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Corozal Bay	28034.0	6.9	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	868.3	3.1 %	0.0	0.0 %	27165.7	96.9 %	0.0	0.0 %	0.0	0.0 %
Gales Point	0.1	0.0	0.0	0.0 %	0.0	0.0 %	0.1	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Monkey Caye	18.3	0.0	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	18.3	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Not Protected	189347.2	46.3	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	11523.3	6.1 %	0.0	0.0 %	64494.4	34.1 %	97384.7	51.4 %	15944.9	8.4 %
Payne's Creek	76.8	0.0	76.8	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Port Honduras	36059.2	8.8	36059.2	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Punta de Manabique	48396.9	11.8	0.0	0.0 %	48396.9	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Punta Izopo	1208.9	0.3	0.0	0.0 %	1208.9	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Punta Sal (Jeanet Kawas)	5552.2	1.4	0.0	0.0 %	898.5	16.2 %	0.0	0.0 %	0.0	0.0 %	4653.8	83.8 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Rio Sarstun	375.6	0.1	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	375.6	100....	0.0	0.0 %
Santuario del Manati	79099.0	19.3	681.0	0.9 %	0.0	0.0 %	78418.0	99.1 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Sarstoon-Temash	351.8	0.1	0.0	0.0 %	351.8	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Sian Ka'An	13254.7	3.2	8597.0	64.9 %	0.0	0.0 %	1033.0	7.8 %	0.0	0.0 %	3624.8	27.4 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Swallow Caye	856.8	0.2	0.0	0.0 %	0.0	0.0 %	856.8	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Tulum	0.2	0.0	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.2	100....	0.0	0.0 %
Yum Balam	3137.7	0.8	3137.7	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
(23 Targets)	408912.6	100.0	49326.4	411.8 ...	52436.1	570.1 ...	80308.5	406.9 ...	12511.4	209.2 ...	8278.5	211.2 ...	91660.1	131.0 ...	98446.7	351.4 ...	15944.9	

Figure 8. Ecosystem report listing total hectares of each ecosystem within each protected area in each of the conservation action classes.

The remaining report headers are the remaining conservation action classes in the following order, reporting hectare totals and percentages of the ecosystem within each protected area:

C1	Improve Viability
C2	Abate Threats

C3	Implement Better Management
C4	Improve Viability and Abate Threats
C5	Abate Threats and Implement Better Management
C6	Improve Viability and Implement Better Management
C7	No Status (No acceptable levels on any of the 3 measures)

2. Protected Area Report (Figure 9) – this report lists each protected area that was included in the analysis along with the breakdown of each ecosystem within the protected area boundaries and the associated conservation action class hectares and percentages. The report includes the following headers, each listing is grouped by protected area:

Ecosystem:	Name of the ecosystem as listed in the ecosystem data
Amount:	Total hectares of the ecosystem within the protected area
Percentage:	Percentage of the ecosystem within the protected area
EC:	Total hectares of the ecosystem within the protected area that are in the conservation action class "Maintain Effective Conservation"
EC%:	Percentage of the ecosystem within the protected area that are in the conservation action class "Maintain Effective Conservation"

Protected Area Report

Target	Amount	Perc...	EC	EC%	C1	C1%	C2	C2%	C3	C3%	C4	C4%	C5	C5%	C6	C6%	C7	C7%
Arrecife de Puerto Morelos																		
Beach	18.7	0.1	0.0	0.0 %	18.6	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Estuaries	400.0	0.1	0.0	0.0 %	400.0	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Mangrove	34.4	0.0	0.0	0.0 %	34.4	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Turtle Nest	84.1	0.1	0.0	0.0 %	64.2	76.3 %	0.0	0.0 %	0.0	0.0 %	21.4	25.4 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
(4 Targets)	537.3	0.4	0.0	0.0 %	517.3	376....	0.0	0.0 %	0.0	0.0 %	21.4	25.5 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Arrecifes de Cozumel																		
Beach	3.5	0.0	0.0	0.0 %	3.5	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Croc Nest	131.0	1.3	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	131.0	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Lagoons	0.8	0.0	0.0	0.0 %	0.8	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Mangrove	4.2	0.0	0.0	0.0 %	4.2	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Turtle Nest	1040.8	1.8	0.0	0.0 %	669.3	64.3 %	0.0	0.0 %	0.0	0.0 %	371.5	35.7 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
(5 Targets)	1180.3	3.1	0.0	0.0 %	677.8	364....	0.0	0.0 %	0.0	0.0 %	502.5	135....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Arrecifes de Sian Ka'An																		
Croc Nest	57.8	0.6	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	57.8	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Estuaries	0.0	0.0	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Lagoons	995.6	1.1	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	995.6	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Turtle Nest	37.0	0.1	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	37.0	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
Whale Shark	1270.7	1.0	1270.7	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %
(5 Targets)	2361.1	2.8	1270.7	100....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %	1090.4	400....	0.0	0.0 %	0.0	0.0 %	0.0	0.0 %

Figure 9. Protected Area report listing total hectares of each ecosystem within each protected area in each of the conservation action classes.

The remaining report headers are the remaining conservation action classes in the following order, reporting hectare totals and percentages of the ecosystem within each protected area:

C1 Improve Viability
C2 Abate Threats
C3 Implement Better Management
C4 Improve Viability and Abate Threats
C5 Abate Threats and Implement Better Management
C6 Improve Viability and Implement Better Management
C7 No Status (No acceptable levels on any of the 3 measures)

4.2.2 Implementation

When making decisions regarding implementation of conservation strategies or prioritization of resources to certain areas, understanding the current viability status, threat level, and conservation management status of each ecosystem is critical. Conservation decision-makers are continually seeking more dynamic methods for addressing questions such as

a) Where is biodiversity reasonably secure and expected to persist within each ecosystem?
b) Where are the gaps in effective management of these ecosystems?
c) Where are there opportunities to expand and enhance biodiversity protection?

These questions require not only solid base data, but advanced GIS processing and reporting functions in order to calculate, map, and report conditions back to the user. In summary, the EAR tool enables conservation decision makers to:

a) **Calculate, query, visualize, and report the *effective conservation* status of each ecosystem, including the other seven conservation action classes.** This involves the integration of ecosystem, threat, and protected area GIS data through the use of the EAR tool that is available as a stand-alone GIS tool or through the internet using ArcGIS Server.

b) **Use model results to identify and have the information needed to prioritize geographic areas in order to achieve conservation goals at multiple scales.** With often limited resources, conservation decision-makers need to know the value of proposed actions before opportunities for protection or treatment arise. This tool provides conservation decision-makers a better understanding of the obstacles that they will face in working to achieve conservation goals across a landscape before implementing conservation actions.

5. Lessons learned, problems and viable solutions

Throughout this project, several questions were raised concerning the use and integration of the EAR tool with other Thematic Networks (TNs). Here is a summary of the questions that came up and the corresponding responses:

1. The tool is already integrated with the Ecosystems and Protected Areas TN, but is it going to be integrated with the Species/Specimens TN and the Invasive Species (I3N)?

   As long as the TNs support the Web Map Service (WMS)/Web Feature Service (WFS) standard, the EAR tool will be able to integrate with these portals, however since the tool operates using overlay analysis, these data need to be spatially explicit (not just a table with x, y coords, but actual WFS-served feature datasets). Users can upload GIS files for processing using the internet version of the tool. There is also a function to add WMS/WFS layer where geographic data from each TN overlaps. During development of the tool, a limited number of WMS/WFS layers were available for testing from the different TNs, however as more WMS/WFS layers come online, this functionality will prove valuable for cross-TN investigations. In summary, here is a brief description of the differences between WMS and WFS:

   Web Map Service (WMS) provides a simple HTTP interface for requesting georegistered map images from one or more distributed geospatial databases. These requests define the geographic layer(s) and area of interest and a georegistered map images is returned and displayed in a browser application. No feature datasets are brought across the internet - only the generated map image is retrieved.

   Web Feature Service (WFS) allows the tool to retrieve the actual geographic features across the Web using platform-independent calls. This standard defines interfaces and operations for data access and manipulation on a set of geographic features. Although it may be slow (depending on the connection) our tool will have the ability to call on geographic features from different WFS platforms to run the overlay analysis and generate a report.

2. Does the tool comply with IABIN standards?

   The tool fully complies with IABIN standards (i.e. serves up data in WMS/WFS). In addition, our data model uses additional fields to answer questions such as:
   - Which ecosystems are least protected?
   - Of these ecosystems, where do we need to improve management?
   - Where are the opportunities to most efficiently reduce threats to these ecosystems?

   These types of questions require consistent, non-bias data that is uniform across geographic space. For this reason the Ecosystems and Protected Areas TNs are appropriate datasets to use since both are developed using standards and common fields. The Management Effectiveness (ME) indicators that have been used in the two pilot areas have used a methodology developed by The Nature Conservancy. Work continues on the World Database on Protected Areas (WDPA) to include a management effectiveness field that could be used in the EAR tool. While this measure has not yet been fully developed, it is in development for future releases. Adding this field will greatly benefit future users of the tool who may not have the necessary management data to derive measure themselves. In the meantime, users of the tool will be able to employ the TNC method, or their own, so the tool is flexible and not dependent on a certain methodology. Until this type of information in available in WDPA, users must enter their own information regarding management effectiveness. This can be down by cross-walking Protected Area Management Effectiveness survey data to pre-defined criteria and classes and computing an overall score. Additional future efforts might include developing a crosswalk of Darwin or Plinian Core data to match the fields used by the EAR tool (e.g. viability, threat, CMS), where relevant.

3. Why is this tool so focused on ESRI software (e.g. ArcGIS Server/Explorer)?

   ESRI software does not limit its ability to integrate with other portals. In fact, the new version of ArcGIS Server greatly expands the ability to be more compatible with other portals that use these standards and a variety of others. Actually the only part of the tool that uses ArcGIS Server is the geoprocessing that occurs on the remote server, so the user will not know (or need to know) that ArcGIS Server is being used. They can input their data using WFS (or other standards like GML) and they receive back the data as a WMS feed.

6. Brief description of how to make the database continues to grow after the completion of the project

TNC has a vested interest in continuing to develop and support the EAR tool because it serves an important role in measuring conservation progress and evaluating effective strategies to take action. Similar to the Protected Area Tools (PAT) for ArcGIS which was developed with IABIN funding, the EAR tool will continue to be enhanced and supported as new version of ArcGIS are released. PAT version 1.0 was released in 2006 for ArcGIS 9.1 and has since undergone two major revisions (version 2.0 and 3.0 each working with ArcGIS 9.2 and 9.3, respectively) with added functionality support. These suite of tools have been downloaded by hundreds of users from around the world and is supporting national ecological gap assessments and helping to shape conservation agendas. These types of tool are essential to build much-needed technical capacity, help inform decision-making at all levels of management, and advance conservation action where it is needed. In simple terms, these tools empower decision-makers to make better, more informed decisions, and consequently achieve better conservation results.

In summary, the EAR tool will continue to grow under the following guidelines:

1. TNC continues to provides updates and technical support as new versions of ArcGIS are released.
2. All IABIN Thematic Network databases follow the IABIN standard and supply their datasets as WMS/WFS layers.
3. PATN develops a management effectiveness field in WDPA that can be used as the MANGEMENT field in the EAR tool
4. Ecosystem viability and threat information becomes more readily available through TNC ecoregional assessments and other national and local ecological investigations.

In summary, the EAR tool will provide conservation decision-makers a valuable and easy-to-use method for considering priorities and measuring progress of conservation activities and goals. This tool will assist users in determining which ecosystems are at most risk, what threats need to be abated, and where management activities need to improve. Ultimately, it is hoped that the EAR tool will assist decision-makers in the IABIN network to more effectively gauge progress towards improving the viability of ecosystems, abating critical threats, and securing appropriate management status for ecosystems.

7. Relevant Literature

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8. Funds (attach a spending report counterpart Excel table)

9. Financial Report (attach a spending report in Excel table)

10. Appendices