

# Belize Marine Science in action



Newsletter of Conservation International's Marine Management Area Science Program

## Welcome to the Marine Management Area Science Program

**P**EOPLE DEPEND ON nature for sustaining our lives. Modern societies lose sight of that fact, but one consequence of global climate change is a renaissance in understanding the importance of our environment for our future. Now all sectors of human enterprise are actively engaged in the growing challenges of resource availability, environmental quality and ecological services.

The Marine Management Area Science Program (MMAS) is an important contribution to the solution. Effective management of ocean places has long been hindered by open access policies and ignorance of the consequences of unsustainable use and waste. The vision of the MMAS Program is to provide the scientific tools for a return to a prosperous ocean through a

**The vision of the Marine Management Area Science Program is to provide the scientific tools for a return to a prosperous ocean through a consolidated strategy of research and practice for achieving management goals.**

consolidated strategy of research and practice for achieving management goals.

The trends of decline in marine resources and ocean quality have to be reversed. In this periodical you will learn about the work of an outstanding group of scientists and conservationists that are on that mission. The ocean can get better if we take care of it. Under the leadership of Dr. Leah Bunce, who heads the program at Conservation International, and Dr. Les Kaufman, (Boston University) the Chair of our Science Advisory Committee, partnering with over 100 scientists and field practitioners from around the world, the MMAS Program is helping us to do just that. ♣

Roger McManus, Vice President for Marine Programs, Conservation International

The Belize Barrier Reef forms a major portion of the broader Mesoamerican Reef system and is recognized for its globally significant biodiversity through its World Heritage Site status. The marine and coastal ecosystems here represent the highest coral reef biodiversity in the Western Caribbean and contain notable endemic and red-listed marine species as well as a variety of patch reefs, atolls, rhomboid reefs, faroes and over a thousand mangrove cayes. Photo: Ilka Feller.

## The Vision of the Marine Management Area Science Program

ONE OF THE most exciting aspects of the MMAS Program is the challenge of drawing together data of so many types, from so many sites, and distilling it into new best practices for marine conservation. This process is made easier by the overall structure of the MMAS Program as a global network of MMA observatories. We use the network somewhat the way that astronomers combine starlight from multiple telescopes, enabling them to see more clearly and farther through time. Our mission, a bit different, is to measure the benefits of local management efforts in a world of rapid global change. To meet the challenging complexity of this enterprise, we employ four complementary approaches.

First, we use parallel field experiments. The MMAS Program works in four places around the world tropics where area management (aka marine zoning) is in effect, affording us a set of experimental treatments from absolute no-take areas, to open access. We then gather primary data on ecological and social parameters in these areas under distinct management regimes, and the difference in their trajectories over time provide a measure of local management effects. Enforcement varies over time, and this, too, can be taken into account. By comparing sites in different oceans, we can take stock of factors most important on a local scale, or common among MMA's around the world.

Second, our network is designed to remove the effects of noise from variables

that are not management-related, thus heightening our sensitivity to management effects. This means putting the several stations in any region near versus far from shore, in the best and the worst areas for coral reef, seagrass, or mangrove development. This is called a covariance design. In Belize, for example, we have inshore and offshore stations, placed in regions of both

good and poor coral reef growth, plus one oceanic site. By factoring out site idiosyncrasies, we can compare the efficacy of management across diverse sites without suffering the apple vs. orange problem.

Our third strategy is dynamic modeling. Modeling is a way to draw together all we know to anticipate the likely outcomes of alternative policies. Modeling produces new insights into system dynamics, and decision tools to help managers cope with tough choices. The MMAS Program has recently joined up with the Gund Institute's MIMES (Multiscale Integrated Modeling of Ecosystem Services) project to accelerate the development of advanced models of use in the coastal zones of tropical developing

These basic studies fill out our work under our six program themes: management effectiveness, connectivity, resiliency, economic and cultural valuation, conservation and economic development, and enforcement.

nations. Our first generation decision tool, MIDAS (Marine Integrated Decision Analysis System) is in development now.

Our final strategy is to push the limits of our knowledge of the ecosystem and society, to come up with better ways to assess the health of both. We have recruited methods ranging from comparative socioeconomics to traditional species surveys to advanced genomics as we build our new



The MMAS Program primarily works in four priority areas (red stars): Fiji, Eastern Tropical Pacific Seascape (specifically Coiba, Panama and Galapagos, Ecuador), Belize and Abrolhos, Brazil. Smaller studies with global impacts are being conducted in Bahamas, Hawaii, Philippines, Phoenix Islands and Sri Lanka (yellow stars).

diagnostic toolkits. These basic studies fill out our work under our six program themes: management effectiveness, connectivity, resiliency, economic and cultural valuation, conservation and economic development, and enforcement.

The MMAS Program is halfway through its initial funding phase. As we move into high gear the view is thrilling, but now we have to keep the momentum going. Our next big challenge is to enrich the dialogue between the scientists manning our observatory network, and the societies they serve. A generation of students has been taught that science isn't science until it is published. For us, it isn't science until it is used. 🌐

Les Kaufman, Senior Scientist

## Ecological Monitoring in Belize's Marine Managed Areas

**CORAL REEFS** THROUGHOUT the world are in decline; however, the factors contributing to this decline are poorly understood. There is a need for good descriptive data on coral reef conditions over long periods of time and across large spatial scales, and for experimental manipulations that can elucidate the effects marine managed areas (MMAs). MMAs are an increasingly popular form of ecosystem-based management with goals of preserving biologically-threatened or economically-important habitats by mediating human activities within defined areas. Since the management practices for each MMA are in essence an experimental manipulation, they create a useful opportunity both to monitor the status of marine resources and to understand the degree to which the management of local human impacts can improve ecosystem integrity. Monitoring reveals the health of coral reefs in Belize's developing MMA network, but monitoring comparatively, inside and outside of MMAs helps to illuminate the determinants of this health and causal agents in reef decline so that something can be done about it.

The primary objective of the Ecological Monitoring Program supported by the MMAS Program and led by Dr. Les

The primary objective of the Ecological Monitoring Program is to help provide a framework for long-term monitoring of the Belize reef system in cooperation with local management agencies.

Kaufman and Burton Shank at Boston University is to help jump-start standardized monitoring in Belize and to provide a framework for long-term monitoring of the Belize reef system in cooperation with local management agencies. To incorporate the variety of reef habitats present in the Belize

address the efficacy of MPA no-take zones as well as to record the status of the reefs within the study area. Thus, we can study fishing effects in each area, separate fishing effects from other environmental stresses and observe the scale of over which important ecological processes occur.

The monitoring program divides effort between the repeated sampling of permanent transects to track specific portions of the reef over time and randomized surveying of representative habitats to enable generalization of reef dynamics. Methods are based on standardized monitoring protocols (*i.e.* MBRS, AGRRA) with added emphasis on pertinent variables like commercial fishes and coral diseases. Sampling is generally constrained to habitats common to all study areas, to maximize comparability among sites in Belize, and between Belize and the three other nodes in the global MMAS Program network of comparative sites (Brazil,

Panama, Fiji).

The monitoring team of Belizean biologists and students from the University of Belize have completed a total of five field seasons between the summer of 2006 and 2008. To date, six biologists have



Biologists with the ecological monitoring team work their transects. Detailed data is collected on the state of plants and animals inside and outside of marine reserves to characterize sites and determine the effects of management actions. Photo: Burton Shank.

reef system, the primary focus of monitoring efforts is in five managed areas: Half Moon Caye Natural Monument, Southwater Caye Marine Reserve, Laughing Bird Caye National Park, the Sapodilla Cayes Marine Reserve, and the Port Honduras Marine Reserve. Sampling involves periodically acquiring monitoring data from each area with a methodology designed to

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### Ecological Monitoring in Belize's Marine Managed Areas

fully-participated in one or more sampling seasons and another nine biologists received training in monitoring techniques and participated in field work for shorter periods of time. Fifty-two permanent transects spread across the five sites have been deployed and most have been re-sampled multiple times. The team has also completed 158 randomized surveys, plus fish, commercial fish, and coral disease surveys associated with the permanent sites.

Early results are enlightening. Coral cover is highest at Half Moon and Laughing Bird Caye but for very different reasons. It appears that reefs at Half Moon Natural Monument have been slower to decline and maintain modest density of large coral colonies. Conversely, reefs at Laughing Bird National Park have declined in recent years but are in a state of recovery with many small coral colonies and high coral recruitment. Actual coral cover at Glovers Atoll, Southwater Caye, Sapodillas, and Port Honduras are statistically similar despite the very different environments in which these reefs are situated. Laughing Bird, a lagoonal system, has the highest coral recruitment

but Port Honduras, the other lagoonal study area, has the lowest coral recruitment. At all locations, many of the coral recruits are members of the genus *Agaricia* and, with the exception of *A. tenuifolia*, species of *Agaricia* typically don't create robust, topographically-complex reefs. Essentially all areas, with the possible exception of Laughing Bird, are suffering from a recruitment failure of the larger, reef-forming coral species. *A. tenuifolia* itself exhibited a massive die-back in the last major bleaching event, and is only now showing modest signs of recovery.

There are also interesting differences in reef structure within study areas attributable to water circulation patterns and wave exposure. Most striking is the gradient in reef structure evident in the Sapodilla Cayes with the eastern reef slope being most similar to other portions of the barrier reef but the western reef slope exhibiting characteristics of lagoonal reefs like Laughing Bird, including smaller coral colonies and higher coral recruitment.

All of this suggests that each study area is unique and may require management plans specific to an area rather than a one-size-fits-all management protocol applicable across the entire reef system.

Underway now is an in-depth analysis of our collected data. This includes:

1. Characterizing individual protected area effects
2. Designing optimum monitoring plans for each MPA
3. Examining geographic variations in the relationship between herbivorous fishes and macroalgal cover
4. Examining geographic patterns in coral disease infection and severity

The next field sampling is scheduled for the summer of 2009 with hopes of resampling all permanent sites and completing the targeted number of randomized surveys for all of our study sites. Beyond this, the goal is to demonstrate to management bodies the utility of an effective, actively adaptive monitoring experiment in Belize, and the added value of linking Belize to partners conducting parallel management experiments around the globe. We are searching for further sources of funding and interested members of our partner organizations in Belize. Our goal is for this program to help galvanize Belize's ability to understand what governs the health of its nearshore marine resources and a key component of that goal is understanding the effectiveness of its marine protected areas. 🌐

## The Bridge Between People and the Environment



The living marine resources of Belize remain an important source of income to local fishers and a life associated with the sea is still a strong cultural tradition.

**M**ARINE MANAGEMENT AREAS (MMAs) are used throughout the globe to manage human impacts on the marine environment by controlling fishing pressure, reducing user conflicts, and promoting compatible marine recreational activities. The establishment of a MMA is often accompanied by extensive surveying of marine habitat conditions before and after MMA establishment. It is much less often accompanied by surveying the socioeconomic conditions of the peoples and communities being impacted by these MMAs. Information on the health of coral

reef and other coastal resources are usually scant with data on how people interact with those resources or what those resources are worth to local communities. Conservation International understands the need to bridge this gap. The MMAS Program is therefore supporting a socio-economic and governance monitoring study in five countries, including Belize.

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**The Bridge between People and the Environment**

### **Why Study People?**

In 2006, the MMAS Program partnered with local government and non-government organizations to implement a study seeking to understand the socioeconomic and governance effects of MMAs in Belize in relation to their impact on factors such as human development, quality of life and livelihoods, environmental awareness, stakeholder participation, and policy enforcement. This study is led by in-country principal investigators, Adele Catzim and Diane Haylock of the Belize ISIS Enterprises Ltd.

In Belize, the socio-economic and governance study focuses on human behavior associated with five MMA sites. The five sites are comprised of three marine reserves and two national monuments. The three marine reserves are Southwater Caye Marine Reserve, Sapodilla Cayes Marine Reserve and the Port Honduras Marine Reserve. The national monuments are the Lighthouse Reef National Monument and the Laughing Bird Caye National Park.

Information is being collected from resource users along the coast with a total of twelve local communities covered in the study. The Belizean researchers have collected information on governance characteristics from MMA management agencies as well as directly from local communities. Similarly, socio-economic data has been collected from local communities as well as from official government sources.

### **The Socio-Economic and Governance Survey**

A socio-economic survey was administered in a random sample of 1,341 households during the months of May, June and July, 2008. The sample size was weighted using statistical methodologies to reflect the entire population (over 14 years) in each of the twelve communities. The results of the survey can therefore be generalized to a total of 14,916 households across the twelve communities.

**A key finding is that 10% of respondents report that their income is 100% dependent on marine related activity, primarily fishing. These and other similar results will help policy makers and stakeholders to have a more comprehensive picture of the socio-economic and governance conditions that impact the five MMA sites in Belize.**

The survey captured socio-economic and governance information on: 1) quality of dwelling and household facilities, 2) migration patterns, 3) household sources of income, 4) characteristics of household head, 5) resource use patterns, 6) non-monetary benefits of MMAs, 7) local values and beliefs about marine resources, 8) level of understanding of the human impact on resources, 9) information dissemination and 10) socio-economic benefit to communities. Data from this socio-economic and governance survey is currently being analyzed.

### **A Snapshot of the Findings**

Preliminary data shows that 28.6% of the population (over the age of fourteen use marine resources within at least one of the five MMA sites being studied. Another

50.2% use marine resources outside the five MMA sites. The data also shows that resource users for all five MMA sites come from multiple communities situated all along the coast, not just those in close proximity to a particular MMA site.

Another key finding is that 10% of respondents report that their income is 100% dependent on marine related activity, primarily fishing. A total of 7% indicate that their income is partially dependent on marine related activities. The study will focus on the extent to which the establishment of the MMAs accounts for this decrease in dependence on marine resources as a primary source of income.

Furthermore, the survey shows that almost two-thirds of the respondents have positive attitude towards protecting the marine environment and have a moderate to high level of understanding of the human impact on the environment.

One-third of the respondents reported that they had received information about the MMAs from the agencies responsible for site management. Those who understood the information indicated that it has helped them to change the way they access and use marine resources.

### **How the Results Will Be Used**

These and other similar results will help MMA policy makers and stakeholders to have a more comprehensive picture of the socio-economic and governance conditions that impact and are impacted by the five MMA sites in Belize. Policy makers can take an evidence-based approach to planning for greater integration of the marine protected areas system with local communities. MMA management agencies can use the data to reshape their management plans and focus their efforts in research, information sharing, community outreach and enhanced livelihoods.

### **The Next Steps**

Analysis of the data will continue and results will be shared with Government, Non-Government Organizations and communities by the end of December, 2008. A final report will be completed by March, 2009. ▲

## Science to Action

ON JUNE 6<sup>TH</sup>, 2007, the Marine Management Area Science (MMAS) Program held its first Science to Action meeting in Belize bringing together the 12 MMAS Program researchers and 17 national and regional representatives from government, environmental non-governmental organizations and academia. The meeting provided a unique opportunity for the stakeholders to meet with the MMAS Program researchers and discuss ways to ensure the research results contribute to definitive, positive changes in how marine management areas are managed in Belize and MesoAmerica. As Lindsay Garbutt, the Coordinator of the MMAS Program—Belize, with years of experience in marine conservation noted, “This is the first time that a project of this scope, involving both the social and natural sciences, has been attempted in Belize. It is also the first time that such attention has been given to avoiding duplication, build capacity of local agencies, and develop each activity from the ground up with strong stakeholder input.”

During the meeting the stakeholders discussed the range of studies, including the cultural and economic valuation, ecological and socioeconomic monitoring, grouper and snapper habitat analysis, and conch genetic connectivity study. Stakeholders felt the results would be instrumental in numerous ways, including: demonstrating the benefits, as well as challenges of managed areas and identifying and mapping critical habitats for protection of commercially important species. The participants also identified communication mechanisms for the studies based on regular communication with stakeholders throughout the research and dissemination of results in user-friendly formats with clear recommendations.

This meeting reflected the project’s commitment to involving stakeholders at all levels to ensure not only the success of the program but to ensure that the actual scientific results and findings lead to clear policy changes. ●



Regional and local stakeholders and MMAS researchers assembled in Belize City to discuss anticipated conservation impacts of MMAS research projects and identify requirements for turning results into action.

## Habitat Mapping and Exploration in Central Belize

THE INTER-REEFAL HABITAT Mapping project, funded by the Marine Management Area Science (MMAS) Program, is focused on mapping selected subtidal portions of shoreline and barrier reef platform areas in Belize found within a complex maze of connected coral reef, mangrove, sea grass, soft-bottom and river plume environments. The research results are intended to provide Belize’s resource managers and policy-makers with more complete data and maps allowing for a deeper understanding of the marine coastal environments to help guide management actions.

The components of this mega-habitat lying among the coral reefs have largely been absent from direct marine conservation activities. These habitats, however, are known to

be sites of significant biodiversity and rare species. It is noteworthy that many non-emergent reefs occur in these areas and the complex mosaic as a whole supports interconnected coastal ecosystems.

The main objectives of this study lead by Dr. Phil Lobel of Boston University are 1) to determine the level at which subtly different inter-reefal environments can be discriminated using sidescan sonar and in so doing assess the range of habitats occurring in the Belize inter-reefal areas and 2) to map several specific target areas using multiple methods to facilitate more detailed work in future investigations. Effective scientific mapping is an essential first step for targeted research and subsequent resource management. The use of advanced side scan sonar,

acoustic Doppler topographic mapping and other survey devices should yield interesting results that can eventually be coupled to the use of Remotely Operated Vehicles (ROV) and video survey cameras.

The managed areas that are the focus for the duration of this particular project are Southwater Cay Marine Reserve, Gladden Spit Marine Reserve and the Sapodilla Cays Marine Reserve. All of these reserves contain large areas of inter-reefal habitats within their boundaries that are still not surveyed or assessed. The team has completed the first field tests for mapping inter-reefal habitats. The current plan is to continue mapping in the spring and summer of 2009. A COBRA-TAC underwater diver navigation and mapping device and side-scan sonar profile mapping system are currently in use after considering these technology’s abilities to map extensive geographic areas. COBRA-TAC is a good tool

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## Are all Conch Populations Connected?

There is very little known about the DNA sequences of snails and sea slugs, which makes investigating the population genetics and dispersal history very challenging.

**T**HE QUEEN CONCH, *Strombus gigas*, is an excellent organism for studying the degree of connectivity among marine populations. Like many marine organisms, its primary mode of dispersal is as planktonic larvae, which are carried by currents and settle, when possible, into their preferred habitat. This dispersal strategy has two potential impacts: first, if a species exists as one big, but patchy, freely mixing population, with local extinction and recolonization, then dispersal rates are needed to predict “metapopulation” dynamics, especially the proportion of available sites inhabited by the species at a particular time. Second, the rate of dispersal and mixing among populations affects the degree to which populations are genetically structured, *i.e.*, how genetically similar or different they are from one another. Dispersal, of course,

is also relevant to conservation, as the rate that a population will recover after intense fishing pressure is dependent partly on how many new individuals come into the area.

In Belize, little is known with regard to the relative importance of dispersal and self-recruitment to its conch populations, and clearly the rates of these processes relate to conch population stability over time. To investigate this, Drs. Richard Kliman and John Cigliano of Cedar Crest College have begun a study to obtain preliminary estimates of genetic population structure in queen conch in Belize. They have focused their efforts on conch at three locations: the Sapodilla Cayes, the Port Honduras Marine Reserve, and Turneffe Atoll. Approximately fifty adults from these locations were sampled, along with seven milk conch (*Strombus costatus*, one of the closest known relatives

to queen conch). They have sequenced a section of the mitochondrial *COI* gene, and found that individuals, on average, differ at about 0.5% of the bases in this segment of DNA. There is no evidence of population structure at this gene. Individuals from different locations (or collected in different years) are no more diverged than are individuals from the same location.

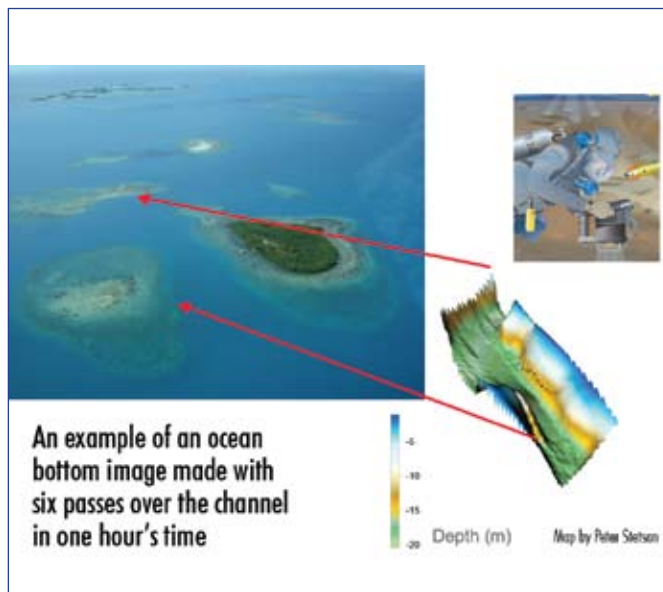
One might conclude from these data that dispersal rates have, historically, been high enough to effectively thoroughly mix conch populations. However, some caution is required as the team has only looked at one gene, and in a fairly small sample. Because mitochondria are inherited only from females, dispersal of males does not influence these data. It is generally not wise to overinterpret data from a single gene. Second, the absence of genetic population structure does not mean that populations are currently dispersing among each other. Even if populations were no longer demographically connected, past dispersal could have prevented the formation of genetic population structure.

There is very little known about the DNA sequences of snails and sea slugs, which makes investigating the population genetics and dispersal history very challenging, so in order to better assess genetic population structure, we need to study more genes. To this end, the team is sequencing approximately 50 million base pairs of the queen conch genome, using a “next-generation” DNA sequencer at Duke University. This will put the team in a position to identify suitable candidate genes for further population genetic analysis.

Ultimately, if population structure is detected, the team can build the data set to estimate ongoing rates of dispersal. While this should not be confused with dispersal over short (current) time scales, it will tell us about the potential for conch to “get around” the western Caribbean. Drs. Kliman and Cigliano are also investigating other approaches to estimate larval dispersal rates, such as elemental analysis of larval shells and will be sharing all their results with the University of Belize, the Dept. of Fisheries and marine resource managers. ▲

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for rapidly mapping small-scale shallow underwater areas and generating low resolution bathymetric maps. Interesting features identified in the acoustic mapping surveys are surveyed by divers in order to describe the biota and to assess if any species of concern are present. Species of concern include Red List species (e.g., *Acropora* spp.), groupers, snappers, conch, and yet not described species. ▲



## Predicting the Future in Belize

**O**VER THE PAST TWO years an interactive decision support tool called MIDAS (Marine Integrated Decision Analysis System) has been developed with the MMAS Program support to predict hypothetical outcomes in marine managed areas (MMAs). The predicted outcomes produced by MIDAS are based on critical ecological, socio-economic and governance factors. Two versions of MIDAS are presently in use; the first is a generic model that is currently being tested for 15 MMAs across the globe; the second model was prototyped for Belize.

The MIDAS model for Belize is a spatial decision support system software designed to support managers of MMAs and policy makers in the decision-making process. This interactive and user-friendly tool is designed to assist users to understand the interplay of critical determining factors (CDFs) for the success of an MMA so that they can plan accordingly. The tool is designed to estimate the likely effects of MMAs based on the available ecological, governance and social data built into it. Managers and stakeholders can explore different what-if scenarios to gain an understanding of the natural constraints and trade offs amongst the CDFs. The outcomes are displayed in the form of interactive charts and a risk map that are currently modeling six MMAs:

1. Lighthouse Reef at Blue Hole and Half Moon Caye Natural Monuments
2. South Water Caye Marine Reserve
3. Laughing Bird Caye National Park
4. Sapodilla Cays Marine Reserve
5. Port Honduras Marine Reserve
6. Hol Chan Marine Reserve

The model is being developed by Dr. Suchi Gopal at Boston University.



Technical working group on governance evaluates MIDAS during the workshop in August 2008. Left to right: Kirah Forman and Miguel Alamilla, Department of Fisheries/Hol Chan Marine Reserve; Jack Nightingale, SEA; and Yvette Alonzo, Association Protected Area Management Organizations.  
Photo: Suchi Gopal.

MMA Effect	Indicator variable
<b>State of governance</b>	Stakeholder involvement
	Stakeholder compliance with rules and regulations
	Management operations
	Empowerment
	Support from government agencies
<b>Livelihoods</b>	Perceived threat level
	Perception of quality of resource conditions
	Enhanced livelihoods/alternative income-generating activities
	Socioeconomic benefits from MMA establishment
	Local seafood availability
<b>Ecosystem health</b>	Level of fishing pressure
	Relative change in habitat extent
	Habitat quality
	Herbivory
	Focal species abundance

Dr. Gopal, a spatial analysis and modeling expert, has led two stakeholder consultation workshops in Belize City in March and August 2008. A great deal of interest and motivation was raised during these two MIDAS workshops which pulled together a diverse group of MMA stakeholders. Participants have included the Department of Fisheries, Department of Forestry, the National Protected Area Commission, the University of Belize, ISIS, and non-government organizations like SEA, FON, Wildlife Conservation Society, Association of Protected Areas Management Organizations, TIDE, the Belize Audobon Society and the Healthy Reefs Initiative.

Each workshop has allowed Dr. Gopal to interact with users and validate the utility of MIDAS through demonstrations and hands-on use. It also provided valuable user feedback on design, functionality and application of MIDAS leading to recent improvements.

As a tool MIDAS has great potential to help MMA practitioners demonstrate the likely effects of existing and new MMAs and will enable professionals working in existing MMAs to determine the relative value of alternative management strategies and, therefore, how they should most effectively focus their resources. ▲

## Cultural Roles Related to Marine Management Areas in Belize

**A**LL CONSERVATION ACTIVITIES are based on human values, and all public and private sector decisions related to conservation issues are human values-based decisions. It is not possible to describe or explain human behavior related to marine managed areas (MMAs) anywhere in the world, including Belize, without understanding the basic human cultural values, attitudes and perspectives that govern behavior with respect to MMA environments and resources. Although the role of culture is clearly considered an important driver of conservation, most of the literature on MMAs focuses on biophysical or economic aspects of conservation.

A team of researchers, including Dr. Joseph Palacio (independent consultant), Noella Gray and Michael Orbach (Duke University), is undertaking this project to 1) incorporate basic cultural science data into the characterization of MMAs, and 2) construct the framework for the on-going cultural data collection necessary for the effective monitoring of the outcomes of the MMAs. More specifically, the objective of the cultural roles project is to describe the human cultures, cultural contexts, cultural values and cultural roles related to Laughing Bird Caye National Park and the Gladden Spit and Silk Cayes Marine Reserve.

Data collection for this project is now complete. The researchers conducted a total of fourteen months of fieldwork in three communities: Placencia, Hopkins, and Sarteneja. Each of these communities

use the two MMAs to varying degrees, primarily for fishing and tourism activities. Fieldwork included participant observation (of fishing and tourism activities, community meetings, and other local events), but relied mostly on interviews with key informants in the three villages. More than 120 interviews were conducted with a range of stakeholders, including fishers (full-time and part-time, current and retired), members and representatives of several producers' co-operatives, government officials, tour guides, tour operators, staff of non-governmental organizations (NGOs), MMA enforcement officers, members of various community organizations, and others.

The results of the project will discuss several key themes related to cultural values and roles in the MMAs. These include: 1) a description of community structure and organizations in the three villages; 2) history and description of fishing in the villages—including fishers, gear, species, locations, seasons, and markets; 3) changes in the villages associated with the MMAs; 4) relationships between the villages and the MMAs management process; and 5) the effects of the rise of the tourism industry.

Having made an assessment of a wide range of topics and stakeholder perspectives this project will be able to analyze the range of cultural impacts, values, and roles associated with these MMAs. The research team looks forward to presenting the results of the work to the MMA communities in Belize to help improve future MMA management strategies. ▲

**A**DULT FISH POPULATIONS of important commercial species are profoundly dependent upon the survival of their earliest life history stages. Mortality of these stages is extremely high even under optimal natural conditions. When mortality is increased by the loss or degradation of important nursery habitats required by settling larvae and maturing juveniles, the long-term impacts upon adult stock sizes can be severe. Unfortunately, the critical nursery habitats are typically in the shallow, near-shore areas that are most subject to local direct and indirect human impacts.

There are few data available in Belize and along the Mesoamerican Barrier Reef that informs us of what habitats are the most important to commercial species during their first three years of life. This is due to the lack of comprehensive sampling of the different habitats thought to be important to the target species. Another limitation may be that many of the habitats used by the different early life stages of the target species are not fully known.

Dr. Leandra Cho-Ricketts of the University of Belize and Dr. Les Kaufman of Boston University are soon to begin

collaborative work supported by MMAS to sample coastal habitats to identify larval settlement and juvenile nursery areas for select grouper and snapper species. They will also use stable isotope analysis to determine the primary migration corridors across the coastal shelf for these early life stages. This information will be useful in informing management actions to preserve the habitats most critical to species' population survival and a sustained fishery product.

The sheer diversity of marine habitats found along the coast of Belize highlights the importance of the need for “hands on” management and conservation of the reef, especially in regards to the fisheries and tourism industries that depend on this resource. Beginning in 2009 this study will provide a foundation of

information on settlement, juvenile habitat usage and fundamental early life history strategies that will have direct applications to marine management, policy interventions, local stakeholder initiatives, and future applied research projects. Tools and communication products for decision-makers and the lay-public will be developed. ▲



### Where Do the Small Fish Go?

## Fostering Sustainable Marine Tourism

**I**NAPPROPRIATE ACTIONS BY tourists—walking on coral, feeding the wildlife, eating threatened seafood species, and buying illegal souvenirs made from threatened species—pose a significant threat to coastal and marine ecosystems. Marine recreation operators can play a pivotal role in correcting this behavior by influencing how tourists interact with their destination, as they manage the interchange between the tourist, the local environment, and the local culture.

The Mesoamerican Reef Tourism Initiative (MARTI)—an alliance of Conservation International (CI), Coral Reef Alliance (CORAL) and Amigos de Sian Ka'an—has been working with marine recreation operators that provide services to the cruise industry in Belize and Cozumel, Mexico to minimize their footprint by adopting environmental good practices. CORAL and CI's joint *Sustainable Marine Recreation Environmental Walk-Through* program (based on the regional ICRAN MAR standards for marine recreation) is providing on-going technical assistance and training to help marine operators integrate environmental practices into their day-to-day operations.

In December 2007, MARTI partnered with the Healthy Reefs for Healthy People's Initiative to conduct a one-year visitor impact study. Their work is to evaluate the extent to which on-going environmental best operating practices for the marine recreation sector influence observed tourism-related impacts on coral reefs visited by tourists from cruise ships and the overnight sector. The aim is to help tourism leaders and resource managers understand the types of direct tourist impacts on reefs, and the effectiveness of voluntary codes of conduct and environmental business practices for protecting coral reefs from visitor impacts. The results of this study will help tourism stakeholders make informed decisions about management of visitation in the most popular marine recreation sites.

The study has three components: (i) basic ecological indicator surveys conducted at the beginning and end of the project, using the AGRRRA coral reef assessment protocol, (ii) coral condition studies using the "Bar Drop" method to assess physical impacts, and (iii) ongoing visitor behavior surveys. Study sites include a handful of highly and moderately used marine recreation sites near Belize City, San Pedro Ambergris Caye and Placencia as well as control sites in each of these locations. Control sites with little/no tourism activity will help assess the extent of other non-tourist related damages that may occur, such as bleaching events or storm damage.

To date, full ecological assessments have been conducted in 12 sites, and 84 visitor behavior surveys have been carried out in 8 marine recreation sites. Preliminary findings will be presented at Belize's International Year of the Reef Symposium. The study will wrap up near April 2009 at which time MARTI and HRI, in collaboration with the Belize Tourism Board and the Ministry of Tourism, will present research findings to tourism stakeholders and the broader conservation community. 🌐

## Gladden Spit Marine Reserve Demonstrates Large Economic Benefits

other marine managed areas and the results will be of relevance to policy makers, MMA managers, local communities and academics. Venetia Hargreaves-Allen (Centre for Environmental Policy Imperial College London), the lead principal investigator for this study has worked with Friends of Nature from the outset, to involve key stakeholders and local communities by keeping them up to date with results and progress. In the process, two Belizeans were trained in survey methodology to enable them to assist in data collection.

The fieldwork is complete and included key informant interviews, focus group discussions and household surveys of fishers, visitors, non-visitors, and tour operators. In addition, local fish buying surveys and fishing characterizations and landings surveys were conducted.

**A**S PART OF THE MMAS Program work in Belize, the economic valuation study will determine the economic value of the marine ecosystems within the Gladden Spit marine reserve. This will be the first study of this kind in Belize as the methods developed will serve as a template for economic valuations in

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## Modeling the Dispersal of Larval Fish from SPAGS

**T**HERE IS A growing global interest in having information and management tools to prevent and reverse the decline of the ocean's living resources. Most management and conservation strategies in the sea are hampered, however, by untested assumptions about the degree to which populations are connected and thereby being replenished from near and far sources of recruits. Direct measurements of marine population connectivity are a huge challenge because larvae can spend days to months in the open ocean before finding suitable habitat to begin adult life. Larvae, therefore, have the potential to travel far from their birthplace along unknown pathways and without fundamental information on larval dispersal, it is very difficult to effectively manage human impacts on marine populations.

The MMAS Program is in discussions now with scientists from Woods Hole Oceanographic Institution and the University of Miami who are proposing to develop a high resolution coupled biophysical model to predict the movement of larvae of coral reef organisms using Glovers Reef, Belize as a

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### *Gladden Spit Marine Reserve Demonstrates Economic Benefits*

Initial results show that tourists have high use (associated with visiting the area) and non-use values (simply knowing that these areas exist and will be passed onto the next generation) for this MMA of on average over US\$100 per individual. The whale shark tourism and the spawning aggregations are seen to add significant value to this reserve. The results also show that people coming to Belize would be willing to increase fees to raise money for marine managed areas. Local people also have significant values for these areas, not only through fishing and tourism, but also as part of their heritage. The final analyses are underway and are expected to be ready in early 2009. The Fisheries Department of Belize is acknowledged for their support to this research. ▲



Venetia Hargreaves-Allen collects data in the village of Monkey River in order to document the economic value of marine reserves and natural phenomenon like spawning aggregations to national and local economies.

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### *Modeling the Dispersal of Larval Fish from SPAGS*

study site. The model will allow researchers to account for bathymetric and open ocean influences on currents, temperature and salinity in the vicinity of Glovers Reef. These processes will then be accounted for when modeling the dispersal of larval coral reef fishes and invertebrates (and can have direct application to predicting the movement of spawn from the Nassau grouper aggregations). Ultimately, this research will generate a scientific foundation for the application of spatially explicit approaches to the conservation and sustainable management of coral reef fisheries.

The expectation is that the proposed model will advance the ability to link the pathway of local production of larvae to juveniles settled back into their natal habitats. This is perhaps the best way to demonstrate the benefits and importance of protection efforts at the larger community level. This study should begin in early 2009 and researchers will be in contact with local resource managers as the idea develops further.

This proposed project is one in a cluster of projects funded by the MMAS Program dedicated to population connectivity studies. The others are examining population structure in queen conch in Belize, connectivity among the islands of Fiji, population structure in important reef building corals in the Pacific, and the spatial recruitment dynamics of fish replenishment areas in Kona, Hawaii. The modeling study proposed here is also part of a cluster of four studies on aggregate spawners, including threatened and endangered food fishes, in Belize. The other three are an exploration of inter-reefal habitats, research on habitat connectivity through ontogeny of snapper and grouper, and ecotourism effects on spawning aggregation behavior. ▲

## Spawning Aggregations and Ecotourism

**T**HE SPAWNING AGGREGATIONS of fish are some of the most spectacular and important phenomena that take place on coral reefs. Most large and commercially important reef fish species aggregate each year in specific times and places, in order to spawn. Some fish migrate hundreds of miles in order to participate and the aggregations can include hundreds to thousands of individuals. These spawning rituals serve as the genetic mixing point for fish and are key sources of larvae for the re-population of large areas of the reef. As dramatic and predictable as these spawning aggregations are, they have attracted the attention of commercial fishers and are harvested heavily—sometimes to the point of extirpation. Indeed, the majority of the known Nassau grouper spawning aggregation sites in the Caribbean have been fished down to the point that they no longer occur. Spawning aggregation sites are in desperate need of conservation and management worldwide.

Belize has been proactive in protecting its spawning aggregations, having declared 11 no-take marine reserves to protect multi-species spawning aggregations in 2002, and a closed season Nassau Grouper during their breeding months. Spawning aggregations of snappers and some groupers are still relatively healthy in Belize. The best-known example is at Gladden Spit, where Cubera and Dog snappers aggregate to spawn and whale sharks congregate to feed on the eggs in April and May each year. Tourists arrive in large numbers to witness this spectacular event. The tourism industry can provide an economic alternative to fishing on vulnerable spawning aggregations and a regular presence that can deter illegal fishing. But the possible negative effects of tourism must be evaluated and mitigated, in order to ensure that the tourism can be sustainable.

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## Looking Globally at MMA Effects

**THE RESEARCHERS SUPPORTED** by the MMAS Program from the WorldFish Center, University of Connecticut (Dr. Robert Pomeroy and Tammy Campson) and the Perry Institute of Marine Science (Dr. Craig Dahlgren) are hard at work on a study of global-scale that will include lessons learned from Belize's internationally recognized system of marine protected areas. Titled the Global Management Effectiveness (GME) Study, this project investigates what effects marine managed areas (MMAs) have had on both people and ecosystems, and what factors are seen to be critical in generating those effects. The preliminary results from eight MMAs are based on an extensive review of literature, key information interviews and household surveys in twenty-four villages linked to the eight MMAs around the world. Preliminary analysis of data collected from respondents associated with these eight MMAs, indicates increases in perceived levels of livelihoods, food security and conflict resolutions.

These outcomes can be explained by several factors such as the existence of community organizations to facilitate stakeholder engagement and clear leadership to promote the MMA concept as well as oversee its implementation. For example, community organizations have played a critical role in MMA establishment and enforcement. The perception that benefits were equitable and that these benefits exceeded costs were also key factors for successful MMAs. For example, the various user groups felt there were clear rules that ensured generally equitable restrictions and benefits, which exceeded the costs.

Over the next few months, the research team will be conducting the GME study household surveys in Belizean coastal communities. We look forward to learning more about what drives MMA success in Belize and to learn if the assessment of the factors impacting MMA outcomes are the same, or different, from their MMA counterparts globally. This study will help to feed into the National Protected Areas Policy and System Plan and strengthen and expand knowledge of Cultural Roles and its importance to proper management of MMAs in Belize. ▲

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*Spawning Aggregations and Ecotourism*

With support from the MMAS Program, Dr. Will Heyman from Texas A&M University and Dr. Phil Lobel from Boston University, are evaluating the effects of ecotourism on reef fish spawning aggregations in Belize. They hope to provide an initial assessment of the potential impacts of divers on fish behavior at spawning aggregations, and provide recommendations for future management to the Dept. of Fisheries, Friends of Nature and Belize Audubon Society. Understanding that there is great variability between the responses of different species and at different times, our initial focus is on Cubera snappers and Nassau grouper.

The first expedition research expedition took place in May 2008 at Gladden Spit and the second will take place in Lighthouse Reef Atoll in February 2009. The scientists are using controlled experiments and video cameras and underwater microphones to record the behavioral response of fishes to various types of disturbance. Our initial studies are focusing on the disturbances created by the presence of divers with or without bubbles, and the sounds of boats and engines. Scientific and outreach materials will be shared as they become available and will be disseminated to the appropriate target audiences. ▲

**The Marine Management Area Science Program provides scientific answers to questions concerning the management of marine managed areas. The program has four major outcomes:**

- assess the effects of MMAs
- conduct research to improve effectiveness
- build in-country capacity
- translate the science into conservation action



Founded in 1987, Conservation International believes that the Earth's natural heritage must be maintained if future generations are to thrive spiritually, culturally, and economically. Our mission is to conserve the Earth's living heritage and demonstrate that human societies are able to live harmoniously with nature.

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