PROJECT FOR THE CONSERVATION OF MARINE RESOURCES

IN CENTRAL AMERICA

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Support for the assessment of systems of physical and biological indicators implemeted in MCPA.

FINAL REPORT

January 2014

TECHNICAL REPORT (Product 1 and 2)

Analytical summary of available information on mangrove and seagrass data from protected areas & Proposal for establishing the baseline for seagrass and mangrove area cover

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INTRODUCTION & BACKGROUND

This report was prepared as part of a consultancy in the framework of the project "Conservation of Marine Resources in Central America" (total volume: € 6.3 million, thereof € 5 million from KfW). This project aims to support best management practices and community participation in the conservation and sustainable use of coastal and marine resources in the initial network of protected areas within the Fund for the Mesoamerican Reef System (MAR Fund).

The following Marine and Coastal Priority Protected Areas (MCPAs) are the main investment areas for the project.

1. Yum Balam Protection Area for Flora and Fauna, Mexico
2. Port Honduras Marine Reserve, Belize
3. Punta de Manabique Wildlife Refuge, Guatemala
4. Sandy Bay-West End Special Protection Area, Honduras

In the first phase of this project, particularly the following technical aspect needs to be addressed:

Development of a method to establish the baseline for measurement of the two key indicators expected from the main objective of the logical framework, i.e.

a) The seagrass meadow area in the four MCPAs should exhibit a same or larger size relative to the baseline
b) The mangrove forest area in the four MCPAs should exhibit a same or larger size relative to the baseline

These two overarching objective indicators (General) are impact indicators and are used to measure the overall positive impact in each area through the implementation of the project. The baseline for each area and for each of the two ecosystem engineers (mangrove forests and seagrass meadows) should be assessed in order to generate initial data sets that could be used as a temporal reference to evaluate the success of the project.

In the fifth year of the project, there will be a second monitoring exercise to measure the achievement of the indicators established. The primary evaluation point will be relative seagrass and mangrove cover over the baseline established in 2013.

In the first months of 2013, preliminary consultancies took place in each of the four Marine and Coastal Priority Protected Areas (MCPA) of interest in order to bring together the existing information sources on the status of each of these target MCPAs. The related documents were received by the end of May 2013.

OBJECTIVES

Specific objectives of this consultative report are:

1) To summarize the available information about seagrass and mangrove coverage for the four MCPAs based on the preceding location-specific documents.
2) To propose a uniform, feasible and affordable (under the given limits) methodology to establish the baseline for seagrass and mangrove area cover in the four MCPAs.
3) To recommend a consultant or/and institution to be contracted for the work described in 2).
4) To formulate the terms of reference for the consultancy described in 3).

The subsequent sections of this report are structured along these four assignments.

METHODOLOGY

For assessment 1), firstly the four location-specific reports were translated (with the help of a Spanish native speaker), read and summarized (see annex). Secondly, information was extracted in order to generate summary tables (Tables 1 and 2). Thirdly, the quality, the character of information, and the methodologies described by the four reports were compared.

For assessment 2), extensive internet and literature research was carried out in order to find out what methodologies were used in similar projects. In addition, remote sensing experts were contacted, and several telephone exchange took place.

For assessment 3), subsequent communication took place with the remote sensing experts, thereby also discussing the specific requirements in the framework of the project. One specific company and two particular consultants (please see descriptions in annexes) proved to be the ideal solutions after these discussions and exchanges.

For assessment 4), the TYPSA template was used and modified based on assessments 2) and 3). This included further exchange with the consultants identified in assessment 3).

RESULTS AND DISCUSSION

Assignment 1) Analytical summary about available information

In the following, an analytical summary related on the key parameters of interest, relative seagrass and mangrove coverage as well as diversity, is given based on the information presented in the location-specific documents. Two summary tables (Tables 1 and 2) are used in order to compare a range of parameters between the four MCPAs in a homogenous way.

Generally, the reports about the MCPAs in Mexico and Guatemala are very informative and provide good and extensive background information about the specific MCPA status. The report about the MCPA in Belize is well written, but rather focused on methodology than on the ecological status and outcomes.

In contrast, the report about the MCPA in Honduras is difficult to read and understand. Its character is rather descriptive and anecdotic. It becomes not clear which methods have exactly been used in order to generate mangrove and seagrass cover.

In summary, it becomes clear from Table 1 and 2 that although there are lots of numbers available on mangrove and seagrass cover as well as diversity in the 4 MCPAs of interest, data are often highly variable depending on used methodology.

Quality of reports and resulting data are highly different, a fact that is also mainly based on the different methodologies used. The spectrum of different methodologies not only includes several remote sensing and GIS applications (Mexico and Guatemala), analyses of old datasets (Belize) and field monitoring tools (Honduras).

Data about mangrove coverage in general seem to be much more reliable than data about seagrass coverage due to turbidity problems reported from several MCPAs.

It becomes clear that in order to accurately assess comparative baseline seagrass and mangrove cover in all four MCPAs identical methods need be used. Such methods need to be adjusted to quantify seagrass cover despite the ongoing turbidity problems.

Table 1. Overview of available information concerning mangrove coverage and diversity.

MCPA	Total area (ha)	References	Time of info	Mangrovearea (ha) Revisar áreas	Mangrove diversity	Used methodology
Yum Balam, Mexico	154000	INEGI CONAFOR CONABIO Vázquez-Lule et al. DUMAC Unsupervised classification	2006-2010 2004-2009 2009 2009 2011 2009	14764 5694 8956 8838 5577 7625	-*Rhizophora mangle* -*Avicenniagerminans* -*Lagunculariaracemosa* -*Conocarpus erectus*	-Coverage analysis: remote sensing and GIS (Satellite images: SPOT5 images) Software: Erdas IMAGINE 2011 - Mapping generation and changes in surface: vectorial layers. Software: ArcMap 10
Port Honduras, Belize	40470	USF (University of SouthFlorida), CATHALAC	2012	715	Not available	- Data compilation: from pre-existing datasets by CATHALAC - For data extraction, geographical buffer was defined - Statistical analysis to estimate coverage area
Punta de Manabique, Guatemala	132900	MARN, PNUMA and CATHALAC	2012	17670 (Pacific area) 1169 (Atlantic area) 410 (Punta de Manabique)	- *Rhizophora mangle* - *Laguncularia racemosa* - *Avicenniagerminans* - *Conocarpus erectus*	- Use of photos and field verification - Coverage classification (image processing, geospatial analysis and remote sensing). Software: ERDAS IMAGINE
SandyBay, Honduras	2846	GIS-PMAIB Atlas of Coastal Marine Resources and Environmental Sensitivity Index	2000	2873 (throughout the island) 10 (within the protected area SandyBay)	- *Rizophora mangle L.* - *Avicenniagerminans L.* - *Laguncularia racemosa* - *Conocarpus erectus*	The methodology is focused on the monitoring of the seagrass meadows; not enough information is given about the method to calculate mangrove coverage

For mangroves, there seems to be a lot of information in the region (see Table 1), and it is possible to determine the extension of each area by satellite images. Remote sensing approaches have been widely proven to be essential in monitoring and mapping highly threatened mangrove ecosystems. Numerous studies have been successfully carried out around the globe and especially in the study area (e.g. FAO 2007, Eakin et al. 2010, Kuenzer 2011).

For sea grasses, there are difficulties in determining its extension, as not all satellite images are provided to measure this aspect, in part because like in Guatemala and Belize (please see above), the coastal and offshore waters have the characteristic of being very turbid due to strong sediment accumulation, so one can hardly detect sea grasses using

this type of images. Additionally, seagrasses may occur in water depths down to 40 m so that they potentially cannot be detected anymore.

Table 2. Overview of available information concerning seagrass coverage and diversity.

MCPA	Total area (ha)	References	Time of info	Seagrass area (ha)	Seagrass diversity	Used methodology
Yum Balam, Mexico	154000	INEGI CONAFOR CONABIO Vázquez-Lule et al. DUMAC Unsupervised classification	2011	13258 (marine zone) 11344 (lagoon zone)	*-Thalassiatestudinum* *-Syringodiumfiliforme* *-Halodulewrightii*	-Coverage analysis: supervised classification. Software: ArcMap - Mapping generation and changes in surface: SPOT5 multispectral images. Combination of remote sensing and visual interpretation (including radiometric, geometric, atmospheric and water column corrections)
Port Honduras, Belize	40470	USF (University of SouthFlorida), CATHALAC	2007	2987	Not Available	- Data compilation: 4 different sources (CZMU, CZMP, NPAPSP, TNC) - For data extraction: geographical buffer was defined - Statistical analysis to estimate coverage area
Punta de Manabique, Guatemala	100000	MARN, PNUMA and CATHALAC	2012	Not available	*- Thallassiatestudinum* *- Halophilabaillonii* *- Halophilaengelmannii* *- Halodulebeaudettei* *- Halodulewrigthii* *- Ruppia maritime*	- Field verification - Remote sensing using satelliteQuickbird images (multispectral images) - Map classification. Software: ArcMap - Image correction
SandyBay, Honduras	50000	GIS-PMAIB Atlas of Coastal Marine Resources and Environmental Sensitivity Index	2000 2001	205 517	*- Thallassiatestudinum* *- Syringodiumfiliforme* *- Halophiladecipiens* *- Halodulewrightii.*	The methodology is focused on monitoring of the seagrass meadows; not enough information is given about the method to calculate seagrass coverage

Assignment 2) Methodology proposal

I therefore propose a combination of remote sensing and GIS tools in order to set the baseline for both seagrass and mangrove cover in all four MCPAs using identical methodology. An integrated approach using existing field data and multi-spectral satellite data has proven successful and is suggested. The creation of accurate maps and baseline data of the MCPAs is a challenging task due to variable water clarity and water depths.

Based on the limited financial frame of the project (10.000 $ per MCPA), I recommend the following detailed methodology for the baseline assessment:

The use of Landsat 8 imagery, which is available cost free from the U.S. Geological Survey(USGS) agency since the beginning of 2013. The Landsat 8 is referred to as the Landsat Data Continuity Mission (LDCM) and will play a critical role in monitoring, understanding and managing the resources needed for human sustainment such as food, water and forests. The Operational Land Imager (OLI) onboard the satellite will measure in the visible, near infrared, and short wave infrared portions of the spectrum. The technical characteristics of the data imply the imagery to be appropriate for this project. Landsat LDCM offers a spatial resolution of 30m in the spectral-mode and 15m in the panchromatic mode. As the system is only available since the beginning of 2013, the availability of cloud-free data is uncertain. A data availability check on 2013-06-26 resulted that at the moment not enough adequate imagery, which has to be cloud-free and requires more or less calm sea, is currently on the USGS server. However, likely new appropriate satellite scenes will be recorded until the start of the project in autumn 2013. This will be checked in the beginning of the consultation. In order to guarantee adequate image data, a fallback solution will be the use of RapidEye data, which have a very good cost-performance ration. The spectral resolution is limited compared to Landsat LDCM, but the spatial resolution of 6.5m will compensate this issue. The constellation of five identical RapidEye satellites has the capability to collect 5 million km² of most current and high quality imagery every day. The extraordinary high revisit frequency of RapidEye allows the acquisition of cloud-free imagery of the investigation sites. In addition, cost-free L8 data will be available for the next years. Hence, the medium-term availability of adequate high-quality data could be the base of future monitoring activities.

In any case, Landsat LDCM data can be used for additional comparison and validation. The satellite imagery will be analyzed in combination with existing GIS and bathymetry data (if available).

Using higher resolution satellite imagery, like WorldView 2 or QuickBird 2 will not be feasible within this project, as the data costs exceed the financial frame of this project by far. However, this approach would be a precious asset and is recommended for a follow-on study. Alternatively, field validation of satellite data may be carried out using GPS-related existing monitoring data from the MCPAs where available (in this context see analytic summary on existing knowledge above). In order to guarantee optimal and reliable

results, MCPA managers should provide the latest available GIS-data of the sites and (GPS-) ground-truth measurements of the respective MCPAs to the consultants.

Accuracy assessment is usually conducted by selecting a sample of reference locations and comparing the classification at these reference locations to the reference data. The reference data is believed to accurately reflect the true ground cover. Reference data may be higher resolution remote sensing data, often maps derived by photo-interpretation or in the best case ground truth GPS-data. The area of sea grass and mangrove cover obtained directly from a map or a classification of satellite data probably differs from the true area because of classification errors. In order to effectively use remotely sensed data and reliably estimate the accuracy of a map, adequate, comparable ground reference data is required and appropriate accuracy analysis techniques must be applied. Here, to estimate the error of the classification maps we will use descriptive and statistical analytical techniques to present the accuracy. This will be an error matrix including user's, producer's and overall accuracy. In addition, kappa coefficient of agreement will be given. Kappa is often used as an overall measure of accuracy. Kappa purportedly incorporates an adjustment for "random allocation agreement".

As mentioned, MCPA managers should provide the latest available GIS-data of the sites and (GPS-) ground-truth measurements of the respective MCPAs to the consultants. We will have to rely on existing GPS-measurements. A validation campaign within this project would surely be an asset, but will not be feasible within the given budget, as considerable effort would be needed, i.e. design of a stratified sampling scheme, divers with GPS- and aquatic and coastal mapping expertise on all four sites. Such a campaign would be cost and time intensive. With additional financial support, ground- truthing within one exemplary region of interest would be suggested. The results may then be interpolated to other comparable MCPAs (only if the ecological characteristics and the phenotypes are similar).

Assignment 3) Draft formulation of terms of reference for the consultation

Establishing the baseline for seagrass and mangrove area cover in the four MCPAs

The main objective indicators are:

- Seagrass area in the project's MCPA equal to or greater than those of the baseline.
- Mangrove areas in the project's MCPA equal to or greater than those of the baseline

The proposed technical assistance performed by TYPSA includes support consultancies carried out by specific experts which cannot be met through the Permanent Expert's experience. This AOP to be approved by KfW has planned a consultancy for the baseline evaluation of seagrass and mangrove areal coverage in the four MCPAs.

Activities planned for this mission are detailed in item 10.

Methodology and Outcomes

The outcome of this consultation will be to provide baseline in all four areas, which will enable measurement of biological indicators under the main objective.

The consultant selected for the ATI mission will establish the baseline. This must be done in a uniform manner for the four areas to ensure future reproducibility and feasibility for implementation by each area.

The work of the mission will be carried out in close coordination with the technical staff of the MAR Fund's Executive Management, project leaders of the member of Member Funds and managers of the protected areas.

Expected outcome of this ITA (International Technical Assistance)
The expected outcomes of the ATI mission are:

Remote sensing-generated data on actual areal coverage of the four MCPAS with seagrass meadows and mangrove forests.

Specification of products and deliverables:

- The consultant will submit a draft report, comprising the major findings, data used and classification methodology according to the format which will be agreed upon with the project manager of MAR fund, in electronic and printed version during the final week of the consultancy. The draft report will be discussed prior to finalizing the consultancy. Each region will be described in a separate report and will include areal statistics.

- The final report in electronic and printed version, incorporating comments from the MAR fund project manager, will be submitted within two weeks after completing the assignment. (Final dates still to be discussed).

- Deliverables

- All original and processed / analyzed satellite data & scenes on CD-ROMs.

- All GIS objects / data files on CD-ROM

- Four seagrass and mangrove maps in A0 in digital form for each of the requested areas (UTM projection)(format to be discussed)

- Four maps of hot spots (to be discussed with the client) in A0 in digital form (UTM projection)

- If the client requests, printed maps might be delivered

The final deliverables will be discussed with the client prior to beginning the consultancy project.

ITA mission activities

The main activities to be performed during the mission will be:

1. Assessment of existing, related map/GIS-data of the four MCPAs (Mangrove extent, Seagrass coverage, Bathymetry) – to be provided by the client, where available
2. Determining the availability of GPS-related existing data on seagrass and mangrove cover data from the four MCPAs
3. Assessment of the availability of adequate Landsat LDCM imagery
4. Assessment of RapidEye data
5. Pre-Processing
6. Classification of remote sensing imagery
7. Integrated analysis of map/GIS-data and remote sensing imagery
8. Post-Processing
9. Accuracy assessment
10. Statistical analysis
11. Design of Seagrass/Mangrove result-maps of the four MCPAs
12. Report writing

Main sources of information and reference

- Landsat 8 imagery
- RapidEye imagery
- Existing mangrove/seagrass maps (to be provided by the client, where available)
- Existing bathymetry maps (to be provided by the client, where available)
- Existing ground truth GPS-measurements (to be provided by the client, where available)

Expert profile

For the performance of this mission, an expert with the following qualifications, characteristics and profile is required:

- Academic qualifications:
  - Professional university training, degree in biology, environmental science, marine science, environmental planning or related fields.
  - Studies in geographic information systems, advanced analysis of remote sensing data, forestry.
- Specific professional experience:
  - At least 10years of experience in professional services and advising on:
  - Studies and activities in marine environmental monitoring.
  - Consulting using geographic information systems and remote sensing data.

- Knowledge of issues and tools for the monitoring and evaluation of international cooperation projects.
- Teamwork experience, communication skills and the capacity to transfer knowledge to multidisciplinary teams.
- Preferably, expertise and experience in the area of intervention and relevant topics.
- Fluency in English, comprehension of Spanish.

Duration and timeline

The mission should be implemented from September until December 2013.

Report submission deadlines

The mission will have duration of about 42 days. The summary document providing the baseline information must be available no later than 31. December 2013.

Reports will be submitted in English in both printed (2 copies) and electronic (MS Word Office) versions and addressed to the TYPSA with a copy for the Executive Management of the MAR Fund, for their approval.In addition, all original and processed satellite data imagery as well as the GIS-data files will be delivered on CD-ROM.

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TECHNICAL REPORT (product 3)

Analytical summary of available information on existing biophysical monitoring in the investment areas of MAR fund project "Conservation of Marine Resources in Central America" & Proposal for additional indicators with methodology recommendations

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INTRODUCTION & BACKGROUND

This report was prepared as part of a consultancy in the framework of the project "Conservation of Marine Resources in Central America" (total volume: € 6.3 million, thereof € 5 million from KfW). This project aims to support best management practices and community participation in the conservation and sustainable use of coastal and marine resources in the initial network of protected areas within the Mesoamerican Reef Fund (MAR Fund).

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1. Yum Balam Protection Area for Flora and Fauna, Mexico
2. Port Honduras Marine Reserve, Belize
3. Punta de Manabique Wildlife Refuge, Guatemala
4. Sandy Bay-West End Special Marine Protection Zone, Honduras

OBJECTIVES

Main objectives of this consultancy were to get an overview of all existing biophysical monitoring activities and related protocols in all 4 MCPAs, to find out how this monitoring could be improved, and to make recommendations about priority of indicators and additional indicators that should be included in existing local monitoring measures and strategies.

Products of this consultancy are a summary document assessing the biological and physical monitoring carried out in all 4 MCPAs and a proposal for monitoring strategy improvements and additional indicators that should be included in the project's monitoring system in each MCPA. This document will include requirements for monitoring protocols of such additional recommended indicators.

METHODOLOGY

During the period November 3rd until November 16th 2013, a field mission to Central America was carried out. This involved a meeting in Guatemala on November 4th (interview with Ana Giró, the Healthy Reefs Initiative (HRI) Coordinator for Guatemala) and visits to the 3 MCPAs Port Honduras Marine Reserve, Belize (November 5th until November 7th), Sandy Bay West End Roatan, Honduras (November 8th until November 12th), and Yum Balam/Isla Holbox, Mexico (November 13th and November 14th).
In the course of the mission, many interviews and discussions with stakeholders from all 4 MCPAs involved in monitoring activities took place. In addition, all available technical reports in Spanish and English were considered.
The comprehensive resulting information was processed and summarized in product document 1. On the basis of this summary document, recommendations were drawn in product document 2.

As conceptual background documents, the IUCN publication "How is your MPA doing?" A Guidebook of Natural and Social Indicators for Evaluating Marine Protected Areas Management Effectiveness (IUCN 2004) and the paper of Pomeroy et al. (2005) with biophysical indicators presented therein were used in order to prepare the interviews and to get information for three major groups of indicators:

1) Water quality monitoring (i.e. nutrient concentration, light availability, pH, bacteria identification)
2) Benthic ecosystem (coral reefs, seagrass meadows, mangrove forests) health assessment
3) Monitoring of focal species (i.e. abundance, population structure, recruitment, connectivity)

RESULTS AND DISCUSSION

Product 1) Summary document of status of biophysical monitoring in the 4 MCPAs

Punta de Manabique Wildlife Refuge, Guatemala

It was very difficult to get any information about biophysical monitoring activities in MCPA Punta de Manabique in advance. The details of a contact person at this MCPA were also not provided. However, during the meeting on November 4th at MAR Fund offices in Guatemala City, Ana Giro Petersen, the Healthy Reefs Initiative coordinator for Guatemala mentioned two interesting measures: a) coral and fish surveys under her coordination (since: 2003; annually assessments) at 3 locations in Punta de Manabique in cooperation with the Healthy Reefs Initiative using Atlantic and Gulf Rapid Reef Assessment (AGRRA) and Meso-American Barrier Reef System Project (MBRS) methodology, and b) some water quality monitoring reflected in the assessment of spatial pesticide concentrations and inorganic nutrients coordinated by Allan Herrera from Center For Marine Research and Aquaculture (CEMA), Guatemala, within the project Monitoreo de Calidad de Agua, Proyecto DIGI. A. Herrera was asked for more information, but did not reply to any of several E-mail requests.

Additionally, connectivity coral and fish data were collected using the Targeted Research and Capacity Building for Management (CRTR) methodology in 2004 and 2005. CRTR is a global research and capacity building project that measures the connectivity of specific marine populations.

For the end of 2013, it is obviously planned to monitor 5 reef sites within Punta de Manabique for the first week of December using AGRRA methodology, but according to Ana Giro this needs to be done with partners, because there is a lack of sufficient funding.

Port Honduras Marine Reserve (PHMR), Belize

James Foley, science director at TIDE (Toledo Institute for Development and the Environment), Punta Gorda, that manages the MCPA Port Honduras, during several meetings and field trips on November 5-7th 2013 provided extensive information about local monitoring activities (see Foley 2013a&b). These include a) coral (including bleaching) and reef fish (including fish stock assessment) surveys using AGRRA and

MBRS methodology since 2006, b) some recent (since 2012) water quality monitoring in terms of assessment of inorganic nutrients (nitrate and phosphate water concentration measurements using a spectrophotometer in the TIDE laboratory); also some comprehensive information on water quality monitoring since 1997, c) assessment of sedimentation rates since 2011, d) focal species assessment including conch (since 2003), finfish, lobsters (since 2003), and recently also sea cucumbers (since 2011) and sea turtles (since 2011), e) assessment of mangrove leaf litter production (since 2011) and sea grasses using Seagrass Net standardized methodology (since 2009; please see: http://www.seagrassnet.org/seagrassnet-monitoring-summary). In addition, there seem to be some activities underway in order to reconstruct food web structures using stable isotope analyses.

According to Tanya Barona, the marine biologist at TIDE, all monitoring activities are designed to compare the situation between the No Take Area (NTA; 5 % of total PHMR areal coverage) and the rest of the PHMR area with the exception of mangrove leaf litter production that is only monitored in the NTA. Monitoring priority of TIDE clearly lies on the water quality monitoring that is conducted in high spatial (9 parallel distance transects, vertical resolution across the water column) and temporal (monthly sampling) resolution. Selection of other indicators is obviously driven by scientific questions.

Products of these monitoring activities so far have been summarized comprehensively only in internal technical reports (e.g. annual report for the TIDE Marine & Freshwater Monitoring Program, Final Report of the TIDE Fisheries Assessment 2009-2012), but not in bachelor/master theses or peer-reviewed publications, although this is obviously envisioned. According to information provided by James Foley, the research and development department of TIDE recently grew from 4 staff members in 2010 to now over 12 staff members, community researchers, research students and interns. Through the support of various donors (particularly the Oak Foundation and MAR Fund – please see Annual Work Plan for 2013 in the present KfW project), TIDE was able to set-up a small laboratory (Fig. 1) and to repair and modernize the essential infrastructure (particularly the jetty and the boats). Selection of research and monitoring activities is now driven by the Belize research priority program (please see: http://www.eriub.org/latest-news/the-national-environmental-and-nrm-research-agenda.html). Key aim of TIDE is involvement of local community and stakeholders (particularly fishermen) in monitoring activities. TIDE also supports outreach activities to the public including scholars. There seems to be some

cooperation with US, Canadian, and UK universities as reflected in the exchange of students that take place in monitoring activities at TIDE.

Fig. 1. James Foley, science director at TIDE, in the new basic laboratory.

Sandy Bay West End Special Marine Protection Zone, Honduras

An extensive discussion on November 9th with Gisselle Brady, coordinator of monitoring and research at Bay Islands Conservation Association (BICA), Roatan, and survey of available documents showed that the following monitoring programs exist:

1) Water quality monitoring since January 2013 divided into biophysical monitoring (water temperature, oxygen availability, pH, salinity using multiparameter probes and inorganic nutrients supported by analyses through external laboratories in San Pedro Sula (Laboratorios Jordan LAB) and microbiological assessments of bacteria (such as *E. coli* and Enterococci) indicating contamination via human feces (external analysis through

medicine laboratories on the island (Woods Medical Center, CoxenHole). The microbiological assessments have been introduced in order to control the proper function of sewage plants and to monitor uncontrolled discharge of waters from households that are not connected to local sewage plants.

2) Coral and reef fish surveys using AGRRA.

3) Post larvae of fish assessments using trap deployments (Fig. 2). This is obviously done with support of University of Miami, USA, MAR Fund, and ECOSUR, Mexico.

4) Inventory of flora and fauna in collaboration with the Centro Universitario Regional del LitoralAtlantico (CURLA), La Ceiba, Honduras.

There are obviously problems with the samples analyses and analyses of data due to the lack of a laboratory (just a store room with a microscope installed) and lack of up-to-date skills for proper scientific sample design and presentation of data at BICA, Roatan. Training and exchange with the other MCPAs would be beneficial in order to improve that.

The inorganic nutrient and microbiological sample analyses are apparently so expensive that replication of sample collection is very low, but in the near future priority locations will be sampled in a higher replication.

Fig. 2. Gisselle Brady from BICA Roatan demonstrating trap deployment for the fish post-larvae assessment.

The Marine Reserve is co-managed by BICA Roatan and Roatan Marine Park (RMP). Another meeting with Giacomo Palavicini from RMP on November 11th revealed that neither BICA Roatan nor RMP are doing any seagrass health monitoring so far. For mangrove health monitoring, both NGOs obviously recently received some training from Oregon State University (thereby using the CIFOR protocol by Kauffman & Donate 2012), but have not started to implement this monitoring. RMP has also started a small-scale reforestation initiative to culture mangroves from seeds to plant small trees particularly in deforested areas at Sandy Bay. This happens in coordination with local communities.

Both NGOs are doing reef health monitoring together (3 Southern stations in the focus of BICA, and three Northern stations in the focus of RMP; monitoring twice a year) using AGRRA, but raw data are then just send to the Healthy Reefs Initiative and then go into

the report cards as a combined “Roatan” info. Obviously, neither BICA Roatan nor RMP are so far able to analyze the data by themselves in order get site-specific information. Consequently, there is no site-specific information available.

Fig. 3. Giacomo Palavicini from RMP explaining ecosystem monitoring strategies at Sandy Bay West End Marine Reserve, Roatan, Honduras.

A discussion with Ian Drysdale, who is coordinating Roatan reef monitoring for the HRI together with his wife Jennifer Myton, confirmed this impression, but according to him soon AGRRA will provide open-access software for reef managers in order to analyze their data by their own. Ian Drysdale also mentioned that it would be beneficial for reef monitoring to include temperature logger deployment and sediment traps close to the reef monitoring sites in order to detect potential causes of bleaching and coral degradation.

Most interestingly, Ian Drysdale was also involved in mangrove monitoring at Roatan this year. This took place in the framework of the Sustainable Wetlands Adaptation and Mitigation Project (SWAMP) (http://www.cifor.org/swamp/home.html) that is carried out by CIFOR based in Indonesia, while the coordinator for the Central and South American sites, Dr. Rupesh Bhomia (E-mail: R.Bhomia@cgiar.org), is based at Department of Fisheries

and Wildlife at Oregon State University, USA. A standard procedure as detailed in Kauffmann & Donato (2012) was used. This methodology was implemented during the first sampling campaign, and local resource persons such as Ian Drysdale were trained in implementation of this protocol. After sample processing and analysis, a final report will be available sometime around late December.

Concerning monitoring of focal species, RMP wants to start monitoring of shark populations (mainly because this lies within the key expertise and interest of Giacomo Palavicini) using a methodology that has not been decided upon yet. Other species of potential interest are lionfishes, conch, and lobsters.

APFF Yum Balam, Mexico

There was almost no information available prior to the mission. A field trip with Jose Juan Pérez Ramirez, the CONANP manager of Yum Balam Protection Area for Flora and Fauna, and several long meetings during November 13th and 14th 2013 revealed the following existing biophysical monitoring activities:

a) Water quality monitoring

This was carried out every 1-2 months since ca. 6 years at 23 stations along the Isla Holbox coastline including inorganic nutrient measurements. Heavy metals, oil pollution, turbidity, salinity have not been included yet, but monitoring is envisioned. Monitoring of nutrients was done in collaboration with CINVESTAV (Merida) that analyzes the samples. Costs for analyses have been shared between CINVESTAV and CONANP. In the last two years, no samples were taken because of a lack in funding. Applied funding did not arrive yet. There are obviously some laboratory reports summarizing the data, but they have not been provided yet.

b) Ecosystem monitoring

Apparently, there are also some coral reefs located within Yum Balam. Monitoring of them at 5 sites was carried out by the NGO OCEANUS A.C. through Gabriela Nava and Miguel Angel Garcia, but detailed information (frequency, methodology,

data summary) on this reef monitoring were unfortunately not provided neither by CONANP nor by OCEANUS.

Seagrass monitoring did not take place yet, but is planned to be carried out starting in 2014 in collaboration with the Centro Investigacion Cientifica de Yucatan (CICY). Methodology is obviously not agreed upon yet, but collaboration with PRONATURA is planned using eventually 15 m^2 x 15 m^2 permanent quadrats within 500 m x 500 m patches and acoustic imaging.

Some mangrove monitoring started in 2013. Photographs using airplanes were taken in order to calculate aerial coverage. There seems to be some more detailed monitoring of mangrove health using quantification of leaf production, but methodology is not clear and no related documents were provided.

Fig. 4. Jose Juan Pérez Ramirez from CONANP discussing monitoring activities in Yum Balam.

c) Focal species monitoring

- Whale shark monitoring (together with National park Isla Contoy and The Whale Shark Biosphere Reserve; in collaboration also with the Georgia Aquarium, Atlanta, USA; some individuals were already marked with radio-sensors and identification along sex, fin length, skin patterns and colors using underwater photographs is planned).
- Turtle monitoring (includes green, hawksbill and loggerhead turtles) during nesting season between April and October and in parallel with the whale shark monitoring in collaboration with the NGO PRONATURA; carried out since 1988; seems to be very strong after a discussion with Dr. Eduardo Cuevas Flores from PRONATURA, who was also present during the meeting on November 13th at Isla Holbox; does include not only species identification and length measurements, but also genetic connectivity analyses; in the future, additional collaboration with WWF is envisioned; international monitoring standards should be met.
- Migrational and residential bird monitoring (in collaboration with NGO PRONATURA).
- Manatee monitoring (in collaboration with ECOSUR).
- Crocodile monitoring (in collaboration with the NGO Amigos de Sian Kaan).
- Some not further specified monitoring of dolphin populations at Isla Holbox by Alejandra del Castillo from the group Alma Verde (dolfinz33@hotmail.com). Unfortunately, no further information about this monitoring have been communicated despite several attempts to contact Alejandra del Castillo via E-mail.

In general, the park management seems to conduct all monitoring activities through external partners or collaborations. The management is obviously rather involved in coordination and planning of monitoring activities than the actual execution.

The special situation at the border between Caribbean Sea and Gulf of Mexico makes Yum Balam to a unique location that attracts some focal species such as large whale shark aggregations. Locations of these aggregations are obviously controlled by prevailing water currents and therefore may vary between years so that they are not always within Yum Balam.

Product 2) Proposal document for additional indicators and methodology recommendations

Table 1 gives a summary on ongoing key monitoring activities in all 4 MCPAs. It becomes clear that Punta de Manabique, Guatemala, apparently lacks even basic biophysical monitoring, e.g. water quality, benthic ecosystem (coral reefs, seagrass meadows, mangrove forests) health and fisheries assessments.

Others (e.g. PHMR, Belize) are engaged in or at least are planning to carry out (Yum Balam, Mexico) a variety of different biophysical monitoring activities.

Table 1. Summary of key monitoring activities at the 4 MCPAs.

	Key group of monitored indicators				
MCPA	***Water quality***	***Ecosystem health***			***Focal species***
		coral reefs	*seagrass meadows*	*mangrove forests*	
Punta de Manabique, Guatemala	no info available	AGRRA	not monitored	not monitored	not monitored
PHMR, Belize	Inorganic nutrients	AGRRA	SeagrassNet	no info available	conch, sea cucumbers, turtles
Sandy Bay, Honduras	Inorganic nutrients	AGRRA	not monitored	CIFOR	not monitored
Yum Balam, Mexico	Inorganic nutrients	no info available	not monitored	no info available	turtles, whale sharks, birds

Main reasons for that are likely the very different institutional capacities and management concepts. On this basis, I would like to recommend the following improvements:

Establishment of basic biophysical monitoring in all 4 MCPAs following a unified methodology so that data quality is ensured and it is possible to compare data sets among each other; this could be supported through training workshops that facilitate experience and methodological exchange between the station managers. Basic monitoring in my opinion involves **water quality monitoring** with a focus on inorganic nutrient (nitrate and phosphate concentrations) measurements in a good spatiotemporal resolution (e.g. monthly and along horizontal and vertical transects) using spectrophotometric assays following standard protocols as described in Grasshoff et al. (1999).
Deployment of simple and cost-efficient temperature and light loggers (please see: http://www.onsetcomp.com/; at least one for each ecosystem type with a 1 h measuring frequency) would be beneficial for all biophysical monitoring activities.

Table 2. Summary of future monitoring recommendation for each MCPA.

	Recommendations for future monitoring				
MCPA	***Water quality***	***Ecosystem health***			***Focal species***
		coral reefs	*seagrass meadows*	*mangrove forests*	
Punta de Manabique, Guatemala	Inorganic nutrients using standard methodologies (Grasshoff et al. 1999)	Reef health using AGRRA	Seagrass health using SeagrassNet protocol	Mangrove health using CIFOR protocol	low priority
PHMR, Belize	Inorganic nutrients using standard methodologies (Grasshoff et al. 1999)	Reef health using AGRRA	Seagrass health using SeagrassNet protocol	Mangrove health using CIFOR protocol	continuation of existing monitoring of conch, sea cucumbers, and sea turtles
Sandy Bay, Honduras	Inorganic nutrients using standard methodologies (Grasshoff et al. 1999)	Reef health using AGRRA	Seagrass health using SeagrassNet protocol	Mangrove health using CIFOR protocol	development of sound monitoring strategies for lion fish, sharks, conch, lobsters, and sea turtles
Yum Balam, Mexico	Inorganic nutrients using standard methodologies (Grasshoff et al. 1999)	Reef health using AGRRA	Seagrass health using SeagrassNet protocol	Mangrove health using CIFOR protocol	continuation of existing monitoring of whale sharks, turtles, manatees, and birds

In addition, key **ecosystem health monitoring** is essential. All 4 MCPAs contain coral reefs, seagrass meadows, and mangrove forests. All have already established or experienced some AGRRA coral reef and fish monitoring. This should be continued (e.g. Punta de Manabique, Sandy Bay, PHMR) or established where it is not yet (Table 2). Particular focus should be put on the site-specific analyses of AGRRA data and not only on the reporting of data to HRI. This would enable the MCPAs to answer site-specific research questions (i.e. the effect of waste water treatment on local coastal ecosystems) in a much higher local resolution.

Seagrasses so far are only monitored at PHMR, but this should be carried out at the other MCPAs as well using the SeagrassNet methodology (Table 2).

Mangrove health monitoring was so far only carried out at Sandy Bay and only started this year, but should be extended to all MCPAs, best using the CIFOR protocol as described in Kauffman and Donato (2012).

All data should be analyzed and processed in identical ways and identical formats that need to be communicated to local communities in an understandable form and language, to the project executing agency, to international networks (such as the HRI, the Global Coral Reef Monitoring Network, Seagrass Net, and CIFOR), and best also to other managers and researchers through accessible databases.

Necessary skills for carrying out these different standard methodologies could be trained in specific training and exchange workshops that bring together stakeholders from all 4 MCPAs. This is highly recommended and would also facilitate experience exchange between area managers.

Supplementary site-specific advanced monitoring may be beneficial, but only if it helps to answer pressing questions and is within the local management and research strategies. This particularly applies to the microbiological monitoring at Sandy Bay West End Special Marine Protection Zone in Honduras as this MCPA contains a Blue Flag beach and is affected by intense coastal development and questionable treatment of waste waters.
Also, some site-specific focal species may be monitored. For PHMR this includes lobsters, and conch. For Sandy Bay West Special Marine Protection Zone, this may include sharks, lionfishes, conch, and lobsters. For Yum Balam this should include whale sharks, birds, turtles and crocodiles.

Specifically and synoptically, based on a comparison between Tables 1 and 2, I recommend as highest priority the funding of the following site-specific monitoring activities:

Punta de Manabique, Guatemala: Start of inorganic nutrient concentration monitoring, deployment of temperature and light loggers, continuation of coral reef monitoring using AGRRA protocol, start of seagrass and mangrove health monitoring using SeagrassNet and CIFOR protocols.

PHMR, Belize: Continuation of inorganic nutrient monitoring, deployment of temperature and light loggers, continuation of coral reef monitoring using AGRRA protocol, continuation of seagrass monitoring using SeagrassNet protocol, start of mangrove monitoring using CIFOR protocol.

Sandy Bay West End, Honduras: Improvement of inorganic nutrient and fecal bacteria monitoring as discussed with BICA, deployment of temperature and light loggers, continuation of AGRRA coral reef monitoring, start of seagrass monitoring using SeagrassNet protocol, continuation of mangrove monitoring using CIFOR protocol.

Yum Balam, Mexico: Continuation of inorganic nutrient monitoring, deployment of temperature and light loggers, start of coral reef monitoring using AGRRA, start of seagrass monitoring using SeagrassNet protocol, start of mangrove monitoring using CIFOR protocol, continuation of turtle, whale shark, birds, and crocodile monitoring using existing established sound protocols and related institutional partnerships.

Summary of funding recommendations

It should rather be of high priority to work on the establishment of good, reliable, meaningful and comparable basic monitoring (please see above) in a reasonable temporal (e.g. monthly) and spatial resolution (i.e. at least 3 sites within each MCPA) than on diversifying and investing limited capacities and funding in a variety of additional monitoring activities.

Funding should therefore best prioritize monitoring recommendations as summarized in Table 2. That means that training, equipment and consumables in order to monitor inorganic nutrient concentrations (i.e. nitrate and phosphate) following spectrophotometric standard protocols according to Grasshoff et al. (1999) should be provided at all sites. At Roatan, this could be supplemented by a continuation of the microbiological analyses in the improved sampling strategy as discussed and agreed with BICA Roatan on place in November 2013.

In addition, funding should support standardized ecosystem health monitoring at all sites (continuation of monitoring or initiation of new monitoring where applicable) using the AGRRA protocol for coral reefs, the SeagrassNet protocol for seagrass meadows, and the CIFOR protocol (Kaufman and Donato 2012) for mangrove meadows. Resulting data should be communicated not only to international networks, but also analyzed in response to site-specific management concerns, i.e. effects of tourism, sewage water treatment, and mangrove deforestation.

This results in a combination of continuation of monitoring of existing indicators at some MCPAs and start of new monitoring of indicators at other MCPAs. The advantage of this strategy is that one the hand monitoring of the mentioned important indicators (see Table 2) is continued at those MCPAs where this monitoring has been already successfully

established and on the other hand those identical methodologies are transferred to those MCPAs where monitoring of such indicators has not yet been established or other non-recommended methodologies have been used (please compare Tables 1 and 2). The methodologies for water quality assessment and ecosystem monitoring recommended in Table 2 have been selected because of their high scientific standard and their established use in international networks. In addition, I think that carrying out the recommended protocols is logistically feasible at all visited MCPAs.

In comparison, focal species monitoring is of clearly lower priority, but should be continued with identical methodologies and in collaboration with specialized partners where it looks successful (Yum Balam, Mexico and PHMR, Belize) and can be initiated at Sandy Bay West End Marine Reserve, Honduras, only if funding is available and not before sound focal species monitoring strategies have been developed. For Punta de Manabique in Guatemala, it is not recommended at this stage to invest any efforts into focal species monitoring before water quality and ecosystem monitoring is established and working.

Generally, I recommend funding support of annual workshops with participation support of all station managers in order to train monitoring protocols, to standardize methodology for improvement of data quality and comparability, and for technical exchange between managers. Such training and exchange workshops should be chaired by international experts with a strong background in water quality and ecosystem monitoring.

Management implications

With the above mentioned recommended continuation or initiation of new monitoring activities, MCPA managers are able to understand ecosystem functioning and health, because all potentially relevant bottom-up (e.g. nutrient and light availability through measurement of inorganic nutrient concentrations and deployment of light loggers) and top-down (e.g. grazer biomass through fish assessments using AGRRA) factors are included. Via the recommended combination of monitored parameters in a good spatio-temporal resolution, managers will be able to follow the status and changes of water quality, the health of their key tropical ecosystems (coral reefs, seagrass meadows, and mangrove forests), and abundance and health of some of their key local species of high economical or/and ecological interest over time in their particular MCPA in a holistic way. Monitoring with the mentioned recommendations and improvements will carried-out in a

proper and standardized way that ensures high data quality and comparability between all four selected MCPAs and also other areas.

This is the fundament for sound science-based management of coastal resources. Information from the combined monitoring are valuable not only for evaluation of MCPA management success (please see IUCN 2004 and Pomeroy et al. 2005), but also for identification of potential local stressors (e.g. functioning of black water treatment) and responding subsequent management action or/and adjustment of management strategies.

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