Rehabilitation program of corals damaged by hurricane "Wilma" in October 2005, Isla Mujeres-Cancun National Park, Mexico.

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ABSTRACT

Hurricane "Wilma", the second most powerful hurricane ever to hit the Mexican Caribbean, stroke the northeast coast of the Yucatan Peninsula between 19th and 21st of October of 2005. It caused considerable damage on the tourism infrastructure of Cancun and within the city itself. It also had a tremendous impact on the coral reef formations of three areas which combined conform the Federal National Park Isla Mujeres-Cancún-Nizuc which surrounds the world famous tourism resort of Cancun. The results of a rehabilitation program are shown here, in which more than 65 trained instructors participated. The steps followed are presented as an example for future events and for the generation of contingency plans for this kind of events. In addition, the costs of the overall project are described and it is explained how federal funds were used for this program. Experience shows that this kind of programs is useful, especially because damage occurred within a protected area with one of the highest visitation levels in the world. It is also shown how the project is used for educational purposes for tourist visiting the rehabilitation sites in the protected area instead of closing the area for natural recovering.

KEY WORDS: Coral reef rehabilitation, Mexican Caribbean, marine protected areas, hurricane "Wilma".

Programa de Rehabilitación de Corales Dañados por el Huracán Wilma en octubre de 2005 en el Parque Nacional Isla-Mujeres – Cancún, en México

El huracán "Wilma", el segundo más poderoso huracán en la historia del Caribe Mexicano, impactó la costa noreste de la Península de Yucatán entre el 19 y 21 de octubre de 2005. Este tuvo un daño considerable en la infraestructura de la Ciudad de Cancún y en la propia ciudad. También tuvo un impacto tremendo en las formaciones de corales de tres áreas que combinadas conforman el Parque Nacional Costa Occidental de Isla Mujeres, Punta Cancún y Punta Nizuc, con carácter Federal, el cual rodea el famoso centro turístico Cancún. Se presentan los resultados de un programa de rehabilitación, donde intervinieron más de 65 instructores capacitados. Se presentan los pasos que se siguieron como un ejemplo a seguir en futuros eventos y para la generación de planes de contingencia para esta clase de eventos. Además, se describen los costos de todo el proyecto y se explica la forma como se utilizaron fondos federales para el desarrollo de este programa. La experiencia muestra que este tipo de programas son provechosos, especialmente porque el daño ocurrió dentro de un área marina protegida, la cual recibe uno de los niveles más altos de visitantes en el mundo. Se muestra también la forma como el proyecto ha sido utilizado para propósitos de educación con los turistas que visitan los sitios de rehabilitación en esta área protegida, en lugar de cerrar el área para que la rehabilitación ocurra de manera natural.

PALABRAS CLAVES: Rehabilitación de arrecifes de coral, Caribe mexicano, áreas marinas protegidas, huracán Wilma.

INTRODUCTION

The Wider Caribbean region is exposed to weather phenomena such as hurricanes. According to Brown (1997) its frequency, on a world-wide basis, has increased since the middle of 1980´s. Hurricane seasons have transformed the life of local people into tense periods due to the extensive damage caused by hurricanes such as "Katrina" in New Orleans and "Wilma" in Cancun both during 2005. This last impacted the north and northeast zones of the Yucatan Peninsula between the 19th and 21st of October of 2005. During the three days that this hurricane stroke the area, it caused severe damages to the Cozumel, Isla Mujeres and Benito Juárez municipalities, the last one being where Cancun is located. The destruction caused by "Wilma" was greater than the one made by hurricane "Gilberto" in 1988. One important factor for it was its very slow travel speed of 3 km/h over Cozumel and of 1 km/h over Cancun. The low speed was the main reason for the high destruction levels.

The coral reefs of the marine protected area "Parque Nacional Costa Occidental de Isla Mujeres, Punta Cancun y Punta Nizuc", which is located around the main tourist resort of Cancun and decreed in 1996, suffered damages during both "Gilberto" and "Wilma" hurricanes. People who were able to see and compare damages of both hurricanes, all of them agreed that last one caused the greater impacts on the reefs close to Isla Mujeres and at Punta Cancun.

The Isla Mujeres-Cancún National Park is not only affected by hurricanes, it is also subjected to the impact caused by high tourist visitation levels. This protected area is visited by close to 800,000 tourists on yearly basis since 1996, being one of the most visited areas in the world, making difficult its conservation.

Based on previous rehabilitation work and the results obtained after hurricane "Ivan" stroke the area of Cancun on July 2004, when coral reef formation units were also damaged, the protected area managers decided to intervene by implementing again a new rehabilitation project on those areas where hurricane heavily affected the reefs. As first step, assessment of the damage was undertaken followed by a cleaning and rehabilitation project aimed at rescuing those pieces of coral that where still alive to increase their chances of survival.

The project initiated once the visibility was clear enough to undertake rescue actions. Strong winds and turbulence, along with the high level of suspended sediments, in general caused that underwater visibility was very reduced during several days after the 2004 and 2005 hurricanes. In the case of "Wilma" these conditions were even more critical. Due to the lack of visibility rehabilitation worked initiated three weeks after the pass of this hurricane. Damages made by "Wilma" were very intense in both the corals and their calcareous structures, especially on those reef units such as "Manchones" and "Chitales" (Map 1), which also suffered damages when hurricane "Ivan" in 2004 and "Emily" in 2005 stroke this part of the Yucatan Peninsula. The assessment of the area showed that broken fragments, as well as the reef calcareous basement impacted as projectiles damaging other reef structures and killing benthic organisms.

METHODS

After the hidrometeoroligical event, the following activities were made simultaneously:

Clean-up of trash and debris

Work started with the removal of debris and trash, most coming from hotels and sea-side houses. They were collected and put into nets and bags in order to carry them underwater; logs and heavier objects were taken out from the water with help from personnel and vessels from the supporting team.

Rescue and rehabilitation of reef formations

Most corals and fragments that remain still in good condition belonged to the species *Acropora palmata*, so

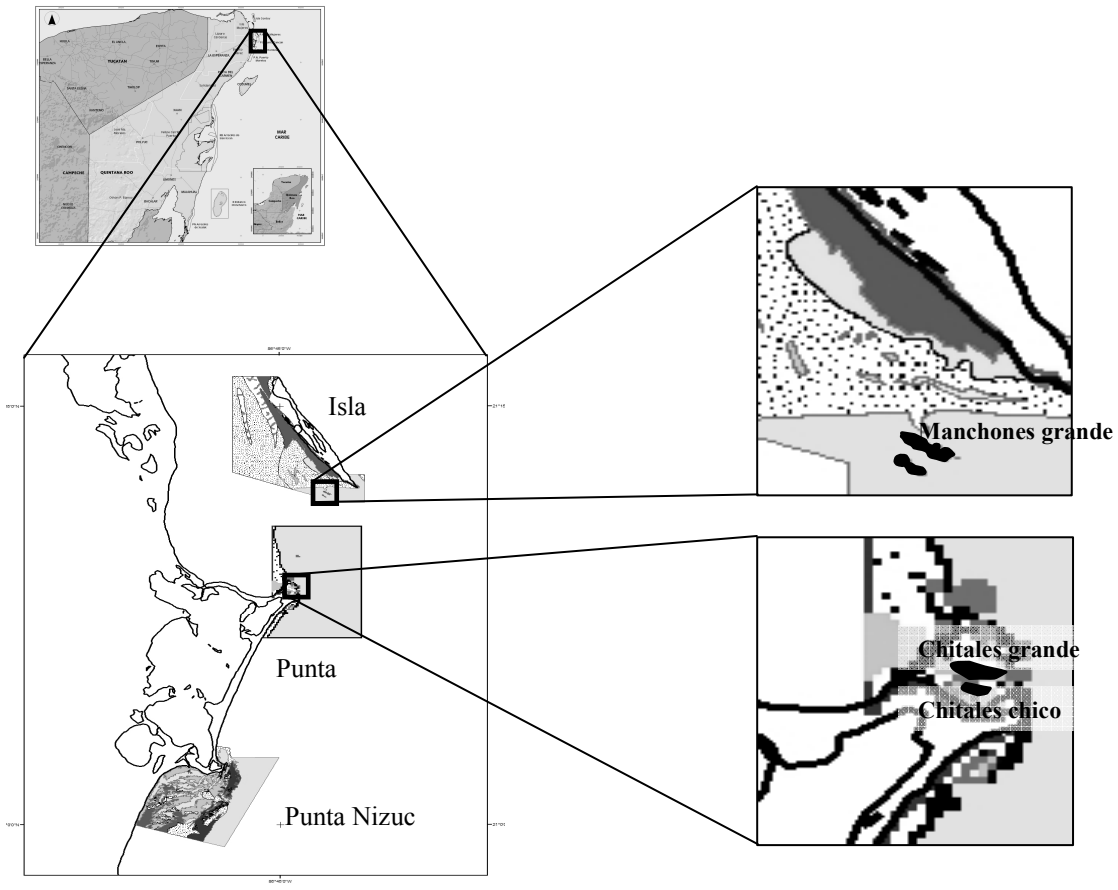

Figure 1. Polygon of the national park "Costa Occidental de Isla Mujeres, Punta Cancún y Punta Nizuc". The more heavily damaged areas caused by "Wilma" hurricane are shown.

efforts centered on the rescue of the greater number of these fragments.

Restoration procedure consisted in: a) the attachment of coral fragments to firm rock or dead coral structures using plastic belts. This last in order to maintain recovered fragments away from the action of sediments and to assure their exposition to light decreasing their probability to falling or getting buried; b) for permanent fixation of fragments to the substrate, construction cement of quick hardening mixed with sea sand and seawater were used, following the methodology described by Auberson (1982) with slight modifications. By recommendation of fishermen who voluntarily worked in the project, fragments were also tight using "monophilastic line". The combination of different ideas and points of view of locals and instructors of the area, enriched the method being employed since 2004 after hurricane Ivan.

In all cases, the work consisted in teams of two divers each to optimize time and increase safety, but especially to avoid causing further damage to the coral fragments. This also permitted to assure that no bags, tools or other things were left behind.

RESULTS

Evaluation of damages.

Reef units that suffered the greatest impacts of escleractinian corals were "Manchones grande", located within the Isla Mujeres polygon, and "Chitales grande" and "Chitales chico", on the Punta Cancun polygon (Map 1). The types of impact to the colonies were: abrasion, burying, the turning up side down of whole colonies, fragmentation and breaking of the whole colony, being these last two the most frequent types found in all areas in all reef units.

The hard coral reef species affected by reef unit are shown in Table 1, whereas the percentage of affected colonies per species and reef unit, are shown in Table 2.

Damaged colonies included species of ramified (*Acropora palmata*, *A. cervicornis* and *Porites porites)* and blade growth (*Agaricia agaricites*), as they are more susceptible to breaking; massive growth species (*Montastreas spp*, *Diplorias spp* and *Siderastreas spp*) were also affected. Heavy swells and strong currents generated by hurricanes favor the break-up of coral colonies, especially ramified species like *Acropora palmata*, which is a colonizer of areas with high hydric tension (Kenyon, 1997).

Work organization

Several tourist permissioners participated in this project; the National Commission of Natural Protected Areas (CONANP/SEMARNAT) provided funds through a Sustainable Development Program (PRODERS) which contributed to hire personnel and the acquisition of materials and tools. A total 65 divers were hired, mostly dive instruc-

Table 1. Escleractinian coral species affected by hurricane "Wilma".

Genus	Species	Chitales grande	Manchones grande	Chitales chico
Acropora	*cervicornis*		■	
Acropora	*palmata*	■	■	■
Agaricia	*agaricites*	■	■	■
Diploria	*strigosa*			■
Madricis	*decactis*	■		
Montastraea	*faveolata*		■	
Montastraea	*annularis*	■	■	
Porites	*astreoides*	■	■	■
Porites	*porites*	■	■	
Siderastrea	*sp*	■		■

Table 2. Percentage of damaged colonies of the two more affected species per reef unit.

Genus	Species	Chitales grande	Manchones grande	Chitales chico
Acropora	*palmata*	34,4%	20,3%	19,5%
Porites	*astreoides*	11,5%	13,8%	8,6%
Other species		3,3%	3,4%	5,8%
TOTAL		37,5%	49,2%	33,9%

tors from the different marinas in Cancun. Three pneumatic drills with hoses adapted to dive regulators were among the equipment bought. Materials and purchased equipment are shown in Table 3.

Dive guides and instructors participation was very enthusiastic and included most of the best divers in the area. These people were certified divers, with diving insurance and a great knowledge of the reef unit areas which became a bonus for this project. Two very important goals were accomplished:

a. A quick response to the rescue and rehabilitation of the more damaged reefs.

b. Provide an income to the participants during a time when the local economy was paralyzed given the post effect of a hurricane of this dimensions.

Further to the participation of the diving community, park permissionaries were called to join the action plan established after hurricane Wilma stroke this area. In fact, all of them respected the deal of not going into the affected areas until the Park managers authorized it. Some permissionaries, including marina and dive shop owners, provided boats, gasoline and personnel for the whole time project implementation. It thus became possible to organize work teams with sufficient boats, equipment and material to

Table 3. Resources used in the rehabilitation project.

PRODERS Funds		
Category	**(Mexican pesos)**	**(US Dollars)**
Diver's salaries	241,500.00	21,756.75
Food	94,809.48	8,541.39
Materials and supplies	70,813.80	6,379.62
SCUBA tanks refills	48,305.99	4,351.89
Fuel	40,000.00	3,603.60
Video services	10,000.00	900.90
SUBTOTAL	**505,429.27**	**45,534. 16**
National Park Permissionaries		
Category	**(Mexican pesos)**	**(US Dollars)**
Boat rentals	120,000.00	10,810.81
Personnel	112,500.00	10,135.13
Fuel	62,500.00	5,630.63
Equipment rental	120,000.00	10,810.81
SUBTOTAL	**415,000.00**	**37,387.38**
National Park (National Commission of Natural Protected Areas)		
Category	**(Mexican pesos)**	**(US Dollars)**
Divers	106, 400.00	9,585.58
SUBTOTAL	**106, 400.00**	**9,585.58**
TOTAL	**1,026, 829.27**	**92,507.14**

work in the most damaged places simultaneously.

In total, eight teams (of eight people each) were integrated. Each conducted by personnel of the monitoring program of the marine park who have had previous experience during Ivan and Emily rehabilitation work. The value of their experience came to be very important and permitted the rescue of live coral fragments and colonies in a faster way.

The amount of damage caused to the hotel infrastructure was evidenced not only by the ragged appearance of the buildings, but also the amount and variety of objects thrown to the sea. The hurricane winds and currents threw bed clothes, carpets, cables and other similar objects outside the hotels and once in the sea, some of them were transported to the reefs where they got tangled to them. Once the cleaning stage was completed, a total of more than three tons of these objects extracted from the reefs had to be sent to the local municipality disposal.

Work accountability

By the end of the project more than 2,200 hours of underwater work by both the park's staff and hired personnel were counted. Approximately 3,000 fragments of *Acropora palmata* were fixed and cemented into the main reef substrate.

In order to follow up the recovery of fragments, these were marked with styrene plaques numbered from 1 to 1,000; the mark's distribution was determined according to the number of fragments fixed per place. At each site 50 colonies were chosen randomly and several parameters are being measured in order to evaluate success of the rehabilitation project after hurricane Wilma.

In Table 3 it is shown the economic financing sources for this rehabilitation project and how the different cost were distributed. PRODERS funds were provided through the national park and the different categories are included. Though presented in the table, park permissionaries donated their work and absorbed their own costs. The park's staff wages are also included. It indicates that the cost of a project of this kind reached a total of 93 thousand dollars, amount which can be compared to those projects exerted in other areas for similar purposes.

DISCUSION

Once the National Park authorities determined that damages were considerable in some reef units, it was decided it was necessary to carry out a rehabilitation program instead of closing the areas for natural recovery, given that this could generate conflict amongst different users. Two main activities were established: a) the cleaning up of the reef units (extraction of land objects) and b) the rescue and rehabilitation of reef fragments. Cleaning up was a necessary step, considering that some containers, rugs and curtains got tangled in some of the live and standing coral colonies; there were also some logs that rolled over the bottom, increasing the damage on the benthic organisms. In these situations, it was also causing physical damage. These were the criteria based upon, the cleaning up was established as one of the priorities within the rehabilitation process.

In relation to the rescue of fragments, it is possible that a high percentage of the coral fragments would have died, if actions had no taken place. As many of them were half-buried or placed into dark areas. Instead, their survival rate increased enormously once they were fixed to the reef substrate where they were able to continue their growth. Given that 3,000 fragments were fixed and cemented, it is easy to valuate the importance of having done the rehabilitation project.

The response of permissionaires who provide recreational services at this National Park and the dive guides was very important for purposes of this project. It contributed to the high amount of rescued coral fragments. The quantity of people involved in the project facilitated the cleaning up and rescue activities, increasing the probabilities of success of this program. Another important result of the project was the opportunity to capacitate all those people that collaborated, and the increased level of environmental awareness that they got. They also acquired a new understanding about the conservation and protection practices that the staff of the national park do, which created a better relationship between all groups as well as the community.

As the next step, and in order to follow these actions, it is proposed a monitoring program to keep recording the survival and growing rates of the transplanted fragments. The information generated this way, could be considered in management decision making and it likely would be an important element to decide on the feasibility of similar future projects.

CONCLUSIONS

The results obtained from evaluations of damages after hurricanes "Ivan" "Emily" and "Wilma" demonstrate that the same reef units located in the channel between the main coast and Isla Mujeres have always been impacted. It is explained given the strong currents generated as a result of a funnel-like effect between Punta Cancun and the southern part of Isla Mujeres Island, especially during storms and hurricanes.

A need to establish a contingency plan after a hurricane becomes of prime importance for the activities and the management of the reef coral units in this national park. A plan of this kind would provide the immediate and effective actions by all the important stakeholders of this park and the staff of this marine protected area. It also would allow the optimization of resources, materials and personnel.

It is also evident the necessity of creating a fund or financial instrument that to enable the National Park to face

the expenses of this sort of restoration projects. To hiring people and to buy the necessary tools and materials for the accomplishment of the different tasks. It is also necessary that a trained group in the community be prepared as volunteers or as conformed group capable of entrying into action as soon as conditions allow the implementation of the different steps described in this document. Additionally, it must be clear that the creation of a contingency economic fund is not only the interest of the park authorities but should also be of great interest of permissioners, who receive the benefits of a well managed marine protected area.

The impact generated by these last three hurricanes is considered to have open an opportunity to show visitors of this marine protected area practices to restoring reef formations. In the near future, some of the areas will be signaled and buoyed and specifically for the demonstration and explanation of this type of work, so tourist would be in the condition to learn about these activities and appreciate the work that the staff of the national park and the diving community has carried out after the pass of hurricanes. It is therefore concluded that this will increase the environmental awareness level of visitors.

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