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US-Mexico joint gulf of Mexico large marine ecosystem based assessment and management: Experience in community involvement and mangrove wetland restoration in Términos lagoon, Mexico

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ABSTRACT

The purpose of this article is to present the Mexican experience related to the US-Mexico joint Gulf of Mexico Large Marine Ecosystem-Based Assessment and Management Project, particularly the community involvement and mangrove wetland restoration, and the challenges for its replication and up-scaling. Results focus on community engagement, environmental education and social participation, strategies for hydrological restoration of mangrove, and difficulties and recommendations for the implementation of the Strategic Action Program. The main conclusions are that the community-based hydrologic restoration approach, is a good way to ensure long-term restoration of wetlands. Changing from mangrove plantations to the hydrological restoration of wetlands, and construction of human capacities resulted in a more efficient strategy for ecosystem restoration and had influenced the forest environmental policy. The involvement of government and education institutions as execution agencies will contribute to a more efficient appropriation of the project and LME approach. The development of economic alternatives and the ecological monitoring are some of the identified challenges within the implementation phase of the Strategic Action Program.

1. Introduction

The Gulf of Mexico Large Marine Ecosystem is a semi-enclosed oceanic basin of about 615,000 mi^2 (1.6 million km^2) shared by Mexico, the U.S., and Cuba (UNIDO, 2011). The Mexican territorial sea and its exclusive economic zone includes five Large Marine

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Table 1
Total coverage and estimated disturbed area of the mangroves in the Gulf of Mexico.

State	Mangrove area (ha)	Disturbed area (ha)	Disturbed percentage (%)
Campeche	197,620	1236	0.625
Quintana Roo	128,049	2039	1.592
Yucatan	91,356	1788	1.957
Tabasco	44,590	100	0.224
Veracruz	37,841	339	0.896
Tamaulipas	3095	1.0	0.032
Total	502,551	5503	1.095

Ecosystems (LME), all of them with different ecosystem health and pollution challenges, as well as particular productivity, fishery, biodiversity, socioeconomic and governance features (Sherman and Hempel, 2008). The Gulf of Mexico is a semi-enclosed sea, located between the tropical and subtropical North Atlantic latitudes, and includes a wide variety of marine habitats. As one of the 66 LMEs in the world, it is one of the most economically important water bodies within the Mexican and US Exclusive Economic Zones. Total fisheries catch in the Gulf peaked 1,480,729 metric tons (around 73% of the total GoM's catch is taken by US fleets) in 1987, while in 2008, around 768,500 t were harvested, not accounting for the large amount of discards (UNIDO, 2011). A very high diversity of marine habitats that includes tropical and temperate ecotones, estuaries, mangrove wetlands, shallow inshore waters with soft bottoms, rocky bottoms and reef communities, and a large extension of deep sea, sustains an ample diversity of living marine resources (LMR). More than 300 species sustain local fisheries (including fish, crustaceans, mollusks, echinoderms and other invertebrates) but also LMR with unique ecosystem value in the trophic structure, such as sea birds, marine mammals, and sea turtles. The Gulf Coast region is especially vulnerable to a changing climate because of its relatively flat topography, rapid rates of land subsidence, water engineering systems, extensive shoreline development, exposure to major storms, and coastal wetlands degradation (Yáñez-Arancibia et al., 1998).

Mexico has a broad experience in Marine Governance (Azuz-Adeath et al., 2014) and Marine Spatial Planning and Policy, which includes the Large Marine Ecosystems Approach (Díaz de León and Díaz-Mondragón, 2013). Also, Mexico is one of the top five countries in the world with large areas of mangroves (Giri et al., 2011). The estimated national extent of mangroves is about 7755.55 km^2 (Troche-Souza et al., 2016). The main mangrove wetland areas present in the south and southeast regions of Mexico, particularly in the Gulf of Mexico and Mexican Caribbean (see Table 1), are about of 5200 km^2 (65.7% of the total mangrove area in Mexico) (CONABIO, 2013).

The impacts on ecological process and the loss of goods and environmental services (e.g. natural barrier protection, carbon sequestration, biodiversity, habitat and water quality) of coastal wetland, such as the mangroves, are common in several locations of the Gulf of Mexico region (GoM) (Giri et al., 2011). Changes in hydrology, erosion, dam construction, urban growth, land use changes for agriculture and livestock activities, gas oil and petroleum industry, chemical pollution, wetlands drainage and the rise of the sea level, are problems shared by Mexico and the United States. Several organizations around the world adopt strategies to restorer degrades sites, they need to have a firsthand knowledge of the socioeconomic as well as ecological factors that promote and hinder restoration efforts. It has been suggested that community involvement maybe a key factor in increasing the potential for successful mangrove restoration (Stone et al., 2008).

1.1. Gulf of Mexico large marine ecosystem project

The US-Mexico joint Gulf of Mexico Large Marine Ecosystem Based Assessment and Management Project (GoM LME Project) started officially in 2009. It was financed by the Global Environmental Fund, under the coordination of the United Nations Industrial Development Organization (UNIDO) as an implementing agency. The governments of United Mexican States (Mexico) and the United States of America (U.S.) appointed to the Ministry of the Environment and Natural Resources (SEMARNAT, by its acronym in Spanish) of Mexico, and the National Oceanic and Atmospheric Administration (NOAA), respectively, as the Technical National Focal Points for the project.

After a transboundary diagnostic analysis (TDA) was conducted using the LME approach, the conclusions were that the main transboundary issues are the pollution control of coastal waters, fishery stocks recovery, habitat restoration, climate change effects, and governance (UNIDO, 2011). Addressing some of these issues, pilot or demonstrative projects (PP's) were also conducted at the Términos lagoon. Such PP's included mangrove restoration, social involvement and organization, assessments of brown shrimp and grouper fish fisheries, and coastal monitoring. Based on the TDA, both countries negotiated a policy document known as the Strategic Action Program (SAP) (UNIDO, 2014). The SAP aims to promote shared policy goals, as well as legal and institutional actions to address priority transboundary problems previously identified by both NOAA and SEMARNAT in the TDA. After formalization of the SAP by both countries, a new project called “Implementation of the Strategic Action Program of the Gulf of Mexico Large Marine Ecosystem” was approved for its implementation. This process took about three years since the formulation until its acceptance by the Global Environmental Fund (GEF). Approval for the purpose of formulating the Full-Scale Project was granted with a Project Preparation Grant (PPG).

In this new project, the implementation of strategies for mangrove conservation and restoration was a major priority in the GoM region. Implementation of the PP´s of mangrove restoration for the GoM LME Project occurred in the Términos lagoon (Zaldívar-

Jiménez, 2015). The Términos lagoon is a Federal natural protected area under the category of "Flora and Fauna Protected Area" and it is administrated by the National Commission for Natural Protected Areas (CONANP, acronym in Spanish). The purpose of the mangrove restoration program is to develop a strategy to recover degraded areas through hydrology restoration. Such program aims to engage local communities in the project, as well as to have institutional coordination (Zaldívar-Jiménez et al., 2010). In order to improve the socioeconomic conditions of the communities that depend on coastal and marine ecosystems and their living resources, it is necessary to consider alternatives to broaden opportunities for economic development that generate employment as well as investment in social programs. These programs should propose a wise use of natural resources and promote the protection and management of important ecosystems (coastal lagoons, mangroves, seagrass beds, sand dunes). There is a need of aware societies that can promote the sustainable management of natural resources through an active participation. Formal and informal environmental education programs targeting different audiences can serve as a tool to mitigate identified problems and to overcome boundaries through effective teaching and learning experiences.

The aims for this document are: i) describe and analyze the Mexican experience in the GoM LME Project, mainly the experience of mangrove hydrological restoration and community involvement; ii) describe the challenges to the implementation of the Strategic Action Program of the Gulf of Mexico Large Marine Ecosystem.

2. Material and methods

For mangrove restoration and community involvement within the project, we constructed strategic alliances with CONANP, the National Forestry Commission (CONAFOR), SEMARNAT, the Autonomous University of Carmen (UNACAR), and inhabitants of local communities at Términos lagoon. We forged these alliances through activities such as workshops, seminars, courses, and conferences, as well as training sessions for administrative skills enhancement.

Mangrove restoration included four years of activities focused on hydrological management and applied research for the recovery of 1300 ha of degraded mangrove in Términos Lagoon, in Campeche, Mexico (Fig. 1).

Our approach consisted in the restoration of ecosystem functions of degraded mangrove sites. According to the local conditions, we used hydrological rehabilitation to promote natural regeneration and strengthen the resilience of mangroves (Lewis and Marshall, 1997; Kairo et al., 2001; Lewis, 2009, 2005; Biswas et al., 2009; Zaldívar-Jiménez et al., 2010; Dale et al., 2014). We involved the local communities in all activities through training activities to focus and transfer technical information for replication purposes.

The ecosystem management and mangrove restoration PP's included five lines of action to replicate in the GoM:

1. Environmental and Social Diagnosis and selection of sites (communities) to generate information concerning the state of the mangrove ecosystem and social situation, and to identify priority problems (Lewis and Marshall, 1997; Biswas et al., 2009).
2. Formulation of a restoration plan with an advisory group, which is in charge of providing advice and training to local stakeholders to implement the actions of planning, conservation, restoration, management, monitoring, environmental education and replication.
3. Community involvement throughout the project workshops of social participation, environmental education and training programs was designed to engage communities, so that they can take ownership of the conservation and management actions performed.
4. Monitoring of restoration success through assessment of specific variables that function as indicators of the achievement of the program, opening up the possibility of applying new actions via adaptive management (Biswas et al., 2009).
5. Transfer of information, training, and socialization, which is intended to use the implemented restoration program as an environmental education issue. Trained participants build capacities to replicate restoration activities in other degraded mangrove sites subsequently. In addition to environmental education workshops and training courses, this step included feedback meetings

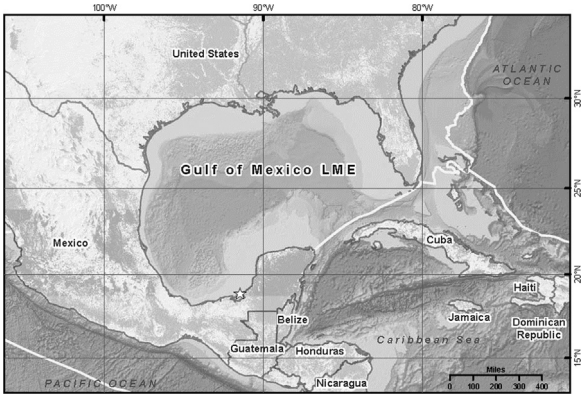

Fig. 1. Location of Gulf of Mexico Large Marine Ecosystem area. The star symbol indicates the location of the Términos lagoon.

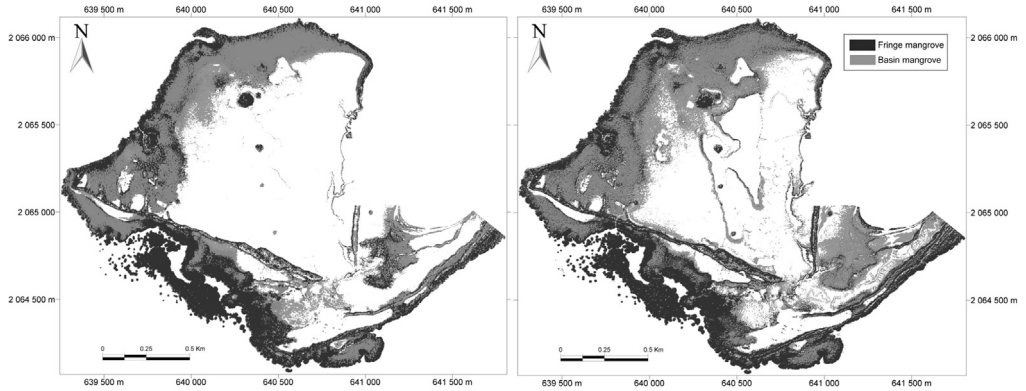

Fig. 2. Images (2009–2012) of Bahamitas (Términos lagoon), a mangrove site restored by hydrological rehabilitation. Dark gray indicates areas with fringe mangrove. Light gray shows the basin mangrove with recruitment by comparing before (left figure) and after (right figure) tidal channel rehabilitation (Pérez-Ceballos et al., 2013).

with the communities to obtain information about former and current use of the resources of the region. This information is analyzed and returned to the community for management purposes.

Based on the above described experiences, we identified challenges and contrasted them with a new GEF proposal coordinated by UNIDO titled "Implementation of the Strategic Action Program of the Gulf of Mexico Large Marine Ecosystem".

3. Results

3.1. Wetland restoration

Hydrological restoration of the mangrove resulted in the rehabilitation of tidal channels in 1300 ha of mangrove (Fig. 2). As compared with methods of planting and plant production in nursery gardens, hydrological restoration showed greater benefit-cost advantages. The participation of local communities was essential to accomplish restoration actions such as dredging of tidal channels, soil elevation beds, seedling mangrove dispersal, and monitoring.

The rehabilitation and dredging of tidal channels promoted the recovery of the natural hydroperiod (Table 2). Monitoring the hydroperiod showed that the degree of improvement of hydrologic connection with the lagoon, measured as flooding frequency before and after the restoration actions, helped to reduce soil salinity (Table 2). The porewater salinity decreased significantly between disturbed and restored mangroves (before and after restoration activities). Moreover, hydrological rehabilitation promoted the natural recruitment, and growth of black mangrove because seedlings are transported through the rehabilitated tidal channels (Table 2). Thus, the major success indicator of the project is the hydrological rehabilitation of tidal channels and the participation of the local communities.

Regarding human capacities, the restoration program required the participation of about ten persons per hectare of mangrove. As recovery programs and conservation of mangroves should account for alternative economic activities that provide support and long-term viability of the communities involved in the project, we propose ecotourism, environmental education, and release sports fishing as viable alternatives to our project area. We built a demonstration site in Términos Lagoon, which includes boat, ramp

Table 2
Comparison of the flooding regime, biogeochemistry and mangrove seedling among disturbed, restored and undisturbed mangrove condition, as a measure of mangrove restoration success.

Mangrove wetland indicator of restoration	Mangrove condition		
	Disturbed	**Restored**	**Undisturbed**
Hydrology			
Water level (m)	0.21 ± 0.07	0.14 ± 0.01	0.08 ± 0.02
Flooding duration (hr month^{-1})	654 ± 50	582 ± 48	297 ± 65
Frequency of flooding (No. month^{-1})	1 ± 0	6 ± 1.3	11 ± 2
Biogeochemistry			
Porewater salinity	63 ± 1.4	45 ± 0.5	58 ± 1.2
Mangrove seedling			
Density (No. 0.01 ha)	0	82 ± 2	3400 ± 500
height (m)	0	0.56 ± 0.15	0.40 ± 0.10

Table 3
Stakeholder involvement strategy.

Approach	Activity	Selected techniques
Early involvement	Informal surveys to determine the main topics of interest. Estimate level of public interest. Identify key individuals.	Informal talks and interviews. Community meetings or gatherings.
Public information/education	Determine information exchange needs. Clarify public involvement objectives. Inform them that our interest in their participation in the sustainable management of marine and coastal resources is for improvement of their life quality and for maintaining ecosystem functions.	Meetings and social participation workshops.
Build confidence of stakeholders. Establishment and strengthening the participation of local communities.	1) Willingness to seek joint objectives cooperatively; 2) Share effort; 3) Mutual respect; 4) Open communication and ongoing; 5) Clear and realistic expectations about the results of the process; 6) Satisfactory and timely completion of agreed tasks; 7) Compliance with the commitments, and 8) Participation of all sectors of the community.	Transversal activities
Information feedback and consultation	Knowledge exchange: 1) Inform, in an everyday language, about the goods and service of wetlands, the mangrove restoration, the responsible fishing, the protected areas and the manatee and dolphins as a key species of the ecosystem. 2) Update information on spatial and temporal presence of natural resources, with special emphasis on living marine and coastal resources. 3) Ask to stakeholders about productive activities they are interested in. 4) Identify alternative economic activities. 5) Participate in discussions.	Social participation and environmental education workshops. Problem solving meetings. Surveys and interviews.
Extended involvement	Participatory decision-making. Organize into cooperatives. Draft documents: Manual of best practices and brochure/guide about mangrove restoration and responsible fishing, e. g.	Social participation workshops. Advisory groups and task forces.
Joint planning	Building of agreements. Implementation of good practice manual. Carry out activities within the legal framework. Community empowerment. Monitoring of the public involvement program.	Consultation Mediation Negotiation

launching, a boardwalk and a bird watching platform, thought to strengthen restoration and alternative economic activities within the project areas. These works also lead to the creation of a formal association of local restorers called Community of Restorers of Isla Aguada, Campeche (nowadays an organization lawfully established), as well as to the strengthening of local capacities through training in restoration techniques.

3.2. Community involvement strategy

The close coordination with CONANP's Flora and Fauna Protected Area of Términos Lagoon (APFFLT) allowed for carrying out a successful participatory planning process. Nearly 60 workshops on conservation and management of natural resources, mangrove restoration, responsible fishing, and identification of alternative economic activities, were held in collaboration with local stakeholders and authorities (Table 3). The workshops reached coastal and riverside communities that are in a situation of poverty and which achieved sustainable productive projects after identification of specific problems. Nineteen communities (including those from Tamaulipas Veracruz, Tabasco, Campeche, and Yucatán) participated in the GoM workshops.

To involve local stakeholders in the conservation and management of wetlands conservation and living marine resources, we promoted alternative economic activities such as bird watching, scientific monitoring, traditional handcrafts production and ecotourism within restoration areas. We also offered training to providers of tour guide services. Thus they could conduct such alternative activities in a sustainable way, organized in a communal cooperative. For instance, considering the current price of a tour, and that each cooperative make at least one trip per day during the summer time, they could earn $ 505.55 USD for a week's work. This amount of money is more than a fisher could obtain in a fishing day. It is important to note that determination of the appropriate price of ecotourism tours, came from the cost-benefit analyses carried out in the workshops. While it is true that there

are low tourist seasons, this economical alternative improved the quality of life of the people from participant communities, who otherwise should have to seek income in activities probably not related to life at sea. The link of environmental training and social participation processes to sustainable productive projects also improved the social structure of the community. Through the social participation workshops, fishermen were able to accept and solve problems and reach agreements that otherwise would have been difficult to achieve. Another model of social participation was the artisans' women group. This group of women plays an important role in their community by recycling glass, polyethylene, and aluminum, transforming these materials into artisanal handcrafts. They collect about 87 t of solid waste per year within the mangrove wetland. The stakeholder involvement strategy emphasized the adoption of an approach that includes watershed, connectivity of ecotones and human activities through different workshops on environmental education and exchange of experiences among communities from natural protected areas (Ladrón de Guevara, 2015). From its engagement in the workshops, the group of women carried out several initiatives to improve their economic income as well as the environment. Because most women live on the edge of one of the busiest roads in southeastern Mexico, 20 of them set up a stand to sell local products (fruits, arts, and crafts made from recycled solid waste), reaching a daily profit of $ 22.00 USD. Because of unemployment of men due to the oil crisis and fisheries that are no longer profitable, women become the house suppliers. Also, their participation in recycling fairs has given them up to $1390.00 USD income by selling their crafts. These economic alternatives have contributed to increased self-esteem as well as to decrease the hostile behavior of their husbands. Gender equality was a major issue within all the project phases and activities and contributed significantly to the empowerment of cooperatives, particularly of women.

The project also leads to collaboration among different institutions regarding research, management, monitoring, and conservation of marine mammals representative of the Términos lagoon (such as manatee and dolphins). A protocol for a manatee survey was standardized and implemented at both the GoM LME Project and the APFFLT CONANP's Manatee Action Program for the Species Conservation.

3.3. Environmental education and social participation

Within the project, we conducted environmental education activities in coastal and riverside rural communities through the exchange of experiences. These activities yielded a change of attitude and interested people to participate actively, mainly to involve the children and their families in the care and monitoring of endangered species such as the manatee, dolphin and birds.

As part of the restoration pilot project, elementary schools at the Términos lagoon hosted the workshops to raise awareness for the conservation and sustainable use of flora and fauna. Participation in these workshops included fishermen, housewives, and children of the "mangrove restorers."

Using manatee as a key species of the mangrove ecosystem played a strategic role in establishing a culture of conservation of this aquatic mammal and their habitat. It was also a major factor in involving the adult population, through children, in the preservation and monitoring of biodiversity, encouraging awareness of the importance of the ecological, social, cultural and economic value of coastal and marine resources.

The analysis of the Management Program of the Términos lagoon Natural Protected Area (NPA) and its comparison with the inputs generated in the workshops of social participation is very relevant. This information was valuable in the updating process of the NPA management program and for the definition of the Strategic Action Program in the NPA and helped to line up with the lines of action of the program of strategic actions in the Gulf of Mexico.

The conservation and sustainable management of living marine resources have a social component, and by integrating social elements, economically sustainable activities can be carried out.

4. Discussion

According to early experiences in degraded mangrove areas, such as the Indian River Lagoon of Florida (Brockmeyer et al., 1997), Louisiana (Turner and Lewis, 1997), the Biscayne Bay Coastal (Ruiz and Ross, 2004), and in Florida wetlands (Lewis, 2000, 2005), restoration of hydrology proved to be a useful tool in the recovery of ecosystem functions. Additionally, implementing management and hydrology restoration, help in the control of mosquito populations (Rey et al., 2012).

This project aimed to restore severely degraded mangrove sites by working together with local communities. Engagement of the local inhabitants with the restoration project and the effective community participation were considered crucial to achieving sustainable impacts. A significant achievement of the institutional coordination, because of the satisfactory results obtained in the restoration of mangrove sites, was the renovation of a collaborative agreement. The coordination between the academy, government, and the technical group, was a key mechanism for the conservation and restoration of the mangroves. The sum of counterparts from different federal subsidy programs, a total of 767,604.00 USD for preservation and restoration of more than 1300 ha of mangroves in Isla del Carmen, and the direct participation of more than 560 community members, lead to successful and satisfactory results of the project. However, as a medium-term program (5 years), it should be guaranteed the financial support to carry out maintenance actions until the mangrove ecosystem regains its resilience.

The monitoring of success indicators should be implemented to determine the effectiveness of the restoration efforts. The indicators can be technical, ecological, social and economic indicators, closely linked to local demands and regional problems such as climate change. On the other hand, the adaptive management approach to ecosystem goods and services has served to generate knowledge and experience on restoration ecology and its replicability.

The institutional coordination strategy between government, academy and the involvement of the communities was advantageous for the recovery of the mangroves implemented by the pilot program. The results of this program are a convincing

model of mangrove restoration and conservation and its replicability around the GoM LME.

With the project, we also achieved the strengthening and empowering of local communities through the cooperative organization of the restorers. The project helped to identify productive or economic alternatives, and awareness by the engaged communities on environmental issues through education workshops and exchange of experiences among the restorers of mangroves in the Tamaulipas, Veracruz, Tabasco, Campeche, Yucatán and Quintana Roo areas. With the active restoration works, they now participate in training every day as "technicians to mangrove restoration" so that they could maintain and replicate the strategy elsewhere.

Although the ecological success of restoration actions is essential for restoration projects, it is necessary to evaluate them from a social and economic point of view. It is important to highlight that the communities involved have training preparation and infrastructure for combining conservation activities of mangrove ecosystem, as well as economic opportunities to undertake the sustainable ecosystem oriented management of the mangroves in the Gulf of Mexico.

4.1. Challenges for the implementation phase

According to the experience of the pilot projects, regarding the community-based hydrological wetland restoration approach, challenges were identified and contrasted with the proposal of "Implementation of the Strategic Action Program of the Gulf of Mexico Large Marine Ecosystem". We found that:

Enhancement of new capacities is needed to ensure the long-term restoration of the wetlands pilot project site. One of those capacities is the environmental monitoring to evaluate the success of the ecological restoration. To address this challenge, the Implementation Phase considers the involvement of several institutions: the National Water Commission (CONAGUA), the National Biodiversity Commission (CONABIO), the Center for Research and Advanced Studies (CINVESTAV), and the Mexican Institute of Water Technology (IMTA). Those institutions will conduct monitoring in the restoration sites to obtain information related to water and other ecological and quality parameters that will be used to determine the success of the restoration actions.

A community-based hydrological restoration is an approach that can be replicated and up-scaled in other mangrove-degraded areas. New restoration sites are being considered in the implementation phase and will be worked out through coordinated actions between institutions involved in the first phase (UNACAR) and new ones such as INECOL (Institute of Ecology).

There was a transformation of subsidies forthcoming from the government to enhance capabilities related to economic alternatives to support communities. The expectations are that SEMARNAT and CONAFOR will maintain the government subsidies.

Other challenges, more related to governance, will also be addressed through the Implementation Project. Such problems include networking between Mexico and the USA for Marine Protected Areas, joint USA-Mexico stock assessments for fisheries management, education and research, which should be addressed through consortiums and alliances in the region.

5. Conclusions

The community-based hydrological wetland restoration approach is a good way to contribute to the restoration of mangroves, it is replicable, and it proved to be a viable recovery model for other sites in the Gulf of Mexico LME. At the location of the restoration project, the communities have consolidated their organizational capacities and environmental awareness. Such abilities are related to environmental monitoring and economic alternatives. Changing from "mangrove gardening" to hydrological restoration of wetlands, and the construction of social capacities has resulted in a more efficient strategy for ecosystem habitat restoration. The hydrological restoration of the coastal wetland is a more effective and efficient practice for resource allocation and for the achievement of results, which had a positive effect on the perception of the community. New sites for community-based hydrological wetland research projects are necessary, to ensure a long-term restoration success. Appropriation of the project strategies for the management by the community itself fosters the self-management and facilitates the communication and consolidation of the experiences. Mangrove management and conservation are key actions for carbon capture and consolidation of the coast, as adaptation mitigation measures to the Climate Change.

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