Fostering a participatory process for ecological restoration of mangroves in Pantanos de Centla Biosphere Reserve (Tabasco, Mexico)

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ABSTRACT
Ecosystem restoration is becoming an urgent global priority to recover degraded areas, especially in tropical regions. Social participation is fundamental for the success of restoration processes, but it needs to be better documented. This article describes a participatory mangrove restoration process developed with two local communities inhabiting Pantanos de Centla Biosphere Reserve (PCBR) in Tabasco, Mexico. Both communities, El Palmar and Tembladeras, rely on numerous ecosystem services provided by mangroves, and the premise of the project was to closely involve them in all phases of the restoration process. During the planning phase, dialogue with PCBR authorities and the participating communities allowed us to: (1) assess local needs and interests to determine the project’s viability; (2) perform social and ecological diagnostics; and (3) make decisions regarding restoration actions. With technical accomplishment, community members themselves executed restoration actions during the implementation phase. In El Palmar, people reforested an area equivalent to 160 ha with 17,038 propagules of Rhizophora mangle. In Tembladeras, they manually cleaned 4,942 m of natural channels to reestablish water flow dynamics across 34.7 ha. These activities were done in parallel with four training workshops for community members focusing on ecosystem services, ecological restoration processes, and monitoring techniques. With guidance from the project team, community members conducted initial monitoring of restoration actions four months after implementation. The local communities’ participation in all stages was fundamental to promoting an integral and sustainable restoration process of the socio-ecosystem and fostering greater awareness of the full range of services mangroves provide.

Introduction
Ecological restoration is an effective means of promoting the recovery of natural systems in response to biodiversity loss and degradation caused by natural phenomena and human activities (Marchand et al. 2021). It has become increasingly evident that the focus of restoration efforts should not only be to assist recovery of the ecological components of ecosystems, but also to promote a holistic approach that simultaneously generates social benefits, given that ecosystems and social systems are inextricably linked in restoration practice (Swart et al. 2018). Although there is a lack of documented evidence describing the manner in which different actors are involved in restoration processes (Furness 2021), many experiences have shown that social participation from the beginning of a restoration project is crucial for long-term success, as it encourages knowledge exchange and mutual learning, enhances local capacities and skills, and instills a sense of project ownership (Montagnini et al. 2008). Diverse social actors must be actively involved in the restoration process, particularly local communities that depend on the goods and services of the ecosystems being restored (Derak et al. 2018; Garzón et al. 2020). This includes marginalized groups like women and youth that have traditionally been excluded from decision-making in many cases. Broad community participation gives projects greater access to traditional knowledge and higher awareness of local socio-ecological needs. It can also help increase social cohesion and act as a transformative agent in the human-nature relationship.

Despite the importance of active and enduring stakeholder engagement in restoration efforts, the most recent international guidelines for restoration practice still fall short in their recommendations for incorporating the ‘human dimension’ in project planning, implementation, and monitoring (Ceccón et al. 2020). Among other shortcomings, traditional ecosystem management practices remain an undervalued source of knowledge for...
restoration that can be a crucial component for designing restoration programs (Méndez-Toribio et al. 2021). In the context of Mexico, social participation has been limited in most restoration projects to assembling a short-term local work force for field-based activities, a reality that suggests effective social participation is not yet well understood by many managers and restoration practitioners (Ceccon et al. 2020).

This article describes a participatory ecological restoration process we developed for restoring mangroves in Pantanos de Centla Biosphere Reserve, in southern Mexico, emphasizing the early, active, and ongoing participation of two local communities inhabiting this natural protected area. The restoration initiative began as an implementation action of the Climate Change Adaptation Program (PACC in Spanish) for Pantanos de Centla, which was developed under the Resiliencia project led by Mexico’s National Commission of Natural Protected Areas (CONANP). The PACC set a goal of restoring 50 hectares of mangroves within the reserve to increase ecosystem connectivity and maintain the services they provide. We proposed a community-based approach for this restoration built on a conceptual framework of participatory restoration defined as an inclusive process of open dialogue for planning, implementing, and monitoring of restoration activities, involving academic, governmental, and local actors with direct and indirect relationships to the ecosystem being restored, and taking into consideration the interests and needs of all. Throughout this process, our goal was to promote a socio-ecological approach that would keep community members engaged in restoration and management activities beyond the life of our project, thereby increasing the likelihood of a sustainable long-term recovery.

Socio-ecological context

Pantanos de Centla Biosphere Reserve (PCBR) is a natural protected area established in 1992, which is located in southeastern Mexico, in the northwestern part of Tabasco state (Figure 1A,B,C,D). It lies in the lower Grijalva-Usumacinta River Basin, the most important watershed in Mesoamerica (Barba-Macías et al. 2015). PCBR was designated as a RAMSAR site in 1995 due to its unique ecological value and importance for migratory species. It is also considered a priority terrestrial region in Mexico (Arriaga et al. 2000). Hydrophytic vegetation is

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Figure 1. Location of the project area: (A) General overview of the area in southeastern Mexico; (B) the state of Tabasco, Pantanos de Centla Biosphere Reserve is delimited in green; (C) a close-up of the PCBR boundaries showing the location of the two communities; and (D) an enlarged view of the communities El Palmar and Tembladeras in orange (Elaborated by Juan Paulo Carbajal-Borges).
the primary natural cover in PCBR, with a plant community dominated by *Typha domingensis* and *T. latifolia* (Barba-Macías et al. 2015; De la Rosa-Velázquez et al. 2017; López-Jiménez et al. 2020). Mangroves also cover a large area of the Reserve (12,935 hectares), mainly in the northern zone. A corridor of 4,155 hectares in this zone of PCBR is a priority for conservation and restoration. These mangroves are predominantly the riverine type, dominated by *Rhizophora mangle* (red mangrove) and *Laguncularia racemosa* (white mangrove).

There is a significant human presence within PCBR, with 109 registered localities and a total population of approximately 22,970 inhabitants (INEGI 2020). Primary livelihood activities include fishing, small-scale livestock farming, and small-scale agriculture (Sánchez et al. 1988). Despite its protected status, deforestation and land conversion do occur within PCBR, albeit at small scales. In addition to land-use change, fires and activities associated with the oil industry also produce high anthropogenic pressure in the region (Domínguez-Domínguez et al. 2019).

The participatory ecological restoration process

Methodological aspects of the restoration process were designed and implemented following the general steps for ecological restoration described elsewhere (Clewell and Aronson 2007; Vargas-Ríos 2011), and the specific recommendations for mangroves (Herrera-Silveira et al. 2020). We promoted the restoration process as a collective construction Figure 2 and incorporated perspectives on gender, sustainability, and resilience to climate change in our approach. Our fundamental premise was that all decisions about the places, actions, methods, and timing of restoration activities would be made by consensus among all social actors involved.

Planning phase

During initial meetings with PCBR authorities, we assessed the needs and viability of restoration activities based on their existing operational guidelines. We then presented our restoration proposal to representatives from several local communities, after which we decided that the restoration process would be developed in the northeastern region of the PCBR (Figure 1(C)) with two local communities (*ejidos*): El Palmar and Tembladeras (Figure 1(D)). These communities were selected because: a) they possess an extensive area of common-use land (i.e. collective land tenure) where restoration activities could be safeguarded into the future; b) they have previous experience working with government-led environmental programs; c) they exhibit strong internal organization; and d) they are easily accessible for travel and fieldwork activities. Members of both communities have low economic incomes and depend almost entirely on fishing for their subsistence (mainly shrimp and crabs caught using handcrafted traps). Moreover, the use of natural resources by these communities is limited by restrictions imposed under the PCBR Management Plan.

We established a frequent dialogue with the communities to disseminate and discuss restoration objectives and understand people’s perceptions and interests related to ecosystem management and community well-being. Using a participatory mapping method (see pictures in planning, Figure 2), we conducted a social diagnostic to identify different characteristics of the territory, including geographic boundaries, location of other projects developed, primary livelihood activities, current and historical threats (e.g. fires, floods, hunting), and potential sites for implementing restoration activities. We also discussed lessons learned from previous projects, including the methods and techniques they used and the factors that determined the success or failure of those projects. Members of El Palmar mentioned that many young individuals planted in past reforestation were burned by fires in recent years. They also shared not having any monitoring protocol to evaluate the plants’ performance and were not fully aware of the ecological importance of mangroves. In Tembladeras we detected a negative perception of mangroves due to unexpected negative impacts associated with several reforestation using *R. mangle* in areas around their settlement over the last fifteen years. One such impact was the interruption of water flow in natural channels because, as they explained, ‘the mangroves grew too much and accumulated soil that clogged the channels’. This adversely affected their main economic activity, fishing. Consequently, they had no interest in new reforestation as part of ecological restoration activities under our project.

With the community members’ participation, we also conducted an ecological diagnosis of potential restoration sites and preserved areas (as reference sites) to establish their baseline ecological conditions. This step constituted an unfamiliar activity for both communities because in previous project experiences, they had only participated as a field labor force. We evaluated: 1) the composition and structure of the vegetation (i.e. species richness, number of individuals, height, and diameter), and 2) the physical-chemical variables of the water (i.e. salinity, pH, temperature, and redox potential). Additionally, we did cartographic analyses to identify ecological corridors, land-use changes, occurrence of fires, and hydrological modelling. Results of these analyses were shared with each community and used to design restoration actions, together with their local knowledge of traditional ecosystem management practices. Likewise, we signed a collaboration agreement with each
community, which specified the goals of the project and the economic income they would receive in the form of payments for different project activities (known as jornales) based on the standard fee used in governmental programs. From the communities’ point of view, both analyses (social and ecological) helped strengthen their prior knowledge of the ecosystem and enhanced their role in decision-making about restoration actions.

**Implementation phase – fieldwork activities**

The community of El Palmar was interested in restoring fishing channels to increase habitat for commercially important species and for the shade that mature mangrove trees would provide in future years during fishing journeys along the waterways. This area had formerly been covered by mangroves 20–30 years ago, but they disappeared due to frequent fires. We selected *R. mangle* for reforestation since this is the dominant species of riverine mangrove in this area. The planting design was developed based on community opinions, species architecture and local environmental characteristics, also considering a balance of sowing density and distance between individuals. Community members performed the plantings over three months. In total, 17,038 propagules were sown along 34,530 meters of channels (counting both sides), an area equivalent to 160 ha under the restoration process.

In Tembladeras, community members were primarily interested in hydrological rehabilitation of natural channels that had been blocked by sediments and organic matter, through manual cleaning to reestablish water flows. We performed a hydrological analysis using LiDAR models to determine the flow direction of regional tides and streams. We then used cartographic tools to select several transects of the natural channels for cleaning. The community conducted several sessions in groups over a period of three months, using manual tools like shovels and machetes to remove all elements that obstructed the channels. Manual cleaning of these transects was done over 4,940 meters, an area equivalent to 34.7 ha under the restoration process.

**Implementation phase – capacity building**

In parallel to implementing the restoration actions, we conducted a series of four workshops in each community to strengthen ecological knowledge and local capacities (Table 1). During these workshops, our team provided scientific and technical information to participants, and they in turn shared their knowledge and perspectives about the mangrove ecosystem and its functions. We actively promoted the participation of women and young people, seeking to reach as many members as possible in both communities as well as to increase interest, commitment, and involvement in the restoration process. It has been shown that natural resource management outcomes improve -and a community’s sense of ownership over a project increases- in direct proportion to the knowledge, capacity, and social cohesion that the project is able to promote (Brooks et al. 2013).
Monitoring phase

We conducted an initial assessment of restoration actions four months after implementation to reinforce the importance of periodic monitoring and verify how the restoration process was going. We involved community members, mostly young people, in using instruments and recording data. In the case of the R. mangle reforestation, this first evaluation was based on the individuals’ performance in terms of survival and growth. General survival was 74.5%. Growth data registered for 1,482 individuals (height, diameter, and number of leaves) will be used as the baseline to estimate the effectiveness of our planting effort from this point forward. Hydrological rehabilitation was more difficult to evaluate at this early stage since responses at the level of ecosystem functions are less evident, even if they recover more quickly (Herrera-Silveira et al. 2020). However, we agreed with community members that they would set artisanal traps in rehabilitated channels over the course of a month to record species captured and their weight. They found that crabs and shrimp, and some other species as well, were already present in the rehabilitated channels, an early indication of recovery in water flow dynamics. We encouraged both

| Workshop and Objectives | Local participation | Main results |
|-------------------------|---------------------|--------------|
| 1. Ecosystem services   |                     |              |
| ✓ Identify the uses and benefits of different species and components of mangrove ecosystems. | El Palmar: 20% Men; Tembladeras: 10% Women | • Participants more easily identified provisioning services due to the habitual use of natural resources as food, construction material, and medicines. |
| ✓ Classify the uses and benefits based on the main categories of ecosystem services. | El Palmar: 41% Men; Tembladeras: 52% Women | • They felt that the aesthetic beauty of their mangroves could generate ecotourism revenues. |

2. The ecological restoration process

|                     | El Palmar | Tembladeras | Both communities: |
|---------------------|-----------|-------------|------------------|
| ✓ Introduce the fundamental concepts of ecological restoration and the steps involved in a restoration project. | El Palmar: 30% Women; Tembladeras: 10% Men | • Participants learned conceptual definitions and basic steps involved in the ecological restoration process by playing the board game “Snakes and Stairs” |

3. Monitoring of mangroves

|                     | El Palmar | Tembladeras | Both communities: |
|---------------------|-----------|-------------|------------------|
| ✓ Teach methods for evaluating the biotic and abiotic characteristics of mangroves. | El Palmar: 20% Women; Tembladeras: 8% Men | • Participants developed a good understanding of the main objectives of ecosystem restoration and the methodological sequence required to develop restoration projects. |
| ✓ Promote the formation of a local monitoring brigade. | El Palmar: 60% Men; Tembladeras: 92% Women | • The participation of women was remarkable and provided a unique opportunity for them to interact and have a “voice” in the communal assembly. |

4. Community experiences exchange

|                     | El Palmar | Tembladeras | Both communities: |
|---------------------|-----------|-------------|------------------|
| ✓ Create a space for interaction between communities around experiences with mangroves restoration and sustainable forestry practices. | El Palmar: 53%; Tembladeras: 47% | • The participation of young people was dynamic and promoted interaction with older people. |

Table 1. Summary of the four workshops conducted in El Palmar and Tembladeras communities during the implementation phase of the participatory ecological restoration process.
communities to take an active role in maintaining the areas under restoration and preserving conditions favorable to the long-term success of the actions implemented.

Lessons learned

Our participatory ecological restoration process was founded on a recognition and respect for each community’s internal organization and decision-making process. This helped us to win their trust and promoted healthy communication among all stakeholders, as well as greater engagement with the project. Our efforts to ensure broad participation from the earliest phases were essential to encouraging a deeper sense of ownership among community members and securing their interest in developing the planned activities. We constantly underscored the fact that their knowledge and customs were valuable in defining our shared goals, and that their participation in all phases was indispensable. The consistent participation of women and young people in workshops and project activities was encouraging, since they do not typically have meaningful opportunities to participate and offer input given that men are traditionally the decision-makers in both communities. We view the positive outcomes of this process as the result of fostering open and straightforward communication among the different actors and taking a broad-based approach to decision-making through multilateral consensus grounded in scientific information and local knowledge.

Although these communities had worked on other projects previously, they mentioned that ‘this is first time we have been involved throughout the complete development of a project and have done a thorough restoration’. Their experiences with this project also helped to change the negative perception about mangroves on the part of some inhabitants from Tembladeras. Whereas they previously felt that conserving mangroves would negatively affect their livelihood activities, by obstructing fishing channels or occupying areas suitable for other uses, they came away expressing more interest in promoting sustainable management for longer-term benefits such as payments for carbon stocks (via the blue carbon economy) and opportunities for ecotourism. We recognize, however, that to achieve truly sustainable results, it is crucial to complement restoration initiatives with productive projects to transform current and future socio-environmental vulnerabilities. Following their experience with our project, the communities have been involved in other activities to improve the management and use of their natural resources, such as prevention and response to forest fires, capacity-building for sustainable fishing practices, agroecology for food security, and water quality monitoring.

Both communities expressed a better understanding of ecological restoration as a socio-ecological process that is ‘more than just planting trees’ and that takes time to generate results and benefits for the ecosystem and the people. In addition to the obvious short-term economic benefits from this project, such as income from fieldwork, community members came to understand that the restoration process can help improve their livelihoods and wellbeing in the long-term. The relationship of El Palmar and Tembladeras communities with mangroves had previously been focused on provision, without much understanding of the ecosystem’s role in providing other important services like regulation, including flood risk reduction. We are pleased to say that after this experience, many participants have greater awareness of the need to conserve and restore their ecosystems and are more conscious of the numerous benefits that mangroves provide to them.

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