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Diagnóstico de áreas degradadas de manglar y propuestas de restauración ecológica en el estado de Guerrero, México

Diagnosis of mangrove degraded areas and proposals for ecological restoration in the state of Guerrero, Mexico

Diagnóstico de áreas degradadas de mangue e propostas de restauração ecológica no estado de Guerrero, México

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Resumen

El incremento de las actividades humanas ha cambiado la hidrología de sistemas estuarinos y lagunares de zonas costeras, lo que ha generado la degradación de bosques de manglar. Por tanto, el objetivo del presente trabajo fue identificar y documentar la degradación de un área de manglar con daños estructurales, para lo cual se diseñó una propuesta técnica metodológica para determinar los factores causantes de la degradación, incluyendo acciones de restauración ecológica por implementar en la zona afectada en el estero de Tila, municipio de Marquelia, Guerrero, México. Se utilizó la metodología cualitativa mediante la técnica de observación participante en la zona de manglar afectada y la toma de fotografías como técnica para recolección de evidencias cualitativas, así como entrevistas a representantes clave que intervinieron en el proceso de identificación de la problemática, planteando la propuesta técnica de restauración de la zona afectada. Se identificaron las especies *Rhizophora mangle*, *Laguncularia racemosa* y *Conocarpus erectus* afectadas en un área de 15 hectáreas de manglar. Se recomendó a la Comisión Nacional Forestal desarrollar acciones para la identificación de la causa de mortandad del manglar y aplicar técnicas de restauración. Se concluye que las recomendaciones y la propuesta metodológica para identificar la mortalidad de los manglares fueron parcialmente abordadas, pues existió escaso monitoreo en el proceso de restauración en el sitio y, en consecuencia, poca efectividad en el proceso de técnicas de ingeniería ecológica.

Palabras clave: gestión forestal, hidrología, humedal, ingeniería ecológica, zona costera.

Abstract

The increase in human activities has changed the hydrology of estuarine and lagoon systems in coastal areas, resulting in the degradation of mangrove forests. The objective was to identify and document the degradation of a mangrove area with structural damage, designing a methodological technical proposal to identify and determine the factors that cause degradation, including ecological restoration actions to be implemented in the affected area in the Tila estuary, Marquelia Municipality, Guerrero, Mexico. Qualitative methodology and participant observation techniques were used in the affected mangrove area, as well as the photographic technique for collecting qualitative evidence, and interviews with key representatives who intervened in the process of identifying the problem, proposing the technical proposal of restoration of the affected area. Species of *Rhizophora mangle*, *Laguncularia racemosa* and *Conocarpus erectus* affected in an

area of 15 hectares of mangrove were identified. The National Forestry Commission was recommended to take action to identify the cause of mangrove mortality and to apply restoration techniques. It is concluded that the recommendations and methodological proposal to identify mangrove mortality were partially addressed, there was low monitoring of the site restoration process and consequently little effectiveness in the process of ecological engineering techniques.

Keywords: forest management, hydrology, wetland, ecological engineering, coastal zone.

Resumo

O aumento das atividades humanas mudou a hidrologia dos sistemas estuarinos e lagunares nas áreas costeiras, o que levou à degradação das florestas de mangue. Portanto, o objetivo deste trabalho foi identificar e documentar a degradação de uma área de manguezal com danos estruturais, para a qual foi elaborada uma proposta técnica metodológica para determinar os fatores causadores da degradação, incluindo ações de restauração ecológica a serem implementadas na área afetada no município. Estuário de Tila, município de Marquelia, Guerrero, México. A metodologia qualitativa foi utilizada através da técnica de observação participante na área de manguezal afetada e a realização de fotografias como técnica de coleta de evidências qualitativas, além de entrevistas com representantes-chave que intervieram no processo de identificação do problema, levantando a proposta técnica de restauração. da área afetada. As espécies afetadas Rhizophora mangle, Laguncularia racemosa e Conocarpus erectus foram identificadas em uma área de 15 hectares de manguezal. A Comissão Nacional de Florestas foi recomendada a desenvolver ações para identificar as causas da mortalidade dos manguezais e aplicar técnicas de restauração. Conclui-se que as recomendações e a proposta metodológica para identificar a mortalidade dos manguezais foram parcialmente atendidas, uma vez que houve pouco monitoramento no processo de restauração do local e, consequentemente, pouca eficácia no processo de técnicas de engenharia ecológica.

Palavras-chave: manejo florestal, hidrologia, pantanal, engenharia ecológica, zona costeira.

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Introduction

Mangrove ecosystems (located in coastal areas, coastal lagoons, river mouths, estuaries and wetlands) are of great importance not only for the different benefits they provide in terms of stabilization and protection of coastlines, refuge areas, food and nesting of various species of aquatic and terrestrial fauna (Calderón, Aburto and Ezcurra, 2009), but also because of their extension, diversity, composition, timber structure and ecological values (Castillo, Gervacio and Bedolla, 2018). Mangroves, therefore, are considered natural engineers that integrate, maintain and determine their physical environment. Its natural resilience includes withstanding conditions of salinity, desiccation, flooding and the ability to sustain itself in unstable substrates (Olguín, Hernández and Sánchez-Galván, 2007).

However, the increase in human activities has changed the hydrological flows of the coastal estuarine and lagoon systems, which has generated high levels of degradation of the mangrove forests in certain regions (National Forestry Commission [Conafor], 2009, 2011) .

Now, in the case of mangroves, the term restoration is used to refer to any process aimed at restoring their previous conditions. In fact, depending on the level of intervention applied, this may be through an “active restoration”, which refers to the deliberate recovery of the degraded system, simulating the natural dynamics of the ecosystem (natural succession) with the intervention of human hands, or through a “natural or passive restoration”, which consists of the natural repair of a degraded system with little or no human intervention, following the basic principles of secondary succession (Holl and Aide, 2011).

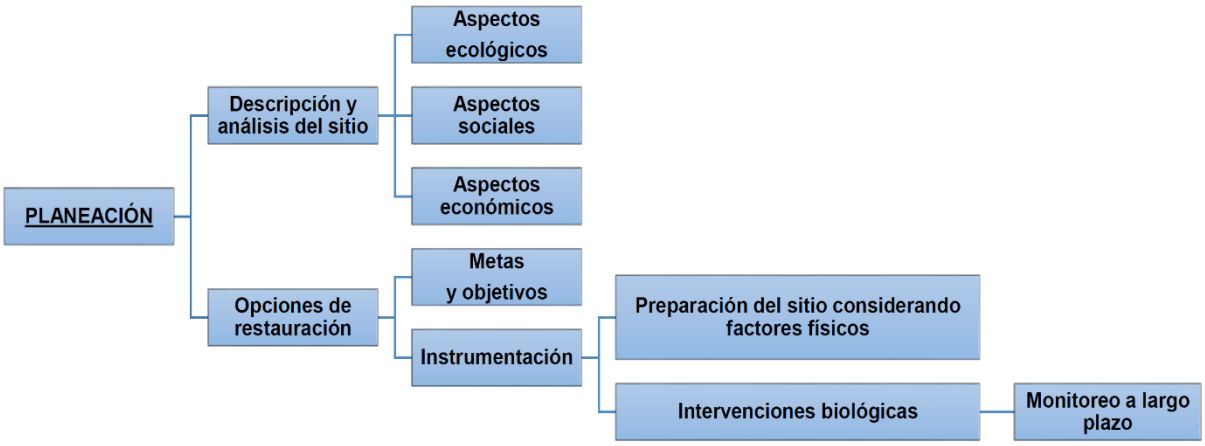
In this sense, Teutli-Hernández, Herrera-Silveira, Cisneros de la Cruz and Román-Cuesta (2020) define restoration as a deliberate activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability; However, most of the restoration projects have been activities aimed at the reforestation of mangrove seedlings, as obsolete “trial and error” practices, without considering adequate restoration strategies that depend on the initial conditions and the reference environmental scenario. of each site, which results in the failure of the restoration (Teutli-Hernández y Herrera-Silveira, 2016; Teutli-Hernández *et al*., 2020).

Frequently, the ecosystem that requires restoration has been degraded, damaged, transformed or totally destroyed as a direct or indirect result of anthropogenic activities, as well as, although to a lesser extent, by natural phenomena such as fires, floods, storms or volcanic eruptions (Moreno -Casasola and Peresbarbosa, 2006; Ochoa, 2010).

Conservation or restoration strategies will depend on the level of degradation of the affected area (Comín, 2014); in the case of mangrove ecosystems, it can be applied to the entire mangrove or to some sections, which could involve the use of conservation or restoration measures (Lindig and Zambrano, 2007).

According to the Society for Ecological Restoration [Ser] (2004), the National Forestry Commission and the Ministry of Environment and Natural Resources [Conafor-Semarnat] (2010), and Gann et al. (2019), the steps to follow and implement an ecological restoration project should be considered, which can be divided into three stages: planning, instrumentation and monitoring (Fig. 1).

Figura 1. Procedimiento general de restauración ecológica



Fuente: Elaboración propia con datos de Lindig y Zambrano (2007)

In the planning stage, the site analysis is included and the physical, biological and social factors are evaluated, considering the following:

- ✓ Assess the level of degradation.
- ✓ Consider the surrounding landscape and its state of conservation as a guide.
- ✓ Social aspects related to restoration include the type of property of the property (private, communal, state, among others).

In the instrumentation and implementation stage, those measures are carried out that will allow directing the system towards the desired state, making use of different suitable restoration techniques.

In the monitoring stage, the area undergoing restoration must be monitored to evaluate performance based on the objectives set for each stage and the goals to be achieved at the end of the project and the evaluation of management and restoration activities. During this phase there is the possibility of making modifications during the restoration process in case, as a result of the monitoring, it is concluded that the system is following an undesired trajectory, thus requiring adjustments in the goal stages. and objectives.

On the other hand, Vanegas (2016) considers five lines of action for efficient restoration:

- ✓ Forensic ecology and mangrove diagnosis.
- ✓ Definition of restoration actions.
- ✓ Monitoring of success indicators.
- ✓ Socialization and public participation.
- ✓ Training and information transfer.

While Lindig and Zambrano (2007), Teutli-Hernández and Herrera-Silveira (2016) and Teutli-Hernández et al. (2020) recommend a series of attributes and variables that can be monitored in a mangrove restoration project, which include the following indicators:

- ➢ Hydrology and topography: It considers the flood regime, level of the water table, flow of water through the wetland, development of channels, changes in the level of wetlands and sedimentation.
- ➢ Water quality: Considers temperature, dissolved oxygen, salinity, pH, light attenuation, turbidity, stratification of the water column, and nutrient concentrations.
- ➢ Soil: Focuses on substrate quality, nutrient dynamics, water content (soil moisture), density, texture, salinity, pH, oxide-reduction potential, organic matter and organic carbon content, nitrogen and phosphorus , decay rates, topography and microtopography.
- ➢ Vegetation: It covers aspects of vegetation cover by species, vegetation architecture, abundance of species (rare, threatened or invasive species), biomass, productivity and timber volume.
- ➢ Fauna: The identity of the species, abundances, species richness and diversity, population structures and residence times are determined (in the case of animals that move, time spent in a habitat).

On the other hand, there are different factors that favor the impact of mangroves, such as the following:

- Poverty of the local inhabitants.
- Lack of environmental education.
- Lack of knowledge of the importance of mangroves.
- Lack of knowledge of the laws on their protection and conservation.
- Inadequate planning of development activities.
- Lack of systematic management of mangrove lands.
- Limited presence of the authorities to provide protection to these ecosystems.

Currently, mangroves remain protected by the following extensive legal framework:

- General Law of Ecological Balance and Environmental Protection (Lgeepa).
- General Wildlife Law.
- General Law of Sustainable Forestry Development (Lgdfs).
- Lgeepa Regulations on Environmental Impact Assessment
- NOM-059-SEMARNAT-2010.
- NOM-022-SEMARNAT-2003.
- Mexican Federal Criminal Code on Environmental Crimes.
- International Ramsar Convention (February 2, 1971).
- Applicable international agreements and decrees.

So far, in the state of Guerrero there are no successful studies of ecological restoration in mangrove systems, and only some reforestation activities have been carried out. In fact, research has focused on plant taxonomy issues (Diego-Pérez and Fonseca, 2005), studies of the physicochemical parameters of the lagoons (Castillo-Elías, Gervacio-Jiménez, Bedolla-Solano, García-Domínguez and Mendoza-Almazán , 2017; De la Lanza, Alcocer-Durand, Moreno-Ruiz and Hernández-Pulido, 2008; Dimas, Ortega and Ortiz, 2018; Ferrara-Guerrero, Castellanos-Páez and Garza-Mouriño, 2007), relation of fishing resources in areas mangrove (Gil, Violante and Rojas, 2008), biomass productivity (Juárez, García, Olivier and Zeferino, 2019), reproductive phenology (Tovilla and Orihuela, 2002), environmental characterization and biotic and abiotic components (Villerías, Tello and García , 2016), forest and floristic structural composition in a mangrove area (Castillo et al., 2018), presence of a plague in mangroves (Castillo-Elías and Gervacio-Jiménez, 2013), mangrove impacts due to anthropogenic activities (Vences-Martínez et al., 2018, García-Domínguez et al., 2020) and p sustainable community mangrove management lanes (García-Domínguez et al., 2019).

Therefore, the objective of this research was to identify and document the degradation of a mangrove area with structural damage. For this, a methodological technical proposal was designed to identify and determine the factors causing degradation, including ecological restoration actions to be implemented in the affected area of the Tila estuary, belonging to the Barra de Tecoanapa ejido, Marquelia municipality, Guerrero.

Materials and methods

Study area

The mangrove area affected is located near the Tila estuary at the geographic coordinates of 16 ° 31 '46.30 "N and 98 ° 44' 47.62" W (Fig. 2), belonging to the municipality of Marquelia, Warrior.

Figura 2. Ubicación de la zona de manglar afectada

Fuente: Elaboración propia con *software* QGIS (2021) y datos de Google Earth Pro (2016)

Its characteristic orography is of the relief type consisting of semi-flat and flat areas, with heights ranging between 5 and 50 m s. n. m. Its hydrography is represented by the presence of the Quetzala rivers (Rio Grande), located in the southeast part, the Marquelia or San Luis river, which runs on the western part of the municipal area, marking the limit with the municipalities of Copala

and San Luis Acatlán . There are other streams of lower flow, such as Zayotlán, El Zapote, Tila, Arroyo Seco and El Guayabal.

The characteristic climate is of a warm sub-humid type, with a temperature of 17 ° C in the winter season, which includes the months of December and January. The maximum temperature, in May, reaches 36 ° C, with the hottest months being spring and summer, with annual average rainfall of 1200 mm. The highest rainfall includes the months of June to September (Gobierno del Estado de Guerrero, 2015).

Sampling

Overland tours were carried out in the study area along the margin of the Tila estuary in the north and south. For this, the qualitative methodology was used through an exploratory, inductive and descriptive analysis (Monje, 2011), using the participant observation technique (Gómez, 2012; Hernández-Sampieri, Fernández and Baptista, 2018; Taylor and Bogdan, 2000).

Qualitative evidence of the damage observed on the mangrove vegetation was collected by means of the photographic technique (González, 2008) in order to have visual inputs of the affectation.

A technical proposal for ecological restoration was designed based on forensic engineering and ecology methodology for mangrove restoration cited by Mitsch and Jørgensen (2003), Lindig and Zambrano (2007), Teutli-Hernández and Herrera-Silveira (2016). For the monitoring of the physicochemical parameters of the lagoon water, the Official Mexican Standard NOM-127-SSA1-1994 (Ministry of Health [Ssa], 1994) and the ecological criteria CE-CCA-001/89 (National Institute of Ecology [Ine], 1989). The microbiological analysis of the lagoon water was based on NOM-127-SSA1-1994 (Ministry of Health [Ssa], 1994) and on the method for determining coliform bacteria CCAYAC-M-004-2006 (Ministry of Health [Ssa] , 2006); Likewise, the analysis of the soil attached to the affected ecosystem was recommended, taking into account the physicochemical parameters recommended by Ruiz-Ochoa, Meléndez, Castellanos and Polanía (2006).

This methodological proposal was presented to the environmental authorities in a forestry forum where the environmental authorities and representatives of the community of Barra de Tecoanapa, Guerrero were present, in order to be implemented in the affected mangrove area of the Tila estuary.

Interviews were conducted with key informants who intervened in the process of identifying the problem, such as representatives of the Guerrero State Attorney for Environmental

Protection (Propaeg), Federal Attorney for Environmental Protection (Profepa), Conafor and Municipal Ecology of Marquelia , Warrior. Also, on-site tours were carried out in the mangrove area intervened to verify the current situation of the ecological restoration process.

Results

Identification of the problems

During June 2016, in coordination with the staff of Propaeg, Conafor and the Municipal Ecology Directorate of Marquelia, overland tours were carried out along the margin of the Tila estuary in the north and south, respectively. Photographic evidence was collected mainly of the damage to the mangrove vegetation in order to have evidence for the technical proposal of ecological restoration and immediate intervention.

The affectation was detected on an approximate area of 15 hectares of mangrove, which presented a phenomenon called aged mangroves (Fig. 3).

Figura 3. Mangles afectados (manglares envejecidos)

Fuente: Fotografía por Benjamín Castillo-Elías

The affectation was mainly identified in the species of red mangrove (Rhizophora mangle), white mangrove (Laguncularia racemosa) and button mangrove (Conocarpus erectus), which are listed in NOM-059-SEMARNAT-2010 (Ministry of the Environment and Natural Resources

[Semarnat], 2010), considered under a risk status and under protection. No damage was detected for other species of accompanying flora, with characteristics of a riparian-type mangrove forest.
Once the field trip had been completed and the evidence was collected, in September 2016 the state forestry forum participated with an investigation entitled Good practices for soil and water conservation, organized by the National Forestry Commission (Conafor) based in Chilpancingo. , Warrior. There, the findings of the diagnosis in the affected area of the mangrove were presented, as well as the recommendations and the technical proposal for restoration, which included the methodology to implement it in the degraded area.

Proposals and recommendations for restoration

It was recommended to consider the indicators of hydrology, topography, substrate quality and nutrient dynamics, water quality, vegetation and fauna as measures to intervene in the mangrove area and identify the cause of mortality. Specifically, the following actions were proposed:

1) Convene working meetings between key actors, such as the Ministry of the Environment and Natural Resources (Semarnat), the Federal Attorney for Environmental Protection (Profepa), the National Water Commission (Conagua), the Ministry of the Environment and Natural Resources of the State Government of Guerrero (Semaren), Procuraduría de Protección Ambiental del Estado de Guerrero (Propaeg), National Forestry Commission (Conafor), Municipal Presidency of Marquelia through the Municipal Ecology Directorate, state and federal health sector (Ssa), academic sector and ejidal authorities of the community, in order to make collegiate decisions about this problem.
2) Carry out the study of water quality by selecting different sampling stations of the body of the estuary through the measurement of the following physicochemical parameters:
   - ✓ PO_4^{3-} (ortofosfatos).
   - ✓ NO_3^- (nitratos).
   - ✓ NO_2^- (Nitritos).
   - ✓ SO_4^{2-} (sulfatos).
   - ✓ OD (dissolved oxygen).
   - ✓ SAAM (active substances to methylene blue).
   - ✓ C_6H_6O (fenoles).
   - ✓ DBO (Biochemical Oxygen Demand).

- ✓ pH (hydrogen potential).
- ✓ GyA (Fats and Oils).
- ✓ SST (total suspended solids).
- ✓ PT (total phosphorus).
- ✓ NT (total nitrogen).
- ✓ Salinity (ppm,%, PSU or UPS).
- ✓ Electrical conductivity (CE).
- ✓ Turbidity (UTN).
- ✓ T ºC (temperature).

From the water quality analysis, in table 1 it is recommended to consider nine physicochemical parameters with their respective reference values (permissible quality limits) in accordance with the Official Mexican Standard NOM-127-SSA1-1994 (Ministry of Health [Ssa] , 1994), ecological criteria CE-CCA-001/89 (National Institute of Ecology [Ine], 1989) and corresponding test methods applicable to lagoon bodies.

Tabla 1. Valores medios de indicadores físicoquímicos de calidad del agua y métodos analíticos

Parámetro evaluado	Método analítico de prueba	Límite permisible de cuantificación *
Nitritos (como N) mg/L	Colorimétrico	1,0
Sólidos totales mg/L	NMX-AA-034-SCFI-2001	No aplica
Oxígeno disuelto mg/L	NMX-AA-012-SCFI-2001	1 mg/L
Grasas y aceites mg/L	NMX-AA-005-SCFI-2000	No aplica
Salinidad % o S (ppm o UPS)	NMX-AA-073-SCFI-2001	No aplica
Conductividad µS/cm a 25 ºC	NMX-AA-093-SCFI-2000	No aplica
Turbiedad UTN	NMX-AA-045-SCFI-2001	5,0
pH	NMX-AA-008-SCFI-2000	6,5 - 8,5
Temperatura ºC	*in situ*	No aplica

* De acuerdo con la NOM-127-SSA1-1994 (Secretaría de Salud [Ssa], 1994)

Fuente: Elaboración propia

Likewise, it was suggested to include in the water quality analysis the determination of toxic substances (eg, heavy metals, pesticides and coliform bacteria) due to the evidence of application of fertilizers and herbicides found in the orchards near the place of the affectation. At this point, for the analysis of the microbiological parameters of total coliforms (TC) and fecal coliforms (CF), it was recommended to consider the NOM-127-SSA1-1994 (Ministry of Health [Ssa], 1994) and

the method of determination of coliform bacteria CCAYAC-M-004-2006 (Ministry of Health [Ssa], 2006) to define the viability of water for recreation and human consumption.

3) Consider the topography and soil analysis attached to the affected ecosystem, contemplating the corresponding parameters according to Ruiz-Ochoa et al. (2006), determining the edaphic properties (description of the soil profile) of the mangrove swamp, salinity (mg L-1), electrical conductivity CE (µS cm-1), organic matter MO (%) and pH (Table 2).

Tabla 2. Métodos utilizados en la determinación de las propiedades edáficas del manglar

Propiedad	Método
Humedad	Secado a 105 °C hasta peso constante.
Salinidad y CE	Potenciómetro. Salinidad (mg L^{-1}) y conductividad eléctrica (tetra con 325 1 µS cm^{-1} a 500 mS cm^{-1} y desde -5 °C hasta 80 °C).
MO	Calcinación a 550 °C en mufla.
pH	Potenciómetro. Multiparamétrico WTW P4 con el electrodos pH Sen Tix 41- 3 (0-14).

Fuente: Ruiz-Ochoa *et al*. (2006)

4) Carry out a diagnosis of the entire estuary reservoir (basin) to identify the behavior of the hydrological flow and determine actions to restore the hydrological conditions and the rehabilitation of the mangrove ecosystem, either by desilting and / or opening of channels.
5) Consider the evaluation of the baseline from selecting the reference forest to have the comparison of the undisturbed area and determine the assisted ecological restoration process.
6) Rescue the mangrove seedlings that are developing in the estuary and that have not been affected to avoid their death, as well as collection of seeds and cuttings in good condition to be transferred to a temporary nursery and have propagules for restoration and afforestation correspondent.
7) Carry out the calculation of the timber volume of the dead wood and its removal as a sanitation measure for the opening of spaces and channels between the dead mangrove vegetation.
8) Identify suitable sites to restore and afforest.

9) Evaluate, monitor and follow up on the restoration program to measure progress, results and indicators of success, which will allow the corresponding adjustments to be made to avoid or minimize a possible failure in ecological restoration.

Following up on the aforementioned methodological proposal, in August 2020 interviews were conducted with officials and key informants who participated in the identification of this problem in the mangrove area to verify whether the proposed restoration proposal in the year was met. 2016, where they mentioned that in 2018, through the environmental compensation program for land use change in forest lands, financed by Conafor-Semarnat, intervention was carried out in the affected mangrove area with the participation of Conafor personnel and some residents of the rural area of Barra de Tecoanapa, Guerrero.

According to the information gathered from the interviews, official information was sought from government agencies (such as Propaeg, Profepa, Conafor and Ecología Municipal de Marquelia, Guerrero), which were unaware of the restoration actions carried out at the affected site.

Therefore, the comparison of the mangrove area was carried out through aerial images before the restoration of 2016 (Fig. 4) and after the restoration corresponding to the year 2020 (Fig. 5). Evidence of intervention was observed in the affected area and it was identified that the mangrove forest cover is scarce in the interior of the estuary after two years of having intervened in said space.

Figura 4. Zona afectada antes de la restauración (junio 2016)

Fuente: Elaboración propia con *software* QGIS (2021) y datos de Google Earth Pro (2016)

Figura 5. Zona restaurada (agosto 2020)

Fuente: Elaboración con *software* QGIS (2021) y datos de Google Earth Pro (2020)

On-site verification of the intervened area

According to the results obtained in the interviews with the key actors, in September 2020 a tour of the intervened site was carried out in order to obtain visual information on the current conditions of the mangrove area. There the sanitation of the dead plant matter and the fluidity of the lagoon body were appreciated, as well as the reforestation activities, mainly on the periphery of the estuary, where specimens of L. racemosa and C. erectus from a manual reforestation activity were observed. , some in good condition and some damaged or dead. No recent monitoring evidence was detected because the tidal level was very high inside the body of the estuary; At that time, there was no evidence of restoration techniques by translocation of soils such as bedding, huacales, chinampas, among others (Fig. 6), which would allow mangrove seedlings or propagules to survive if it had been implemented correctly. the methodological restoration technique initially proposed. The foregoing confirmed that no follow-up, monitoring and maintenance has been given in the restored area.

Figura 6. Condición actual de la zona de manglar (septiembre de 2020)

Fuente: Fotografías por Herlinda Gervacio Jiménez

Discussion

According to the results obtained, it was determined that the symptoms observed in the study area in 2016 presented the phenomenon called aged mangroves. In fact, in studies carried out in mangrove areas, Castillo-Elías and Gervacio-Jiménez (2013) determined that various anthropogenic activities are the cause of this phenomenon, such as livestock, logging and

desiccation (Castillo et al., 2018) , discharge of wastewater or chemical products that affect the aquatic ecosystem and dramatically impact the mangrove area due to the contamination of the lagoon water quality (Castillo-Elías et al., 2017; Dimas et al., 2018), due to the presence of of pest insects, which (due to climate change conditions) proliferate and affect mangrove forests (Castillo-Elías and Gervacio-Jiménez, 2013), and by infestation of pathogenic fungi, such as the species Cytospora rhizophoreae (Perdomo, Miniño, Rodríguez by Francisco and León, 2018). This causes the death of seeds, suckers and the destruction of the aerial roots of R. mangrove, as well as the lack of supply and exchange between continental waters and oceanic water to keep the salinity concentration balanced and regulate the hydroperiod, as mentioned by Teutli -Hernández et al. (2020). Therefore, it is necessary to consider the water quality analysis in the area attached to the mangrove studied to determine the cause of the damage.

During the in situ tour in 2020, no representative mangrove forest cover was observed before degradation, so it was determined that the restoration intervention carried out in 2018 has not been successful so far; According to the qualitative evidence detected, it was necessary to implement a program of constant monitoring of activities, as recommended by Aguilar-Garavito and Ramírez (2015) and Evans and Guariguata (2016), who propose monitoring to measure progress and optimal results in ecological restoration programs.

Likewise, the Ministry of the Environment, Natural Resources and Fisheries and the National Institute of Ecology [Semarnap-Ine] (2000), as well as the National Water Commission [Conagua] (2006) and Castillo-Elías et al. (2017) recommend that, for a successful intervention, the first step should focus on water quality studies through the analysis of physicochemical parameters, as this will allow the design of the appropriate methodology for the intervention in the affected site, which obviously it was not carried out during the restoration intervention in 2018.

It was also detected that there was no proper sanitation in the affected area due to the fact that during the period of identification of the damage, a large amount of dead mangrove wood was observed, which had to be used as firewood and / or charcoal by the inhabitants of the area. community; The timber volume must be calculated to determine the cubic meters of affected timber (Castillo et al. (2018).

In this same context, Teutli-Hernández and Herrera-Silveira (2016) and Teutli-Hernández et al. (2020) point out that to achieve a successful restoration, an appropriate diagnosis and follow-up and monitoring of the intervened area is necessary, which will allow the ecosystem to create favorable conditions for its self-regeneration through a secondary succession, achieving the

acceptable restoration of hydrology. and the vegetation with a minimum period of two years after the restoration, reaching its complete restoration up to a maximum of 17 years. According to the results and the evidence obtained, the methodological recommendations proposed for this study area were not properly addressed.

Another documented aspect was the lack of involvement of the entire local community, since their participation is fundamental in any ecological restoration program, as pointed out by Aronson et al. (2010) for a project to be successful. In fact, in addition to considering the ecological aspect, community intervention should be considered, as well as the socioeconomic and cultural condition of the region, in such a way that along with a restoration project, the impulse of productive and compensatory projects is alternately generated. recommended by the National Commission of Protected Natural Areas [Conanp] (2018) through the Conservation Program for Sustainable Development (Procodes), to optimize the quality of life of the inhabitants and the socioeconomic conditions of the region.

Another important element that was documented was that government authorities at the federal, state and local levels were unaware of the restoration intervention in the Tila estuary due to the lack of coordination between authorities and the community; In the case of this study, Conafor was the government institution responsible for making the federally funded program of environmental compensation transparent and providing follow-up, monitoring and evaluation of the intervened area in that mangrove area; In this regard, Vanegas (2016) points out the importance of involving, socializing and informing about the general ecological restoration procedure, promoting public participation, considering it an obligation to publicly disclose the results of all restoration activities, as well as the favorable success indicators. or unfavorable for future corrections of the methods and strategies implemented, in order to regulate the actions through accountability among all the actors involved.

Likewise, Lindig and Zambrano (2007) and Teutli-Hernández and Herrera-Silveira (2016) explain that to ensure success in restoration it is necessary to integrate local communities to jointly establish the construction of sustainable solutions that directly benefit them, developing a mangrove community management plan and training the inhabitants in the different restoration techniques to be implemented, since they will be the ones who will monitor the restored site (Aronson et al., 2010), actions that were obviously not implemented in the restoration from the Tila estuary, as mentioned by specialists on the subject.

On the other hand, there was evidence that the stipulations of NOM-022-SEMARNAT-2003, which establishes the specifications for the preservation, conservation, sustainable use and restoration of coastal wetlands in mangrove areas (Secretariat of Environment and Natural Resources [Semarnat], 2003).

Finally, based on the findings obtained in the present study, it was determined that the correct methodology proposed for the restoration of the mangrove area of the Tila estuary was not followed; therefore, it is necessary to deepen the methodological-scientific review that provides adequate technical elements for a correct process of ecological restoration of these coastal ecosystems.

Conclusions

The intervention carried out in 2018 by Conafor and some community residents did not obtain the expected results in the restoration process, which was confirmed by the evidence obtained in 2020. Undoubtedly, the participation of the community, the environmental authorities of the three levels of government and academics specialized in mangrove restoration are essential, as only collaborative work will achieve the desired success.

On the other hand, it was evident that in order to identify the factors causing the death of mangrove vegetation, the proposed methodology was not followed, with which the structural and functional damages of this ecosystem can be evaluated; For this reason, follow-up, monitoring and evaluation in the area intervened with the restoration are essential.

Another determining factor for the failure to carry out a successful restoration was the monitoring and supervision by the corresponding environmental authorities, in this case Conafor was responsible for monitoring the ecological restoration process, however, two years after The intervention in the mangrove area, when seeking information related to this study, the corresponding authorities were unaware of the existence of information regarding the restoration program implemented in the Tila estuary.

During the realization of this study, no documented evidence was found to support the performance of this restoration activity, no scientific publications were found on the results, findings, progress, monitoring and evaluation of the restoration process on the study area, which They are essential elements to know the success or failure of the intervention, so this study will allow to lay the foundations on the issue of restoration in mangrove areas in the state of Guerrero.

Future lines of research

The present diagnosis developed is considered a reference for future research related to the process of ecological restoration in mangrove areas, because so far in Guerrero there are no scientific studies or methodological experiences that have been successfully carried out on the subject of restoration for these coastal ecosystems, hence the relevance of this study. This diagnosis contemplates the methodological guidelines for a correct intervention in areas affected by anthropogenic activities and / or natural phenomena that need to be restored through the implementation of restoration techniques and methods applicable to mangrove areas. Likewise, this study is a watershed for future lines of research in other sites with the same problem, since methodological proposals and recommendations for a successful restoration that could be applied in other affected sites were contemplated.

The following lines are considered as a reference to carry them out in future studies:

- ✓ Identify the environmental problems caused by anthropogenic activities in the mangrove areas and their adjoining areas.
- ✓ Determine the ecological importance of the mangrove through the structural, timber, floristic and fauna composition.
- ✓ Implement participatory workshops and actions for dissemination, awareness and environmental education among the inhabitants for the care and protection of mangrove ecosystems.
- ✓ Promote the establishment of nurseries as Management Units for the Conservation of Wildlife (Umas) for the production of mangrove plants and contribute to the conservation and afforestation of the species to generate alternatives for integral sustainable use in the communities attached to the zones mangrove.

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