Community Perception and Adaptation to Climate Change in Coastal Areas of Mexico

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Abstract: Climate change adaptation is an increasingly important topic addressed in the face of the current and expected future impacts by climate change that the social, economic and ecological systems are experiencing worldwide. Despite the advances reported in the literature, adaptation to climate change is still considered a challenge to move from planning to the practical implementation of successful interventions. In this regard, identifying international key barriers, exchanges of experiences and lessons learned may facilitate the progress of the coasts’ sustainable and resilient future. The coast of Mexico is an excellent study area. High population densities occur along the coastal zone, whose main economic activity is related to primary and tertiary sectors. Additionally, a great diversity of coastal ecosystems exists, which are threatened by anthropogenic and hydrometeorological impacts. Under these circumstances, the population is becoming aware of the urgent need to adapt to the consequences of climate change. In this sense, this paper reviews research contributions concerning population perception to climate change and adaptation strategies in Mexico’s coastal zone. The findings highlight critical institutional difficulties and social barriers that have impeded the effective implementation of adaptation strategies to climate change in Mexico and consider steps to address them. However, adaptation strategies that show the prevention culture of some coastal communities have been found and also results of successful projects carried out, especially on mangrove forest and coral reef restoration, which are of essential importance to consider to progress on the path of a successful adaptation to climate change in Mexico.

Keywords: perception; adaptation strategies; Mexico; climate change; implementation constraints; recommendations

1. Introduction

In the past few decades, an increasing number of studies have addressed the need for adequate adaptation responses to climate change given the substantial losses and growing impacts in coastal areas across the world [1–3]. Sea level rise at a rate of 3.6 mm/yr has been globally reported [4], together with changes in salinity, ocean temperatures, alteration of precipitation patterns and changes in the frequency and intensity of extreme weather events [5–7]. As a result, coastal flooding is one of the critical environmental problems for low-lying coasts [3,5,8]. Studies indicate that the costs of inaction may be much greater than the cost of being proactive in relation to climate change effects [9,10].

Adaptation initiatives comprise multiple systems particularly vulnerable to climate change and sea-level rise, including agriculture, coasts, the environment and urban areas [11]. Among the coastal ecosystems threatened by the effects of climate change, mangroves are declining globally at a faster rate than tropical forests and coral reefs [12]. Adapting to climate change means taking measures to prepare for both the current effects of climate change and the expected future impacts, which are put into practice through three main goals: (1) increasing adaptive capacity, i.e., the ability to adjust effectively to changes, managing or reducing risks; (2) increasing resilience, i.e., the capacity of a system
to withstand adversity and continue operating when faced to stress or (3) reducing vulnerability, i.e., the susceptibility of a system to damage when exposed to an external hazard [11]. Adaptation strategies encompass a wide range of solutions, classified broadly in three main categories: 1. ‘Protect’, 2. ‘Accommodate’ and 3. ‘Retreat’ options. ‘Protect’ strategies include hard engineering defenses (e.g., breakwaters), soft engineering interventions (e.g., beach nourishment) and ecosystem-based solutions (e.g., mangrove conservation/restoration). Non-structural mitigation options, such as land-use regulations or information systems (e.g., flood hazard mapping or emergency preparedness programs), are included in the ‘Accommodate’ options category. Finally, the ‘Retreat’ option includes realignment (e.g., shoreline building setbacks, soft tolerant crops or land-use change) [13]. Owen et al. [11] divided the adaptation activities into three overarching groups, according to the classification of the Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5): 1. ‘Social Adaptation Activities’, containing ‘Educational’, ‘Informational’ and ‘Behavioral’ actions; 2. ‘Institutional Adaptation Activities’, which include ‘Economic options’, ‘Law and Regulations’ and ‘Policies and Programs’; 3. ‘Physical and Structural Adaptation Activities’, with the subcategories ‘Engineered and Built Environments’, ‘Technological Innovation’, ‘Ecosystem-Based Adaptations’ and ‘Services’. Several studies highlight the importance of conserving and restoring coastal ecosystems such as mangrove forests and coral reefs. The main goal is to take advantage of the flood and erosion protection benefits they provide as natural defenses to coastal communities while maintaining their environmental value [14–16]. Coastal adaptation measures should allow landward migration of mangroves and other tidal forests across coastal lowlands, which is already greatly impeded by urban developments along many coastlines [17]. Accommodation space is also an essential requirement to ensure dune zone mobility and development and thus the functioning of foredune morphologies under sea-level rise [18]. Nevertheless, there is much to be completed regarding adaptive capacity to move from planning to implementing adaptation measures [11,19,20]. A key development challenge is that the poorest and most vulnerable societies are the least able to cope with the threats of climate change [21]. Other significant challenges to consider for planning and decision-making concerning climate change are: (1) insufficient funding, (2) lack of political and public support, (3) confluence of ecological and social priorities, (4) management of risk and uncertainty, (5) increased coastal ownership (private or concessioned) and (6) coordination of cohesive adaptive planning [22]. Barriers regarding social factors or ideologies, the desired long-term lifestyle and communities’ customs and traditions are more challenging than those concerning scientific knowledge, information sharing, uncertainties in risks and responses and organizational coordination [22]. In this sense, the subjective assessment of community experiences and perceptions of climate change are of considerable importance to understand how people make sense of climate change for their lives, especially in small-scale communities dependent on the climate for their subsistence [21,23–26]. Currently, coastal tourism plans and policies largely ignore how tourism destinations can respond and adapt to the impacts of climate change in the short and medium term, despite the importance of coastal tourism to the global economy and impacts of climate change on the coast [27]. Finally, it can be difficult to discern climate adaptation from other related activities, such as environmental disaster risk reduction or poverty alleviation, complicating the attribution of successful adaptation efforts to climate change and coasts simultaneously, as proposed by the integrated coastal zone management vision [11,28]. Globally, Mexico is among the most vulnerable countries in terms of coastal flooding in the face of a 1 m sea-level rise [8,29,30], with an estimated inland flood propagation of up to 50 and 60 km in the most low-lying areas [5], especially along the coasts of the Caribbean Sea and the Gulf of Mexico. The high population density, tourism infrastructure, rural communities living in poverty along its coasts and the great diversity of marine–coastal ecosystems make climate change one of Mexico’s most important adverse impacts [25]. Mexico has made significant progress on climate change; however, additional efforts are required to
effectively implement actions that improve local resilience and the capacity to react to climate hazards [26,31].

In this paper, a literature review on community perception and adaptation strategies to climate change in coastal areas of Mexico is presented. The work is organized as follows. Section 2 presents the description of the study area. Section 3 details the steps followed to perform the literature review. Section 4 presents the results: firstly, aspects related to community perception of climate change; secondly, barriers to implementing adaptation strategies and finally, examples of studies and adaptation strategies to climate change carried out in Mexico. Lastly, Section 5 contains the discussion on the main findings and some recommendations.

2. Study Area

The study area is Mexico’s coastal zone, with 12,018 km of coastline across 17 coastal states [32] (Figure 1). The Yucatán Peninsula is called the region of Southeastern Mexico, comprising the three coastal states of Campeche, Yucatán and Quintana Roo. Land use is mainly destined for tourism infrastructure, crop and livestock fields and a great diversity of coastal ecosystems (Figure 2). Tourism is the primary source of income and economic growth in several coastal states in Mexico, especially in Quintana Roo, on the Caribbean Sea [10] and in Baja California Sur, on the Pacific Ocean coast [19].

Figure 1. Study area—17 Mexican coastal states bordering the Pacific Ocean, the Gulf of California, the Gulf of Mexico and the Caribbean Sea. Source: [33].
Mexico is also recognized as one of the countries with the most significant economic benefits provided by mangroves worldwide [16]. Total coverage of 905,086 Ha [34], with four species of mangroves (Rhizophora mangle, Laguncularia racemosa, Avicennia germinans and Conocarpus erectus), are distributed in four distinct regions along the coast of Mexico (Northwest Mexico, Mexican Pacific, Gulf of Mexico and Mexican Caribbean) [35]. Additionally, a great diversity of flora on beaches and dunes has been reported in almost all sandy coasts of Mexico [36]. Seagrass meadows perform vital ecological functions and are an essential marine ecosystem in all the seas surrounding the country, as well as coral reefs in three regions, on the Pacific Ocean coast, on the coasts of Veracruz and Campeche, in the Gulf of Mexico and as part of the Mesoamerican Reef in the Caribbean Sea [37].

![Figure 2. Land use in 2020: (A) Mexico’s coastal zone; (B) detail in Campeche, Yucatán and Quintana Roo coastal states in 2020. Source: [38].](image)

The Mexican coast is extremely vulnerable to the annual impact of tropical cyclones and storms of polar origin (known locally as ‘Nortes’). Strong winds, rainfall, intense waves and storm surges are effects associated with these natural phenomena that cause beach erosion, coastal flooding on low-lying areas and impacts on biodiversity and the functionality of coastal ecosystems [19,39–41]. The consequences are aggravated by climate change, loss of coastal vegetation due to land-use change, deforestation and increasing rates of human development in the coastal zone. In the period 1990–2015, the population settled in Mexico’s coastal zone increased at an annual national average rate of 1.83%, reaching a value of up to 4.46% in the most impacted coastal state, Quintana Roo [42] (Figure 3A). Most coastal cities have expanded due to the development of tourism projects, especially in the Caribbean Sea and South Pacific, or due to the oil industry in the Gulf of Mexico [43,44] (Figure 3). These regions are considered the most susceptible to the impacts of climate change [44].
The increasing environmental and anthropogenic pressures in recent decades have affected the physical functional integrity of coral reefs, especially in the northern region of the Mexican Caribbean [43,46,47]. Significant extensions of mangrove forests have been deforested for conversion to agriculture, aquaculture, urban development and tourism [48,49]. Agriculture and livestock land use is the one that has most altered the natural vegetation of the coasts. Forests transformed into pastures and coconut groves are the dominant uses on the coasts of the South Pacific and Gulf of Mexico [44].

Predictions of sea level rise showed an increase ranging from 1.9 to 3.4 mm year$^{-1}$ for the Gulf of Mexico [50] and a regional trend from 0.6 to 2.8 mm year$^{-1}$ for the Mexican Caribbean [51]. On the Pacific Ocean coast, in the Gulf of California, a long-term trend of wave power increasing was recently identified [41]. In the Caribbean, considered one of the most vulnerable regions to heat stress on coral reefs, an increase in heat exposure has been found on most ecoregions within the last 3 decades, showing a highly heterogeneous distribution of the greatest values across the Mesoamerican Reef region [52,53]. According to IPCC climate projections, by the end of the twenty-first century, on the Pacific and Gulf of Mexico coasts, mangroves will be affected as salinity increases, freshwater becomes scarce and the temperature reaches critical thresholds more frequently. In the Caribbean, mangroves will decrease as the sea level rises, and there is no appropriate upland space for colonization [6].

In terms of ecosystem protection instruments, Mexico has 176 Natural Protected Areas (NPAs), of which 68 are located in marine and coastal ecosystems [54]. These cover 7 of the 9 marine ecoregions distributed along both coasts of the country; 29 NPAs protect the country’s main coral reefs [55] and cover 60% of the country’s mangrove forest.
extension [56]. However, there is still a need to protect zones that have been identified as priority areas for conservation, including reefs and islands that are not yet protected [55].

3. Materials and Methods

A systematic review of research literature was carried out using Google Scholar and Scopus to find articles containing any variations of these terms: climate change, Mexico, adaptation, Caribbean. A total of 69 articles were extracted focused on the coastal zone and grouped, on the one hand, those corresponding to particular studies in Mexico (48), and on the other hand, in a global context of the world (21). Most of these studies correspond to journal articles, with three book chapters; a decision-making guide and a technical report were included. It was also essential to consider literature in Spanish, in particular, eight articles with relevant data on population perception of climate change in rural communities (the oldest from 2013 and the most recent from 2018) about sea-level rise projections due to climate change in Mexico or on governance barriers for the effective implementation of climate change in Mexico.

In general, there are a considerable number of recent publications in Mexico criticizing the institutional barriers that impede the efficient planning and implementation of climate change adaptation policies at the different levels of government in Mexico, as well as the absence of communication systems to keep the population adequately informed about the effects of climate change and adaptation measures. Additionally, a few publications were found on the current and projected effects of sea-level rise or changes in wave characteristics due to climate change in Mexico and the consequences climate change could lead on the tourism sector, despite the importance of this sector for the national economy. Most of the studies related to coastal ecosystems were about mangrove and coral reef ecosystems, especially on rehabilitation/restoration of these ecosystems. For this reason, a subsequent search was carried out for studies that included examples of restoration projects of these ecosystems in Mexico and the results observed since their application.

At the global level, articles were specially selected to put the aspects found in Mexico into a global context.

4. Results

4.1. Community Perception to Climate Change

In general, a greater awareness of climate change impacts and, thus, the urgent need for action has been detected in some regions of Mexico where local livelihoods, subsistence or health of the population were directly affected by climate change. For example, in the rural population of Ixil, in the coastal state of Yucatán, one-third of the population associates the term climate change with anthropogenic causes and feels vulnerable due to impacts mainly on crops and harvests and their health [25]. In three rural areas of the lagoon system of El Carmen, El Pajonal and La Machona, in the coastal state of Tabasco, in the Gulf of Mexico, the most exposed and sensitive individuals recognize their greater vulnerability [26]. In Guasave, Sinaloa (west coast of Mexico), 96% of the population is receptive to implement climate change adaptation measures due to the impacts observed in fishing, agricultural and livestock activities [57]. Similarly, the rural coastal population of Jalisco recognizes the term ‘climate change’ and associates it with some impact on their community through primary activities such as fishing, agriculture and livestock, or their contact with tourism. In turn, among the urban population of Puerto Vallarta, Jalisco, only a few consider that the climate change effects will affect their daily lives, hindering climate change adaptation actions at the local and regional level [24].

On the other hand, most people settled in Natural Protected Areas of Baja California Sur know the meaning of climate change. They perceive the effects of the reduction of the forest area due to land-use changes, the decrease of fishing activity due to changes in sea conditions, the frequency and intensity of hurricanes, the increase of droughts and the reduction of ecotourism activities due to changes in beaches [58]. However, a high level of socio-ecological vulnerability to tropical cyclones has also been found in Baja California Sur.
due to insufficient knowledge among the inhabitants regarding these hydrometeorological events that annually threaten the region [19].

4.2. Barriers for Implementing Adaptation Strategies to Climate Change

Some of the difficulties encountered for effective implementation of climate change adaptation measures in Mexico include [21,31,44]:

- Institutional discrepancies in the implementation of adaptation strategies at the national and local level;
- Weak governance structures that impede informed and effective participation of society in climate change policy;
- Subordination of climate change strategies to the country’s economic growth and poverty reduction objectives;
- Overexploitation of natural resources, lack of information on climate hazards and data monitoring systems;
- Disinterest in communicating to society about the adopted adaptation strategies, also due to lack of resources.

In particular, the population settled in areas at risk of floods and other natural phenomena, exposed to climate change, often faces political, economic, social and educational limitations to their practical and informed participation in climate change policy at the national and city level [31]. There is no federal instrument that takes into account the importance of local and traditional knowledge built within a community for its integration into the institutional and scientific risk-reduction activities [59], resulting in a lack of coherence, continuity and noticeable importance to individual livelihoods and contexts of actions proposed in state and federal plans [21]. An example of this problem is the impact of government funding plans to encourage replacing traditional wooden houses in San Felipe, Yucatán, with concrete blockhouses, despite rapid deterioration due to the salinity of concrete, in addition to designing new constructions that disregard the local traditions known to attract tourism [59].

The limited effectiveness of government support projects on climate change, aimed at reducing the vulnerability of small farmers and fishers to climate change and extreme phenomena [21], is also preventing successful climate change adaptation. For example, in the coastal state of Veracruz, this is mainly caused by a lack of concordance between the objectives established by donor countries with the objectives, priorities and particular needs of the territories and specific local context of the recipient countries [60]. In San Felipe, Yucatán, funding received through plans to support fisheries, tourism or the natural environment was not used as intended. Additionally, the government support plans were only available for certain privileged landowners, and the isolated, non-integrated and sometimes contradictory interventions, with a lack of monitoring and evaluation, did not meet the objectives established in the federal plans [21]. In addition, the impacts of climate change and land-use or land-cover changes are unevenly distributed across the country, making it difficult to implement conservation practices [61].

Another barrier is the geopolitical divisions that influence regional cooperation between ecoregions. This is the case of the mangrove ecosystem in the Mesoamerican Reef System, encompassing coasts of Mexico, Guatemala, Belize and Honduras, where lack of resources, lack of transparency in the Governance Framework and the disconnection between Ramsar site managers and researchers have contributed to reducing the effectiveness of mangrove protection, leading to significant losses of mangrove cover, especially in Mexico [12].

4.3. Studies and Examples of Adaptation Strategies to Climate Change

This section presents the different studies and strategies for adaptation to climate change found in the literature following the three categories of the classification of adaptation actions by Owen [11]: 1. ‘Social Adaptation Activities’; 2. ‘Institutional Adaptation Activities’; 3. ‘Physical and Structural Adaptation Activities’.
4.3.1. Social Adaptation Activities

Sosa-Rodríguez [31] stated that adaptation actions in Mexico had focused mainly on strengthening early warning systems, regarding the integration of local knowledge and traditional practices for climate change adaptation in the local populations of the Yucatán coastal zone. These practices have gained importance by disaster risk reduction specialists but not yet by all stakeholders involved in disaster prevention [59]. The analysis in three of these coastal communities, San Felipe, Río Lagartos and Las Coloradas, all in Yucatán, shows the existence of various types of traditional practices and adaptation strategies, from time-honored family customs to institutionalized practices at the municipal level. For example, citizens protect houses from hurricanes by covering windows or tying roofs with ropes.

When warning systems by the authorities agree with the fishermen’s observations, the community’s participation is recognized and included in prevention policies using local knowledge, not often considered before. As an adaptation method to reduce the vulnerability of the communities, different livelihood diversification strategies have been adopted [59]:

- In San Felipe, people are diversifying their resources between agriculture, livestock and fishing;
- In Río Lagartos, people use fishing and tourism resources for subsistence (e.g., boat trips);
- In Las Coloradas, a portion of the population works in the salt company.

This adaptation strategy was also found in other communities of the Yucatán Peninsula (Tzucacab, in Yucatán and Calakmul, in Campeche), through changes in traditional farming methods, the expansion of the range of economic activities, the more extensive use of trees for medical purposes or even dietary change, aiming to increase the resilience of individuals and communities [21].

4.3.2. Institutional Adaptation Activities

At the institutional level and as a motivation for implementing adaptation measures, Seingier et al. [44] conducted a study to identify the coastal municipalities with the best tools to face the effects of climate change. They used, as indicators, the number of land planning policy instruments provided for attending emergencies caused by climate change. In addition, regional analyses aimed to join efforts and create regional schemes to strengthen the municipalities that share coastal vulnerability to climate change. The results of this study showed the administrative weakness of most of Mexico’s municipalities in terms of their ability to adapt to the effects of climate change, with only 11% of coastal municipalities showing high adaptation capacity. The Gulf of Mexico (Tabasco, Guerrero, Michoacán and Yucatán) and South Pacific regions stood out for their lack of legal protection instruments, with reduced extension and institutional capacity. On the other hand, the North Pacific and Gulf of California regions, especially Baja California, were considered more prepared as they had legal protection instruments or institutions in charge of preparing local development plans and strategies for adaptation to the effects of climate change.

As an example of an innovative adaptation strategy, Calliari et al. [20] demonstrated the applicability of a social network analysis approach on a fragile socio-ecological lagoon system in southern Mexico. They assessed the quality and strength of linkages between formal organizations and local coastal communities potentially targeted by adaptation interventions and the bonding ties that connect community members to facilitate adequate collaborative arrangements in adaptation governance.

4.3.3. Physical and Structural Adaptation Activities

The activities described in this section are mainly related to rehabilitation/restoration actions on mangrove and coral reef ecosystems, which belong to the ‘Ecosystem-Based Adaptations’ subcategory of the classification by Owen [11]. One study was only found attending to the ‘Engineered and Built Environments’ activities. To the author’s knowledge, there are no studies on hard engineering for coastal defense adaptation in Mexico.
In Xcalak, on the southern coast of the Caribbean Sea, the population has shown its culture of prevention and knowledge about the climatological events they are exposed to. The main actions they have conducted are: substituting materials and the design of their homes, reinforcing the elements of buildings to turn them more resistant to wind and increasing the building heights. These actions have increased the resilience to the effects of hurricanes and rising sea levels due to climate change [62].

Regarding ecological rehabilitation/restoration of mangroves, Mendoza-Ponce et al. [61] applied a spatial prioritization method to identify the regions, municipalities and ecosystems that are most important for the conservation of species. They found that more than 45% of Mexico should be protected to face the impacts of climate change, suggesting, therefore, the definition of new protected areas to preserve distinguished critically threatened populations. They also considered it relevant to include, in future land use planning, specific areas dominated by endemic species at risk and provided some recommendations to improve agricultural practices and reduce pressure on natural vegetation (e.g., native crop varieties and different management practices such as agroforestry). These authors also proposed a practical, valuable and informative index of adaptive capacity, based on calculating the relationship between habitat cover and habitat protection, considering that areas in which protection is more significant than anthropogenic land conversion exert less pressure on the environment. Other strategies proposed to conserve the natural resources include:

- The creation of biological corridors that enable genetic flourishing;
- The prioritization of patch restoration to ensure the conservation of biodiversity;
- The design of studies and policies to understand and mitigate the local impacts of land-use change and climate change;
- The prevention of the negative impacts of invasive species;
- The design and planning of strategies to protect the genetic variability of threatened populations.

Kumagai et al. [49] also used a prioritization model to identify coastal areas in Mexico, at local government scale, to focus mangrove conservation efforts to most efficiently harness the potential of mangroves for carbon sequestration currently threatened by high rates of deforestation and the impact of climate change.

Cinco-Castro et al. [48] conducted a study to evaluate the vulnerability of mangroves in the Yucatán Peninsula to sea level rise based on exposure, sensitivity and adaptive capacity. For this purpose, four sites (Celestún, in Yucatán, Los Petenes, in Campeche, Cancún and Mahahual, in Quintana Roo) were selected, with different ecological characteristics and levels of human intervention on mangrove forests, but with similar exposure. The best-conserved mangroves showed low vulnerability and good health due to their sensitivity, while mangroves disturbed by anthropogenic activity were more vulnerable to sensitivity and adaptive capacity. Different management actions were proposed to improve the sensitivity and adaptive characteristics of the ecosystems and the presence of organizations with ecosystem management capacity. These include:

- Improve the adaptive capacity.
- Strengthen conservation policies.
- Plan migration in the area.
- Strengthen legislation and promote stakeholder participation in mangrove conservation and restoration activities.

Regarding the sensitivity variable, recommendations were related to:

- Characterize and monitor mangrove forests’ structure and functioning.
- Favor the maintenance of a healthy environment.
- Improve mangrove vertical accretion.

Different projects show the success of implementing hydrological restoration actions in mangrove forests to reestablish the hydrological connection. A study by Zaldivar-Jiménez et al. [63] highlights that in Yucatán, mangrove restoration programs have not
been successful because they have focused, in most cases, on reforestation and not on the rehabilitation of the hydrological conditions necessary for mangroves. Examples of these practices, which have even increased degradation at times, are reforestation, designing springs and constructing and removing artificial ridges and water passages. These authors proposed a methodological approach for the ecological restoration of mangroves in the Yucatán Peninsula, based on studies conducted in the last 10 years, consisting of: 1. site identification and determination of the causes of mangrove deterioration and loss; 2. characterization of existing environmental conditions and objectives; 3. identification of actions to achieve ecological restoration objectives; 4. implementation of a monitoring program to evaluate the effectiveness of adaptive management strategies.

On the other hand, the Mexican experience in the participation in the US–Mexico joint Gulf of Mexico Large Marine Ecosystem-Based Assessment and Management Project for mangrove forest restoration showed the success of changing from mangrove plantations to a more efficient community-based hydrological ecosystem restoration strategy, resulting in the rehabilitation of tidal channels in 1300 ha of mangroves. Construction of human capacities and environmental education in rural coastal and riverside communities, the influence on the forest environmental policy and the involvement of government and education institutions as execution agencies are the most important challenges achieved. Local communities’ participation was fundamental to fulfilling restoration actions such as dredging of tidal channels, seedling mangrove dispersal, soil elevation beds and monitoring. The hydrological rehabilitation of tidal channels promoted the recovery of the natural hydroperiod, the natural recruitment and the growth of black mangrove by seedlings transported through the rehabilitated tidal channels [64].

Another successful mangrove hydrological rehabilitation strategy was observed after monitoring the natural regeneration of *Avicennia germinans*. Desilting tidal channels and modifying the microtopography to enhance or restore water flow were the main regeneration actions, which lead to the natural establishment of black mangroves. In this case, the results showed microtopography and hydroperiod as the most important factors for the natural establishment and development of this mangrove species [65].

In Laguna de Términos, Campeche, the hydrological rehabilitation strategy allowed the establishment and development of mangrove vegetation, the dispersal of propagules to degraded areas and soil physicochemical variables’ improvement, which led to the establishment and incorporation of new mangrove species in the restoration area. The diversity and forest structure of natural mangrove sites also proved to be a critical factor in the process of recovery and natural regeneration in degraded and adjacent areas, since, after the inclusion of natural mangrove areas with good forest structure, an increase in dispersal, establishment and growth of mangrove seedlings was observed, depending on the distance from these natural mangroves, as well as an increase in diversity [66].

In a degraded area of a barrier island in the Gulf of Mexico, by excavating desilting clearing channels in identified preferential hydrological flow paths, a more effective restoration strategy was achieved than direct opening to the nearest primary water body without regard to microtopography [67].

Finally, Franco et al. [41] found two herbaceous *Ipomoea* climbers growing on trees planted to restore a freshwater forested wetland in the Gulf of Mexico, causing high tree mortality and limiting restoration success. To address this problem, they suggested, as control strategies for *Ipomoea*, the prioritization of areas with higher flooding levels for tree planting, where the proliferation of the most problematic species is not favored, and the production of regrowth of both species of *Ipomoea* is limited, at least in the short term.

Regarding coral reef restoration activities, there are currently some successful projects implemented in the Caribbean Sea. These results were recently compiled, so far unknown, following the 2018 Reef Futures Symposium, where more than 400 reef restoration experts shared their knowledge [68]. In the Mexican Caribbean, three projects were implemented led by the following organizations: 1. Oceanus A.C.; 2. CORALIUM (Universidad Nacional Autónoma de México); and 3. The Iberostar & CINVESTAV Groups. The project carried
out by Oceanus A.C. includes monitoring before and after transplantation of corals to evaluate the survival and growth of restored corals since 2014, in an estimated spatial extent of 6.3 ha. As success indicators of the project, 52,053 colonies were added to the Mesoamerican Reef (2014–2019), with the 85% survival of planted colonies measured at the end of 2019, average coral cover ranging between 2 and 5% at all sites pre-restoration (2014) increased to an average of 8.4% in 2019. The project performed by the CORALIUM team over 5 years has planted corals to nine reefs along the Mexican Caribbean. Finally, The Iberostar & CINVESTAV Groups project is under development. In all projects, capacity-building programs have been carried out for local restoration teams, training restoration techniques to support the maintenance of the ecosystems [68].

On the other hand, Zepeda et al. [15] highlighted the importance of identifying the stressors that produce reef degradation as the first and most crucial step to ensure the success of reef restoration actions, the leading cause, has led to many restoration projects failing. They further consider that specific strategies to restore and maintain reef resilience to the effects of climate change should include managing local reef stressors (e.g., through MPAs), ensuring connectivity within protected areas, protecting natural refugia and applying adaptive management based on monitoring and evaluation of management practices.

In this sense, Martínez-Rendis et al. [69] also highlighted the importance of reef monitoring actions to understand their spatial and temporal response to apply management strategies and reduce the effects of biodiversity loss on coral reefs. These authors used fishes, coral and algal communities as indicators to assess changes in three coral reef systems in a Marine Protected Area (MPA) composed of three management zones in the Cozumel Coral Reef National Park, the Mexican Caribbean, over 11 years (2004–2014). The diversity indices of each fish trophic group showed a reduction in the three management zones over time. On the other hand, Muñiz-Castillo et al. [52] highlighted the importance of the 3 decades of heat stress exposure, monitoring systems implemented in Caribbean coral reefs as a new baseline and regionalization of heat stress enhanced conservation and planning efforts.

The results by Randazzo-Eisemann et al. [53] suggest that MPAs can buffer the impacts of local human stressors on coral reefs. However, a spatial mismatch between hotspots of structural complexity and the level of protection has been identified, as 41% of 158 sites analyzed in the Mesoamerican Reef (MAR) were not protected in 2016. They recommend considering these hotspots of structural complexity as priority areas to increase protection coverage in the Mesoamerican Reef.

The area of interest that could be prioritized for conservation at Puerto Morelos Reef is the region known as ‘Limones Reef’, a bottom reef site with a high cover of highly resilient builder species such as Acropora palmata. Improving understanding of the mechanisms underlying the persistence of sites such as this reef will be essential to aid management and restoration efforts on other Caribbean reefs [47].

4.3.4. Other Studies on Coastal Adaptation to Climate Change

Haer et al. [3] showed a multidisciplinary approach, composed of hazard modeling, risk modeling and cost–benefit analysis, to determine economically efficient adaptation strategies in the face of climate change impacts in the state of Tabasco. Recommended adaptation strategies are: limiting urban sprawl in natural floodplains, upgrading buildings to withstand flood, rain and wind impacts better, improving early warning and forecasting systems and evacuation planning to minimize casualties during floods [3].

Finally, few studies have analyzed the impact of climate change on the tourism sector. Some recommendations to develop plans that allow the tourism industry to adapt are oriented to examine: 1. how tourists experience places where structural changes occur; 2. the rebranding of the entire destination, taking into account the scenario of global climate change that may include, for example, rapid or abrupt increases in sea level; and 3. the impact of technological advances on representations of the tourism landscape [70].
5. Discussion

Mexico faces several relevant challenges regarding climate change adaptation, namely: the improvement of coastal governance, promoting the institutional coordination under a practical collaboration framework, the creation of synergies between environmental, social and economic sectors, providing the space for active participation of the civil society, the allocation of sufficient and well-directed economic resources and the adequate dissemination of information among the population [25,28,44]. The longer the country takes significant steps on each challenge, the larger the coast’s vulnerability to threats such as flooding, beach erosion and environmental services loss.

Another factor to be taken into account is the effective regulation of land use to reduce the rate of mangrove deforestation and annual degradation, as well as to discourage illegal settlements in at-risk areas [31]. Irregular and illegal settlements are highly vulnerable to coastal threats, and, in some places, it is pretty difficult to improve the life quality of poorly planned urbanizations. Michetti et al. [26] suggested that factors that positively shape vulnerability (i.e., influencing sensitivity and exposure) may be more influential than those that reduce it (i.e., improving adaptive capacity) in producing risk perceptions, although adaptive actions are no less important. The difficulties encountered in Mexico are similar to those reported in various studies worldwide [22], especially in developing countries. This means that integrative international collaboration can benefit large coastal areas.

In the literature, it is repeatedly stated that adaptation strategies can be successfully implemented with an informed, engaged and prepared community, where the active participation of different stakeholders, including the most disadvantaged and marginalized groups, would help policymakers to develop more effective adaptation strategies focused on climate justice [13,71–73]. This leads to the need for permanent, systematic monitoring programs of the coast, which is a weakness in Mexico and other countries [41–74]. In addition, effective governance should operate integration between different institutional arrangements at both local and regional scales [13]. In Mexico, greater recognition of local-scale adaptation strategies is needed [3,75], which should support Mexico’s developing National Adaptation Policy and provide a model for approaches at the international level as adaptation becomes an increasingly important part of the global strategy to cope with climate change [21]. Several studies highlight the lack and importance of conducting local-scale studies in Mexico. For example, in poorly studied regions of Baja California Sur, beach erosion and flood inundation events occur due to anthropogenic and hydrometeorological impacts [41].

In addition, it is crucial that the scientific community and government agencies commit to providing information regarding biotic and abiotic aspects of the coast gathering time series as long as possible in order to understand better the regional and local dynamics and interchanges and to improve the capacity of forecasting systems and future projections [30]. Systematic data collection on local damage and exposure conditions is also required to calibrate depth–damage curves, which can be conducted using surveys after inundation events [3]. The development of efficient communication systems to keep the population informed about hydrometeorological risks [19] and possible adaptation measures to be adopted are of great relevance to promote rapid adaptation to natural hazards [26].

Mexico is among the countries considered to have the most significant loss of global biodiversity globally, along with Australia, China, Brazil, Ecuador, Malaysia, Indonesia, Colombia and the USA [61]. Spatial prioritization has been applied in Mexico recently as an adaptation strategy for conserving ecosystems [41,49,61], which is considered essential in megadiverse countries worldwide [76]. Greater awareness of climate change impacts has been identified in regions where local livelihoods, subsistence or health of the population were directly affected by climate change, especially in Yucatán, Tabasco, Sinaloa and Jalisco. Adaptation actions in Mexico related to the integration of local knowledge and traditional practices for climate change adaptation have been mainly found in the coastal communities of Yucatán and Campeche. Diversification has been a vital adaptation strategy considered in these rural communities, facing an increasingly variable climate in an economy hostile to
small-scale and subsistence agriculture and fisheries [21,59]. The Gulf of Mexico (Tabasco, Guerrero, Michoacán and Yucatán) and South Pacific regions stood out for their lack of legal protection instruments, and thus with reduced extension and institutional adaptation capacity. On the other hand, the North Pacific and Gulf of California regions, especially Baja California, were considered more prepared, as they had legal protection instruments or institutions in charge of preparing local development plans and strategies for adaptation to the effects of climate change [44]. Several restoration projects on mangrove forests have shown successful results, more numerous in the Yucatán Peninsula [63–67] and also on coral reefs in the Caribbean Sea [68]. However, a better understanding of the connectivity between ecosystems is still required [77], which can be built by expanding the governance of ecosystems from national boundaries to the larger scale of ocean processes [12,78]. It is considered important to collect data, conduct and publish coral reef restoration [68] and mangrove restoration/rehabilitation. Being successful or not, this information is the best way to contribute to generating a robust scientific basis that allows moving towards success in adaptation actions [79,80].

Unfortunately, although some successful efforts exist, Mexico lacks significant adaptation actions, while several phenomena related to climate change affect and degrade its coastal systems. Variables of concern, which are much more relevant than sea level rise, include reef mortality, seawater acidification and massive sargassum arrivals. Undoubtedly, new threats may appear, so there is a strong sense of urgency.

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**References**

1. Nicholls, R. *Adaptation Options for Coastal Areas and Infrastructure: An Analysis for 2030*; Technical Report 2007; UNFCCC: Bonn, Germany, 2007.
2. Martínez, G.; Bizikova, L.; Blobel, D.; Swart, R. Emerging climate change coastal adaptation strategies and case studies around the world. In *Global Change and Baltic Coastal Zones*; Springer: Dordrecht, The Netherlands, 2011; pp. 249–273.
3. Haer, T.; Botzen, W.W.; Zavala-Hidalgo, J.; Cusell, C.; Ward, P.J. Economic evaluation of climate risk adaptation strategies: Cost-benefit analysis of flood protection in Tabasco, Mexico. *Atmosfera* 2017, 30, 101–120. [CrossRef]
4. IPCC. 2019: Summary for Policymakers. In *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*; Pörtner, H.-O., Roberts, D.C., Masson-Delmotte, V., Zhai, P., Tignor, M., Poloczanska, E., Mintenbeck, K., Nicholai, M., Okem, A., Petzold, J., et al., Eds.; in press.
5. Levin, E.; Jacob, J.; Bustillos, L.E.R.; Ortiz, I. Policy frameworks for Adaptation to Climate Change in Coastal Zones: The Case of the Gulf of Mexico. *OECD Pap.* 2007, 7, 1–68. [CrossRef]
6. Alongi, D.M. The impact of climate change on mangrove forests. *Curr. Clim. Chang. Rep.* 2015, 1, 30–39. [CrossRef]
7. Knutson, T.; Camargo, S.J.; Chan, J.C.; Emanuel, K.; Ho, C.H.; Kossin, J.; Mohapatra, M.; Satoh, M.; Sugi, M.; Walsh, K.; et al. Tropical cyclones and climate change assessment: Part I: Detection and attribution. *Bull. Am. Meteorol. Soc.* 2019, 100, 1987–2007. [CrossRef]
8. Reguero, B.G.; Losada, I.J.; Diaz-Simal, P.; Mendez, F.J.; Beck, M.W. Effects of climate change on exposure to coastal flooding in Latin America and the Caribbean. *PLoS ONE* 2015, 10, e0133409. [CrossRef]
9. Tobey, J.; Rubino, P.; Robadue, D., Jr; Ricci, G.; Volk, R.; Furlow, J.; Anderson, G. Practicing coastal adaptation to climate change: Lessons from integrated coastal management. *Coast. Manag.* 2010, 38, 317–335. [CrossRef]
10. Pedrozo-Acuña, A.; Damania, R.; Laverde-Barajas, M.A.; Mira-Salama, D. Assessing the consequences of sea-level rise in the coastal zone of Quintana Roo, México: The costs of inaction. *J. Coast. Conserv.* 2015, 19, 227–240. [CrossRef]
11. Owen, G. What makes climate change adaptation effective? *A systematic review of the literature. Glob. Environ. Chang.* 2020, 62, 102071. [CrossRef]
12. Canty, S.W.; Preziosi, R.F.; Rowntree, J.K. Dichotomy of mangrove management: A review of research and policy in the Mesoamerican reef region. *Ocean Coast. Manag.* 2018, 157, 40–49. [CrossRef]
13. Anfuso, G.; Postacchini, M.; Di Luccio, D.; Benassai, G. Coastal Sensitivity/Vulnerability Characterization and Adaptation Strategies: A Review. *J. Mar. Sci. Eng.* 2021, *9*, 72. [CrossRef]

14. Arkema, K.K.; Guannel, G.; Verutes, G.; Wood, S.A.; Guerry, A.; Ruckelshaus, M.; Kareiva, P.; Lacayo, M.; Silver, J.M. Coastal habitats shield people and property from sea-level rise and storms. *Nat. Clim. Chang.* 2013, *3*, 913–918. [CrossRef]

15. Zepeda-Centeno, C.; Marino-Tapia, I.; McLeod, E.; Rodriguez-Martinez, R.; Alvarez-Filip, L.; Banaszak, A.T.; Escudero-Castillo, M.; Silva-Casarín, R.; Mendoza-Baldwin, E.; Beck, M.; et al. *Guidance Document for Reef Management and Restoration to Improve Coastal Protection: Recommendations based on lessons learned in Mexico*; The Nature Conservancy: Mexico City, Mexico, 2018; p. 81.

16. Menéndez, P.; Losada, I.J.; Torres-Ortega, S.; Narayan, S.; Beck, M.W. The global flood protection benefits of mangroves. *Sci. Rep.* 2020, *10*, 1–11. [CrossRef] [PubMed]

17. Saintilan, N.; Khan, N.S.; Ashe, E.; Kelleway, J.J.; Rogers, K.; Woodroffe, C.D.; Horton, B.P. Thresholds of mangrove survival under rapid sea level rise. *Science* 2020, *368*, 1118–1121. [CrossRef] [PubMed]

18. Psuty, N.P.; Silveira, T.M. Global climate change: An opportunity for coastal dunes? *J. Coast. Conserv.* 2010, *14*, 153–160. [CrossRef]

19. Marín-Monroy, E.A.; Hernández-Trejo, V.; Romero-Vadillo, E.; Ivanova-Boncheva, A. Vulnerability and Risk Factors due to Tropical Cyclones in Coastal Cities of Baja California Sur, Mexico. *Climate* 2020, *8*, 144. [CrossRef]

20. Calliari, E.; Michetti, M.; Farnia, L.; Ramieri, E. A network approach for moving from planning to implementation in climate change adaptation: Evidence from southern Mexico. *Environ. Sci. Policy* 2019, *93*, 146–157. [CrossRef]

21. Metcalfe, S.E.; Schmöck, M.; Boyd, D.S.; De la Barreda-Bautista, B.; Endfield, G.E.; Mardero, S.; Che, M.M.; González, R.M.; Munguía Gil, M.T.; Olmedo, S.N.; et al. Community perception, adaptation and resilience to extreme weather in the Yucatán Peninsula, Mexico. *Reg. Environ. Chang.* 2020, *20*, 1–15. [CrossRef]

22. Stephens, S.H.; DeLorme, D.E.; Hagen, S.C. Coastal Stakeholders’ perceptions of sea level rise adaptation planning in the Northern Gulf of Mexico. *Environ. Manag.* 2020, *66*, 407–418. [CrossRef]

23. Howden, S.M.; Soussana, J.F.; Tubiello, F.N.; Chhetri, N.; Dunlop, M.; Meinke, H. Adapting agriculture to climate change. *Proc. Natl. Acad. Sci. USA* 2007, *104*, 19691–19696. [CrossRef]

24. López-Fletes, C.; Chávez-Dagostino, R.; Davydelva-Belitskaya, V.; Cornejo-Ortega, J.L. Percepción de la población costera de Jalisco, México, sobre el cambio climático. *Memorias 2015*, *13*, 81–91. [CrossRef]

25. Soares, D.; Sandoval-Ayala, N.C. Perceptions of Vulnerability to Climate Change in a Rural Community in Yucatán. *Water Technol. Sci.* 2016, *7*, 113–128.

26. Michetti, M.; Ghinò, S. Climate-driven vulnerability and risk perception: Implications for climate change adaptation in rural Mexico. *J. Environ. Stud. Sci.* 2020, *10*, 290–302. [CrossRef]

27. Becken, S.; Whittlesea, E.; Loehr, J.; Scott, D. Tourism and climate change: Evaluating the extent of policy integration. *J. Sustain. Tour* 2020, *28*, 1603–1624. [CrossRef]

28. García Chavarría, M.; Enriquez, G.; Rivera-Arriaga, E. Análisis y evaluación gubernamental de mares y costas en México: Hacia una evaluación integral. In *Gobernanza y Manejo de las Costas y Mares ante la Incertidumbre. Una Guía para Tomadores de Decisiones*; Rivera-Arriaga, E., Azuz-Adeath, I., Cervantes Rosas, O.D., Espinoza-Tenorio, A., Silva Casarín, R., Ortega-Rubio, A., Botello, A.V., Vega-Serratos, B.E., Eds.; Universidad Autónoma de Campeche: Richamar, Spain, 2020.

29. Nath, P.K.; Behera, B. A critical review of impact of and adaptation to climate change in developed and developing economies. *Environ. Dev.* 2011, *13*, 141–162. [CrossRef]

30. Jevrejeva, S.; Bricheno, L.; Brown, J.; Byrne, D.; De Dominicis, M.; Matthews, A.; Rynsders, S.; Palanisamy, H.; Wolf, J. Quantifying processes contributing to coastal hazards to inform coastal climate resilience assessments, demonstrated for the Caribbean Sea. *Nat. Hazards Earth Syst. Sci.* 2020, *20*, 2609–2626. [CrossRef]

31. Sosa-Rodríguez, F.S. From federal to city mitigation and adaptation: Climate change policy in Mexico City. *Mitig. Adapt. Strat. Glob. Chang.* 2014, *19*, 969–996. [CrossRef]

32. CONABIO. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. 2019. Available online: https://www.gob.mx/conabio/ (accessed on 22 February 2021).

33. INEGI. Instituto Nacional de Estadística y Geografía. *División Política Estatal 1:250000.2020, Escala 1:250000*. 2021. Available online: http://www.conabio.gob.mx/informacion/gis/ (accessed on 23 March 2021).

34. CONABIO. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. 2021. Available online: https://www.biodiversidad.gob.mx/monitoreo/smmm/extensionDist (accessed on 23 March 2021).

35. Vázquez-Lule, A.; Colditz, R.; Herrera-Silveira, J.; Guevara, M.; Rodríguez-Zúñiga, M.T.; Cruz, I.; Ressl, R.; Vargas, R. Greenness trends and carbon stocks of mangroves across Mexico. *Environ. Res. Lett.* 2019, *14*, 075010. [CrossRef]

36. Espejel, I.; Jiménez-Orocio, O.; Castillo-Campos, G.; García, P.; Álvarez, L.; Castillo-Argüero, S.; Durán, T.; Ferrer, M.; Infante-Mata, D.; Iriarte, S.; et al. Flora on beaches and coastal sand dunes of Mexico. *Acta Botánica Mex.* 2017, *121*, 39–81.

37. CONABIO. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. 2020. Available online: https://www.biodiversidad.gob.mx/ecosistemas/arrecifes (accessed on 23 March 2021).

38. CONABIO. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. *Mapa de uso del Suelo y Vegetación de la Zona Costera Asociada a los Manglares de México en 2020. Escala 1:50,000*. 2021. Available online: http://www.conabio.gob.mx/informacion/gis (accessed on 23 March 2021).
39. Silva-Casarin, R.; Marín-Tapia, I.; Enriquez-Ortiz, C.; Mendoza-Baldwin, E.; Escalante-Mancera, E.; Ruiz-Rentería, F. Monitoring shoreline changes at Cancun beach, Mexico: Effects of Hurricane Wilma. In Proceedings of the 30th International Conference on Coastal Engineering, San Diego, CA, USA, 3–8 September 2006; pp. 3491–3503.

40. Escudero, M.; Silva, R.; Mendoza, E. Beach erosion driven by natural and human activity at Isla del Carmen Barrier Island, Mexico. J. Coast. Res. 2014, 71, 62–74. [CrossRef]

41. Franco-Ochoa, C.; Zambrano-Medina, Y.; Plata-Rocha, W.; Monjardín-Armenta, S.; Rodríguez-Cueto, Y.; Escudero, M.; Mendoza, E. Long-Term Analysis of Wave Climate and Shoreline Change along the Gulf of California. Appl. Sci. 2020, 10, 8719. [CrossRef]

42. SEMARNAT. IC 6.3-5 A. Población en la Zona Costera y Tasa de Crecimiento Poblacional Anual por Entidad Federativa. Available online: https://apps1.semarnat.gob.mx:8443/dgeia/indicadores17/conjuntob/indicador/06_biodiversidad/03_oceanicos/6_3_5.html (accessed on 23 March 2021).

43. Rodríguez-Martínez, R.E. Community involvement in marine protected areas: The case of Puerto Morelos reef, México. J. Environ. Manag. 2008, 88, 1151–1160. [CrossRef]

44. Seingier, G.; Espejel, I.; Jiménez-Oroco, O. Gobernanza ambiental ante el cambio climático: Municipios costeros de México. In Gobernanza y Manejo de las Costas y Mares ante la Incertidumbre. Una Guía para Tomadores de Decisiones; Rivera-Arriaga, E., Cervantes Rosas, O.D., Espinoza-Tenorio, A., Silva Casarin, R., Ortega-Rubio, A., Botello, A.V., Vega-Serratos, B.E., Eds.; Universidad Autónoma de Campeche: Ricomar, Spain, 2020.

45. CONABIO. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. Mapa de uso del suelo y vegetación de la zona costera asociada a los manglares de México en 1981. Escala 1:50,000. 2013. Available online: http://www.conabio.gob.mx/informacion/gis (accessed on 23 March 2021).

46. Rodríguez-Martínez, R.E.; Ruiz-Rentería, F.; Tussenbroek, B.V.; Barba-Santos, G.; Escalante-Mancera, E.; Jordán-Garza, G.; Jordán-Dahlgren, E. Environmental state and tendencies of the Puerto Morelos CARICOMP site, México. Rev. Biol. Trop. 2010, 58, 23–43.

47. Estrada-Saldivar, J.; Jordán-Dahlgren, E.; Rodríguez-Martínez, R.E.; Perry, C.; Alvarez-Filip, L. Functional consequences of the long-term decline of reef-building corals in the Caribbean: Evidence of across-reef functional convergence. R. Soc. Open Sci. 2019, 6, 190298. [CrossRef]

48. Cinco-Castro, S.; Herrera-Silveira, J. Vulnerability of mangrove ecosystems to climate change effects: The case of the Yucatan Peninsula. Ocean Coast. Manag. 2020, 192, 105196. [CrossRef]

49. Kumagai, J.A.; Costa, M.T.; Ezzurra, E.; Abarco-Oropeza, O. Prioritizing mangrove conservation across Mexico to facilitate 2020 NDC ambition. Ambio 2020, 49, 2002–2002. [CrossRef] [PubMed]

50. Zavala-Hidalgo, J.; de Buen-Kalman, R.; Romero-Centeno, R.; Hernández-Maguey, F. Tendencias del nivel del mar en las costas mexicanas. In Vulnerabilidad de las Zonas Costeras Mexicanas Ante el Cambio Climático, 2nd ed.; Botello, A.V., Villanueva-Fragoso, S., Gutiérrez, J., Rojas Galaviz, J.L., Eds.; Universidad Autónoma Metropolitana-Iztapalapa, UNAM-ICMYL, Universidad Autónoma de Campeche: Campeche, Mexico, 2011; pp. 315–334.

51. Ruiz-Ramírez, J.D.; Eguí-Avila, J.L.; Rivera-Monroy, V.H. Vulnerability of coral reef coastal systems to mean sea level rise in the Mexican Caribbean. Coast. Manag. 2019, 47, 23–43. [CrossRef]

52. Muñiz-Castillo, A.L.; Rivera-Sosa, A.; Chollett, I.; Eakin, C.M.; Andrade-Gómez, L.; McField, M.; Arias-González, J.E. Three decades of heat stress exposure in Caribbean coral reefs: A new regional delineation to enhance conservation. Sci. Rep. 2019, 9, 1–14. [CrossRef]

53. Randazzo-Eisemann, Á.; Arias-González, J.E.; Velez, L.; McField, M.; Mouillot, D. The last hotspots of structural complexity as conservation targets in the Mesoamerican Coral Reef. Biol. Conserv. 2021, 256, 109021. [CrossRef]

54. PROFEPA. Procursaduría Federal de Protección al Ambiente. Available online: https://www.profepa.gob.mx/innovaportal/v/13/80/1/mx.wap/areas_naturales_protegidas_marinas_y_litorales.html (accessed on 15 March 2021).

55. CONANP. Comisión Nacional de Áreas Naturales Protegidas. Programa Nacional de Áreas Naturales Protegidas 2020–2024. Available online: https://www.conanp.gob.mx/ (accessed on 20 May 2021).

56. CONANP. Comisión Nacional de Áreas Naturales Protegidas. 2016. Available online: https://www.gob.mx/conanp (accessed on 23 March 2021).

57. Ahumada-Cervantes, R.; García-López, P.A. Conocimiento y percepción acerca del cambio climático en comunidades costeras del municipio de Guasave, Sinaloa, México. Investig. Y Cienc. Univ. Autónoma Aguascalientes 2018, 75, 38–45. [CrossRef]

58. Olmos Martínez, E.; González Ávila, M.E.; Contreras Loera, M.R. Percepción de la población frente al cambio climático en áreas naturales protegidas de Baja California Sur, México. POLIS Rev. Latinoam. 2013, 12, 1–17. Available online: https://www.redalyc.org/articulo.oa?id=30528720020 (accessed on 15 April 2021). [CrossRef]

59. Audefroy, J.F.; Sánchez, B.N.C. Integrating local knowledge for climate change adaptation in Yucatán, Mexico. Int. J. Sustain. Built Environ. 2017, 6, 228–237. [CrossRef]

60. Virués-Contreras, P.; Monjardín, L.R.; Del Valle-Cárdenas, B. International Cooperation in Adaptation to Climate Change: Foreign Agendas or Local Necessities? Am. J. Clim. Chang. 2020, 9, 480. [CrossRef]

61. Mendoza-Ponce, A.V.; Corona-Núñez, R.O.; Kraxner, F.; Estrada, F. Spatial prioritization for biodiversity conservation in a megadiverse country. Anthropocene 2020, 32, 100267. [CrossRef]

62. Poot, H.D.S.S.; Correa, G.R. Vivienda costera y Cambio Climático en el sur de Quintana Roo. Piat. Educ. 2018, 35, 155–165.
63. Zaldívar-Jiménez, M.A.; Herrera-Silveira, J.A.; Teutli-Hernández, C.; Comín, F.A.; Andrade, J.L.; Molina, C.C.; Ceballos, R.P. Conceptual framework for mangrove restoration in the Yucatán Peninsula. *Ecol. Restor.* **2010**, *28*, 333–342. [CrossRef]

64. Zaldívar-Jiménez, A.; Ladrón-de-Guevara-Porras, P.; Pérez-Ceballos, R.; Díaz-Mondragón, S.; Rosado-Solórzano, R. 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. *Environ. Dev.* **2017**, *22*, 206–213. [CrossRef]

65. Pérez-Ceballos, R.; Echeverría-Avila, S.; Zaldívar-Jiménez, A.; Zaldívar-Jiménez, T.; Herrera-Silveira, J. Contribution of microtopography and hydroporphy to the natural regeneration of Avicennia germinans in a restored mangrove forest. *Cienc. Mar.* **2017**, *43*, 55–67. [CrossRef]

66. Echeverría-Avila, S.; Pérez-Ceballos, R.; Zaldívar-Jiménez, A.; Canales-Delgadillo, J.; Brito-Pérez, R.; Merino-Ibarra, M.; Vovides, A. Natural regeneration of degraded mangrove sites in response to hydrological restoration. *Madera Y Bosques* **2019**, *25*, 1–14.

67. Pérez-Ceballos, R.; Zaldívar-Jiménez, A.; Canales-Delgadillo, J.; López-Adame, H.; López-Portillo, J.; Merino-Ibarra, M. Determining hydrological flow paths to enhance restoration in impaired mangrove wetlands. *PLoS ONE* **2020**, *15*, e0227665. [CrossRef]

68. Bayraktarov, E.; Banaszak, A.T.; Montoya Maya, P.; Kleypas, J.; Arias-González, D.; Arias-González, D.; Blanco, M.; Calle-Triviño, J.; Charuvi, N.; Cortés-Uñeca, C.; Galván, V.; et al. Coral reef restoration efforts in Latin American countries and territories. *PLoS ONE* **2020**, *15*, e0228477. [CrossRef]

69. Martínez-Rendis, A.; Acosta-González, G.; Arias-González, J.R. A spatio-temporal long-term assessment on the ecological response of reef communities in a Caribbean marine protected area. *Aquat. Conserv. Mar. Freshw. Ecosyst.* **2020**, *30*, 273–289. [CrossRef]

70. Buzinde, C.N.; Manuel-Navarrete, D.; Kerstetter, D.; Redclift, M. Representations and adaptation to climate change. *Ann. Tour. Res.* **2010**, *37*, 581–603. [CrossRef]

71. Cambers, G. Caribbean beach changes and climate change adaptation. *Aquat. Ecosyst. Health Manag.* **2009**, *12*, 168–176. [CrossRef]

72. Robinson, S.A.; Wren, C. Geographies of vulnerability: A research note on human system adaptations to climate change in the Caribbean. *Geogr. Tidsskr. -Dan. J. Geogr.* **2020**, *120*, 79–86. [CrossRef]

73. Hügel, S.; Davies, A.R. Public participation, engagement, and climate change adaptation: A review of the research literature. Wiley Interdisciplinary Reviews. *Clim. Chang.* **2020**, *11*, e645.

74. Hopkinson, C.S.; Lugo, A.E.; Alber, M.; Covich, A.P.; Van Bloem, S.J. Forecasting effects of sea-level rise and windstorms on coastal and inland ecosystems. *Front. Ecol. Env.* **2008**, *6*, 255–263. [CrossRef]

75. Ibarra-Ramírez, M.E.; Malone, E.L.; Brekert, A.L. Climate change vulnerability and resilience: Current status and trends for Mexico. *Environ. Dev. Sustain.* **2010**, *12*, 365–388. [CrossRef]

76. Brooks, T.M.; Mittermeier, R.A.; da Fonseca, G.A.; Gerlach, J.; Hoffmann, M.; Lamoreux, J.F.; Mittermeier, C.G.; Pilgrim, J.D.; Rodrigues, A.S.L. Global biodiversity conservation priorities. *Science* **2006**, *313*, 58–61. [CrossRef]

77. Odérez, I.; Gómez, I.; Ventura, Y.; Díaz, V.; Escalante, A.; Gómez, D.T.; Bouma, T.J.; Silva, R. Understanding Drivers of Connectivity and Resilience Under Tropical Cyclones in Coastal Ecosystems at Puerto Morelos, Mexico. *J. Coast. Res.* **2020**, *95*, 128–132. [CrossRef]

78. Cortés, J.; Oxenford, H.A.; van Tussenbroek, B.I.; Jordán-Dahlgren, E.; Cróquer, A.; Bastidas, C.; Ogden, J.C. The CARICOMP network of Caribbean Marine Laboratories (1985–2007): History, key findings, and lessons learned. *Front. Mar. Sci.* **2019**, *5*, 519. [CrossRef]

79. López-Portillo, J.; Lewis, R.R.; Saenger, P.; Rovai, A.; Koedam, N.; Dahdouh-Guebas, F.; Agraz-Hernández, C.; Rivera-Monroy, V.H. Mangrove forest restoration and rehabilitation. In *Mangrove Ecosystems: A Global Biogeographic Perspective*; Springer: Cham, Germany, 2017, pp. 301–345. [CrossRef]

80. Teutli-Hernández, C.; Herrera-Silveira, J.A. The success of hydrological rehabilitation in mangrove wetlands using box culverts across coastal roads in Northern Yucatán (SE, México). In *Threats to Mangrove Forests*; Springer: Cham, Germany, 2018; pp. 607–619.