Nature Based Solutions

Joint International Master of Environmental Sustainability

Restoring the Urban Lagoon Edge: A Nature-based Solution for Coastal Resilience in Nichupté Lagoon, Cancún”

By: Alexa Barrera Zink

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Introduction

Coastal cities are increasingly confronted with the dual challenge of sustaining economic growth while responding to escalating environmental risks. In tourism-dependent regions such as Cancún, this tension is particularly visible, as rapid urbanisation has often come at the expense of critical ecosystems that provide natural protection and support local livelihoods. Within this context, Nature-based Solutions (NbS) have emerged as an alternative to conventional “gray” infrastructure, offering approaches that work with ecological processes to address climate risks, biodiversity loss, and social needs simultaneously.

This report examines the potential of an NbS intervention in the Nichupté Lagoon, focusing on the urban waterfront areas of Malecón Tajamar and Puerto Cancún. The proposal combines living shorelines, mangrove restoration, and community engagement strategies to address flooding, environmental degradation, and urban pressure. Rather than presenting NbS as a universal solution, the report critically evaluates its design, governance, benefits, and limitations, situating the intervention within the broader socio-ecological dynamics of the lagoon system.

Site and Challenge Description

The proposed Nature-based Solution is located within the Nichupté Lagoon in Cancún, Mexico, a complex system of seven interconnected water bodies separated from the Caribbean Sea by the narrow barrier known as the Hotel Zone (Caribbean, n.d.)The intervention focuses on the waterfront areas of the Tajamar promenade (Malecón Tajamar) and the adjacent edges of Puerto Cancún, a residential and commercial development, where rapid urbanisation has significantly altered the lagoon’s ecological and physical dynamics.

The site is currently facing a multi-layered environmental and urban crisis. One of the most visible impacts is biodiversity loss, particularly following the large-scale clearing of mangroves in 2016, when approximately 49 hectares of protected forest were removed in Tajamar (Jorden, 2026). This event resulted in the destruction of critical habitat and the loss of species such as the Morelet’s crocodile, demonstrating the fragility of the ecosystem under development pressure. At the same time, water pollution has become

a persistent issue. Since the late 1980s, the lagoon has been affected by wastewater discharge and runoff from surrounding hotels, residential areas, and marinas (Mendoza Del Valle, 2017). Due to limited water exchange with the open sea, pollutants remain in the system for extended periods, contributing to declining water quality and ecological degradation.

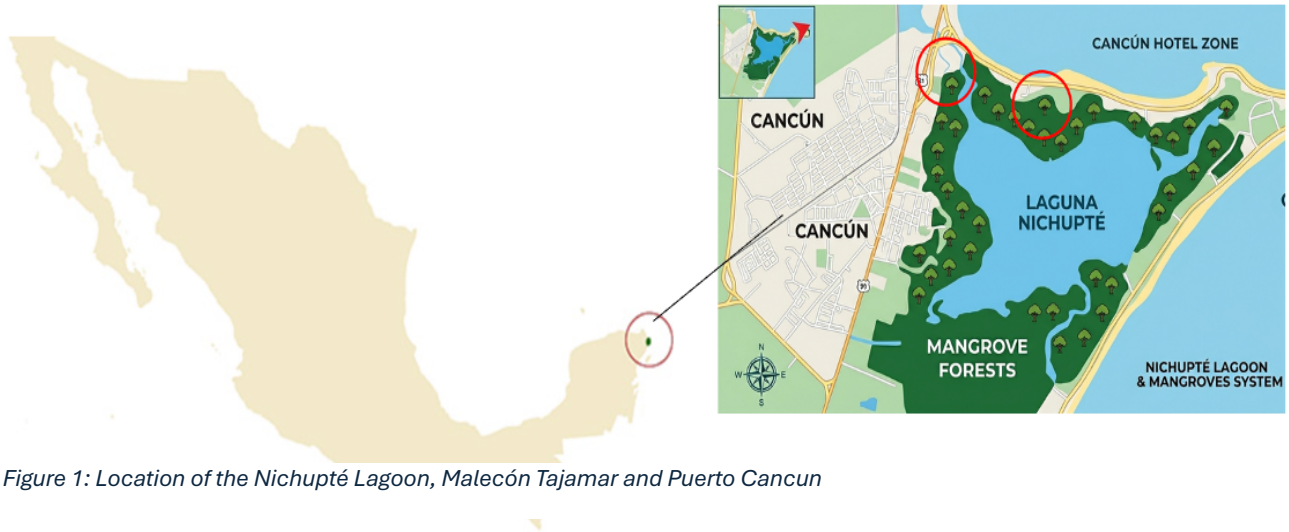


Figure 1: Location of the Nichupté Lagoon, Malecón Tajamar and Puerto Cancun

Urban pressures further compound these challenges. As Cancún continues to densify, Malecón Tajamar has become one of the few remaining public green spaces, providing space for recreation and community activities. However, it is increasingly threatened by real estate development, raising concerns about equitable access to urban nature. At the same time, the area remains highly exposed to coastal hazards, with hurricanes such as Wilma (2005) causing severe flooding, erosion, and long-term ecological damage.

These impacts are unevenly distributed. Residents and lagoon users face declining environmental quality and loss of public space, while the tourism sector, which is central to Cancún's economy, depends on the very ecosystems being degraded.

Conventional responses, largely based on hard infrastructure and top-down planning, have proven insufficient. Such approaches often neglect ecological processes, prioritise short-term economic gains, and have repeatedly failed under extreme weather conditions (Gomez et al., 2025). FONATUR, the agency responsible for promoting tourism in Mexico, has prioritized projects to benefit high-density tourism and shopping malls instead of long-term resilience (AP News, 2016). Given these challenges, there is a clear need for interventions that operate beyond isolated fixes. This proposal therefore adopts a

neighbourhood-to-watershed scale, focusing on restoring ecological function along the urban lagoon edge while contributing to the broader resilience of the Nichupté system.

Figure 3: Malecón Tajamar

Figure 2: Puerto Cancun

Proposed Intervention

The proposed intervention consists of 3 main components: a living shoreline approach, mangrove restoration and an educational component. The intervention aims to transform a rigid, engineered waterfront into a hybrid ecological edge that enhances coastal protection while maintaining the site's urban and recreational functions.

Living shorelines are nature-based coastal management strategies that use vegetation, sediment, and low-impact structural elements to stabilise shorelines while maintaining natural dynamics (Fisheries, n.d.). Unlike conventional hard infrastructure, which reflects wave energy and often exacerbates erosion, living shorelines are designed to absorb and dissipate wave energy, promote sediment deposition, and support habitat creation. In this context, they provide a more flexible and adaptive alternative to seawalls, particularly in environments exposed to fluctuating water levels and storm events. Natural features are introduced seaward of existing infrastructure to reduce exposure to flooding and erosion. As illustrated in the project sketch, the current hard bulkhead is not entirely removed but reconfigured. A layer of sediment (proposed sand fill) is placed against the existing structure, creating a gradual slope that replaces the abrupt vertical edge. This transition

allows wave energy to dissipate progressively rather than being reflected, reducing local erosion and improving shoreline stability.

Mangrove restoration forms the ecological core of the intervention. Dense mangrove reintroduction zones are established seaward of the transition area, following species-specific zonation. For example, *Rhizophora mangle* is positioned closer to the waterline, where its prop roots can effectively trap sediments and attenuate wave energy. These systems not only reduce erosion but also contribute to localised water filtration by capturing suspended particles and nutrients. Importantly, the design prioritises the protection and integration of existing mangrove patches, using them as ecological anchors for restoration.

The intervention also extends into the urban realm through the replacement of conventional pavement with permeable surfaces along the Malecón. This reduces surface runoff and allows rainwater infiltration, improving local drainage and reducing the direct discharge of pollutants into the lagoon. Importantly, the promenade itself is preserved as a public space, ensuring that recreational uses, such as walking, exercise, and social activities, are maintained while being ecologically enhanced. Additional

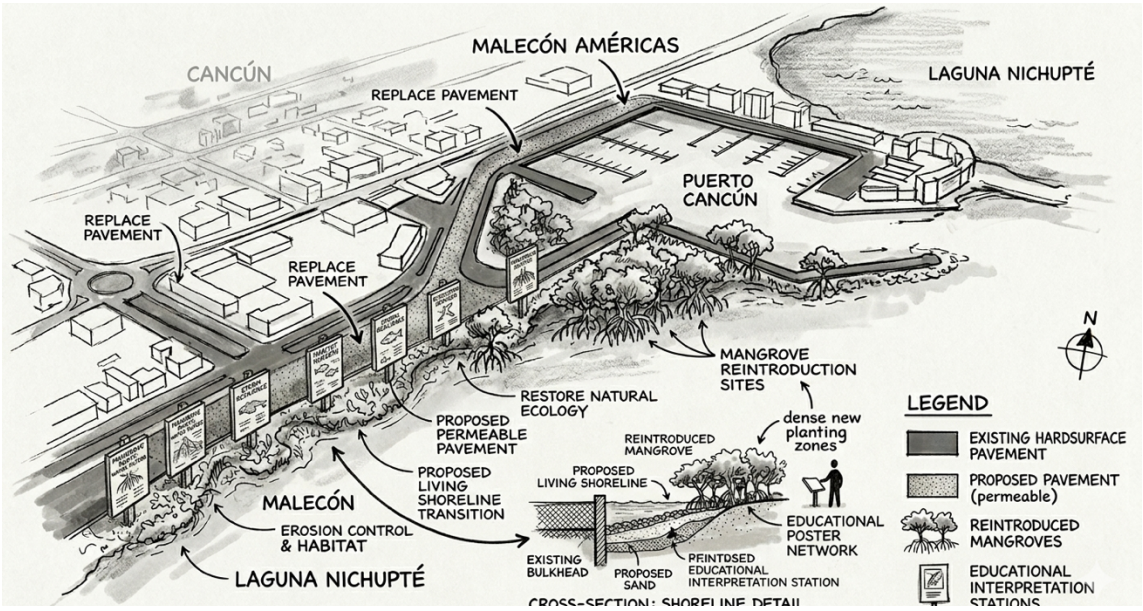


Figure 4: Intervention sketch

elements, such as educational interpretation stations distributed along the Malecón, aim to strengthen public engagement and awareness of mangrove ecosystems. This is

particularly relevant in a context where environmental degradation has historically been driven by development pressures.

While the living shorelines and mangrove restoration provide multiple benefits, it is not presented as a complete solution to all challenges. Mangroves can significantly reduce wave energy and improve local water quality, but they cannot fully resolve lagoon-wide pollution, particularly given the scale and persistence of existing contaminants. Similarly, while they enhance resilience to storms, they remain vulnerable to extreme hurricane events, especially during early stages of establishment. This proposal combines minimal engineering with ecological processes. By working with, rather than against, the natural dynamics of the lagoon, the intervention aims to create a shoreline that is both protective and regenerative, while remaining compatible with the existing urban context.

Stakeholders

The effectiveness of this design depends on governance and stakeholder engagement. Therefore, ther intervention requires a multi-level and participatory governance framework. Given the history of top-down planning and environmental conflict in areas such as Malecón Tajamar, stakeholder engagement is not treated as a procedural step, but as a central component of the project design and long-term viability.

A diverse set of stakeholders is involved. Government agencies play a regulatory and coordinating role, particularly the Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT), responsible for environmental permitting, and the Secretaría de Infraestructura, Comunicaciones y Transportes (SICT), which has led large-scale remediation efforts in the region. Additional actors such as the Comisión Nacional de Áreas Naturales Protegidas (CONANP) and the Fondo Nacional de Fomento al Turismo (FONATUR) reflect the intersection of conservation and tourism-driven development. At the local level, community groups, including the “Guardianes del Manglar”, as well as residents and lagoon users represent key stakeholders, particularly in relation to access to public space and environmental quality. Non-governmental organisations such as Flora, Fauna y Cultura de México contribute technical expertise in mangrove restoration, while research institutions and the local university (Anáhuac) support ecological monitoring and hydrological analysis. The private sector, especially developers and

businesses operating in Puerto Cancún, plays a key role as both a source of environmental pressure and a key partner in financing and implementation.

Stakeholder roles are differentiated across project phases. During the design phase, government agencies establish the regulatory frameworks, including principles such as zero net loss of mangrove cover, while NGOs and research institutions provide ecological data to guide restoration. Participation is imperative to the success of the NbS so methods such as diagnostic interviews with fishers, residents, and business owners, alongside validation workshops, are used to incorporate local knowledge and identify priority areas. In the implementation phase, SICT and specialised contractors oversee physical interventions, including shoreline modification, while NGOs lead mangrove planting and community-based restoration efforts. In the maintenance phase, the project transitions toward a shared governance model, with local communities, NGOs, and public institutions jointly responsible for monitoring mangrove health and water quality.

To ensure that the proposal moves beyond the planning phase and remains viable over time, the governance framework is designed to anchor responsibilities within existing institutional structures while distributing ownership across stakeholders. The project builds on existing civic engagement, including youth-led movement, the “Guardianes del Manglar,” by integrating education and stewardship programmes, including school-based initiatives and community-led monitoring schemes (“Adopt a Mangrove”). The preservation of the Malecón as an accessible public space ensures that benefits are not restricted to private developments, while participatory processes are designed to be accessible and continuous rather than one-off consultations.

Benefits and Trade-offs

From an ecological perspective, the intervention enhances supporting ecosystem services through the restoration of mangrove habitats. These systems improve habitat connectivity and contribute to biodiversity recovery, supporting a wide range of species, including over 200 bird species and fauna such as the Morelet’s crocodile. This represents a net ecological improvement compared to current degraded conditions, aligning with the objective of achieving biodiversity gains (IUCN criterion 3) rather than simply preventing further loss.

The proposal also strengthens key regulating ecosystem services, which are central to addressing the site's exposure to climate risks (IUCN criterion 1). Mangroves and living shorelines attenuate wave energy, reduce erosion, and provide protection against storm surges, contributing to disaster risk reduction in a hurricane-prone region. In addition, their root systems trap sediments and filter pollutants, improving water quality along the lagoon edge. However, these improvements are primarily localised and do not fully resolve lagoon-wide pollution, particularly given the system's long water residence time. This highlights both the potential and the limits of the intervention in addressing broader environmental challenges.

In terms of cultural ecosystem services, the project maintains and enhances the role of the Malecón Tajamar as a public space for recreation and social interaction. By preserving access and integrating educational interpretation elements, the intervention supports community well-being and environmental awareness. This is particularly relevant in the context of Cancún, where urban development has reduced access to open and green spaces. Ensuring that these benefits remain publicly accessible is critical (IUCN criterion 5), especially given the historical prioritisation of tourism-driven development.

Economic benefits emerge primarily through regulating services, particularly coastal protection. By reducing damage from storms and erosion, the project lowers long-term maintenance and repair costs and supports the stability of tourism-related infrastructure. While the lagoon is not a major site of extractive use, improved ecological conditions may also indirectly support small-scale livelihoods and local economic activity.

Despite these benefits, the intervention involves several important trade-offs (IUCN criterion 6). The creation of mangrove buffer zones reduces the availability of land for commercial development, directly challenging ongoing urban expansion. There is also a shift from predictable, engineered systems to more dynamic and adaptive natural processes, which may be perceived as a loss of control. Additionally, ecosystem services are not delivered immediately; mangroves require time to establish, resulting in a lag before full protective capacity is reached.

These trade-offs are closely linked to issues of equity. While tourism development has historically contributed to environmental degradation, it also stands to benefit from increased coastal protection and improved environmental quality. The project therefore

seeks to rebalance these dynamics by maintaining the Malecón as a public space and involving local communities in stewardship and monitoring. At the same time, governance and financing mechanisms must ensure that benefits are not disproportionately captured by private actors.

Monitoring

The success of the living shoreline and mangrove restoration in the Nichupté Lagoon will be assessed through a multi-dimensional monitoring framework, covering ecological, physical, social, and economic outcomes.

Ecologically, key indicators include mangrove survival rates, total restored area, species richness, and improvements in water quality, with attention to indicator species such as the Morelet's crocodile. Physical performance will be measured through shoreline stability and flood reduction, reflecting the effectiveness of the living shoreline in attenuating wave energy.

Social outcomes focus on public use of Malecón Tajamar, levels of stakeholder engagement, and perceptions of environmental quality. Economic indicators include avoided storm damage costs, changes in tourism and property value, and reduced long-term maintenance costs compared to grey infrastructure.

A clear baseline will be established prior to implementation, including current mangrove cover, biodiversity data, hydrological conditions, pollution levels, and socio-economic use patterns in Puerto Cancún.

Monitoring responsibilities are shared between government agencies (SEMARNAT, SICT), NGOs, and community groups such as the "Guardianes del Manglar," ensuring continuity and local ownership. Data collection will be continuous, with higher frequency in the early stages of mangrove establishment.

Importantly, monitoring feeds into an adaptive management system Rather than functioning as a passive reporting mechanism, data is used to inform decision-making in real time. For example, if mangrove survival rates fall below defined thresholds, replanting or maintenance interventions are triggered. This ensures the project can respond to changing conditions over time.

Barriers and Scaling Strategy

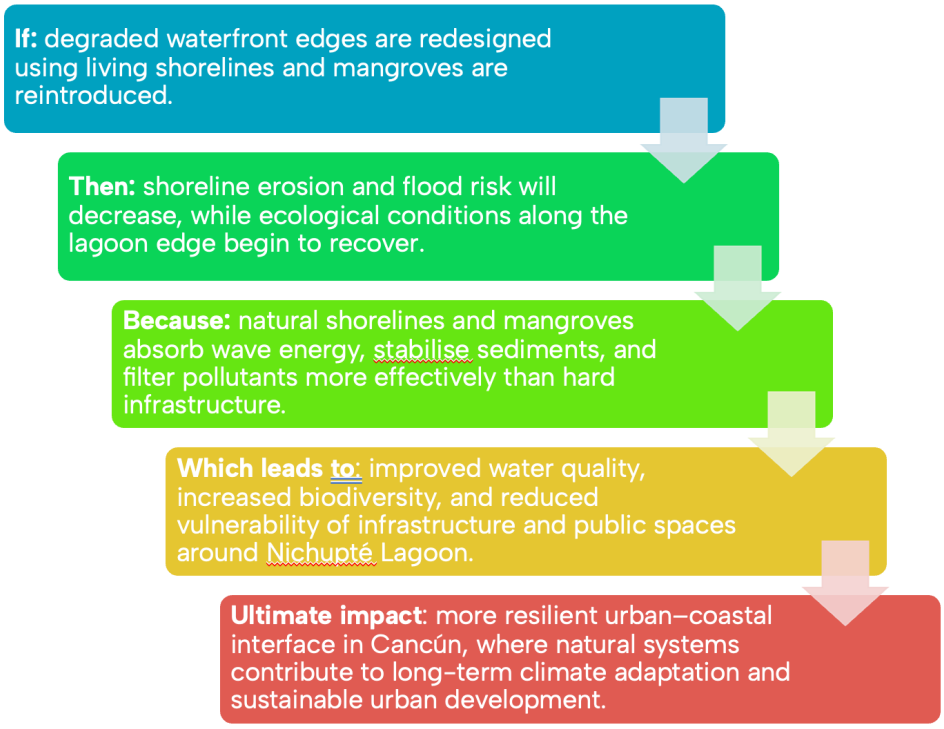
Given the high economic value of coastal land, conflicts between conservation and development interests are inevitable. These are addressed through a combination of legal protections, including court rulings that prioritise environmental rights, and clear policy boundaries, such as defined buffer zones and construction limits. In addition, economic alignment mechanisms, including co-financing models and potential resilience or tourism-based fees, seek to unite the private sector interests with ecological objectives. By combining participatory design, institutional coordination, and conflict management, the project searches to establish a more stable and inclusive governance framework for long-term coastal resilience. Institutionally, overlapping responsibilities between federal, state, and municipal authorities, particularly agencies such as SEMARNAT and SICT, can lead to fragmented decision-making and weak coordination. Past cases, such as development pressures in Malecón Tajamar, highlight the persistence of short-term economic priorities over long-term environmental planning. Financially, the reliance on short-term funding mechanisms poses challenges for sustaining the continuous monitoring and adaptive management required for living shorelines. Technical barriers also remain, including limited local expertise in NbS design and uncertainty associated with the time required for mangroves to reach full functionality. Socially, resistance may arise due to perceived loss of developable land in high-value areas such as Puerto Cancún and a continued preference for “gray” infrastructure.

To address these constraints, the proposal adopts a phased and adaptive strategy. Pilot interventions at Tajamar can demonstrate effectiveness and build trust, while adaptive management allows for iterative adjustments based on monitoring results. Strengthening a practice community and involving NGOs and research institutions, helps bridge technical gaps. Legal protections and stricter enforcement mechanisms are critical to prevent future mangrove loss.

Long-term viability is supported through blended financing mechanisms, including coastal resilience fees for waterfront properties, tourism eco-fees, and alignment with federal remediation programmes. In parallel, scaling potential lies in extending living shoreline approaches across the wider lagoon system and embedding NbS into urban planning frameworks. Policy instruments, such as mandatory NbS consideration in Environmental

Impact Statements and defined buffer zones, are really important to move from isolated interventions to mainstreamed coastal resilience strategies.

Figure 5: Theory of change



Conclusion

This proposal demonstrates that Nature-based Solutions can provide a viable pathway for enhancing coastal resilience in highly urbanised and economically contested environments such as the Nichupté Lagoon. By combining living shorelines with mangrove restoration, the intervention addresses key challenges related to flooding, biodiversity loss, and water quality, while maintaining the social function of the waterfront. However, the analysis also highlights that NbS are not without limitations. Their effectiveness depends on long-term governance, sustained funding, and the willingness to accept trade-offs, particularly in relation to urban development. The success of the project therefore lies not only in its ecological design, but in its ability to balance competing interests and embed resilience within existing planning frameworks.

Ultimately, this case illustrates that NbS are most effective when understood not as standalone technical solutions, but as adaptive, negotiated processes that integrate ecological, social, and economic dimensions over time.

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