NATURE-BASED SOLUTIONS ON MEGA-BIODIVERSE COASTS: EXPERIENCES AND CHALLENGES IN MEXICO

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INTRODUCTION

Coastal ecosystems in tropical areas have a very complex biodiversity where, in a small space, a large number of species is concentrated. They provide important ecosystem services to society, such as carbon sinks, habitat, fisheries, scenic beauty, recreation, and storm protection. Because of their location, coastal ecosystems are resilient and resistant to extreme climatic events such as hurricanes, which frequently occur in tropical latitudes. The vast majority of these mega-biodiverse coastal areas are found in developing countries, and, because of the need to improve socio-economic conditions, the land use has often been substantially modified, mainly for urbanisation, the building of ports and power generation plants, resource extraction and exploiting the areas for tourism.

TROPICAL COASTAL ECOSYSTEMS

The most common tropical ecosystems, coral reefs, seagrass beds, beaches, coastal dunes, coastal lagoons and mangrove forests, are found along the Mexican coast, the target of this analysis. Depending on geological, climatic, and nutrient conditions, some, or all of these ecosystems may be present in any one coastal unit. Within a very small distance, it is common to find several of these ecosystems which can be preserved or altered by human use. As an example, a typical coastal profile found in the Mexican Caribbean is shown in Figure 1.

Based on the work by Silva et al., (2021), through the application of the DESCR framework (Drivers - Exchanges - State of environment – Consequences - Responses, Silva et al., (2020), Figure 2) analyses were made of more than 20 Mexican case studies to assess the effectiveness of nature-based solutions. The cases were chosen after reviewing a wide range of interventions along more than 11 000 km of coastline. A classification of these cases was proposed, following the types of coastal green infrastructure determined by Chavez et al. (2021), Figure 3. In general, the scale proposed by Chavez et al. (2021) reflects the degree of naturalness, the time needed for implementation, the space required, the level of uncertainty of the solution and its associated economic cost. In particular, the degree of uncertainty of more natural solutions is more associated with the fact that the response of ecosystems is highly dependent on their state of maturity and condition (e.g. associated with low water levels or floods).

With the exception of De-engineering/Relocation, interventions of the other green infrastructure types were identified as: Nature reclamation, Engineered ecosystems and Ecologically enhanced engineering. In addition, the goals of each type of intervention range from habitat conservation and restoration (nature reclamation) to a combination of infrastructure with different levels of naturalness (Hybrid alternative).

The degree of success of the interventions was characterised in terms of the disturbances induced or avoided and their consequences on the resilience and resistance of these coastal zones. The main disturbances analysed were classified as: anthropic (e.g. soil and water pollution, erosion, groundwater overexploitation, invasive species, land-use change, marine traffic, overfishing), climate change (e.g. sea level rise and saltwater intrusion, rising seawater temperature, changes in precipitation regimes, ocean acidification, coral bleaching, massive sargasso influx) and natural (e.g. inter- and multi-annual oscillations, hurricanes).

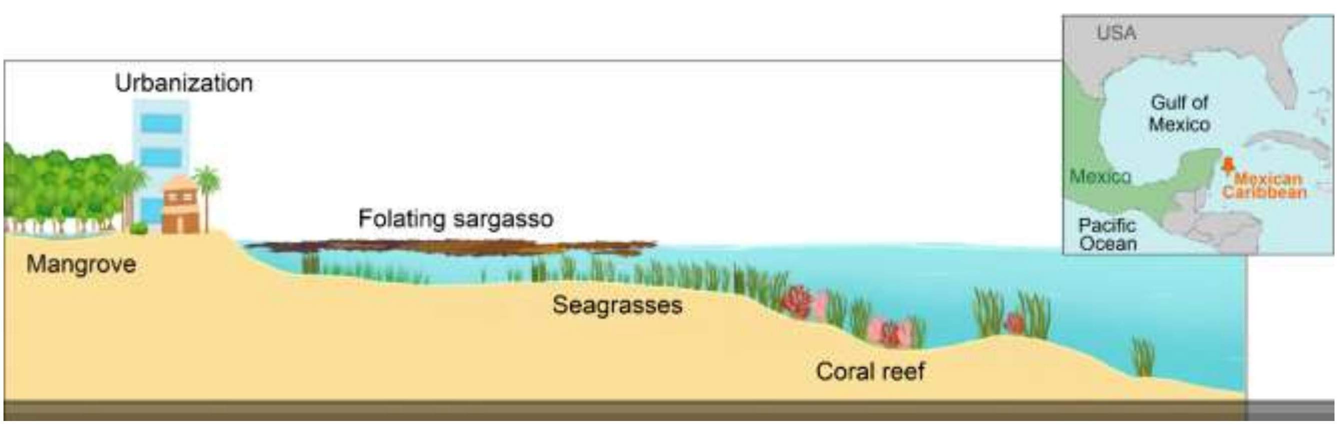

Figure 1– Typical beach profile in the Mexican Caribbean.

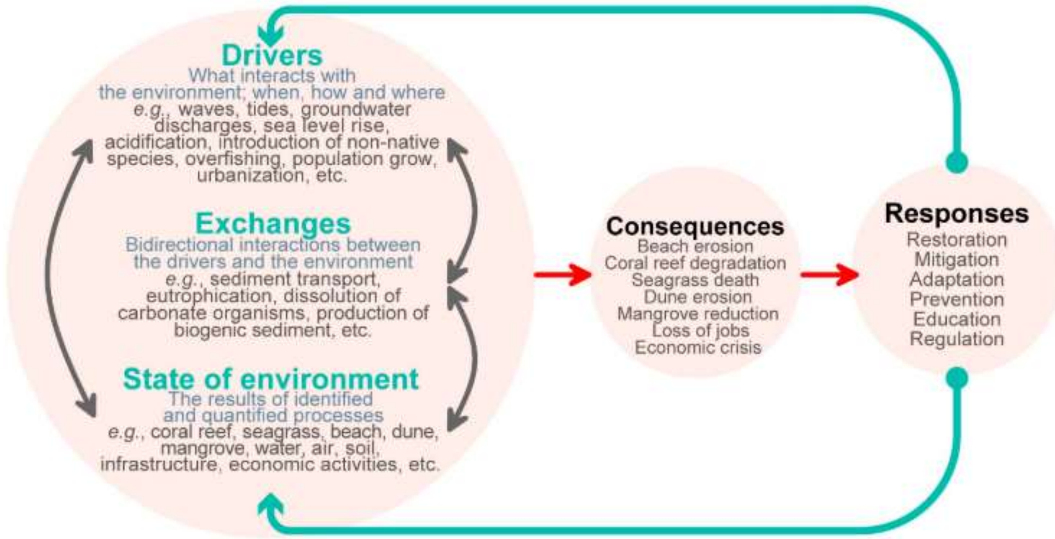

Figure 2. The DESCR framework -drivers, exchanges, state of the environment, consequences and responses- applied to a tropical coastal unit (from Silva et al., 2020).

Type	Description	Local characteristics
1 Nature reclamation	Habitat conservation and restoration	↑ Degree of naturalness, time, space, uncertanty
2 Engineered ecosystems	Ecosystems rehabilitation	
3 Ecologically enhanced engineering	Traditional hard and/or soft engineering that imitates natural ecosystems	
4 De-engineering/ Relocation	To recover the system and move towards more natural functioningnatural	
Hybrid alternative	Combines infrastructure with different levels of naturalness	↓ Cost

Figure 3 - A classification of coastal green infrastructure according to the degree of naturalness of the project vs the financial cost of implementation of the type of solution (data from Chávez et al. 2021).

CONCLUSIONS

All projects involving land-use change or use of assets have impacts on the environment. Coastal developments that are accompanied by proper monitoring from the preliminary stages to the operation of the projects, allow the analysis of possible scenarios and environmental alterations. Based on this, it is possible to use this information to determine, understand, and correct unforeseen consequences. Furthermore, nature-based solutions can become more successful in terms of socioeconomic development and the conservation of ecological wealth, because they have led to a more educated, knowledgeable and equitable society.

Ecological restoration projects, when accompanied by proper engineering, are less costly, less uncertain, and more successful because natural cycles and fluxes of energy and matter can be restored more effectively That is why one of the lessons learned in recent years is that multi- and trans-disciplinary work is essential. On the other hand, recent findings have shown that the engineers' conception of controlling nature does not always work and unexpected side-effects may occur. Instead, it is increasingly accepted that it is more cost-effective to carry out multidisciplinary projects that avoid irreversible damage to ecosystems.

The importance of our ecosystems for the dynamic balance of the planet has been underlined in recent works (e.g. Odériz et al 2020), but the mass and energy balances that occur as a result of the inter- and intra-connections of all ecosystems in highly biodiverse areas is perhaps most important in tropical areas.

The analysis concludes that there is no perfect solution, but at least comprehensive solutions have been identified that are more or less acceptable from a socio-economic and environmental points of view. The most successful interventions over time are those in which the ecological solutions are based on good engineering and those in which the engineering interventions are compatible with natural flows and ecological processes.

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