CHAPTER 23

The Mayakoba touristic development: a model of sustainable tourism in the Mexican Caribbean

D. Zárate-Lomelí[1], H. Alafita-Vásquez[1], J. L. Rojas-Galaviz[1], A. Sarasola[2], C. Leo[2], J. W. Day[3], M. Villasuso-Pino[4] & C. Padilla-Souza[5]
[1]*Consultores en Gestión Política y Planificación Ambiental S.C, México.*
[2]*Obrascón Huarte Lain, Spain.*
[3]*School of the Coasts & Environment, Louisiana State University, LA, USA.*
[4]*Consultores en Agua Potable, Alcantarillado, Geohidrología & Hidráulica Costera I.C, México.*
[5]*BACABES S.C, Mexico.*

Abstract

The Mayakoba Touristic Development (MTD) belongs to Obrascon Huarte Lain (OHL). It is located in the central coastal Mexican Caribbean, where there are ecosystems of great ecological value and fragile balance.

MTD is inserted into an environmental matrix with high valuable ecosystems, such as mangroves, coastal dunes, tropical forests, and reefs. The process for the design of this project was focused in the conservation of these ecosystems and their natural processes.

The interaction between the project, the manmade system of water canals and the implementation of good and better environmental practices during the design, construction and operation processes, have allowed MTD to be considered as a model of sustainable development by the Mexican Ministry of Environment and Natural Resources, as well as national and international organizations such as Rainforest Alliance, MARTI, and World Tourism Organization.
Keywords: Riviera Maya, reef ecosystem, marine environment, Punta Bete, Punta Maroma.

WIT Transactions on State of the Art in Science and Engineering, Vol 64, © 2013 WIT Press
www.witpress.com, ISSN 1755-8336 (on-line)
doi:10.2495/978-1-84564-756-8/023

1 Introduction

Tourist activities in Mexico, in the last decade, have become one of the main axes of the internal economy, secondary only to manufacturing and oil. Income perceived by tourism in 2010 amounted to 11,871.9 million United States Dollars, an increase of 5.3% when compared to 2009. This places Mexico as 11th in the worldwide ranking of income from tourism. The flow of incoming tourism into Mexico exceeds 10 million people per year, out of which 63% comes to the State of Quintana Roo, particularly to the tourist destinations of Cancun and the Riviera Maya [1–4].

Tourism is the main economic activity in the state of Quintana Roo. In the year 2010, the state perceived 5522.62 million United States Dollars from this activity, which represents 46.51% of the nations' total SEDETUR [3].

Currently, the coastal zone offers 893 hotels with 82,983 rooms, out of which 29,951 are concentrated in the City of Cancun, which is considered as the first of five fully planned beach centers in the country. The second most important touristic region in the state is the zone denominated Riviera Maya, where there are currently 377 hotels with 38,402 rooms (Fig. 1). Both regions annually perceive more than 6.3 million visitors [2–5].

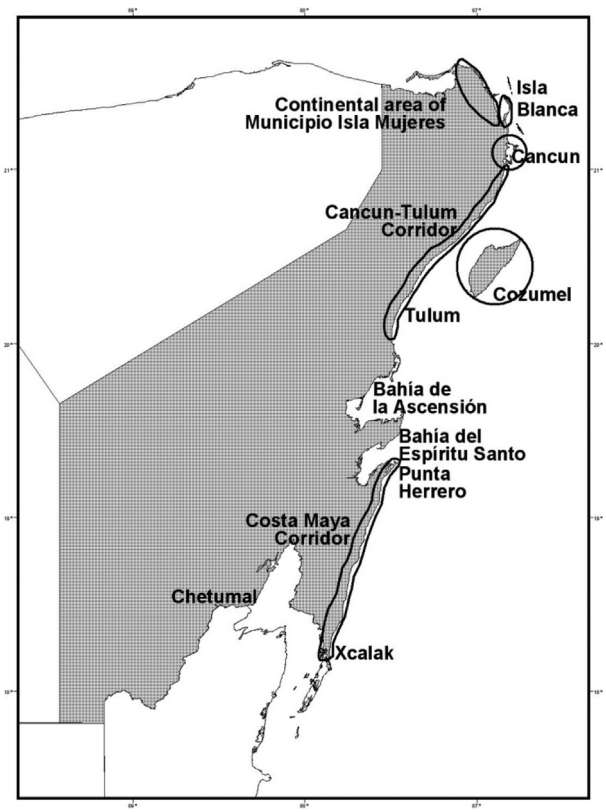

Figure 1: Main touristic development poles in the State of Quintana Roo, México.

Touristic activity and infrastructure is concentrated in the coastal area of the state, mainly in five development poles (Fig. 1): a) the continental area of the Municipality of Isla Mujeres, b) Cancun, c) the Cancun-Tulum Corridor (Riviera Maya), d) the Islands of Mujeres and Cozumel, and f) Costa Maya (Mayan coast).

The sustainable touristic development model described in this chapter is Mayakoba, and it is located in the Riviera Maya zone (Fig. 1).

2 Environmental scenario

The Mayakoba Touristic Development (MTD) is located in the Riviera Maya zone and covers the coastal area from Punta Bete (Cape Bete) to Punta Maroma (Cape Maroma), in the Municipality of Solidaridad, state of Quintana Roo. Below, the environmental scenario for this Environmental System (ES) is described.

Along the littoral strip from Punta Bete to Punta Maroma, there is a coastal physiographic unit denominated Punta Bete-Punta Maroma Environmental System (PBPMES) [6] (Fig. 2).

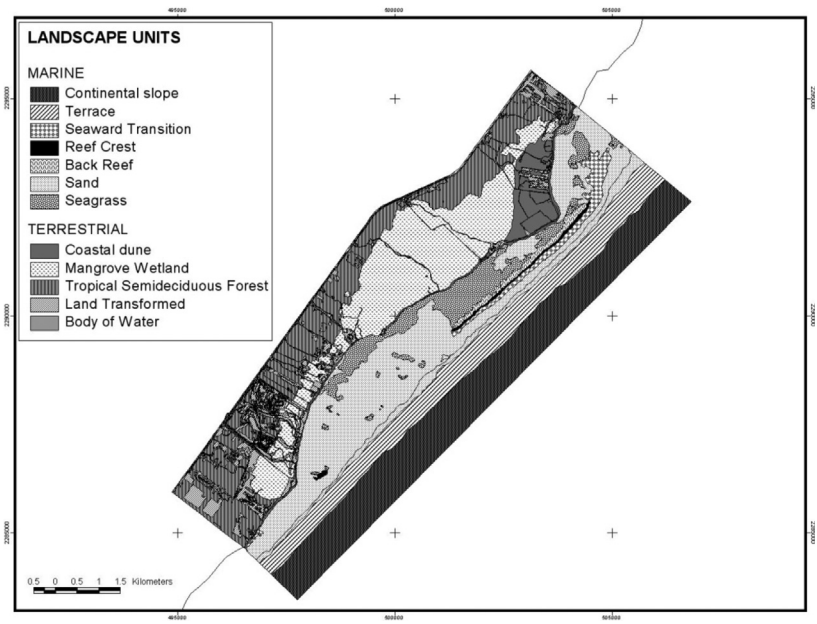

Figure 2: Punta Bete–Punta Maroma Environmental System, Quintana Roo. The ecosystems that are present in this region have complex ecological interactions which determine their existence. Alterations to the basic environmental structure and functions in any of them due to a badly designed project or activity might result in environmental impacts for the rest of the coastal ecosystems with which it is ecologically linked, negatively impacting, as a consequence, all of the environmental system and the economic activities developed in the area.

The PBPMES belongs to the humid tropic eco-geographic zone and is part of the Yucatan Karst and Low Coast ecological provinces of Quintana Roo [2], [6–8]. The weather in the region is subhumid warm with rainfall in the summer and part of the winter. The average annual temperature is 27°C, and the average annual rainfall is between 1200 and 1300 mm. It is part of the Yucatan platform, so its topography is mainly flat. Due to this geological and topographic conformation, its hydrological system mainly determines a subterranean water pattern and the formation of 'cenotes' (sinkholes) [8–10].

The boundaries of the PBPMES are naturally limited by two littoral accumulation and accretion zones (Punta Bete and Punta Maroma), whose existence is determined by bordering-type coral structures which generate a low energy environment. In the case of Punta Bete, the coral formation is incipient and propitiates the formation of an accumulation zone in the shape of a tip or a loop (Fig. 2) [6, 8, 10, 11].

In the case of Punta Maroma, the reef has a better structure and forms a typical reef crest that enables the existence of a littoral accretion zone in the continent, characterized by the formation of littoral ledges. Between both accumulation zones, there is an area in the shape of a cove, where the beach is sandy and the coastal dynamics are characterized by a dominant littoral transport perpendicular to the coast line, and a predominant low-magnitude longitudinal transport traveling from North to South (Fig. 2) [9, 12].

The natural production of biogenic sand in this zone is insignificant, and the dominating littoral process is that of erosion, which varies in a North to South direction from 2.5 to 4.5 m/year [9, 12–14].

The bordering-type reef ecosystem exists only in front of the two Capes (Bete and Maroma). The cause for the reef ecosystem being interrupted between both structures is that the zone corresponds to a great underground sweet water discharge region directly heading into the adjacent marine zone. In general terms, the reef system developed between Punta Bete and Punta Maroma is found to be underdeveloped, both in its geological structure and its community structure. Scleractinian coral is poorly represented; there are only a few small, isolated colonies, and the large-sized, massive coral growth is practically absent (Fig. 2) [6, 8, 15, 16].

In the marine coastal zone, there are records of 12 species of scleractinian coral, 2 of hydrocorals, 17 of gorgonians, 31 of macroalgae, 2 of phanerogams, 32 of fish, and 13 of sponges. Of these species, one (*Plexaura homomalla*) is found mentioned in the Norm NOM-059-SEMARNAT-2010 [19]. In a perpendicular direction to the coast line, it is possible to identify six types of environments (Table 1).

Adjacent to the marine zone and on the continental portion, there are four types of ecosystems aligned parallel to the coast line: a) coastal dunes, b) mangrove wetlands, c) transition zone or rainforest–mangrove ecotone, and d) a deciduous low rainforest zone (Fig. 2, Table 2). These ecosystems are a consequence of the climatic, edaphic, geomorphic, and hydrological characteristics present in the region, and have a great environmental value due to the ecological functions they perform, and due to the great diversity of biological and natural resources they contain [6, 8, 15, 17, 18].

Table 1: Description of the marine environments of the PBPAES, Quintana Roo [6, 8, 15–17].

Marine environments	Main characteristics
Sea grasses	Sandy bottom zone covered by sea grasses (*Thalassia testudinum* and *Syringodium filiforme*). In the zones with a lesser sweet water influence, *T. testudinum* is dominant, and houses a wider diversity of species, both of microalgae and invertebrates, even small coral colonies from the *Porites* and *Siderastrea* genus are present. In the sea grasses zones located in front of the sweet water discharge sites, both species are present.
Sand bar	It is the dominant bottom type, and it corresponds to sand plains where small patches of sea grasses and algae are found, as well as small isolated hard substratum areas, and where gorgonians and sea algae develop. In these environments, isolated gorgonians, mainly from the *Pterogorgia anceps* species, are found, along with *Manicina areolata* coral colonies, and the *Millepora* rocky hydrocoral, which are species that develop in high sedimentation sites. In the areas where the littoral erosion process has been more insidious, peat is the main bottom type.
Reef Shoal	In the marine zone, coral structures are located in the north, near the deep part of the reef, which correspond to remnants of the reef barrier located in front of Punta Maroma. Their structure consists of a dead *Acropora palmata* matrix, where gorgonians grow, along with some coral colonies. In the deepest part of the shoal, the *A. palmata* matrix is better consolidated, since in other sites it has grown covered with sediment forming a reef matrix. There is a large number of coral colonies, mainly of the *Porites asteroides* species, of a scale-forming growth. Colonies from the *Zoanthus* and *Millepora* genus are also present.
Posterior reef	This zone is part of the reef crest located in front of Punta Bete and Punta Maroma. This site is characterized by the presence of medium-sized heads of coral, mainly formed from the *Montastrea annularis* species, where coral colonies from the *Agaricia* genus abound. There are numerous colonies of gorgonians of various species and growth forms, and it is one of the zones with a high fish diversity in the region. Its depth ranges between 2 and 3 m, and the substratum deposited among the heads of coral is mainly bits and pieces and rough sand.
Barlovento Transition	The Barlovento transition occurs at a depth of 5–15 m, on the exposed face of the reef (Barlovento), located in front of Punta Bete and Punta Maroma. The substratum consists of calcareous flagstone, and the dominant benthic community consists mainly of colonies of gorgonians, which grow in an isolated pattern and with a more or less uniform distribution, that is, they don't form groups. The colonies of gorgonians are of medium size, and the *Eunicea mammosa* species is the dominant one, followed by *Pseudopterogorgia americana*. Some colonies present damages in their

Continued

Table 1: *Continued.*

Marine environments	Main characteristics
	live tissue, such as the growth of *epibiontes* in *P. americana*, or the presence of viruses in the species of the *Gorgonia* genus. The *scleractinian* coral is common, but appears in medium-sized colonies, mainly from the *Siderastrea siderea* species in massive numbers, which present a high rate of damage.
Scarp	It corresponds to a zone where the sea floor presents unevenness with a 5 m differential in the calcareous flagstone over an old coastline that looks like a step. This unevenness is located at a depth of 30 m and is subjected to strong currents traveling in a south to north direction caused by the Yucatan current. Coral colonies of various species are present, but they are small in size and include few gorgonian colonies. Sponges are more abundant in this area.

Table 2: Description of the land environments present in the PBPAES, Quintana Roo [6, 8, 15, 17, 18].

Land environments	Main characteristics
Coastal dunes	Coastal dunes along the physiographic unit are interrupted in some places of the southern and central portions due to the construction of coastal infrastructure. In this ecosystem, there are records of at least 30 plant species, 2 of which are cataloged under the application of Norm NOM-059-SEMARNAT-2001 [19] as endangered. In terms of fauna, this ecosystem is relevant, since there are records of at least 43 animal species, 8 of which are cataloged in the above-mentioned Norm.
Mangrove wetlands	Adjacent to the dunes zone, there is a flooding plains system that enables the development of a mangrove wetland ecosystem. These specific wetlands are distributed from the south of Punta Bete to the northern part of Punta Maroma, where their continuity is intew rrupted completely because of the construction and operation of touristic infrastructure. From the hydrological and geomorphic point of view, the wetlands are located on a flooding plain or flatland. The surface runoff in these areas is determined by the seasons. In the rains season, there are two components: one is dominant, which is perpendicular and runs in the direction of the coast line, determined by regional runoff, and the second component, which is secondary, is determined by rainfall and the slope of the land (the dominant orientation runs in a northeast to southwest direction). In the dry seasons, surface runoff strictly corresponds to the exposition of the phreatic mantle which forms a continuous unit throughout the wetlands.

Continued

Table 2: *Continued*.

Land environments	Main characteristics
	The dominant hydrological process in the physiographic unit is the flow of underground water, through preferential flows and cracks which drain sweet water to the adjacent marine zone through various cavities (Fig. 3). An average volume of underground water discharge of 175 $m^3/d/m^2$ of unit area located over the coastline is estimated for the physiographic unit. In this area, the aquifer is in transition and in motion, so its physical–chemical characteristics and quality depend on the range of tides and underground sweet water drainage (CAPA, 2005 and 2006). In the mangroves ecosystem, there are records of at least 20 plant species, 4 of which are cataloged under the application of Norm NOM-059-SEMARNAT-2001 [19]. In terms of fauna, the wetlands are used by at least 69 animal species, 7 of which are considered in the above-mentioned Norm.
Rainforest–mangrove ecotone	In the posterior part of the mangrove strip, there is a piece of flatland which is slightly more elevated than that of the wetlands. The topography of this unit determines the formation of an ecotone between the mangrove and rainforest ecosystem. This transition area is dominated by low deciduous rainforest elements and is dominated by low deciduous rainforest elements and is distributed in a south to north direction, without exceeding the limits of the physiographic unit, figs. 2 and 3. Studies for the region reveal the existence of at least 20 plant and 36 animal species, two and six of which, respectively, are catalogued under the application of Norm NOM-059-SEMARNAT-2001 [19].
Deciduous low rainforest zone	Between the highway and the rainforest–mangrove ecotone, there is a littoral ledge zone corresponding to old coastal lines, which form a plain that extends south to north beyond the limits of the physiographic unit. In this plain a deciduous low rainforest zone developed and exhibits different degrees of preservation. The diversity of this ecosystem is higher in comparison to the ecosystems analyzed before. There are records of at least 111 plant species and 99 animal species, 11 and 6 of which, respectively, are cataloged as endangered species by the Norm NOM-059-SEMARNATL-2001 [19]. Regarding the plant species, there are records of 16 endemic plant species and 1 fauna species.

3 Environmental problems

Based on a multitemporal evaluation using geo-referenced aerial photography (2004, 2005, 2006, and 2010), on the use of a geographic information system, and on verifications in the field, it has been possible to assess the degree of preservation and deterioration of the PBPMES [15, 17, 20].

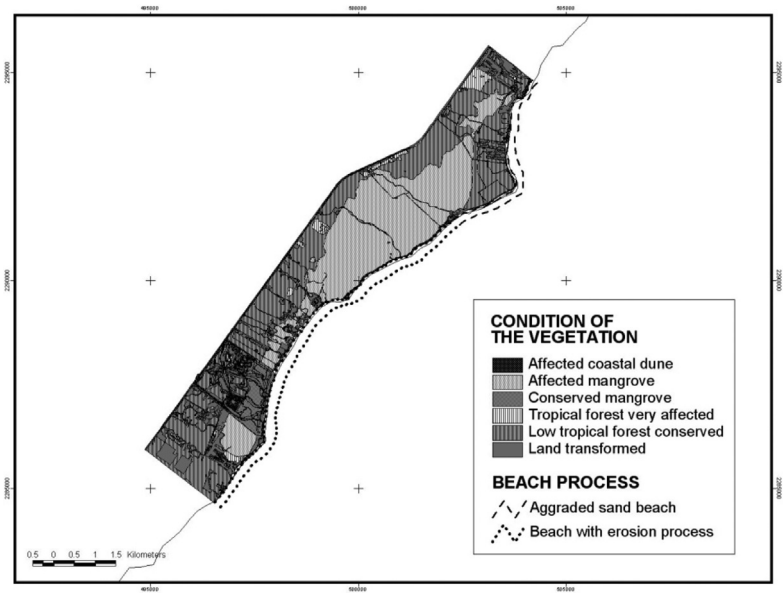

Figure 3: Environmental quality of the Punta Bete-Punta Maroma environmental system.

Table 3: Land and vegetation use in the PBPAES, Quintana Roo. Conditions of the existing plant coverage [6, 15].

Status of the plant coverage and beach coverage	ha	%
Affected coastal dunes vegetation	24.76	1.02
Mangrove with various degrees of disturbance	866.04	35.57
Preserved mangrove	62.72	2.58
Rainforest with a high degree of disturbance	68.48	2.81
Low rainforest	959.71	39.41
Body of water	1.25	0.05
Areas transformed and occupied by touristic infrastructure	419.99	17.25
Accumulative beach	15.67	0.64
Erosive beach	16.37	0.67
TOTAL	**2434.97**	**100.00**

Figure 3 and Table 3 show the environmental conditions of the PBPMES up to 2010. It is clear that of its total surface (2434.97 ha), 17.3% is occupied by touristic infrastructure (including artificial water bodies, roads, and highways), 40.1% is occupied by disturbed vegetation areas (rainforest, mangroves, and dunes), and 42.6% is occupied by natural vegetation areas in good preservation conditions (rainforest and mangroves). Most of the touristic infrastructure has been built on the central–south part of the PBPMES, generating a fragmentation process and the

loss of valuable ecosystems and vegetation, mainly mangroves and dunes. The design of the projects in this part of the SA has interrupted the ecological link between the mangrove, rainforest, the rainforest–mangrove ecotone, the dune–beach, and the adjacent marine zone ecosystems.

Landfill works for the construction of touristic-residential infrastructure, as well as roads and highways, along with the absence of bridges and manholes, has occasionally caused interruptions in the surface runoff of mangrove areas in the central–south portion of the PBPMES, causing evidence of disturbance in at least 35% of the existing mangrove of the PBPMES. The most affected areas are located in the central–south portion (Fig. 3).

The fragmentation and loss of ecosystems in the central–south portion of the PBPMES is caused by the loss of biodiversity and the migration of fauna toward the better preserved areas and ecosystems which, in this case, correspond to the central–north portion of the PBPMES [6, 15].

In the PBPMES, currently there is a recorded operation of at least 6064 hotel rooms and residential units, as well as a golf course, which require the extraction of brackish water from the aquifer for human-consumption tap water, green areas irrigation, and golf course maintenance, for which extraction wells are necessary.

Currently, it is estimated that the extraction of water amounts to 20,215 m^3/day in order to satisfy hotel's operation and tourists' housing needs, plus, at least, 1967 m^3/day used to irrigate golf courses. The estimated liquid waste from the operation of the touristic-real estate infrastructure in the SAPBPA, amounts to 11,119 m^3/day brine (backwater from inverse osmosis plants) and 7276 m^3/day sewage. In the case of backwater, it is re-injected into the underground and sewage is processed from residual water treatment plants so that, later on, according to the NOM-001-SEMARNAT-1996 [21] and NOM-003-SEMARNAT-1997 [22] they may be used for irrigating green areas (including golf courses); excess water is injected into the underground. There are no studies that monitor the quality of water in the aquifer that would make it possible to assess the impact caused by the extraction of brackish water and the injection of residual water. A deficient design of extraction or injection wells may imply the contamination of the aquifer and, therefore, impact plant life and the marine-reef area adjacent to the PBPMES (Fig. 2), as is the case of some touristic projects in the area [8, 17]; personal communication Miguel Villasuso, 2011.

Another source of soil, aquifer, and the adjacent marine zone contamination is the use of agrochemicals for the maintenance of the hotels' green areas and golf courses, as well as the use of exotic plants in their gardens, which claim large amounts of supplies for their maintenance (irrigation water and agrochemicals).

As a consequence of the increase in the mean sea level and the increase in intensity and frequency of storms and hurricanes along the coastline of the state of Quintana Roo, an intense erosion process and retreat of the coastline has become evident. Regarding the PBPMES, some authors [11, 13, 15] have measured an erosion rate and coast line retreat of 2.5 ha and 4.5 m/year in average, respectively. This environmental impact due to natural causes is permanent and cumulative; and it is provoking serious modifications to the dune and mangrove ecosystems. In the mangroves, a saline intrusion process is taking place which impacts inner areas of

the wetlands, along with a burying and dying off process in the areas closest to the coastline. In the dunes ecosystem, erosion is causing the retreat of the coastline and the loss of this important ecosystem in most of the PBPMES [11, 13] (Fig. 3).

Notwithstanding the natural erosion process and coastline retreat, some touristic projects, such as those located in the smallest plots of the PBPMES, did not consider giving maintenance and carrying out preservation activities in the dunes ecosystem, which has magnified the erosion process and caused serious damage to the touristic infrastructure (Fig. 3). In order to mitigate the effects of erosion and the damages to the touristic infrastructure, developers have invested millions of dollars in the construction of littoral protection and restoration works.

Beyond the PBPMES, some activities endanger its environmental stability: a) there are open sky garbage dumps which, apart from eliminating major vegetation areas, contaminate the soil and the aquifer and impact the adjacent coastal–marine ecosystems, and b) there are residential developments and golf courses that have generated the massive loss of important rainforest areas, mangroves, and dunes, thus increasing the risks of soil contamination, aquifer pollution, and damage to the coastal–marine ecosystems due to the deficient handling of liquid and solid waste.

4 The Mayakoba model

The MTD is a real estate-touristic investment owned by the Spanish company Obrascon Huarte Lain (OHL). MTD covers a surface of 649.7 ha and consists of touristic zones I and II. Zone I is located in the PBPAES and zone II is located adjacent to that system (Fig. 4). Touristic zone I, which is part of the PBPAES, is the one described in this chapter and is considered by the Ministry of the Environment and Natural Resources (MENR) as a nationwide model for sustainable touristic developments [6].

OHL's total investment for the MTD is 2049 million United States Dollars. Currently, 1040 million USD have been invested in the development of touristic zone I, and it is estimated that 1 billion USD will be invested in the construction of touristic zone II. Throughout the 7 years that has taken the development of touristic zone I, the MTD has created 1500 direct and 1200 indirect jobs. For the current operations phase of touristic zone I, the MTD has created 3000 direct and 1200 indirect jobs, permanently.

For the purpose of designing, constructing, and operating a sustainable touristic development, OHL defined a strategy and governing axis for the design, planning, and environmental management of the MTD (chart 1 and Fig. 5), in order to insure the development of touristic infrastructure that is completely harmonic and fully integrated with the structure and function of the ecosystems that exist in the PBPMES.

4.1 Planning and environmental design stage

Taking the contents of chart 1 as the governing axis for the sustainable development of the MTD, OHL formed a multidisciplinary group of 49 internationally renowned

Figure 4: Location and degree of implementation of the Mayakoba Touristic Development. a) MTD approved by the federal environmental authorities and b) current degree of implementation of the MTD.

Figure 5: Planning and environmental management process for the Mayakoba touristic development.

researchers and experts from 12 Mexican research centers, 3 American research centers, and 4 environment consulting companies specialized in the environment, urban and touristic planning, legislation, architectural design, geology, geo-hydrology, financial feasibility, golf-course design, construction processes, among others [8].

The main objectives for this stage were to precisely and objectively determine: a) the types of ecosystems present in the PBPMES and their preservation status,

b) the current and potential coastal–marine environmental impacts caused by the urban-touristic development of the MTD and the other tourism projects of the PBPMES, c) environmental and legal restrictions, and the land's and adjacent marine zone risk areas, d) convenient areas for the location and construction of the proposed touristic infrastructure, e) the identification of preservation areas based on their environmental value, f) the definition of environmental, technical, and governing criteria which guided the architectural group in the design of the project.

The main products in this phase were the design of the project (Master Plan) and the elaboration of the environmental impact assessment of the MTD. Both products were authorized by the MENR in the year 1988, under the application of the Ecological Regulations Program for the Region Denominated Cancun-Tulum (Periódico Oficial del Gobierno de Quintana Roo, 9 de junio 1994) [23].

The authorized project considers the construction of 6924 rooms distributed in 13 hotels, an 18-hole golf course, recreational areas, beach clubs, a system of channels and lakes with docks, as well as real estate developments in touristic zones I and II (Fig. 4).

4.2 Environmental management and operation stage

Within touristic zone I, the Fairmont Mayakoba, Rosewood Mayakoba, and the Banyan Tree hotel are currently in operation, as well as the 'El Camaleón' Golf Course, along with different general service areas (Fig. 4). For the purpose of insuring the implementation of the environmental impacts mitigation and monitoring measures promised by OHL and those imposed by MENR, the company launched the Mayakoba Environmental Management System (MEMS) for the construction, operation, and maintenance stages of the MTD [10, 24].

- **Environmental**: Design, construction, and operation of a touristic-real estate development coherent with the preservation and sustainable use of the ecosystems and resources of the land and the region.
- **Standards**: Design, construction, and operation of a touristic-real estate development that strictly adheres to all applicable governing, legal, and environmental policy provisions.
- **Architectural**: Design of a high-quality touristic-real estate development whose infrastructure and services combine luxury and comfort, but which are fully integrated to the landscape and the environment.
- **Touristic commercial**: Design and operation of a touristic-real estate development whose target tourism segment is of a high acquisition power, but sensible to high-quality tourism scenarios and respectful of nature.
- **Social**: Contribution to the global development of the region through the generation of important social and economic benefits for the local and regional population.

Chart 1: Governing axis considered by OHL for the design, construction, and operation of the MTD.

Figure 5 and Table 3 describe the system in general. Its main objectives are as follows.

- To build and operate a responsible touristic development committed to the environment through the application of management strategies that guarantee the preservation and sustainable use of the ecosystems, its goods, and its environmental services.
- To monitor the strict compliance with the applicable federal and state legislation and norms, as well as the MEMS, throughout the construction, operation, and maintenance stages.
- To monitor and permanently supervise the environmental quality of the ecosystems and natural resources, in order to implement management strategies that make it possible to correct potential damages caused by the construction and operation processes.

5 Good environmental practices

This section describes some examples of Good Environmental Practices (GEP) that the MTD has developed through the MEMS in its design, construction, and operation stages, in order to be considered as one of the best nationwide and international sustainable touristic models [6, 25].

Over 80% of the surface covered by the design of MTD was occupied by disturbed vegetation, maintaining sensitive ecosystems, and those which are very valuable to the environment (dunes, mangroves, and medium rainforest) as preservation areas. This implied that the hotels and the massive touristic infrastructure of touristic zone I was located more than 600 m from the beach area, in order to insure the preservation of the dune and mangrove ecosystems. Only low-impact touristic bungalows were created at the back part of the dune, and two fairways of the golf course were located in low environmental quality areas of the mangrove zone. This design and care for the ecosystems is unique in Mexico and the world, if one considers that the general norm for the construction of coastal touristic developments is to place them on the littoral strip that is closest to the beach areas, even directly over the dunes zones.

The design of the project had, as its main ecological premise, to guarantee that in MTD's property and influence zone (PBPMES): a) there would be the lowest possible fragmentation of ecosystems, b) the connectivity between coastal ecosystems (dune, mangrove, and rainforest) would be preserved, and c) biological corridors would exist.

In order to improve the hydrological conditions of the mangrove and to increase its ecological value, as well as for the possibility of offering waterscapes to tourists, the project considered the design and construction of a system of artificial channels (Fig. 6), spanning 13.15 km in length, coving a surface of 25.76 ha, and with an average depth of 1.5 m, supported by original scientific hypotheses, very detailed surface and underground hydrology studies, and mathematical simulation models. The ecological premise for the design of the channels system was that it

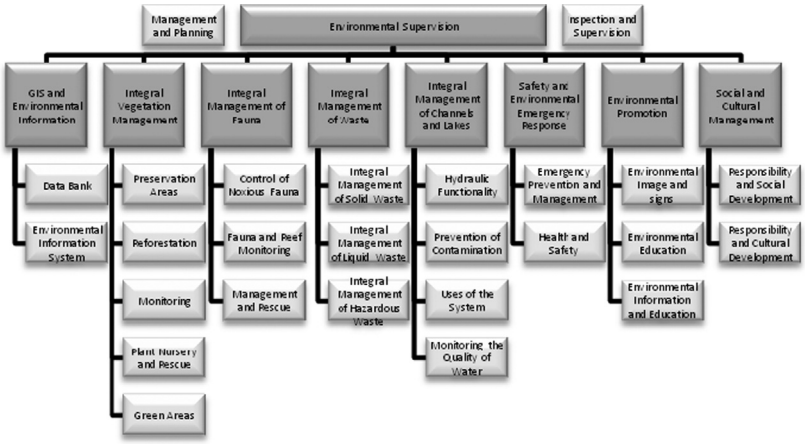

Figure 6: Environmental management system of the MTD.

would work naturally (without pumping), taking advantage of the geo-hydrological potential and water's preferential underground flows, as well as the nondisturbance of the aquifer in terms of quantity and quality of the water [17, 26, 27].

The system of channels has brought about an artificial low-salinity, low-nutrients concentration, well-oxygenated, high-transparency estuarine ecosystem with a natural operation and maintenance, with good motion and positive water replenishment. This system has determined the creation of: a) new aquatic and littoral estuarine habitats in rainforest and mangrove areas for rest, feeding, and refuge of at least 285 species of birds, fish, reptiles, crustaceans, and mollusks (Table 4), and b) an ideal habitat which did not exist for feeding, protection, and reproduction of at least 16 species of fish, of which 5 are sweet water species, 2 of them endemic and are sweet water species that penetrate brackish and mangrove waters, 2 marine species that penetrate brackish and mangrove waters, and 7 marine species that penetrate brackish environments [15, 28, 29].

With the construction of the channels system and the contribution of nutrients from the treated waste waters, the mangrove has improved in terms of forestry and in its role as a habitat for various animal species [15, 29].

Through the ecological monitoring of the MTD's fauna, it has been possible to document an increase in the number of species of 560% (Table 5), from the beginning of the construction to the current state of operations [15, 29].

The spiny lizard or 'pergarayo' *Sceloporus lundelii* is an endemic species to the Yucatan Peninsula, that by being registered in the MTD widened its distribution by more than 60 km, from its reported distribution limit up to the year 2000 by Lee [30], which includes the Northern and Northwest part of the states of Yucatán and Campeche, and a small part of the state of Quintana Roo.

The ecological link between the mangrove, the channels, the dunes, and the rainforest of the MTD nowadays means the presence of species that indicate a high environmental quality, such as: a) the *Mycteria americana* stork, b) the white ibis (*Eudocimus albus*), c) the Roseate Spoonbill (*Platalea ajaj*), d) the osprey

Table 4: Objectives of the environmental management system of the MTD.

Program	Sub-program
Environmental Supervision. To verify the fulfillment of: a) the MEMS programs, b) the environmental obligations of the project in its preparation, construction, and operation stages, and c) the applicable legal framework through inspections and permanent environmental audits.	Environmental Planning and Management. To perform planning and management activities geared toward the design and implementation of sustainable development strategies, such as the GEP, national and international environmental certification, implementation of eco-technologies, and adjustments to the project.
	Environmental Supervision. To monitor through internal environmental audits: a) the fulfillment of the environmental commitments of the project, b) the measures for the prevention, control, and mitigation of environmental damages as committed by the MTD, and c) the environmental health conditions of the ecosystems and natural resources within the premises of the project.
Integral Management of Waste. To implement an integral liquid, solid, and hazardous waste management program.	Integral Management of Liquid and Sanitary Waste: a) to employ the best available eco-technology and sanitary infrastructure for the treatment of waste water, b) to reduce the risk of soil, water, and ecosystems contamination caused by waste water, c) to reduce the sources that generate waste water, d) to use biodegradables chemicals and products that are compatible with the technology used for water treatment, e) to reuse treated waste water in the irrigation of green areas and the golf course, and f) to implement the use of the mangrove ecosystem and sweet water swamps (man-made) for the assimilation of nutrients and as tertiary treatments.
	Integral Management of Solid Waste. To implement: a) measures for the reduction of sources of solid waste, b) strategies for the separation, reuse, and recycling of materials, and c) good practices in the management and final disposal of waste.

Continued

Table 4: *Continued.*

Program	Sub-program
	Integral Management of Hazardous Waste: a) to limit the use of products that generate hazardous waste, b) to promote the use of certified biodegrading products and chemicals, c) to temporarily dispose of hazardous waste using the appropriate infrastructure, d) to assign the transportation and disposal of hazardous waste to companies and disposal sites that are certified by the environmental authorities, and e) to use appropriate equipment and materials to respond in emergencies (hydrocarbons spills or any other hazardous substances into the soil or water).
Integral Management of Vegetation. To implement management measures those that insure the proper maintenance of natural vegetation preservation areas.	Management of Preservation Areas: a) to care for preservation areas with their natural vegetation in their current state, so they may act as a biological refuge for feeding, protection, reproduction, and nestling purposes for the associated and migrating wild life, b) to guarantee the preservation of the goods and services offered by the vegetation and the ecosystems of the land, c) to eradicate and control the presence of exotic species.
	Management of Green Areas: a) to produce a natural landscaping view for each of the green areas and gardens of the MTD, b) to use native species that are indigenous to the region for ornamentation of the green areas, and c) to implement management measures and GEP for the golf course.
	Plant nursery and Rescue: a) to have germplasma sources that will guarantee the continuity through time and space of the various existing plant species of the MTD and the PBPMES, mainly those that are endangered or under any protection status according to the Norm NOM-059-SEMARNAT-2001 [19], b) to rescue and produce vegetal material, as well as endemic and natural species in the region for the reforestation of the preservation areas in the premises, its garden areas, for the ornamentation of paths and roads, and for green areas in general,

	c) to reduce the costs of gardening and ornamentation of the project through the use of native rescued species and/or those produced in the plant nursery, d) to offer tourists as a source of value and appeal, the enjoyment of the ecosystems and biophysical elements existing in the premises through the plant nursery.
	Reforestation: to implement a general reforestation campaign in the project's areas, which are authorized for the establishment of infrastructure and services, as well as in preservation areas.
	Environmental Monitoring. To evaluate the environmental structure and quality of the preservation areas of the project, and the effectiveness of the mitigation measures proposed for the environmental impact study, as well as the environmental-sanitary supervision and management in green areas and the golf course.
Integral Management of Animal Life. To mitigate the direct and indirect impacts on animal life generated by the implementation of the MTD.	Management and Rescue of Animal Life: a) to guarantee the maintenance of the critical areas and ecosystems for relevant wild life in the premises and the region, b) to protect wildlife in the premises and its adjacent areas, c) to implement a permanent rescue and integral management of wild life plan, d) to implement management and monitoring strategies that make it possible to preserve and appreciate land, water fauna, and birds in the region, e) coordination agreements with federal and state wild life management programs with MENR and the state's research centers, and f) to offer tourists as a source of value and appeal, the enjoyment of wildlife and the biophysical elements that exist in the premises.
	Control of Noxious Fauna: a) to implement measures for the management and control of larger species that imply a risk for tourists and personnel, b) to implement measures for the control of noxious insects, c) to elaborate a noxious and dangerous species catalog (arthropods, amphibians, and reptiles), d) to rescue and transfer species (amphibians, reptiles, and mammals) that involve a risk for employees, users, and guests within the touristic development, and e) to manage and control insects and control noxious mastofauna.

Continued

Table 4: *Continued.*

Program	Sub-program
	Environmental Monitoring. a) to evaluate the environmental effects of the touristic development over the wildlife resources in the land and the marine influence zone of the project in order to define mitigation strategies, b) to generate technical–scientific data that will support decision-making processes regarding the sustainable management of wildlife resources, and c) to generate information that makes it possible to define critical species preservation plans and programs.
Environmental Promotion and Dissemination. To promote the value of the environmental goods and services offered by the ecosystems and natural resources to guests and personnel of the MTD, as well as tourists and population.	Environmental Information and Education: a) to disseminate information among the users of the development on the ecological, social, economic, and cultural value of the involved ecosystems and natural resources, b) to promote the results of the success of the Environmental Monitoring Program, c) to disseminate information to the employees, users, and the local population on the management and sustainable use of resources, as well as the prevention of contamination problems and environmental impact, and d) to design regulations for touristic activities in the context of environmental obligations of the project.
	Environmental Image and Signs. To implement mechanisms and instruments for: a) information or prevention regarding the use of the touristic infrastructure and preservation areas, and b) the management and sustainable use of ecosystems, flora, and fauna.
	Environmental Education: a) to promote the understanding and awareness among builders and operators of the MTD of the value and importance of preserving the ecosystems and natural resources, b) to educate constructors and operators of the project in the application and fulfillment of the applicable environmental standards and regulations, c) to inform all personnel about the environmental obligations they acquire by becoming a part of the project's work force, d) to promote among the employees a responsible attitude in the use and management of the natural resources in the region, e) to fulfill the criteria of socially responsible tourism.

Integral management of Lakes and Channels. To implement management measures those that insure the operation and environmental quality of the aquatic system, as well as its associate fauna.	Hydraulic Functionality. To implement measures those that insure the continuity of the operation of the hydraulic system.
	Uses of the System: a) to implement measures and guidelines for the recreational use of the system, b) to manage the artificial aquatic ecosystem for the normal development of the native aquatic fauna (fish, amphibians, and reptiles), and for the rest and feeding of a large number of resident and migrating birds, c) to reforest littorals with appropriate plant communities per type of environment, and d) to generate and induce an aquatic environmental image at the MTD, derived from the environmental commitments.
	Prevention of Contamination: a) to supervise and control that the quality of the water in the system meets the criteria established in the environmental regulations, and b) to implement measures for the prevention and control of the contamination of the system.
	Monitoring the Quality of Water: a) to monitor the quality of the water in the channels and lakes system, in the adjacent marine zone and at the phreatic level, b) to apply mitigation measures in response to changes in the quality of the water, which might endanger the equilibrium of the aquatic ecosystems and the channels and lakes system, c) to quantitatively evaluate the impacts of the touristic development on the quality of water and the effectiveness of the measures proposed for their mitigation, and d) to implement management measures that guarantee the quality of water adhering to touristic and recreational use standards.
Safety and Attention to Emergencies. To prevent and manage involuntary or accidental risk situations which endanger the users, tourists, or personnel in the development, or the ecosystems and natural resources in the premises, along with those derived from habitual natural phenomena in the region (forest fires, flooding, hurricanes).	Health and Safety: a) to implement a safety program, attention and prevention in accidents and work risks, and b) to operate a committee for safety and environmental emergency for environmental crisis, in coordination with the competent authorities.
	Prevention and Emergency Management: a) to implement a prevention and emergency response system in response to forest fires, floods, hurricanes, spills of hazardous substances into the soil and water, among others, and b) to operate a safety and environmental emergency committee, in coordination with the competent authorities.

Continued

Table 4: *Continued.*

Program	Sub-program
GIS and Environmental Information. To use a geo-referenced environmental data bank and cartography system, permanently updated as a tool for environmental monitoring, management, and supervision of the MTD.	Data Bank: To generate a database with a geographic referencing for consultation and management of multitopic information (environmental, architectural, engineering, commercial, legal, and administrative, among others).
	Environmental Information System: a) to evaluate the degree of progress of the construction process, b) to quickly detect the generation of unforeseen environmental impacts, in order to spatially evaluate their magnitude or importance and determine the appropriate mitigation measures, c) to spatially evaluate environmental attributes of the land (soils, topography, vegetation, hydrology, among others), and d) to simulate scenarios for the planning and decision-making processes.
Social and Cultural Management. To promote socio-cultural activities and programs for the benefit of the region.	Responsibility and Social Development: a) to promote cultural, sports, and recreational activities, as well as products and services of neighboring communities, b) to implement behavior guidelines and policies against commercial sexual exploitation, and to carry out activities in or near neighboring communities, c) to use the services and products of local micro, small, or medium-sized companies, especially those of a sustainable nature, d) to promote hiring and training local personnel at all levels of the company, e) to promote the manufacture and purchase of handcrafts and other local products, and f) to promote and support, in coordination with the state and local governments, initiatives for social development and creation of infrastructure.
	Responsibility and Cultural Development: a) to promote the cultural and historical values of the region and the state, b) to promote knowledge and respect for the indigenous culture and customs, c) to promote the appreciation for local historical and cultural sites and monuments, and d) to incorporate elements of the local art and architecture in the design and decoration of the MTD.

Table 5: Inventories of Fauna recorded for the MTD from 2001 to 2010 [15].

Taxon	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Fish	Na	Na	Na	Na	Na	6	8	9	12	16
Amphibians	4	11	4	11	8	12	12	12	12	12
Reptiles	4	21	14	23	16	50	57	58	61	61
Birds	31	54	45	70	57	115	133	142	148	152
Mammals	10	19	20	24	10	36	37	37	41	43
Total	49	105	83	129	91	219	247	258	274	284

(*Pandion haliaetus*), e) the American coot (*Fulica americana*), e) the common nighthawk (*Chordeiles minor*), f) the yellow-throated warbler (*Dendroica dominica*), g) the Magnolia warbler (*D. magnolia*), h) the yellow warbler (*D. petechia*), i) the black-and-white warbler (*Mniotilta varia*), j) the mangrove vireo (*Vireo pallens*), and k) the eastern kingbird (*Tyrannus tyrannus*).

In the specific case of the *Mycteria americana*, an increase in its population and in the residence time at the MTD is observed. Since it is a species that migrates locally, it is considered an indicator of environmental quality.

There is a nestling record of at least 14 species of birds, among which the soprey (*Pandion haliaetus*), the Yucatan jay and the green jay (*Cyanocorax yucatanicus* and *C. yncas*), and the common moorhen (*Gallinula chloropus*), the latter being endemic, is to be highlighted.

In the MTD four of the five species of felines reported for the Yucatan Peninsula are registered (six species of felines are distributed in Mexico), such as the jaguarundi (*Herpailurus yagouaroundi*), the ocelot (*Leopardus pardalis*), the margay (*L. wiedii*), and the jaguar (*Panthera onca*), all registered in the mangrove.

Of the 284 animal species registered in the MTD, 57 are listed in the Norm NOM-059-SEMARNAT-2010 [19] in the category of special protection (28), endangered (10), or threatened (19). There are also records of seven endemic species in the Yucatan Peninsula.

The MTD has the Mayakoba's Common Fauna Guide (Guía de Fauna Común de Mayakoba) where guests and visitors of the touristic development are offered environmental information about 70 animal species that can be easily observed. This guide is offered as a tool for the comprehension and knowledge of the biodiversity found in the MTD and the region Rivas [29].

The environmental regulations (Periódico Oficial del Gobierno de Quintana Roo, 9 junio 1994) established the following as obligations for the MTD: a) to use treated waste water from the waste water treatment plant (WTP) to irrigate green areas and golf courses and b) to re-inject the excess treated waste water into the aquifer. Zárate *et al*. [31]. determined that both processes might generate an organic contamination problem to the phreatic mantle, the system of channels and lakes of the MTD, and the adjacent marine zone due to the transfer of 14,800.37 kg/year of total nitrogen (N) and 2331.14 kg/year of phosphorus (P_2O_5) into the aquifer and adjacent marine zones.

In order to mitigate these environmental impacts, the MTD decided to use the mangrove ecosystem in the land to assimilate and retain those nutrients. For that purpose, the golf course (61.77 ha) has a drainage system that channels rainfall into the mangrove, guaranteeing the assimilation of 100% of the total load of nutrients (P and N) which are applied as fertilizers for maintenance [31]. In order to monitor the environmental quality of the mangrove, a permanent environmental monitoring program is implemented (Fig. 5, Table 3).

For the purpose of avoiding and mitigating the environmental impact caused by these nutrients, the MTD implemented as a good environmental practice the use of mangrove areas for the assimilation of the nutrients and to fully mitigate the contamination problem. In that regard, a conduction system was implemented that captures rainfall from the golf course as well as excess treated waste water and discharges it into the mangrove preservation units [31].

Another good environmental practice in the golf course is that throughout its surface (61.77 ha) there is a 90% proctor compacted 'sascab' sub-base. This layer is fully watertight and avoids the percolation of irrigation water and agrochemicals (fertilizers and pesticides) into the aquifer and the adjacent marine zone [17, 26]. Through a drainage system, the golf course channels all rainfall toward the mangrove units for the assimilation of nutrients [31].

Due to the construction of the system of artificial channels and lakes and the assimilation of nutrients coming from the golf course drainage and the treated waste water from the WTP, the mangrove has improved in its structure and function. The mangrove of the MTD (Fig. 7) has gone from a short basin-type

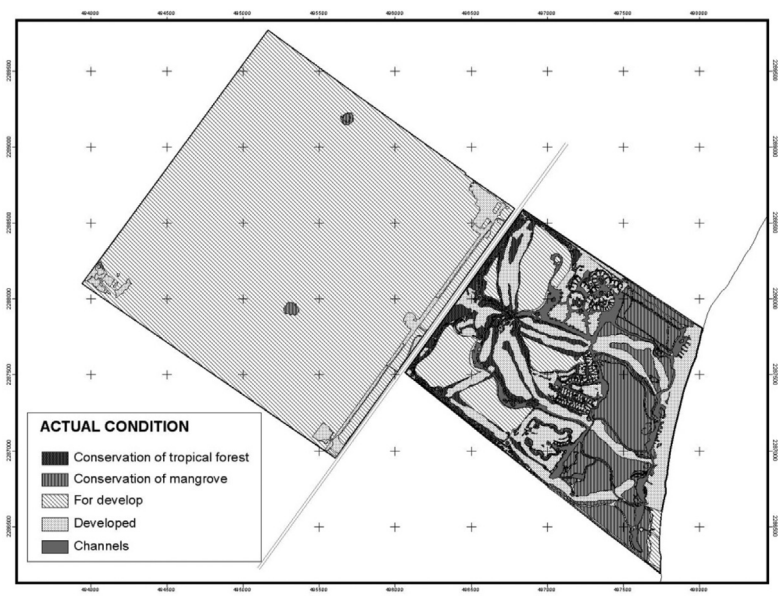

Figure 7: Types of vegetation and system of artificial channels of the Mayakoba project.

Table 6: Data on the structure of the mangrove ecosystem of the MTD from 2001 to 2008 [15, 17, 37].

	Mayakoba land plot before the construction of channels (1998)	Adjacent land plot south of Mayakoba in 2008	Mayakoba land plot in 2008 (with channels)
# Shafts (ha)	1876	7916	10,142
Basal area (m^2/ha)	11.3	11.5	13.0
Height (m)	2.8	2.0 a 2.5	3.0 a 4.0*
Dead mangrove (%)	?	25	2.5

*There are trees of up to 12 m height.

mangrove to one that has increased structure and environmental services (Table 6). The mangrove of the MTD shows the best environmental development and quality in the PBPAES [6, 15].

In strict adherence to the legal environmental framework and with scientific support as well as the traditional Mayan wisdom, the MTD uses only native plants, original to the region in the creation and maintenance of its green areas and gardens. For that purpose, there is an Integral Vegetation Management Program (Fig. 5) and a Reforestation and Gardening Catalog with Native and Regional Species [20]. The use of these species minimizes the vegetation structure and the soil and aquifer contamination risks caused by the use of agrochemicals.

The good practices of the MTD, its hotels, and the golf course that have been implemented in the ecological, social, architectural, and touristic areas among others have gained national and international recognition. Some of the acknowledgements it has received are as follows.

The design, construction, and operation process of the MTD has been recognized by the MENR as national model for sustainable touristic developments, through a publication titled 'Reflections and Actions for the Sustainable Touristic Development Derived from the Evaluation of Environmental Impacts in the Mexican Caribbean: Punta Bete - Punta Maroma Environmental System' [6].

On July 1, 2009, the president of Mexico, Felipe Calderón Hinojosa inaugurated the Banyan Tree Hotel of the MTD praising the hotel and the MTD as a nationwide sustainable environmental model [32].

The 'El Camaleón' golf course has received, since 2006, six Audubon International certifications: a) as a Cooperation Sanctuary, b) in the field of Habitat and Wildlife Management, c) in terms of Water Quality Improvement, d) in terms of Water Conservation, e) in terms of Environmental Awareness and Education, and f) in terms of Reduction and Safety in the Use of Chemical Products [15, 33].

The 'El Camaleón' golf course was designed by Greg Norman based on sustainability criteria determined by OHL and its hired group of environmental consultants which due to its landscaping, functional, and environmental qualities make it unique among golf courses outside of the United States of American and Canada, particularly in the PGA Tournament in 2007 to date [33–35].

Table 7: Awards, acknowledgments, and environmental and touristic certifications granted to the MTD hotels [38–40].

Fairmont Mayakoba Hotel	• 5 Diamonds Certification (2008, 2009, 2010, 2011) to the Fairmont Mayakoba Hotel by the AAA. • 2011 Sustainable Standard-Setter Award from the Rainforest Alliance. • Top 7 Sustainable Hotels. 2009. Fairmont Mayakoba Hotel by the MARTI. • Environmental Hotel of the Year 2007 for the whole Fairmont Hotels & Resorts Chain. • Environmental Certification Green Key 4. 2010 by Green Key Global.
Banyan Tree Mayakoba Hotel	• Graduation with Honors by the MARTI. • 2011 Sustainable Standard-Setter Award by the Rainforest Alliance. • 45 Best New Hotels by Travel + Leisure USA IT List 2009 • Best Lobby and Spa for Boutique Design Award. • Top 10 resorts in Mexico for Coastal Living, USA-Mexico's 10 Best Seaside Hideaways. • Best Spa for Conde Nast Traveler Spain The Gold List 2010 • Top 10 Hotels for Service, Romance and Relaxation Hotels in the Caribbean. TripAdvisor Awards 2010. • Top 10 Hotels for Romance and Relaxation/SPA Hotels in the World. TripAdvisor Awards 2010. • Listed as one of the 11 Best Hotels in México. Bleu & Blanc Magazine- 11 Best Hotels in Mexico. • Hot List Hotels. Conde Nast Traveler USA Hot List 2010
Rosewood Mayakoba	• Graduation by the MARTI. • 2011 Sustainable Standard-Setter Award by the Rainforest Alliance. • **2011** Condé Nast: Top 125 Golf Resorts International, no. 1. • **2010**. AAA Five-Diamond Award. • **2010**. Travel + Leisure: 500 World's Best Hotels Mexico Overall, no. 18. • **2009** Condé Nast Hot List: Spas Sense, A Rosewood Spa® • 2009. Gayot.com: Top 10 Romantic Hotels Worldwide HotelWorld Global Hospitality & Design Awards Opening of the Year, no. 2. • 2009. Spa Finder: Top 10 Spas in Mexico & Top 10 Beach Spas. • 2009. Travel + Leisure: World's Best (Readers' Choice) Top 15 Resorts in Mexico, no. 1 Top 100 Overall, no. 18.

The MTD participates in a project with Rainforest Alliance (RA) and the alliance with the Mesoamerican Reef Tourism Initiative (Iniciativa de Turismo del Arrecife Mesoamericano) (MARTI), for the implementation of good practices for tourism management based on Global Touristic Sustainability Criteria (GTSC). Once this project is completed, the MTD will be one of the first international touristic developments in fulfilling the GTSC. In this sense, on May 11, 2011, RA awarded the MTD and each of its hotels – Fairmont, Rosewood and Banyan Tree – the Sustainable Standard-Setter Award, for its commitment to sustainable tourism and the preservation of the environment [25].

The World Tourism Organization of the United Nations Organization awarded the MTD, the 2011 UNWTO Ulysses Award for Innovation in Enterprises, for its contributions to the progress of tourism through innovation and in harmony with the Development Objectives of the United Nations Organization for the Millennium [36].

The MTD and its three hotels are part of the Initiative for a Low-Carbon Tourism in Quintana Roo (Iniciativa para un Turismo Bajo en Carbono en Quintana Roo) coordinated by the World Wildlife Foundation since 2010. The MTD as a founding partner will be one of the leaders and promoters in Quintana Roo in the implementation of actions that combat Climate Change and in creating, among the different parties involved, the awareness of the importance of defining actions for the mitigation of Greenhouse Gases and adapting to the effects of Climate Change, World Wildlife Foundation [41].

The Fairmont, Rosewood, and Banyan Tree hotels of the MTD are part of a select group of hotels in Quintana Roo that have been certified by the Mesoamerican Reef Tourism Initiative (MARTI) on the implementation of its Environmental Management System and Good Environmental Practices [42].

Table 7 shows some of the awards that the Fairmont Mayakoba, Banyan Tree Mayakoba, and Rosewood Mayakoba hold in the areas of the environment and tourism.

References

[1] CNET, Panorama de la Actividad Turística en México. Información para la toma de decisiones de los empresarios, Universidad Anáhuac. *Consejo Nacional Empresarial Turístico*, **2011(2)**, p. 66, 2011.

[2] INEGI-SEMARNAP, Estadísticas del Medio Ambiente, México 1999. Instituto Nacional de Geografía, Estadística, Geografía e Informática, Secretaria de Medio Ambiente, Recursos Naturales y Pesca, Vol I y II, p. 844, 1999.

[3] SEDETUR, 2010, Indicadores Turísticos Diciembre 2010, www.sedetur.qroo.gob.mx

[4] SEMARNAP-INE, *Medio Ambiente y Turismo: Logros y Retos para el Desarrollo Sustentable 1995–2000*, Secretaría de Medio Ambiente, Recursos Naturales y Pesca. Instituto Nacional de Ecología, p. 55, 2000.

[5] SECTUR, 2010, Indicadores Relevantes de la Actividad Turística, www.datatur.sectur.gob.mx
[6] Juárez, P.R, Rojas-Galavíz, J.L, Chacón H, A, Zárate-Lomelí, D, Pasquetti H.G. & Alafita-Vásquez, H, Reflexiones y acciones para el desarrollo turístico sostenible, derivadas de la Evaluación de Impacto Ambiental en el Caribe Mexicano: Sistema ambiental Punta Bete-Punta Maroma. Secretaría de Medio Ambiente y Recursos Naturales, p. 112, 2006.
[7] CIFSA, Corredor Cancún-Tulum, Quintana Roo Condiciones Oceanográficas. Fideicomiso Caleta de Xel-Ha y del Caribe, p. 38, 1990.
[8] EPOMEX/ECOMAR, A.C, Estudio de Caracterización Ecológica del Predio Correspondiente al Proyecto Turístico Mayaluum en el Corredor Cancún-Tulum, Quintana Roo, Programa EPOMEX/ECOMAR A.C.: México, p. 257, 1997.
[9] Juanes, J.L, *Proyecto ejecutivo para la recuperación del frente costero del Predio Tres Ríos*, Instituto de Oceanología: Gamma S.C, p. 60, 2006.
[10] GPPA S.C.-DTM, Manual de procedimientos en materia de impacto ambiental del Desarrollo Turístico Mayakoba. OHL/Consultores en Gestión, Política y Planificación Ambiental S.C, p. 86, 1999.
[11] GPPA S.C, Análisis ambiental del Sistema Punta Bete-Punta Maroma. Informe Interno. Consultores en Gestión, Política y Planificación Ambiental S.C, p. 60, 2010a.
[12] Juanes, J.L, *Estudio de Factibilidad Mejoramiento de la Playa en el Predio Tres Ríos*, Instituto de Oceanología: Gamma S.C, p. 42, 2004.
[13] GPPA S.C, Diagnóstico ambiental de la zona costera del Desarrollo Turístico Mayakoba. OHL Consultores en Gestión, Política y Planificación Ambiental S.C, p. 23, 2005.
[14] GPPA S.C, Diagnóstico ambiental de la zona costera del Sistema Ambiental Punta Bete-Punta Maroma. Consultores en Gestión, Política y Planificación Ambiental S.C, 18 pp, 2010b.
[15] GPPA S.C. -DTM, Informe Anual de Cumplimiento de Términos y Condicionantes Ambientales Desarrollo Turístico Mayakoba 2010. Consultores en Gestión Política y Planificación Ambiental S.C./ Desarrollo Turístico Mayakoba, 276 pp. + anexos + CD, 2001, 2002, …, 2009, 2010.
[16] Pérez-Soto, L, Padilla Souza, C, Pizaña Alonso, J, Urquiza, R. & Nava Honc, T, Caracterización de 4 áreas arrecifales de la costa de Quintana Roo. Desarrollo arrecifal y estructura de la comunidad. Informe Técnico. Programa de Ecología, Pesquerías y Oceanografía del Golfo de México, p. 37, 1995.
[17] GPPA S.C, Informe preventivo Desarrollo Turístico Mayalumil, Quintana Roo. OHL/GPPA S.C, p. 121, 1998.
[18] Tecnoconsult e Instituto de Ecología A.C, Estudios de ecología costera y determinación de zonas de preservación ecológica del Corredor Turístico Cancún-Tulum. Corporación Internacional Tecnoconsult S.A. de C.V, Instituto de Ecología A.C, 101 pp. + Apéndices, 1990.
[19] Norma Oficial Mexicana NOM-059-SEMARNAT-2010, Que determina las especies y subespecies de flora y fauna silvestres terrestres y acuáticas en peligro de extinción, amenazadas, raras y las sujetas a protección especial, y

que establece especificaciones para su protección.
[20] GPPA S.C, Catalogo de reforestación y jardinado de especies nativas y propias de la región para el Desarrollo Turístico Mayakoba. Consultores en Gestión, Política y Planificación Ambiental S. C, p. 60, 2007.
[21] Norma Oficial Mexicana NOM-001-SEMARNAT-1996, Que establece los límites máximos permisibles de contaminantes en las descargas de aguas residuales en aguas y bienes nacionales.
[22] Norma Oficial Mexicana NOM-003-SERMARNAT-1997, Que establece los límites máximos permisibles de contaminantes para las aguas residuales tratadas que se reúsen en servicios al público.
[23] Periódico Oficial del Gobierno de Quintana Roo, Acuerdo de Coordinación para el Ordenamiento Ecológico de la región denominada Corredor Cancún-Tulum. Tomo X, No. 7 Extraordinario, 5ª Época + 3 Anexos, 1994.
[24] GPPA S.C.-DTM, Sistema de manejo y gestión ambiental del Desarrollo Turístico Mayakoba. OHL/Consultores en Gestión, Política y Planificación Ambiental S.C, p. 43, 2000.
[25] www.rainforest-alliance.org
[26] CAPAGHC, Geohidrología, diseño y simulación del sistemas de canales del Desarrollo Turístico Mayakoba. Consultores en Agua Potable, Alcantarillado, Geohidrología & Hidráulica Costera, I.C, p. 143, 1998.
[27] CAPAGHC, Estudio geohidrológico predio Fairmont del Desarrollo Turístico Mayakoba. Consultores en Agua Potable, Alcantarillado, Geohidrología & Hidráulica Costera, I.C, p. 120, 2010.
[28] Amezcua-Linares, M, Estudio ictiofaunístico del sistema de canales artificiales del Desarrollo Turístico Mayakoba, p. 17, 2010.
[29] Rivas, H, Fauna común de Mayakoba. OHL/Consultores en Gestión Política y Planificación Ambiental S.C, p. 171, 2010.
[30] Lee, J.C, *A Field Guide to the Amphibians and Reptiles of the Maya World: The Lowlands of Mexico, Northern Guatemala, and Belize*, Comstock Publishing Associates-Cornell University Press: Ithaca, U.S.A, p. 402, 2000.
[31] Zárate, L.D, Day, J.W.,Rojas, J, & Galavíz, L, Informe final y acuerdos manejo drenaje campo de golf del Desarrollo Turístico Mayakoba. Consultores en Gestión, Política y Planificación Ambiental S.C, p. 13, 2004.
[32] Rojas- Galavíz, J.L, Experiencias en los humedales costeros de Punta Bete a Punta Maroma, Quintana Roo: 1994–2011. Consultores en Gestión, Política y planificación Ambiental S.C, p. 63, 2011.
[33] www.presidencia.gob.mx
[34] www.mayakoba.com
[35] www.audubooninternational.org
[36] www.mayakobagolfclasic.com
[37] www.unwto.org
[38] www.wwf.org.mx
[39] www.banyantree.com/en/mayakoba
[40] www.fairmont.com/mayakoba
[41] www.rosewoodmayakoba.com
[42] www.mesoamericanreef.org