

## Tourism Development on the North Yucatan Coast: Human Response to Shoreline Erosion and Hurricanes

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**ABSTRACT:** The barrier coast of north Yucatan has been evolving into a beachfront recreational landscape since the introduction of passenger rail service between Mérida and Progreso in 1881. Beginning in the 1950s, middle-class vacation home construction spread laterally outward from Progreso, and even distal fishing and salt-gathering villages became engulfed by a recreational landuse overlay. In spite of geomorphic evidence of marine transgression, such as dune scarps and washover fans, the focus of recreational urbanization has been the beachfront. And although attempts at retarding shore erosion have taken place since the 1960s, hazard perception has remained generally low until the late 1980s. When Hurricane Gilbert blew across the Yucatan peninsula in 1988, damage to beachfront structures, highways, boats, and salt ponds was extensive. The barrier environment exhibited extensive overwashing and breaching, especially in areas of human modification, and the lagoon ecosystem experienced considerable ecologic disruption. Because the north Yucatan coast is a locus of domestic tourism, and the thousands of uninsured summer homes are owned largely by members of Mérida's middle class, reconstruction since Gilbert has been slow. Incipient trends of international tourism development have slowed since 1988.

### Introduction

Although not lying directly in the paths of most hurricanes that strike the peninsula, the N coast of Yucatan is nonetheless vulnerable to various physical and socio-economic impacts resulting from storm activity. Its geographic orientation makes the N coast vulnerable to waves and storm activity generated by polar outbreaks (*nortes*) in addition to periodic hurricanes. Perhaps partly because of the adverse physical environment, the N coast remained sparsely urbanized throughout the Mayan and Spanish colonial historical periods.

When the late 19th century henequen (sisal) boom stimulated construction of a railroad and a port (Progreso) at the closest coastal access to the Yucatecan capital of Mérida, a new phase of beachfront urbanization began. Although much of this urbanization was directly related to port development, an increasingly larger share was related to tourism and summer home (*casa veraniega*) development. This latter form of

urbanization depended in large part upon levels of disposable income by the citizens of Mérida (*Meridianos*), and successive economic booms (including the henequen boom of the Gilded Age, the post-Revolution Roaring 1920s, and the postwar 1950s and 1960s) were accompanied by corollary increases in rates of beachfront urbanization. Additional factors of proximity (35 km) and size of Mérida (about 600,000 in 1990) have helped to create one of the few resort clusters along Mexico's Gulf of Mexico shoreline (Meyer-Arendt 1987a; 1987b). Centered on Progreso, contiguous beachfront housing extends over 20 km in length from Chuburná Puerto to east of Chicxulub Puerto (Fig 1). The 'recreational frontier' continues to expand eastward, and smaller fishing and salt-gathering towns – from Telchac Puerto to Dzilam de Bravo – have increasingly become subjected to touristic encroachment. Unlike Yucatan's Caribbean coast, which is better endowed with physical characteristics popular with international tourists (eg. clearer water whiter and sandier beaches, coral reefs, and

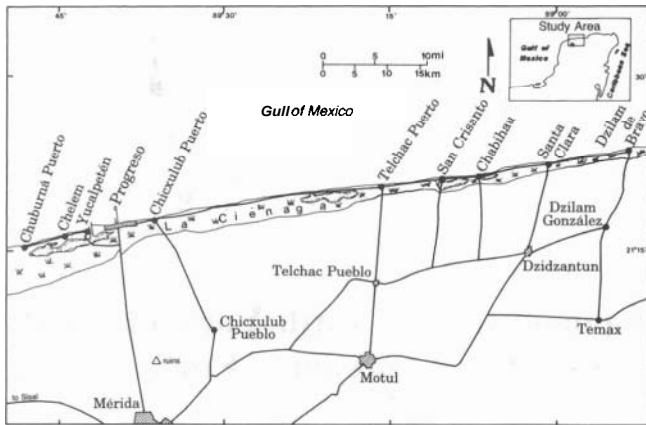


Fig 1 The urbanized north coast of Yucatan (from Meyer-Arendt 1987a)

steady trade winds), the N coast has remained a locus of domestic tourism – popular especially with Meridanos as a weekend or vacation retreat (Meyer-Arendt 1990).

Awareness of hurricane and storm damage along the N Yucatan coast has historically been higher among local residents than among summer home owners. Oral accounts of past storms and lagoonal flooding abound, and physical evidence of shoreline erosion and coconut palm blow-downs is easily seen. Even the beachfront summer home owners have become aware of physical hazards since the intensive construction began in the 1960s, and shoreline retreat has been futilely combatted by haphazard groin (*espolón*) and seawall construction. When Hurricane Gilbert passed, in the early evening of September 14th, 1988 (local time), the impact came perhaps as a surprise but not as a total shock.

It is the aim of this paper to present a brief background of human occupation of the fragile coastal environment of north Yucatan, in particular the impact of tourism development. Both the physical and cultural landscapes of the N Yucatan coast are distinct from those of the E coast of Yucatan, and this may explain differences in both the impacts of and recovery rates from Hurricane Gilbert.

### Coastal Geologic Setting

Characterized by multiple beach ridges, which reflects Holocene accretionary shoreline regression over the submerged limestone platform, the North Yucatan coastal barrier is locally fronted by vegetatively stabilized dunes up to 3 meters (m) high, such as at Chuburná. Dune height and the width of the beach ridge plain varies along the N coast. In the vicinity of Progreso, as many as 12 sand ridges comprise a beach ridge plain nearly one km in width. The coast from San Crisanto to near Dzilam

de bravo contains only one to three ridges, and the narrow barrier is subject to periodic breaching and overwash activity. Approaching Dzilam de Bravo, wave energy decreases and the sand beach turns to a finer-grained mud. Nearshore beach ridge development is occasionally seen by emergent vegetated bars, and interbar deep muck extends a least 100 m seaward (Edwards 1954). The beaches are composed of carbonate materials on a wave-cut surface developed on the limestone platform (Tanner 1975). The shoreline is generally long and straight, except where interrupted by small Pleistocene limestone outliers (Sapper 1945). Some of these outliers lie in the nearshore, where they function as natural breakwaters and reduce wave energy. Some even have produced tombolos. The 200-km long barrier is separated from the limestone mainland by an extensive mangrove-fringed lagoon, referred to as La Ciénaga (Estero Yucalpetén in the vicinity of Progreso). This shallow lagoon system, which extends across most of the NW Yucatan peninsula, is noted for its variety of waterfowl, fish, and salt-gathering potential (Edwards 1954; Wilson 1980).

The N Yucatan coast has experienced varying rates of annual shoreline erosion. Retreat rates of 1.8 m/yr over a 110-year period have been reported (Gutierrez 1983), but rates of between 30 and 60 cm/yr were found in the Progreso area for the 1948–1978 period (Meyer-Arendt 1987b). East of Progreso, shore erosion has been reported to exhibit a high degree of cliffing of beach ridges (Tanner 1975). Ocean currents enter the Gulf of Mexico through the Yucatan Channel (between Yucatan and Cuba), and current divergence sets up an east-to-west longshore current – and a corollary east-to-west longshore sediment transport – along the N coast. Although longshore sediment transport rates have not been calculated, estimates easily could be made on the basis of net sediment accretion updrift of jettied harbor entrances (Gutierrez-Estrada et al. 1988). By the same token, most shoreline erosion has occurred downdrift of the jettied harbor entrance at Yucalpetén, where rates of 90 cm/yr were calculated for the 1948–1978 period (Meyer-Arendt 1987b).

### Settlement History

In the pre-colonial era the region was part of the Yucatec Maya province of Cehpech. Salt production and fishing were the primary aboriginal economic activities, and several early habitation sites dotted the N coast, including a village at Chuburná Puerto and several small shell middens along the lagoon (Eaton 1978).

During the colonial era, fishing and salt production remained important in the many small hamlets of the Gulf of Mexico coast of Yucatan. Salt production was the major economic activity at several locales, including Chuburná Puerto, Chicxulub Puerto, Telchac Puerto, San Crisanto, Chahihau, and Santa Clara, and also the pre-

colonial saltworks at Las Coloradas E of Dzilam de Bravo (Edwards 1954). Chelem was a fishing encampment (*rancho*) during the colonial era (Eaton 1978).

The seaport for Yucatan during most of the colonial period was Campeche, located 200 km SW of Mérida. In 1810, during the final years of colonial rule, successful petitioning by Yucatecan commercial interests led to a shift of the official port to Sisal, a fishing settlement about 50 km NW of Mérida (Moseley and Terry 1980). By the 1830s, as the export market for henequén (used for binder twine) began to increase, it became apparent that a new port closer to Mérida was needed to replace Sisal, which frequently was inaccessible during the rainy season. (Henequén had become known as sisal, because of stamps imprinted on the bales of fiber at the point of export.) In 1840, a scouting expedition determined that the stretch of coast closest to Mérida, between the *vías* (coastal lookout points) of Chicxulub and Chuburná, would be suitable. In 1856, after various studies and legal investigations, authority was granted to construct a port settlement, named Progreso de Castro, at the selected site, and within a year the first houses were built. By 1861, a crude road from Mérida to the new settlement had been constructed (Ferrer 1945). The first wharf was completed in 1870, and in 1871 the customs authority was formally transferred from Sisal to the newly-opened port of Progreso. Train service between Merida and Progreso began in 1881 as Yucatan was entering its "Gilded Age" because of high worldwide demand for henequen (Moseley and Terry 1980). A second rail line (narrow-gauge) from Chicxulub Pueblo reached the new port in 1886, and Progreso developed rapidly.

Although the main function of the railroad was the shipment of cargo (mainly the export of henequén), passenger service also was available to transport Mérida residents to the coast. Many Meridanos soon traveled to the beaches as day users, and wealthier families began to build summer residences at Progreso during the 1880s and 1890s for summer season occupation. By 1907, Progreso boasted of three hotels. A large beachfront recreational facility with game rooms and dance hall was constructed by North American interests, and by 1912, Progreso had established a reputation as a popular vacation destination for Mérida residents (Frias and Frias 1984; Meyer-Arendt 1987a).

In 1928, the Merida-Progreso highway was paved, and the shorefront of Progreso was recreationally improved. A *malecón*, or beachfront promenade, was constructed east (updrift) of the docks, and restaurants and dance clubs located along the landscaped beachfront drive. Opulent summer homes came to line the Progreso shorefront, behind the *malecón* and extending eastward toward Chicxulub. Tourism became a significant component of Progreso's economy, after fishing and port-related functions.

Contemporaneous with an expanding touristic infrastructure during the late 1920s and 1930s was a

deterioration of Progreso's port facilities (Frias and Frias 1976). As the two wooden wharves didn't offer enough docking space, small cargo carriers of the local "mosquito fleet" were often diverted to the ports (*puertos*) of Chicxulub and Chelem, and at the former a wooden pier was constructed in the 1940s. Chelem, only an "official" settlement since 1905 when a town plan was platted (Frias and Frias 1976), became a "backup port". The port functions of Chicxulub and Chelem declined after a 2-km-long concrete wharf at Progreso was completed in 1947.

Although the only paved road during the 1930s was the Mérida-Progreso highway, graded local coastal roads extended toward Chicxulub Puerto in the E and Chelem in the W. Unimproved sand roads were extended eastward as far as Dzilam de Bravo and westward as far as Chuburná Puerto. Roads and tram rail lines were laid across the extensive coastal lagoon at various locations during this period. Although the aim was to facilitate export from the mainland, the provision of access, during a period of growing usage of buses and private automobiles, expanded the potential for coastal recreation and urbanization. By 1945, Chicxulub and Telchac Puerto were established *playas de veraneo* (summer beaches), and many of the small fishing and salt-producing settlements along the north coast between Progreso and Dzilam de Bravo were considered *lugares de recreo* (recreation spots) (Ferrer 1945). The initial pattern of recreation was one of day use, but vacation home construction soon began to expand beyond Progreso. Mérida, with a 1945 population of almost 100,000, provided the majority of recreationists to Progreso, but the smaller eastern beaches such as Miramar Beach at Telchac Puerto also drew recreationists from closer, secondary urban centers such as Motul and Temax (Meyer-Arendt 1987a).

Throughout the 1940s, the beaches closest to Progreso remained most popular for summer home construction because of the availability of utilities and proximity to Mérida. After Progreso's beachfront filled in with summer homes during the 1950s, Chicxulub became the primary locus of recreational development. A secondary direction of expansion, in the latter 1950s, was toward Chelem. In both directions from Progreso, the 'recreational frontiers' encroached upon *cocales* (coconut groves) and barren beach ridges. Because of its location downdrift of the port (and corollary higher shoreline erosion rates as well as lower land values), Chelem allegedly attracted the middle class strata of Mérida society. The local *ejidos* (cooperatives) which owned most of the uninhabited land between settlements soon recognized an easy source of revenue and began to illegally subdivide their own lands for sale to seasonal residents from Mérida (Meyer-Arendt 1987a).

A 1964 tourist guide to the N coast referred to the Progreso area as a "summer home center" and paved roads were shown as extending to Chicxulub and Chelem (Ellis 1964). A graded road connected Chelem with

Chuburná, and only sand roads continued beyond Chuburná and Chicxulub. The only modern beach hotel on the N coast was the newly built Hotel Los Cocoteros between Progreso and Chicxulub (which in 1980 was converted to a private club).

Summer home development continued throughout the 1970s and 1980s, and a contiguous Chuburná-Chelem-Yucalpetén-Progreso-Chicxulub urban strip has emerged. Considerable recreational development has taken place east of Chicxulub since the late 1970s, and many former cocals have become converted to vacation cottage *fraccionamientos* (subdivisions). The port of Yucalpetén, a safe harbor for the Progreso fishing fleet which opened in 1968, has forced a relocation of the main coastal highway west of Progreso, and the channel entrance now separates the residential areas of the port city from the recreational landscape that extends almost continuously from the jetties to Chuburná. By 1982, 4,000 *casas veraniegas* were tallied for the municipio of Progreso, which includes Chuburná, Chelem, and Chicxulub (Castillo 1982). Perhaps a few hundred more summer homes and several *balnearios* ("bathing resorts", replete with changing quarters, a restaurant, and usually a bar) were located in the small settlements between Chicxulub and Dzilam de Bravo.

The single-family beachfront summer home landscape still typifies the N Yucatan coast, and hotels mostly are clustered in Progreso. In 1985, the municipio of Progreso contained 14 hotels – 8 in the city of Progreso (with a total of 118 units), 1 in Yucalpetén (76 units), 2 in Chelem (14 units), and 3 in Chicxulub (28 units). The region's first modern resort hotel in the area opened in 1982, adjacent to the public balneario at Yucalpetén. The hotel – Centro Vacacional – is administered by ISSTEY, the federal social security administration. Due to a policy of preference to Mexican federal employees and social security recipients, international tourists rarely can receive a room during the high-demand summer tourist season. First class hotels with potential to appeal to international tourists date to 1987 when the La Fiesta hotel/marina (several hundred units) began construction on sands accreted updrift of the Yucalpetén harbor entrance jetties. A second major hotel – the Spanish-Italian-financed 400-unit Hotel Nueva Yucatan – was nearing completion near the Telchac Puerto safe harbor in late 1988.

In the late 1980s, efforts were being made to expand the tourism hinterland (market area) to beyond Mérida. A Chuburná subdivision advertised in Mexico City, and envoys from Mexico's Secretaria de Desarrollo y Turismo promoted Yucatecan coastal tourism (in addition to archeological tourism) in the US, Europe, and the USSR. Extension of the Progreso dock, at 2 km already the longest in the world, began in 1985 and the additional 2 km (mostly of riprap foundation) was intended to accommodate deep-draft vessels, including cruiseships. Cruiseship passengers initially presumably will be whisked to Mérida and inland archeological sites, but the

potential for local tourism infrastructural expansion also may be capitalized upon. Plans were drawn up for an *Isla Chelem* project, in which multi-family housing totalling 2,000 dwelling units plus 4,000 residential villas would front two large artificial lakes. The idea of the project was to copy retirement communities in Florida and Arizona and attract US retirees and winter visitors. Although this plan apparently is still under consideration, a major state/federal project – to reclaim a large portion of the dying mangrove zone immediately south of Progreso for the purpose of low-income residential housing construction – was initiated in 1986 and is presently (1990) still underway.

### Human Reaction to Physical Hazards

The adaptation of both permanent and seasonal residents to such a storm-prone and erosive coastal setting as the N Yucatan coast has been characterized by both adjustment to and modification of the physical environment. The oldest human modification of the physical environment of coastal Yucatan is perhaps the aboriginal impoundment of lagoonal waters for purposes of solar salt production, a folk and commercial industry still practiced in the same historic and prehistoric locations. Periodic inundation of barrier settlements resulting from lagoonal flooding – in turn caused by both hurricanes and polar outbreaks – stimulated environmental modification at least by the early 20 century, and efforts to combat shoreline erosion can be traced to the 1960s when beachfront urbanization first reached extremely high rates.

The Yucatan peninsula experiences 1 hurricane or tropical storm a year on the average (Wilson 1980), but because of the N coast's geographic position – facing N and in the lee of prevailing Caribbean and Atlantic tropical cyclones – impact frequency is much lower. One of the first references to beach recreation along the N Yucatan coast is contained in a report of a 1903 hurricane, which caused extensive roof damage to homes, tossed boats upon the beach, and toppled trees in Progreso (Frias and Frias 1984). Following the lagoonal flooding that accompanied the hurricane, federal officials proposed draining the lagoon to minimize danger from backflooding and disease outbreaks and also building a seawall along the whole shoreline to "impede the invasion of water" (Frias and Frias 1984). These proposals were never enacted, however. In 1916, high waters in the lagoon again threatened to cause serious flooding in Progreso, and a *zanja* (ditch) was cut through town to allow the lagoon waters to drain into the Gulf. This ditch allegedly served a useful drainage function for several years (Frias and Frias 1984). A 1944 hurricane caused significant shore erosion W of the dock in Progreso, and half a residential block was damaged. A second *zanja* was dug through the barrier at the west end of town to drain the high lagoonal waters (Meyer-Arendt 1987a).

Because of an absence of hard data, little is known about additional historic storm impacts. Edwards, on a reconnaissance mission in 1954, did note that many of the cocalas contained open spaces where palms were obviously uprooted by storm activity (Edwards 1954).

As far as impacts upon shoreline processes, the extensive port modifications at Progreso – from original wooden docks to the modern 4-km long concrete-and-riprap wharf and to the nearby Yucalpeten safe harbor – have all accelerated downdrift shoreline erosion because of interruptions to longshore sediment drift patterns. The portion of Progreso downdrift from the dock has historically suffered most from erosion, and this was exemplified by the 1944 hurricane. Perhaps not by coincidence, the zone for beach recreation and summer home development was initially exclusively E of the Progreso dock.

In spite of documented port development impacts upon shoreline erosion, the first structural human responses to shore erosion were efforts to improve the beaches for recreationists. In 1964, a series of rock-and-timber groins (*espolones* or *escolleras*) were designed by government engineers and installed along the Progreso malecón (Meyer-Arendt 1987a). The espolones proved to be relatively successful in trapping sand and widening the beach fronting the popular bathing area.

Armoring of the recreational shorefront intensified following the opening of the safe harbor (*puerto de abrigo*) at Yucalpetén in 1968. Although the storm-protected safe harbor has provided a suitable base for the Mexican navy, the Progreso fishing fleet, a yacht club, and a growing seafood processing industry, the dredging of a channel through the barrier island has led to many negative environmental consequences, not the least of which was an acceleration of shoreline erosion downdrift of the jettied entrance. In response to the high rates of erosion – as much as 30 m since the jetties were built – widespread unauthorized construction of espolones began. Unlike the 1964 groin field at the Progreso malecón, the groins extending from the Yucalpetén jetties to W of Chelem were not properly designed. Beachfront property owners individually made decisions to build espolones, and although construction permits were legally required, these were not obtained. Over 75% of the vacation home properties west of the Yucalpetén jetties presently encroach to within the 25-m wide federal beach easement (de la Cruz 1985, pers. comm.), and many seasonal landowners perceive groins as a means of saving their property. However, groin construction has actually increased local downdrift erosion (Fig 2). Between 1968 and 1985, the leading edge of espolon construction has shifted westward in response to this higher erosion. During a 1984 aerial survey, 178 espolones were noted along a 8.8-km stretch from Yucalpetén to Chuburná Puerto, for an average of one every 50 meters. Groin concentration is highest between the jetties and Chelem. As a consequence of the groin construction, the widths (and aesthetics) of the beaches

has diminished. By the early 1980s, the cause-and-effect relationship between groins and erosion was recognized, and Chuburná officials formally complained that groin construction had accelerated shoreline erosion within their jurisdiction (Castro 1985, pers. comm.). By April 1985 the ban on espolón construction became actively enforced (Villet 1987, pers. comm.), and several groins have been removed from the Chuburná ejido beachfront since then.

During field surveys in 1984 and 1985, the author interviewed summer home owners in the Chelem/Chuburná area as to their perceptions of shoreline erosion and potential storm impacts. Although most seasonal residents felt there had not been any problems since the recreational landscape first appeared in the 1960s, local Mayan fishermen (who would never live adjacent to the beachfront) told tales of significant shoreline retreat since summer homes first appeared. Although local claims of 100 m of shore retreat could not be substantiated by aerial photograph analyses, patterns of short-term transgression were evident. In regard to perception of future erosional or storm hazards, over half of the 20-plus seasonal residents surveyed did not anticipate any problems. Some of these optimistic responses were made only days prior to Hurricane Juan in late October 1985.

The tropical cyclone that was to become Juan formed in the western central Gulf of Mexico in late October 1985. On October 27th, it reached hurricane strength on a slow northward track. On October 29th, after switching course several times, Juan made landfall in south Louisiana as a minor hurricane, causing beach erosion and flooding in the New Orleans suburbs (Penland et al. 1986).

In spite of the publicity generated in the US and international press regarding Juan's impacts along the central US Gulf Coast, some of the greatest damage was actually felt along the north coast of Yucatan. Hovering over the Gulf of Mexico for over a week led to elevated water levels around the entire perimeter of the Gulf. Also, the counterclockwise circulation set up a rare westwind in Yucatan, a condition the Maya refer to as a *Chirkin-ik*. Over the course of a week, the author witnessed gradual water level rise and beach erosion, especially at vulnerable groin locations, where human-caused shore erosion was already evident. By October 30, extensive undercutting of summer home foundations had occurred, and the façade of the Hotel Costa Azul in Chelem (where the author enjoyed the beach view while it lasted) collapsed into the sea. Only days earlier, interviewees told the author that erosion was not a problem, and then Hurricane Juan caused the first storm-induced beachfront structural damage since recreational urbanization began in the area in the 1960s.

A resurvey of the N coast in early 1987 revealed that new structural responses to shoreline erosion had been implemented, particularly in erosion-prone Chelem. Unlike two decades earlier, when espolones were



Fig 2



Fig 5



Fig 6



Fig 3



Fig 7



Fig 4



Fig 8



Fig 9



Fig 11



Fig 10

- Fig 2 Groin field fronting Chelem, January 1984 (view toward east. entrance to Yucalpetén safe harbor faintly visible at top)
- Fig 3 Beach erosion resulting from polar outbreak, Chelem, January 1987
- Fig 4 Chelem beachfront, October 1988 (note undamaged seawall)
- Fig 5 West Indian freighter beached at Chelem, October 1988.
- Fig 6 Foundation undermining because of overwash processes, Dzilam de Bravo, October 1988.
- Fig 7 Restaurant destroyed along Progreso's malecón, October 1988. (Progreso's landmark lighthouse at far left)
- Fig 8 Progreso's malecón, October 1988.
- Fig 9 Barrier complex and coastal highway breached at entrance to Telchac Puerto safe harbor, October 1988.
- Fig 10 Coastal highway breached in Chabihau, October 1988
- Fig 11 Coastal highway breached between Santa Clara and Dzilam de Bravo, October 1988 (note colonial-era saltworks in distance)

regarded as the solution to combat shoreline retreat, the new strategy was one of personal property protection by foundation reinforcement or seawall construction. (The espolones were in fact gradually deteriorating in the surf zone.) Both raw material (limestone) and labor are relatively inexpensive in Yucatan (by Western as well as middle-class Mexican standards), and much cement was poured between 1985 and 1987. Most of the Hurricane Juan damage – which primarily had been foundation undermining – was repaired via the infusion of cement, and several home owners also built seawalls at the seaward limits of their property. (Again, this construction took place within the 25-m federal beach easement.) The Hotel Costa Azul had repaired its façade (sans balconies) and reinforced its foundation, which was the equivalent of a seawall because of its position directly on the beach. Coincidentally, the first major storm (norte) – and corollary shoreline erosion – to affect the N coast since 1985's Hurricane Juan struck during the author's visit in early 1987. Beach retreat was accompanied by renewed wave attack upon foundations, including ones only recently repaired. A secondary function of the beach, as an artery of travel, was also seriously impaired by this winter storm (Fig 3).

Much more shoreline reinforcement took place during 1987 and 1988, especially the building of private seawalls. Many of these were of quite solid construction, and the "stair-step" design was quite popular. It is estimated that, between Yucalpetén and Chelem, approximately one-sixth of the beachfront homes had added seawalls by 1988.

### Impacts of Hurricane Gilbert

As Hurricane Gilbert tracked WNW across the Yucatan peninsula, the eye of the storm almost directly passed over Progreso early in the evening of September 14th (local time) (Meycr-Arendt 1991). Wind speeds were still estimated at about 100 knots, or 185 km/hr (Clark 1989, pers. comm.), and roof damage in Mérida was extensive. On the N coast, winds and waves

dominantly out of the NE drove a storm surge – estimated at between 2 and 3 m high – across the coastal barrier, widespread overwash and breaching. Property damage was extensive along the entire N coast because of mostly wind and wave action and also because of lagoonal flooding in certain areas. West of Progreso, the jettied entrance to the Yucalpetén safe harbor, dredged across the barrier in 1968 and oft criticized by environmentalists for its disruption of the lagoon ecosystem (particularly to fisheries and mangroves), minimized backbarrier lagoonal flooding by functioning as an outflow valve for lagoon-impounded hurricane waters. In spite of extensive damage to property and economic systems, no loss of life was reported for the N Yucatan barrier coast.

Along the entire study area, the first line of beachfront housing was essentially totally destroyed, and this was especially visible in the highly urbanized Chuburná-to-Chicxulub axis, where most structures within 100 m of the shoreline exhibited hurricane damage (Fig 4). The Hotel Costa Azul was reduced to rubble as were most shorefront summer homes. A small freighter from St. Vincent, West Indies, recently loaded with cement at the port of Progreso, attempted to outrun Hurricane Gilbert but wound up stranded on a Chelem beach (Fig 5), where it actually offered protection to one or two summer homes in its lee. In urban areas, shore-normal roads functioned as conduits for the Gulf waters to cross the barrier to the lagoon, and during this process of overwashing much road-scouring and foundation undermining occurred (Fig 6). Progreso's recreationally popular malecón was severely damaged, any many of the restaurants and nightclubs were totally destroyed (Fig 7). Within three weeks after the storm, the only improvement to the malecón area was removal of sand from the beachfront drive (Fig 8). The 2-km wharf extension was also seriously damaged, as the riprap was easily rearranged by the hurricane. In spite of the ubiquitous beachfront destruction by wave action, the beach itself actually experienced sand accretion. Some of the decaying *espolones* were completely covered by sand following the storm. Longshore sediment drift driven by the NW hurricane winds apparently introduced sands eroded from updrift locations. Overwash processes dominated along the wide, sparsely developed beach-ridge barrier complex between Chicxulub and Telchac Puerto. However, Gilbert cut a major washover channel across the barrier complex where the entrance to the Telchac Puerto safe harbor had been dredged partly into the beach ridges in 1977 (Fig 9). As at Yucalpetén, the connection between the sea and lagoon allowed more rapid outflow and probably minimized flood hazards along the lagoon edges of the coastal settlements.

In the narrow barrier beach zone west of Telchac, hurricane breaches were much more common. In towns such as San Crisanto and Chibihau, breaches cut through the settlements and removed homes that were in the path of the cut (Fig 10). Much of the coastal lagoon in this

zone has been modified to function as evaporation ponds for salt gathering, and the breaching of the ponds by Gulf water lowered the 1989 volumes of gathered salt. More seriously, transportation access was briefly shut off by the numerous breaches (Fig 11), and water exchange between lagoon and Gulf continued for many months after the hurricane. At the time of the author's visit in early October 1988 (in the company of Dr. Clifton V. Dixon and Mr. Peter N. Vogel), damaged causeways across the lagoons recently had been repaired and electrical services still were being restored to homes and businesses.

Disruptions to natural ecosystems were also quite extensive along the north Yucatan coast, particular in the estuarine nesting grounds of the pink flamingo around Rio Lagartos (60 km west of Dzilam de Bravo). Breaches in the narrow barrier allowed entering Gulf water to cause sufficient short term salinity changes to temporarily disperse the flamingo population (Clark 1989, pers. comm.). And in spite of some fishermen's efforts to keep at least one breach open – to facilitate access to the sea, a natural equilibrium is being restored and most flamingos had returned by 1989.

### Recovery from Hurricane Gilbert

Because tourism is largely domestic and the region is less economically important to either the region or the nation, reconstruction since Hurricane Gilbert has been slow. Unlike at Cancun, where tourism infrastructure caters to the international tourist and hotels and condominiums are almost all insured against natural disasters such as Gilbert, few insurance policies were in effect along the N Yucatan coast. In the fall of 1988, thousands of laborers migrated to Cancun from all over Mexico to work 12-hour shifts (at extremely high unskilled labor wages equivalent to \$1 US/hr) to restore the resort to its pre-hurricane touristic glory in time for the winter recreation season. Along the N Yucatan coast, little such reconstruction frenzy was apparent.

Although two years have passed since Gilbert's landfall, segments of the recreational beachfront landscape (such as at Chelem) still have the appearance of a war zone. Due to the lack of insurance, the rate of reconstruction of summer homes has varied according to the availability of money as well as attitude of the homeowner. Gradually rubble is being removed and trucked to the wetland reclamation project south of Progreso. Some *espolones* are also being removed. But progress is slow in the middle-class resorts of Chelem and Chuburná.

In Progreso, the malecón has been rebuilt and most hotels are back in business, including the La Fiesta and the Centro Vacacional in Yucalpeten. The riprap wharf extension has been repaired, but the large Hotel Nueva Yucatan near Telchac Puerto, nearly completed at the time Gilbert hit, still has not opened for business, apparently for finance-related rather than hurricane-



related reasons. The major breach through the barrier at Telchac, which runs adjacent to the Nueva Yucatan, still has not healed nor been sealed artificially. (A sand causeway looping through the lagoon permits traffic to flow between Progreso and Telchac Puerto.)

West of Telchac Puerto, recovery has also been slow. The coastal highway is still breached at numerous locations, and access to several of the salt-gathering settlements is via the causeways across the lagoon and along the mainland highways. Most of the breaches that directly impacted the folk and commercial salt ponds were repaired in 1989. The relative lack of importance of this area to Yucatan's economy is apparently responsible for the slow progress in repairing the highway for its entire length along the coast.

As opposed to the E coast of Yucatan, where the inflow of foreign revenues is a direct stimulus for immediate reconstruction, the N coast of the peninsula will recover at a very slow rate. Permanent residents on the coast will adjust to Gilbert's impact, and even the seasonal recreationists from Mérida will not forgo their seaside pleasures. Progreso will recapture its image as a weekend and summer entertainment zone for Meridanos, and summer home owners will eventually clean up their beachfront properties. The natural ecosystems have already largely recovered, and more sedimentary healing of breaches (via sand accretion) is also anticipated. Eventually, the Yucatan government will build some bridges and repair the coastal highway. Perhaps the greatest impact of Hurricane Gilbert has been the slowing

of the incipient trend toward the internationalization of tourism. Unlike at Cancun, where in late 1990 evidence of Hurricane Gilbert was seen mostly by a narrower beach and some structural shoreline reinforcements, the N coast still looks hurricane-ravaged. The optimistic plans by local tourism promoters to attract cruiseship visitors and fly-in tourists away from Mexico's E coast may just have to be put on hold a little bit longer.

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#### Maps and Aerial Photographs

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