

A Coastal Ecosystem in Northwestern Yucatan

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The northwest coast of Yucatan between Campeche City and Sisal has an unusual landscape and stands in sharp contrast to the better known interior, which is typified by deep sinkholes, deciduous vegetation, henequen cultivation, and Indians living from shifting agriculture. The northwest coastal zone contains springs, surface streams, circular islands of tall evergreen trees surrounded by low mangrove or savannas, and it has less rainfall than the interior and many small canals leading inland from the shore. Although geographers have observed the unusual vegetation and hydrologic patterns (Edwards 1954, 6; Sauer 1967, 24), there have been no systematic investigations to explain the presence and interrelationships between these features. The purpose of this paper is to show how the ground water flow, vegetation, weather and climate, and the human use are related in an ecosystem that is unique in Yucatan.

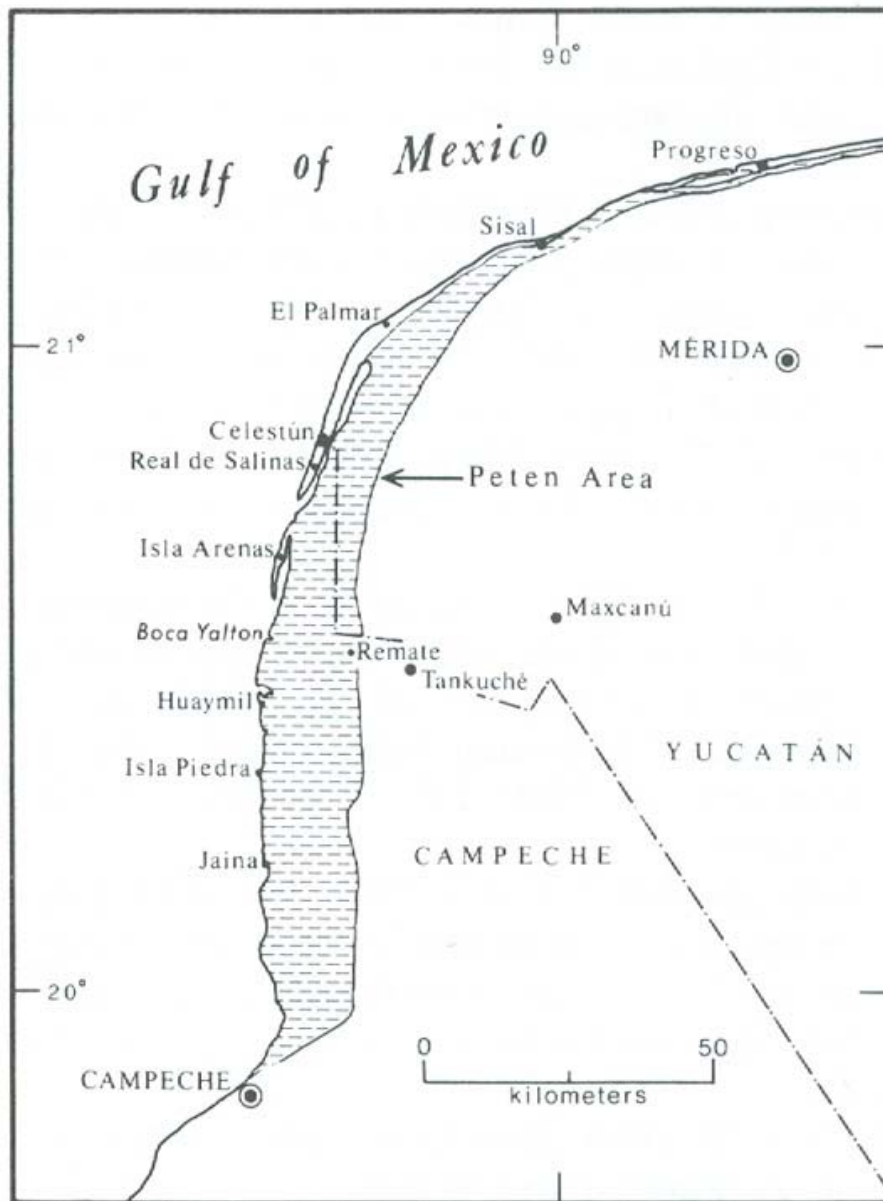


Fig. 1. Northwest coast of Yucatan and location of peten area (shaded).

The coastal area under discussion is a seasonally flooded, gently sloping surface extending approximately 150 km from Campeche City to the vicinity of Sisal (Figure 1). Its maximum width east-west is about 17 km near Huayamil and narrows to about 5 km near Sisal where it continues eastward as a narrow swamp separating tierra firma from the barrier beach. From Campeche City 80 km north to Isla Arenas, the beach is very narrow or absent and the area is open to the Bay of Campeche. This unprotected coast has a mangrove forest extending about one km inland. Behind this are mostly open mud flats up to 3 km wide with scattered patches of tall trees. Farther inland is a low, dense, mangrove forest. A short distance north of Isla Arenas is the end of a large barrier beach, an extension of the beach along the north coast.

The interior is dominated by mangrove forests, with savannas in the northern section, above which rise a large number of circular, tall forest communities (Figures 2 and 3). These special plant communities form islands of trees within the lower mangrove forest (Wilson 1980, 32), for which the term *petenes* has been used (Casares 1907, 211; Andrews 1977, 65). [end p. 82]



Fig. 2. Aerial View of vegetation near Celestun. (1) Estero (estuary) de Celestun; (2) red mangrove; (3) canals; (4) savanna; (5) peten. Aerial photos, 1960, courtesy INAH, Merida. Scale approximately 1:20,000.



Fig. 3. Aerial view of petenes and savannas near Celestun, March 1976.

PETENES

From a distance, the petenes appear to be low, circular hills covered with tall trees and surrounded by low mangrove, grasses, and standing water. Despite the mounded appearance, no elevated surface was observed. Instead, petenes contain moist ground, pools of water, or open ponds (*cenotes*, or collapsed sinkholes), in the center of which the water is at ground level. Thus, indications are that the tall trees result from available soil moisture and that vegetation height and species distribution reflects decreasing moisture away from the center.

Examination of petenes through which roads have been cut near Celestún and at Remate affirms that petenes generally do not have a topographic high upon which trees grow but have open water in sinkholes, or damp soil in the center. This further suggests a sequence of sinkhole evolution and perhaps a sequence of plant communities associated with each stage. Without an understanding of the ground water flow, the presence of tall forest trees appears as an anomaly in an area with annual rainfall of about 60 to 100 cm.

HYDROLOGY

The water level in the peten zone fluctuates seasonally. In the dry winter season, the ground surface may have no water except around springs and sinkholes, but in summer up to two feet of water covers the surface. This seasonal change seems to be in response to low winter rainfall and high summer rainfall. While occasional hurricanes and cold front induced winds may cause flooding along the coast, the summer flooding appears to be more directly related to higher ground water levels. The coastal vegetation patterns are tied in with the hydrologic system in northern Yucatan, that is, greater summer rainfall in the higher elevations of the interior produces hydrostatic pressure that forces water from springs and sinkholes in the petenes. This water drains off into the Gulf of Mexico in many small streams, which are absent elsewhere in northern Yucatan.

The subsurface water flow in the limestones of northern Yucatan has been generally understood for many years. It was described by Reclus (1897, 152), and Cole (1910, 329-30) went into detail, publishing a diagram of cenotes and subterranean flow, reproduced in later papers by other authors. The fresh water springs at the shore and off the coast, called *ojos de agua*, have long supplied water to settlements along the dry northern coast (Oviedo y Valdés 1853, 282, cited in Ternér 1954, 9; Reclus 1897, 153; von Humboldt, cited in Cole 1910, 329). Dampier also mentioned that about two miles south of the salinas (near Celestún) "about 200 yards from the Sea, there is a fresh Spring, which is visited by all the Indians" along a path through the mangrove (Dampier 1906, 146). A short distance south of the present location of Real de Salinas, and at the mainland edge of Estero Celestún, is a large spring that has a strong discharge of fresh water. Dampier further observed that on the coast between Sisal and El Palmar good fresh water could be obtained by digging in the sand above the high water mark (Dampier 1906, 144).

HUMAN USE OF THE PETENES

In the swamp east of Celestún, fires have burned the low mangrove, shrubs, and grasses to the margins of the petenes, resulting in abrupt changes in vegetation. These burns have become grass cov-[end p. 83]



Fig. 4. Dry season track leading toward Celestun with a peten in the background. Black mangrove dominates areas between petenes and outside the savannas. September 1977.

ered, forming savannas that have been present at least since 1675, as they were mentioned by Dampier in his travels (Dampier 1906, 121). The savannas occur inland from 1 to 7 km from the beach and extend from near Sisal south to the vicinity of Isla Arenas. They are still burned periodically, probably by hunters, chicle collectors, or loggers, and this has created an expanse of grassland with scattered petenes.

As the petenes appear to be hills or low mounds, archaeologists have speculated that they may be archaeological sites or are associated with archaeological sites. At least one prehistoric site has been found inland about 2 km and can be reached by a small canal, or *zanja*, 7 to 10 ft wide (Andrews 1977, 65; Matheny 1978, 195). There is no indication, however, of archaeological remains associated with other petenes.

At least 100 small canals extend inland from the coast (Eaton 1978, 30; Matheny 1978, 196), most leading into petenes. Some canals, however, are extensions of historic trails or roads across the swamp, for example, part of the old track from Maxcanú to Celestún is a canal during the rainy season (Figure 4). Some small canals extend 10 km or more inland in a straight line. These may tap water supplied from flowing springs and serve as communication routes to cross the swamp, like the canal at Remate, near Tankuche, that leads to Boca Yaltón. Some canals may have been dug to obtain access to potable water during pre-Hispanic time (Turner, pers. comm. 1987). The canals are large enough for a small boat, such as a dugout. Many canals were extended from small streams into interior petenes. The straightness of some canals suggests the use of a surveying instrument, or at least a compass. Furthermore, a high point of observation, like the mast of a vessel, would be needed to see over the mangrove fringing the coastline in most places.

The petenes are small tropical forests and contain economically important trees, thus wood collecting is the explanation usually given for digging the canals (Table 1). Small scale logging was observed by the authors in March 1987 and at least some canals are still used for gaining access into petenes for cutting building material or firewood. Chicle has been collected from the petenes in the recent past as the scars on chicle trees attest. However, one of the important wood products of the colonial period, *palo de tinta*, logwood, or Campeche wood (*Haematoxylon campecheanum*), has not been identified in the petenes observed by the authors, and according to Dampier, no logwood grew between Cabo Catoche, in present northeastern Quintana Roo, and the Río Champotón, south of Campeche City (Dampier 1906, 146, 149).

COASTAL WEATHER AND CLIMATE

The peten zone of northwest Yucatan is located in [end p. 84] one of the most unusual climate anomalies in the Western Hemisphere. Most of the northern half of the Yucatan Peninsula has a tropical wet and dry climate with annual rainfall totals

averaging 100 to 130 cm. The peten zone, however, is part of a narrow arc of semi-arid and dry savanna climate that stretches for more than 300 km along the Gulf of Mexico. The peten zone receives from 60 cm annual rainfall in the north to 100 cm in the south.

The climate of the peten zone is controlled by the prevailing trade winds and a strong diurnal sea breeze (Williams 1976, 15-19). The former is particularly dominant in the winter when the region experiences its driest weather, a pattern consistent with the remainder of the peninsula. During this time, the Atlantic subtropical anticyclone settles to a lower latitude bringing the system close to Yuucatan. As a consequence, a northeast trade wind is established that inhibits the development of convective showers through subsidence. Occasional cold fronts (*nortes*) sweep across the Gulf of Mexico, producing a cool, gusty wind and low cloud cover. However, these surges are most often too shallow to produce sufficient lifting for rain. As a result, the peten zone is generally dry with water confined to the cenotes.

With the onset of summer, the Atlantic anticyclone shifts northward, allowing the trade winds to assume a more southeasterly trajectory. This greatly increased distance between the anticyclone and the arriving trades results in a deepening of the trade wind layer, weakening of subsidence, and, consequently, a trend toward instability. For the peten region, summer is clearly the wettest season. However, rainfall is lower, less frequent, and generally less intense, than farther inland. The summer rainfall pattern is due to a combination of trade wind acceleration and a diurnal sea breeze. The trade winds are more unstable in summer, however, these winds accelerate offshore and this causes increased subsidence over the northern and northwest coastal region. At the same time, it appears that the trade winds are responsible for upwelling in the offshore waters (Trewartha 1966, 70-71). Although the upwelling is not dramatic, the temperature contrast between the offshore waters and the coastal zone is sufficient to create a very pronounced and stable sea breeze.

Table 1. Identified peten plants, vicinity of Celestun,
Western Yucatan State.

<i>Achras zapota</i> , chicle tree, common in moist areas	
<i>Avicennia nitida</i> , black mangrove, common in wet sites, standing water	
<i>Rhizophora mangle</i> , red mangrove, common in standing water, fringes the shoreline and esteros	
<i>Conocarpus erecta</i> , button mangrove, common around edge of tree islands	
<i>Laguncularia racemosa</i> , white mangrove, common	
<i>Jacquinia aurantiaca</i> , shrub or small tree	
<i>Dalbergia glabra</i> , shrubby climbing plant	
<i>Smilax</i> spp., common woody vine	
<i>Solanum verbascifolium</i> , shrub	
<i>Cladium jamaicensis</i> , sawgrass, frequent in savannas	
<i>Ficus radula</i> , a hemiepiphyte, strangling fig	
<i>Nephrolepis biserrata</i> , fern, common in wooded, damp areas	
<i>Acrostichum aureum</i> , fern, common in wooded, damp areas	
<i>Bavaisia tubiflora</i> , shrub or small tree	
<i>Sabal japa</i> , palmetto, common in damp sites	
 <i>Drier Localities and Edge of Petens:</i>	
<i>Metopium toxiferum</i> , poison tree, common large tree in peten interior	
<i>Krugi dendron ferrum</i> , common tree in peten interior	
<i>Bursera simaruba</i> , common small or medium tree	
<i>Thevetia gaumeri</i> , common tree	
<i>Gyneranthus lucida</i> , small tree	

Forming during the later morning hours, the sea breeze rapidly strengthens and advances inland in direct opposition to the prevailing trades. Because of coastal trade wind subsidence, rainfall is unlikely along the leading edge of the sea breeze as it crosses the coastal zone. As a result, skies there remain mostly cloud free while cumulus clouds slowly build over strongly heated inland surfaces. However, once the advancing sea breeze reaches the well-heated and unstable interior, thundershower formation is rapid.

The thunderstorms that form inland occasionally produce rain over the peten region. However, it is not until the later afternoon hours when the sea breeze subsides that thundershowers establish a westward drift in response to the winds aloft. This may produce rain along the coast. However, by the time most of the thundershowers reach the coast, they have lost

considerable strength. As a consequence, rainfall amounts during the wet season are substantially less in the north and northwest coastal zone than in other areas of Yucatan. When heavy rainfall from tropical storms and easterly waves occurs, the normal rainfall pattern is disrupted for several days. These migratory systems make an important contribution to the annual rainfall budget, for without them, the rainfall deficiency would be much more pronounced.

Despite the summer rainfall deficiency, the peten zone along the northwest coast is flooded during the wet season. This would suggest a greater contribution from diurnal thundershowers than was earlier noted. However, a close examination of the surface [end p. 85] conditions during the wet season revealed that surface water emerges from the springs and cenotes that form the nucleus of each peten. This water then flows across the gently sloping surface to the shore in small creeks or gradually evaporates in the sea breeze.

The origin of much of the ground water that seasonally floods the petenes can be found inland at the convergence of the sea breeze and southeasterly trades, usually 15 to 25 km from the coast. In summer, the thundershowers recharge the ground water almost daily. The resulting subsurface flow is directed to the coast where hydrostatic pressure forces ground water to the surface. Thus, the magnitude of surface flooding during the summer season is largely related to the amount of sea breeze-induced rainfall that occurs inland.

SUMMARY AND CONCLUSIONS

An unusual ecosystem exists along the northwest coast of the Yucatan Peninsula. The system involves a nearly flat, gently sloping land surface, seasonal atmospheric pressure changes, prevailing trade winds, a strong sea breeze, limestone hydrology, and the growth of petenes, or tall tropical forest communities, where ground water emerges at the surface. The area has formed a barrier to human activity, yet it has provided basic resources of fresh water, fish and game, and forest products. Periodic burning has altered the vegetation and resulted in savannas in part of the area. Wood collecting has partially altered the forest composition, but some petenes appear not to have been disturbed. Because it is flooded during the summer, the growing season for subsistence farming, the area has not been cleared for traditional agriculture. The density of mangrove makes access and movement extremely difficult, but this has been remedied somewhat by burning, which produced savannas, and by the digging of small canals in order to reach springs and petenes. Crossing from the dry land to the coast required cutting trails and roads to connect small sea level and spring-fed canals. Environmental characteristics and isolation make the northwest coast of the Yucatan one of the least disturbed areas left in Yucatan. Its unique character and relatively undisturbed state gives insight into the relationship between physical processes, vegetation patterns, and human land use in northwest Yucatan.

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