Changes in Microclimate Tracked by the Evolving Vegetation Cover of the Holocene Beach Ridges of the United Arab Emirates

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ABSTRACT: At 24° N, the U.A.E. has an arid, subtropical climate, with an annual temperature range 50 to 0 °C. This causes a widespread occurrence of carbonates and evaporites, and the restricted character of the vegetation, though diurnal dews, associated with onshore late afternoon and evening winds, support vegetation on dunes at the shoreline and near shore hillsides. In the eastern U.A.E., barrier islands are positioned on a narrow shelf with little protection from heavy seas. They have steep beach faces landward of which are subaerial dunes that are greater than 5 m in height. In contrast in the western U.A.E. landward of the Khor al Bazam and west of Abu Al Abyad, parallel sets of small subaerial dunes 1 to 2 m in height are common along the landward edge of a broad intertidal platform.

These local dunes closer to the sea and areas of higher topography are colonized and stabilized by the halophyte, *Salicornia* sp. The occurrence of these halophytes appears to be directly related to the occurrence of diurnal dews. The wetting effect of the dews dies out landward across the dune belt, and is matched by a corresponding loss of vegetation and the deflation of the dunes. The inner lagoons of the Holocene shallow-water carbonate and supratidal evaporite tract that lines the U.A.E. are rimmed by a series of stranded and deflated beach ridges that now lack dune ridges, formed at the end of the last major sea level change some 3000 to 4000 years BP. Supratidal flats are now encroaching on these lagoons through the development of cyanobacterial flats in the place of the beach ridges. It is predicted that all the coastal lagoons of the U.A.E. will fill naturally or by man driven reclamation. A concurrent change in microclimate will cause the demise of the current halophyte cover of the coastal dunes.

INTRODUCTION

This paper describes how the evolution of the vegetation cover of the coastal dunes of the U.A.E. is related to dews. It shows how these diurnal dews are associated with moisture brought inland from the humid Arabian Gulf by the late afternoon and evening onshore winds (Kendall and Skipwith, 1969; Ministry of Water, Oman 1995). During cloudless nights radiation of heat into the atmosphere causes a drop in temperature over the land areas and initiate the precipitation of dew along the near shore areas and sometimes the development of thick morning fog. These dews support a local quite dense cover of halophytes (Figure 1) on the dunes that line the immediate coast just landward of the berms that form on most of the beaches. This vegetation is also found on some of the hills that occur in the nearshore.

The dews lose their intensity and eventually disappear landward across the dune belt, and this decrease in precipitation is matched by a loss of the vegetation cover found close to the coast. The result is that the vegetation dies as the coast progrades seaward.

SETTING OF THE U.A.E.

Sitting astride the tropic of Cancer, the U.A.E. coast (Figure 2) has an arid, sub-tropical climate. Since the Arabian Gulf is surrounded by land, this climate is continental in character and consequently has marked seasonal fluctuations in temperature (Purser and Seibold, 1973). This, coupled with the narrow Straits of Hormuz inhibiting the exchange of marine water, creates conditions in which the local seawater temperature and salinity vary widely. The air temperatures in the summer commonly reach 45-
Figure 1. Photograph of Salicornia Sp. capping some small dunes in the UAE.

Figure 2. Location of the United Arab Emirates and the Arabian Gulf (with depth of water by Phathum). (Purser and Seibold, 1973).
50°C, or in the winter may be as low as 0°C (Purser and Seibold, 1973).

The combined effect of strong winds, high temperature and low rainfall results in significant evaporation and high salinities (Purser and Seibold, 1973) and the precipitation of the evaporite minerals gypsum and anhydrite in the coastal sabkha settings accompanied by a lack of natural vegetation in these regions.

Winds blow dominantly from the northwest throughout the year (Kinsman, 1964) and this continuously drives the dews and associated humid air landward. The strongest winds are the northwest gale-force "shamals" which occur during the winter. When these winds coincide with spring tides they cause flooding of large parts of the coastal plain. As with the hurricanes of the Caribbean and Florida (Pray, 1966), the shamals carry sediment landward from the frontal edges of the carbonate coastal shoals onto the supratidal flat, breaching and flattening coastal dunes and uprooting the vegetation that colonize them; they also initiate intertidal spits and beach ridges at the top of the intertidal flat on which the coastal dunes develop. This dominant wind direction has been constant through the Holocene and Quaternary, and the Pleistocene “miliolite” dunes exhibit a cross bedding that invariably dips southeast.

Large waves (over 1 m high) generated by the shamal winds are dissipated by the offshore shoals and barrier islands of the U.A.E. before they can reach the lagoons they protect. Tides and tidal currents are more important in the lagoons and on the lee of the shoals. Tidal currents reach high velocities through the constrictions of channels, producing deltas often up to 8 km in diameter.

On the intertidal and terrace areas of the U.A.E., landward of the break point of waves, there is a steady movement of material toward the east which is only interrupted by tidal channels and headlands. This longshore drift is caused by northwest winds creating northwest waves, which break obliquely on the east-west trending coastline. Within the shoal and channel area east of Abu al Abyad there is very little longshore drift, although movement of material on the shoals results from both wave and tidal action (Figure 3).

The average rainfall of the U.A.E. is less than 50 mm (Evans et al, 1969) and consequently vegetation is restricted. These rains fall in autumn, winter or spring. Although infrequent, they may be torrential. The rain locally has a short-term effect on the vegetation but although producing ephemeral changes in the evaporite mineralogy, this has little effect on the sediments and groundwater (Butler, 1965). Fluvial input is low in the Arabian Gulf and is mainly confined to the Iranian side of the Gulf where the Zagros Mountains are a source of alluvial sediments. Fluvial input is significant at the Shatt al Arab where most of the fluvial sediment load accumulates in the marshes of Iraq (Berry et al., 1970). On the Arabian side of the Gulf, fluvial input does not occur, so the depositional setting favors little vegetation and the accumulation of almost pure carbonate (Purser and Seibold, 1973).

Evaporation rates in the southern Arabian Gulf were estimated by Privett (1959) to be as much as 124 cm per annum. High summer salinities recorded by Sugden (1963) for part of the southern Gulf suggest that evaporation is greatest in summer, especially in restricted lagoons.

Salinity studies of the Arabian Gulf were made by Emery (1956) and Sugden (1963). Salinities range from 37 percent near the Strait of Hormuz to greater than 65 percent in the lagoons of the Arabian Coast. The low influx of fresh water and the high rates of evaporation produce these high salinities. Kinsman (1964), working in the lagoon just west of Abu Dhabi, recorded the salinity values shown in Table 1. He found that salinity changed with the state of the tide; the more restricted the circulation, the greater the salinity variation.

Brines collected by Butler (1965) from the ground waters of the sabkha both before and after storm-induced marine flooding showed no appreciable difference in the concentrations of the various salts. There was, however, some effect on the evaporites. Halite was washed from the surface sediments, while anhydrite on the surface above the intertidal zone was eroded.

From the above description it is clear, with the exception of diurnal dew, the climate and surface hydrology does not favor the growth of lush vegetation.

<table>
<thead>
<tr>
<th>Table 1. West Abu Dhabi Lagoon Salinity (After Kinsman, 1964).</th>
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<tr>
<td>(a) Open sea</td>
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<tr>
<td>(b) Open sea coral reefs</td>
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<tr>
<td>(c) Tidal delta</td>
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<td>(d) Inner coral reefs</td>
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<td>(e) Mid lagoon</td>
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<td>(f) Inner lagoon</td>
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<td>(g) Creeks</td>
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<td>(h) Pools on algal flats</td>
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Figure 3. Map of the Holocene marine facies of Abu Dhabi, UAE.

Figure 4. Aerial Photograph of the area to the south west of Abu Dhabi showing the morphology of the barrier islands and ancient beach ridges.
THE SETTING OF THE COASTAL DUNES OF THE U.A.E.

The coastal dunes of the U.A.E. are part of a coastal complex of the different depositional systems (Figure 3) that are prograding over seaward carbonate shoals (Evans, Kinsman, and Shearman, 1964; Kendall and Skipwith, 1968; and Purser and Evans, 1973). Numerous tidal channels dissect the region (Figures 3 and 4) and its seaward edge is marked by coral reefs. The seaward margins of the barrier islands accumulate sediment, which initially forms on the ebb deltas to the beaches and the adjacent coastal dunes (Figure 5). These barrier islands and shoals in turn protect a series of sheltered saline lagoons (Purser and Evans, 1973). To the west these lagoons are less protected (Kendall and Skipwith, 1968). Here the Khor al Bazam, the largest lagoon of the U.A.E., is 130 km long and is lined by shallow coastal terraces that are from 0.5 km to 8 km wide and covered by thin veneers of sediment (Figure 6). Seaward these platforms are often underlain by cemented Pleistocene windblown sediment (miliolite) while landward they are often composed of wave cut Holocene beachrock pavements. Linear beaches and coastal spits characterized by beach faces, berms, vegetated dunes (Figure 7) and cliffs occur in the more exposed portions of the intertidal/supratidal boundary of the platform (Kendall and Skipwith, 1968).

On the protected parts of the coast algal mats and landward accumulations of gypsum and anhydrite commonly accrete and prograde across the upper part of the wide tidal flat that flanks much of the U.A.E. coastal sabkha (Kendall and Skipwith, 1968) (Figures 8 and 9). This sabkha is composed of carbonates and evaporites that commonly characterize the coast of the mainland coastal plain (Figure 5). The sabkha extends from the high-water mark, inland to the alluvial fans skirting a low escarpment of Miocene rocks that reach the coast in a series of northwest-southeast-trending elongate spurs. Alluvial fans of outwash sediment often lacking vegetation surround the bases of the hills and stand slightly above the general surface of the coastal plain (Figure 6). Where the escarpment of Miocene rocks occurs near the coast, they merge with the beach ridges and sometimes become cliffs.

COASTAL DUNES, VEGETATION COVER AND MICROCLIMATIC CONTROLS

As indicated in the previous sections there are at least two types of coastal dune common to the coasts of Abu Dhabi in the western U.A.E. These are:

1. Subaerial dunes greater than 5 m. in height that are adjacent to steep beach faces and berms associated with the higher energy conditions north of the barrier islands of Sadiyat, Abu Dhabi and Halat al Barani. Sediments feed these beaches and dunes from an adjacent narrow shelf which is subject to sporadically heavy seas when the shamal winds blow. The dunes are in turn fixed by Salicornia sp (Figure 1). However if these dunes are traced landward the vegetational cover gradually disappears within a few hundred meters (Figure 5).

2. Small subaerial dunes, 1 to 2 m. in height landward of the small beach ridges of the exposed coasts of western Khor al Bazam which are common at the landward edge of the intertidal platform. As with the large dunes, these small dunes are commonly fixed in place by Salicornia sp. and as in the case of the larger dunes associated with the barrier islands their vegetational cover gradually disappears within a few hundred meters (Figures 4 and 7).

The pattern of vegetation cover reflects the local microclimate coinciding with the distribution of the diurnal dews associated with moisture brought inland from the humid Arabian Gulf by the late afternoon and evening onshore winds described earlier (Kendall and Skipwith, 1969; and Ministry of Water, Oman 1995).

The dews lose their intensity and eventually disappear landward across the dune belt, and this decrease in precipitation is matched by a loss of the vegetation cover found close to the coast. The result is that the vegetation dies as the coast progrades seaward and the microclimate changes.

As suggested by Patterson and Kinsman (1981), and Kirkham (1997), the evolution of the U.A.E. Coast began some 4000 to 3000 BP. Tracing the evolution of the area south of Sadiyat, Abu Dhabi, Halat al Bahraini, and Abu Al Abyad the lagoons appear to have been deeper and consequently the wave energy expended in them was greater than today. The coastal sabkha is rimmed by un-vegetated stranded beach ridges which have a relief of about a meter above sabkha and often occur landward of the algal flats and their associated evaporates (Figures 4, 8, and 9). These beach ridges developed during the early stages of the Holocene, when the western U.A.E. area of the Khor Al Bazam and portions of the lagoons to the lea of Abu Dhabi island were actually open bodies of water, subject to higher wave energies than today.
Figure 5. Block diagram of the seaward margin of the barrier islands of the eastern U.A.E. showing the distribution of the larger dunes and their vegetation cover.

Figure 6. Block diagram of the eastern end of the Khor al Bazam (western Abu Dhabi) showing the distribution of algal flats, sabkha, stranded beach ridges and the adjacent Tertiary hills.
Figure 7. Block diagram of the western end of the Khor al Bazam showing the distribution of the small dunes and their vegetation cover lining the beach line and the adjacent tidal flats.

Figure 8. Map of the eastern end of the Khor al Bazam with algal flats and stranded beach ridges.
Figure 9. Block diagram of the eastern end of the Khor al Bazam showing the distribution the wide tidal flat, their algal mats, surface and nearsurface character and relationship with the stranded beach ridges from an earlier coastline and their lack of vegetation cover.
The result is that chenier-like beach ridges formed of cerithid gastropod debris lined the coasts some 3000-4000 years BP (Patterson and Kinsman, 1981; Kendall and Skipwith, 1968 and Kirkham, 1997). Subsequently, the lagoon margins filled, shallowed, became more restricted, and the beach ridges ceased to develop. On the protected coasts of the inner lagoons, intertidal algal mats began to form while shallow offshore just subtidal sands or muds accumulated. These algal stromatolites and their associated evaporite cover have prograded five to six kilometers seaward encroaching on the inner coastal lagoons since 3000-4000BP (Figures 4, 8 and 9).

Landward of the beach ridges, early Holocene aeolian carbonates have accumulated and sediments have washed out as fans from Tertiary outcrops (Figure 6). On the landward side of the sabkha, particularly within the sabkhas close to the Abu Dhabi Island, the anhydrite layers and nodules are replaced by gypsum. This replacement is a response to the influx of the fresher continental waters from the Arabian interior entering the coastal system (Patterson and Kinsman, 1981).

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REFERENCES


CONCLUSIONS

This paper records how diurnal dews support coastal vegetation. These dews, reflecting the local microclimate, die out landward across the dune belt, and are matched by loss of vegetation. When this happens deflation of the dunes occurs and we contend that nature and man will cause the fill of the coastal waters. As this occurs so the current vegetation belt will move seaward paralleling the current coastline. Finally as the population and the economy of the U.A.E. change so will the natural landscape and vegetation cover.


