Historical Development of the Port Royal Mangrove Wetland, Jamaica

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ABSTRACT


Studies on the historical development of mangrove wetlands are rare in contrast to the vast array of information on the geological development of these systems. Historical development of the Port Royal mangal was investigated so as to improve understanding of recent changes occurring in relation to the increasing threat of sea level rise to their existence. The historical development of the Port Royal mangal, Jamaica, began with the first documented spatial record for the area in 1692 and traced to 1991 using historical maps and aerial photographs. The mangrove system is a fringe mangrove community type, composed of primarily Rhizophora mangle L. located along the northern shore of the Palisades, which is a composite tombolo on the south coast of Jamaica. A general trend was determined for the morphology of the mangal which showed relative stability, displaying little significant variation in its areal extent over a period of 300 years. The horizontal extension by colonizing mangroves has not been significant, with forested areas being restricted to sharply defined geomorphological units, probably because of the response of the system to a combination of factors. These include: i. a small tidal range; ii. geomorphology of the system; iii. a lack of large sediment inputs and iv. episodic events such as hurricanes. This stability of the Port Royal mangrove system is atypical of the understanding of development of these wetlands, which has been accepted to be a constant state of migration or movement. The stable trend of this mangrove system has implications with regard to its response to occurrences such as sea-level rise. Coastal wetlands of this type will probably experience complete collapse when sea levels begin to rise.

ADDITIONAL INDEX WORDS: Mangroves, geomorphology, sea-level rise, Jamaica.

INTRODUCTION

Previous studies on the development of mangrove forests have often assumed a successional model following a distinct zonation from sea to land with vegetational changes continuously taking place along the areal extent of the ecosystem. The work of DAVIS (1940), a classical view of mangrove development in Florida, described the geologic role of mangroves as land builders through sediment accumulation and colonization. The vegetational model was based on a Clementsian pattern of seral stages of succession where each stage was represented as a distinct monospecific zone in the mangrove forest. The most seaward zone would be dominated by the “pioneer stage” and be represented by Rhizophora mangle. Further inland, it was inferred that the relationship between the vegetation and sediment accretion would promote succession since geomorphic conditions would be actively changed by the plants themselves. Thus the pioneer community would be replaced by a secondary community, which in time would be replaced until a climax community was finally achieved, a terrestrial forest. Since each zone was understood to be a progressively later stage in the succession model, the entire system was believed to be constantly moving seaward.

However, EGLER (1952) and THOM (1967) successfully challenged the concept of seral succession in mangroves, limiting it to a particular geomorphic condition. This condition occurred where the shoreline was prograding, such as that of some salt marshes described by CHAPMAN (1960), where the vegetation did promote rapid sediment accumulation and the increase in sediment levels promoted further successional changes. Egl er (1952) demonstrated that in some cases the mangroves in Florida were migrating inland rather than seaward as a response to rising sea level. Egl er (1952) and Thom (1967) both suggested that these mangroves were responding passively rather than actively to geomorphic processes. Vegetational changes within tropical deltaic-estuarine environments were regarded as being the passive response of the plants to habitat changes induced by geomorphic processes, such as sedimentation and subsidence (Thom, 1967). This geomorphological approach to mangrove distribution focused on the plant responses to geomorphologic processes and conditions. Thom et al. (1975) further illustrated this approach in a study of the Cambridge Gulf-Ord River region of Western Australia, in which the variety of mangrove habitats was related to sediment complexes. Stoddart (1980) also suggested that the opportunistic pattern of mangrove development could be a response to substrate topography, as was the situation of mangroves colonizing old reefs tops. More recently, Woodroffe (1982) extended this concept to the

95158 received 12 November 1995; accepted in revision 28 February 1997.
mangrove colonization of the Cayman Islands, where the development and geomorphology of the mangrove swamps were controlled principally by the relationship between land and sea during Holocene submergence. As a result of submergence, terrestrial environments which became inundated and offered ideal wave and current conditions for colonization by mangrove seedlings, were invaded by mangroves migrating inland.

STODDART (1980) demonstrated through the mapping of the development of mangrove islands on old reef tops in Australia, that the extent of mangroves in the Low Isles area increased from 27 ha to 36.5 ha over a 44 year period. But it was also shown that other mangrove islands within the study area had remained constant over the same time period. If mangrove communities are responding to different environmental conditions, it is important in order to accurately predict future responses, that a better understanding of historical changes be obtained. Most studies of mangrove development have concentrated on the evolution of these systems over geologic time. Historical studies involving shorter time intervals have been rare. The purpose of this study was to investigate the configuration and speed of development of a mangal ecosystem using historical records for the last 300 years.

**AREA OF STUDY**

The Port Royal mangal (76° 49’W, 17° 56’N) has been described as a fringe mangrove community type (ALLENG, 1990) following the classification scheme of LUGO and SNEDAKER (1974). The system is located on the northern shore of the Palisadoes Spit (Figure 1) which forms the southern boundary of Kingston Harbour on the south coast of Jamaica. CHAPMAN (1939) and STEERS (1940) have suggested that the spit was formed by the coalescing of several cays through littoral drift. The cays according to GOREAU and BUREK
Development of Mangroves in Jamaica

Figure 2. (a) A map of the harbour of Port Royal in Jamaica (Gascoigne, J. 1728). (b) A plan of Kingston Harbour (Unknown, 1780). (c) A map of Port Royal (Unknown, 1780).

Figure 3. (a) Trigonometric survey of the channels heading to Port Royal, Kingston (Unknown, 1824). (b) British Admiralty Chart, G. Stanley, 1873-74. (c) British Admiralty Chart, J. Combe, 1914.

(1966), seem to have been built upon the limestone erosional residuals of an old Pleistocene surface. More recently, the spit has been determined to be a composite tombolo in accordance with the tied-island theory (HENDRY, 1979). It has been dated to be post Pleistocene.

Colonization of the tombolo by wetland vegetation is not known but probably took place during Holocene submer-

gence. The wetland consist of a fringing mangrove forest which is bordered on its southern flank by a terrestrial thorn-scrub association of acacia and cactus. The distribution of the mangrove vegetation differs from that of the monospecific zones described by DAVIS (1940) and CHAPMAN (1944), where each mangrove species dominates a clearly defined zone. In the Port Royal area there are only two distinct monospecific zones which have been identified, a fringe Rhizophora mangle.
zone bordering the edges of all water bodies in the wetland and a narrow transition zone of Conocarpus erectus which separates wetland from terrestrial forest (Alleng, 1990). In between these two zones are extensive areas of mixed mangrove forest similar to that described by Woodroffe (1982) for Grand Cayman Island. Some of these mixed areas are dense thickets of small Rhizophora mangle, Avicennia germinans and Laguncularia racemosa trees and is comparable to areas described in Puerto Rico (Cintron et al., 1978) and Grand Cayman (Woodroffe, 1982).

The associated lagoons of the mangrove forest display marine conditions (annual average range 28–35 ‰) with little diurnal change (average diurnal variation <1 ‰). There are no freshwater inlets issuing into these lagoons from the landward side of the wetland, resulting in a low sediment load of the waters within the lagoons. However these lagoons can at times display brackish or hyposaline conditions and high sediment levels. Salinities can reach as low as 10.9‰ (Siung, 1976). These low salinities only occur during extreme rainfall events when runoff from a large river along the north-western boundary of the harbour apparently affects the system. Normally, discharge from this river system is directed out along the western end of the harbour, by-passing the Port Royal mangroves (Goodbody, 1989a). The episodic events, including hurricanes, are considered to be an integral part of the ecology of the mangal and may be a limiting factor to the growth and development of the forest. The frequency of hurricanes affecting the area parallels the time it takes the mangroves to mature (Lugo and Snedaker, 1974; Alleng, 1990) and thus limits structural development of the forest. The mean tidal range for the Port Royal area has been given as 20 cm with a spring range of 27–30 cm (Chapman, 1944) and an extreme range of 90 cm (Goodbody, 1970) or 24 cm with an extreme spring range of 87 cm (Goodbody, 1989b). The later figures from Goodbody (1989b) were used in this study.

**METHODOLOGY**

An attempt was made to determine the historical changes in the geomorphology of the Port Royal mangal. The data sets used for this process consisted of: a) old maps and nautical

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**Table 1. Changes in areal extent of mangrove forests in the western sector of Port Royal, 1954–1991.**

<table>
<thead>
<tr>
<th>Year</th>
<th>Gallows Point</th>
<th>% Change</th>
<th>Refuge Cay</th>
<th>% Change</th>
<th>Cemetery Area</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1958</td>
<td>30.38</td>
<td>-1.8</td>
<td>1958</td>
<td>—</td>
<td>—</td>
<td>1958</td>
</tr>
<tr>
<td>1968</td>
<td>31.48</td>
<td>+1.9</td>
<td>1968</td>
<td>8.94</td>
<td>+33.0</td>
<td>1968</td>
</tr>
<tr>
<td>1986</td>
<td>30.99</td>
<td>+0.3</td>
<td>1986</td>
<td>7.91</td>
<td>+17.7</td>
<td>1986</td>
</tr>
</tbody>
</table>

- Data not available
charts of varying scales and dating from 1692–1970. A plan-variograph (R. & A. ROST 19514) was used to enlarge some of the maps and charts in order to bring them to a common scale. b) Aerial photographs taken in 1958, 1968, 1986 and 1991. A Vertical Sketch Master (Ryker Model L-1) was used to transfer data from the aerial photographs to base maps (scale 1:10,000). A hand-held stereoscope was used in the analysis of stereoscopic pairs of aerial photographs.

The datasets were used to determine the changes over time in the areal extents of forested areas, zonation, die-back and lagoon areas. A planimeter (Model K&E 620002) was used to measure areal extents. However this proved to be difficult for many of the older maps and charts because of an inherent inaccuracies, and also distortions after the enlargement to a common scale. In spite of this, it was possible to determine general trends.

The bathymetry of the lagoons between the forested areas was investigated using a Fishray radar gun mounted behind a small boat. A total of 20 transects was sounded in the lagoons and the results compared to British Admiralty Chart 456. Salinity readings were taken in the lagoons using a hand-held refractometer.

RESULTS

The historical development of the Port Royal mangal is divided into two sections based on the map material.

Early development

Some of the earliest maps of the Port Royal area are shown in Figure 2. These represent the late 17th Century to early 18th Century period. The earliest map of the area (1728) shows the town of Port Royal separated from the Palisadoes spit and a series of breaches in the eastern sector. These changes were due to a great earthquake which occurred in 1692. It also destroyed large sections of the town. However, it can be determined that the main mangrove areas north-west of the town, on the northern side of the spit, had already been established and easily recognizable, when compared to the present mangrove distribution as shown in Figure 1.

The 1780 maps show Port Royal reunited to the Palisadoes, which would have occurred sometime between 1728 and 1780. At the end of this period, the mangal is shown as a distinct fringe mangrove community type, developed along the northern sides of the spit. There are indications based on these records, that there have not been any macro-changes in the profiles of the main mangrove forests. Furthermore, the lagoons and channels separating these areas also display stability in their general shape and size. This trend continued throughout the late 18th century and into the late 19th century (Figure 3). The exception to this is the development of a lagoon on the southern side of the spit (1914 map). This was probably caused by the accumulation of sediment transported by longshore drift along the Palisadoes (HENDRY, 1979). The development of this lagoon took place between 1873 and 1914, under different conditions to the sheltered northern side of the Palisadoes.

Recent Development

Western Sector

The profiles of three major forested areas in the western sector of the Port Royal system are presented in Figure 4. They are overlain each other to form a matrix and represent a 37 year period of historical mangrove development. The physiography of these forested areas and water bodies separating them, indicate a general stability of the mangal. Table 1 gives the varying areal extents of the forests over the 37 year time period. There is no significant change in the areal extents over time, as any minute differences maybe due to inherent inaccuracies in the data sources, particularly the aerial photographs.


<table>
<thead>
<tr>
<th>Year</th>
<th>Area (ha)</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1958</td>
<td>1.03</td>
<td>0</td>
</tr>
<tr>
<td>1968</td>
<td>1.36</td>
<td>32</td>
</tr>
<tr>
<td>1986</td>
<td>4.29</td>
<td>317</td>
</tr>
<tr>
<td>1991</td>
<td>4.26</td>
<td>314</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Year</th>
<th>Area (ha)</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1958</td>
<td>6.46</td>
<td>0</td>
</tr>
<tr>
<td>1968</td>
<td>5.81</td>
<td>-10.1</td>
</tr>
<tr>
<td>1986</td>
<td>4.71</td>
<td>-27.1</td>
</tr>
<tr>
<td>1991</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

- Data not available
But there have been micro-changes taking place within these forested areas. There has been the rapid development of a large salina or salt flat in the north-western sector of the Gallows Point area. When this area was first formed is not known, but it appears on the aerial photographs taken in 1958. It was once covered by mangroves, based on the presence of dead, bleached mangrove tree trunks and some clumps of living *Avicennia germinans* L. trees. These mainly persist in the centre of the barren area. The salina is approximately 4.3 ha and is seasonally inundated, becoming dry during the drier months of the year (except for the central section), but completely inundated (<25 cm of water covers the surface) during the wetter months. The substrate is a peaty soil but firm enough to be walked upon, except close to the centre. Salinities of between 73 and 77%o were recorded at the edge of the central section in August 1989; surface water salinity of 37%o was recorded approximately 50 m off Gallows Point at the same time. It is estimated that the salina has expanded by approximately 300% between 1958 and 1991 (33 years), as a result of the dying back of trees on all margins of the salina.

In addition, there is another salina located southeast of this area, which is also displaying a similar tendency of expansion through the dying back of trees. During the same time interval (1958–1991), its area increased by approximately 100%. The formation of these barren areas or salinas within the forest, may suggest the maturation of the system. A similar situation has been reported by BACON (1970) in the Caroni Swamp, Trinidad, who suggested that these bare areas were a natural stage in the succession from soft mud to consolidated sediment.

**Central Section**

The central section or Rose’s Hole Lagoon of the mangrove system also displays the general stability of its profile over an extended period of time, similarly to the western section (Figure 5). Table 3 provides an indication of the limited changes in the profile of this forested zone over a 28 year period. However, as with the western section, there have been micro changes. In its north-eastern end, a fringe of *Rhizophora mangle* L. died over the period of time, leading to the incorporation of a small lagoon with the waters of Kingston Harbour. The breaching of the fringe took place sometime between 1968 and 1986 and displayed a similar trend of the die-back phenomenon occurring in the Gallows Point area described earlier. In addition, this north-eastern edge of Rose’s Hole is showing signs of denudation which may be the adverse effects of reclamation in 1967. In time, the thin strip of mangrove may be removed. If degradation continues, it is likely that the main mangrove area may be cut off, creating an isolated mangrove island.

**Eastern Section**

The profile of the mangrove forest within the eastern section or Plumb Point Lagoon continues the trend of stability along its

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**Table 4. Changes in area extent of the mangrove forest at Plumb Point Lagoon, 1958–1991.**

<table>
<thead>
<tr>
<th>Year</th>
<th>Area (ha)</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1958</td>
<td>3.89</td>
<td>0</td>
</tr>
<tr>
<td>1968</td>
<td>8.1</td>
<td>+108.2</td>
</tr>
<tr>
<td>1986</td>
<td>7.68</td>
<td>+97.4</td>
</tr>
<tr>
<td>1991</td>
<td>7.39</td>
<td>+90</td>
</tr>
</tbody>
</table>
Figure 7. a–c Bathymetric profiles of the lagoons of the Port Royal Mangal.
outer margins, even though internally, there has been active expansion by red mangroves into small lagoon areas (Figure 6).

Table 4 shows that between 1958 and 1968, there was an initial increase in the forested area by approximately 100%, followed by a period of stability at this limit up to 1991. The increase was due to the filling of some of the small internal lagoons within the main sections of the mangrove forest. This resulted in an increase in the vegetation to water ratio of the forested area. However in comparison, there has not been any similar type of expansion of the mangrove forest into the larger Plumb Point lagoon, during the same period.

**Bathymetry**

The bathymetry of the lagoons shows the existence of relatively deep areas separating the forested islands (Figure 7.a-c). The gradients of these lagoons are steep, declining rapidly from the edges of the mangrove areas into deep water (5-13 meters). In addition there are no mudflats present along the edges of the forest. The bathymetric profile is corroborated with data obtained from the British Admiralty chart. These lagoons may represent former oceanic sides of developing spits (personal communication—M. Hendry, Coastal Geologist) as there are two shal areas north of Port Royal which possibly mark the former positions of the Palisadoes Spit (Goreau and Burke, 1966).

**DISCUSSION**

The development of a mangal is often determined to be the response of the ecosystem to geomorphic processes such as sea level fluctuation and sedimentation. Mangrove forests over time, are expected to extend their limits into landward zones in response to rising sea level or into seaward zones as a result of increased sedimentation. They may also contract in size in response to rising sea level, if the topographic setting presents a physical barrier to expansion, such as at the base of a cliff. The Port Royal mangrove system in its development over time does not display any of these responses but maintains a stable profile over a 300 year period.

The historical records from the Port Royal system indicate that there is a general stability in the morphology of the mangrove forest. This is atypical of the current understanding of the development of mangrove systems, as they are often considered to be constantly changing. As has been suggested by Thom (1967) and others, the growth and development of these ecosystems are determined by the influence of geomorphological processes. But this should also apply to situations where these processes are not as acute, such as in areas with a slow rate of increase of sea level or a low rate of sedimentation. In the Port Royal, this seems to be the situation, as there is a slow rate of mean sea level rise, 0.1 cm yr⁻¹ (Maul and Hanson, 1989) and a noted absence of large sediment inputs. This is reflected in the lack of any significant forward movement into the adjacent lagoons by the mangrove forest and absence of any landward shifting of the mangrove forest into the terrestrial thorn/scrub association. In addition to these elements, there are other negating factors such as the depth of the adjacent lagoons and the small tidal range which limits any expansion by prop root extension or fringes of colonizing trees because of the non-establishment of mangrove propagules. Episodic events such as hurricanes also hinder the growth and development of the mangrove forest.

The general stability of mangrove systems like the Port Royal area has implications on the response of these systems to occurrences such as sea-level rise. As these systems have developed and conformed to sharply defined geomorphological units and moderate coastal processes, it is expected that minor alterations to these conditions can have severe impacts on these ecosystems. There is the great possibility that there can be the complete collapse of the ecosystem, since there is very little space for inland migration. This would occur even if the rate of increase of sea level is slow. It is also expected that community changes within the forested zone would occur because of increased submergence.

Therefore it is recommended that more site specific, historical analysis of coastal ecosystems be undertaken, in order to greatly increase the accuracy of predictions of their responses to expected climatic change. There is the possibility that these systems will respond differently to changes because of the wide range of coastal and sedimentological processes and geomorph settings.

**ACKNOWLEDGEMENTS**

The author wishes to thank the following persons for their significant contributions to this manuscript. Dr Peter Bacon, Professor of Zoology, University of the West Indies, for advice and support in writing this paper; Jack Tynadle-Biscoe (professional photographer) for old photographs of the area; Hilary Baptiste, Institute of Marine Affairs, Trinidad and Tobago, for her cartographical work.

**LITERATURE CITED**


