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## THE CYCLE OF CASUARINA-INDUCED BEACH EROSION – A CASE STUDY FROM ANDROS, BAHAMAS.

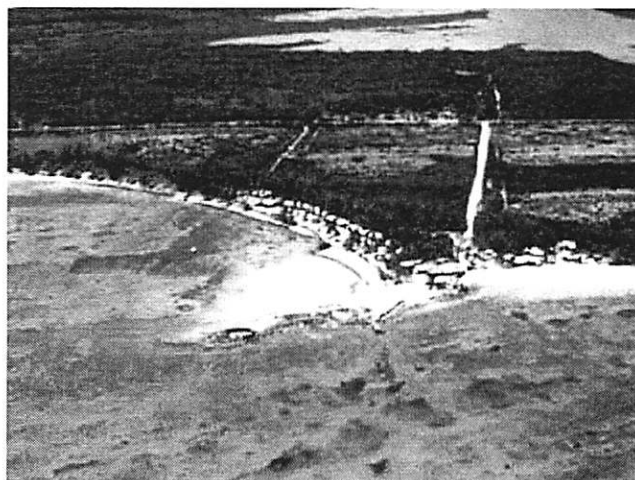
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### ABSTRACT

For decades, sand loss leading to beach erosion has been a problem in many parts of the Bahamas. After hurricane Michelle, immediate action was needed to protect property and maintain business at the Small Hope Bay resort in Andros. A study of the area from the air and on foot indicated long-term problems due to the unrestricted growth of casuarina trees. The specific role of casuarinas and other factors was evaluated under long-term seasonal sea conditions as well as episodic storm events. Recommendations were made and implemented in order to stabilize the area. The use of gabions as a first line of defence was rejected. Dune reconstruction and reinforcement was undertaken to a limited extent. A cycle of casuarina-induced beach erosion is proposed and illustrated. Follow up visits in 2003 and 2004 suggest the cycle is progressing as predicted to the south, while remedial measures are being undertaken to the north.

### INTRODUCTION

Small Hope Bay is located north of Fresh Creek, Andros, on a small low headland with a sandy foreshore extending north and south (Figures 1 and 2). Reports of erosion in this area, and specifically at the hotel property, had been recorded some years before, but after hurricane Michelle in 2001 the situation became critical. As a result of extensive sand loss and damage to buildings it was proposed to construct some form of protection immediately in front of the dining



*Figure 1. Aerial view of Small Hope Bay Resort Andros, looking west, with wooden dock projecting from rocky point. Note groyne to left of point.*

hall, and to undertake longer-term restoration and protection of the area.

### OBSERVATIONS

The site was visited in May 2002 and inspected from south to north. The southern section extending away from the property was a narrow beach area littered with fallen casuarinas and other trees, mainly coconut, whose roots pretty much extended to the shoreline (Figure 3). The shoreline in front of the resort's cabins consisted of a number of small bays separated by a short groyne that had clearly been in place for some years (Figure 4). This area was separated from the northern section by a rocky point from which a wooden dock had been extended, and be-

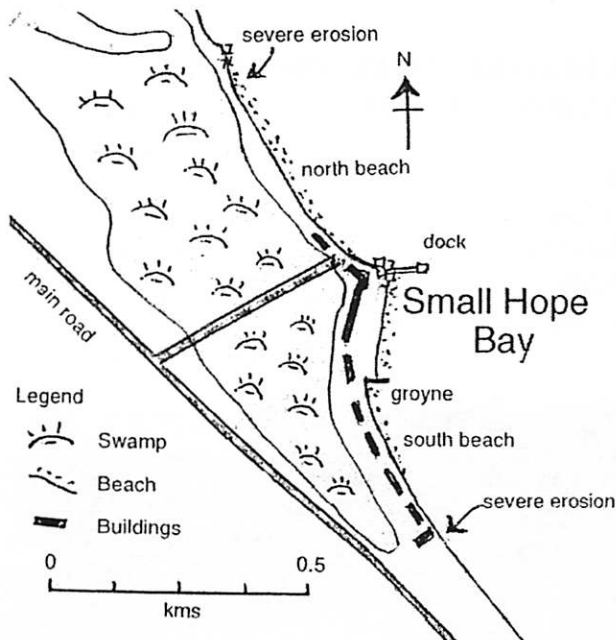


Figure 2. Location map showing basic features of Small Hope Bay area.

hind which the main facilities of the resort were located. It was this area that received the heaviest damage. The northern section consisted of a fairly wide beach, but this beach was itself divided according to the landscape immediately behind it.

The first part fronted buildings and suffered severe erosion with sand being lost behind the buildings and in the car park and approach road. North of this area was a short section backed by smaller buildings set well back from the shore and also a line of natural but eroded sand dunes. The remainder of the beach extending about a kilometre to the north was backed by mature casuarinas, although at the furthest extremity erosion had caused the collapse of a number of trees (Figure 5). This section terminated at a rocky headland.

#### EROSION AND REMEDIES

The presence of the groyne indicated that earlier erosion had been addressed. Despite this the buildings in this area are threatened, and the collapse of the casuarinas immediately south shows that beach retreat is progressive in this area.

The proprietor's response was to add to the



Figure 3. Critical erosion south of resort, beach has effectively been eroded away.



Figure 4. Erosion south of old groyne fronting cabins. This groyne is longer than the others and has been effective in trapping sand.

groyne, which indicate modest longshore drift in a southerly direction. However this was not recommended as it would starve other areas of the resort from much needed sand and it would not address the root of the problem, which is chronic sand loss.

In the critical area in front of the main facilities it was proposed to build a sea wall comprised of gabions. This was strongly advised against and the idea has since been abandoned. Gabions are only suitable in the absence of wave action, such as training walls along river banks. Where they have been installed as sea defences at several places in New Providence, Abaco and

Eleuthera they have totally failed to prevent erosion and have contributed to further sand loss as well as becoming dangerous objects in themselves. Ultimately gabions in stainless steel baskets were used as anchors for rebuilt dunes in the most heavily eroded areas, and an attempt has been made to plant native dune vegetation on the new dunes. In themselves these are unlikely to withstand heavy wave action, nor are they likely to build up naturally due to the present lack of sand supply. Despite this, it is a constructive step, and in conjunction with casuarina removal will aid in the stabilization of the shoreline (Figure 6).



*Figure 5. Main area of beach erosion north of resort.*



*Figure 6. Rebuilt sand dune with young vegetation showing resistance to summer wave action.*

Ultimately the evidence suggests that the entire area is suffering from permanent sand loss induced by uncontrolled casuarina growth along the shore. Restoration of the beaches and sand dunes will require the removal of all the casuarinas and the replanting of native species to trap the sand. Solid material, if used to anchor rebuilt dunes, would stabilize them in the early stages, and relatively cheap material, such as chopped down casuarinas, would be adequate. The gabions used here should also work but seem an expensive and unnecessary solution. Similarly buttressing the rear of rebuilt dunes would be worthwhile, and this has been done successfully with concrete walls in New Providence at the Poop Deck property at Delaporte, which has a similar narrow width of beach with which to work. Vigilance will be needed to prevent the rapid resurgence of casuarina growth.

In order to better understand the role of casuarinas in beach erosion, a cycle of erosion based on the Small Hope Bay situation was developed as a hypothesis for casuarina-induced beach erosion.

#### THE CONCEPT OF CASUARINA-INDUCED BEACH EROSION

Consideration of the processes around the Small Hope Bay Resort ultimately focuses on the role of the casuarina as an agent of erosion. Examination of the various shorelines on Bahamian islands over many years has confirmed that this is not a unique situation. Particularly telling are those sites where casuarinas do not dominate the shore but occur in clumps interspersed with the native vegetation. In these cases there is evidence of significant sand loss from the top of the dune, or a complete breaching, where the casuarinas are growing, but only in these locations. Visits after storm events also show considerable dune and beach retreat at the casuarina locations whereas the naturally vegetated dune has remained intact. Specific examples of this phenomenon have been identified at Staniel Creek, Andros; Windermere Island, Eleuthera; and Paradise Island, Nassau.

The idea of dunes destroyed by interference with the native vegetation is not at all new, and a classic study directed by Paul Godfrey demonstrated how the huge roving naked dunes of Cape Cod became that way after their forest of beech and maple had been stripped (reported in Kaufman and Pilkey, 1979).

As there is clearly a pattern to this erosion, repeated wherever the casuarinas occur, it prompts comparison with the general model of beach/dune recovery reported for the Bahamas, and specifically for East Beach on San Salvador (Beavers et al., 1995; Brill et al., 1993; Anderson and Boardman, 1989). Bahamian beaches will generally prograde if the sand supply is not interrupted, although it is recognized that dunes themselves "are not static, rigid, permanent structures" (Bush et al., 1996). The casuarinas disrupt the natural process, and as their impact is consistent and predictable it can also be viewed as a model, in this case in the form of a cycle, because the process does not end, but continues the process of erosion indefinitely by eating back into the land, and with changing sea level will return to do the same again.

Conditions along the North Andros shoreline are fairly representative of east-facing shorelines on many other islands, and certainly favour the process reported here. It is likely that the whole Andros shoreline at Small Hope Bay (and indeed much of the North Andros shoreline from Morgan's Bluff to Cargill Creek) has resulted from the evolution of an offshore ridge which ultimately created a mangrove swamp in the shallow lagoon behind it (Love and Boardman, 1991). This type coastal development is common along the eastern shores of Bahamian islands, and has been recorded for Long Island and San Salvador (Mitchell and Keegan, 1988; Anderson and Boardman 1989), and New Providence (Sealey, 1994).

Nevertheless any beach/dune system in the Bahamas is vulnerable to casuarina invasion, and this will be vigorous and overwhelming ('infestation' is commonly used to describe the impact) if there has been major disturbance to the land, such as site clearing. Consequently it was decided to outline the stages of this Cycle of

Casuarina-Induced Beach Erosion (Figure 7) by way of a schematic set of stages, each one matched to their presence at Small Hope Bay. If casuarinas are present along a sandy shoreline the stage in the cycle can be identified and therefore the future erosional history of the beach can be forecast.

## THE CYCLE OF CASUARINA-INDUCED BEACH EROSION ( FIGURE 7)

### Stage 1

This represents the first stage of the cycle, prior to casuarina invasion. There is only a small portion of this stage left at Small Hope Bay, just south of the main buildings (Figure 7).

### Stage 2

In times of heavy seas the beach sand is washed offshore and the front of the sand dune eroded. As the sand is merely moved out into the bay it returns with the resumption of seasonal weather, and is again fixed in the dune by native species of dune vegetation, and the beach is thus built up by normal wave action. Within as little as a season, or as long as several years, the original profile will be regained and transport of sand from the sea bed to the shore will be resumed. With abundant vegetation the sand is trapped and with the aid of the wind the beach may be progressively widened. Long term monitoring of East Beach on San Salvador by various researchers on San Salvador (Beavers et al., 1995; Brill et al., 1993) shows how a well-vegetated dune encourages prograding, and an annual addition of some 10 000 cu metres of sand per kilometre of beach has been calculated (Anderson & Boardman 1989; Beavers et al., 1995). Recent studies indicate that progradation continues up to the present time, despite beach erosion from hurricanes Lili and Floyd in the intervening years (Godfrey, Paul, pers. comm. 2003) (Figure 8).

CYCLE OF CASUARINA-INDUCED BEACH/DUNE EROSION

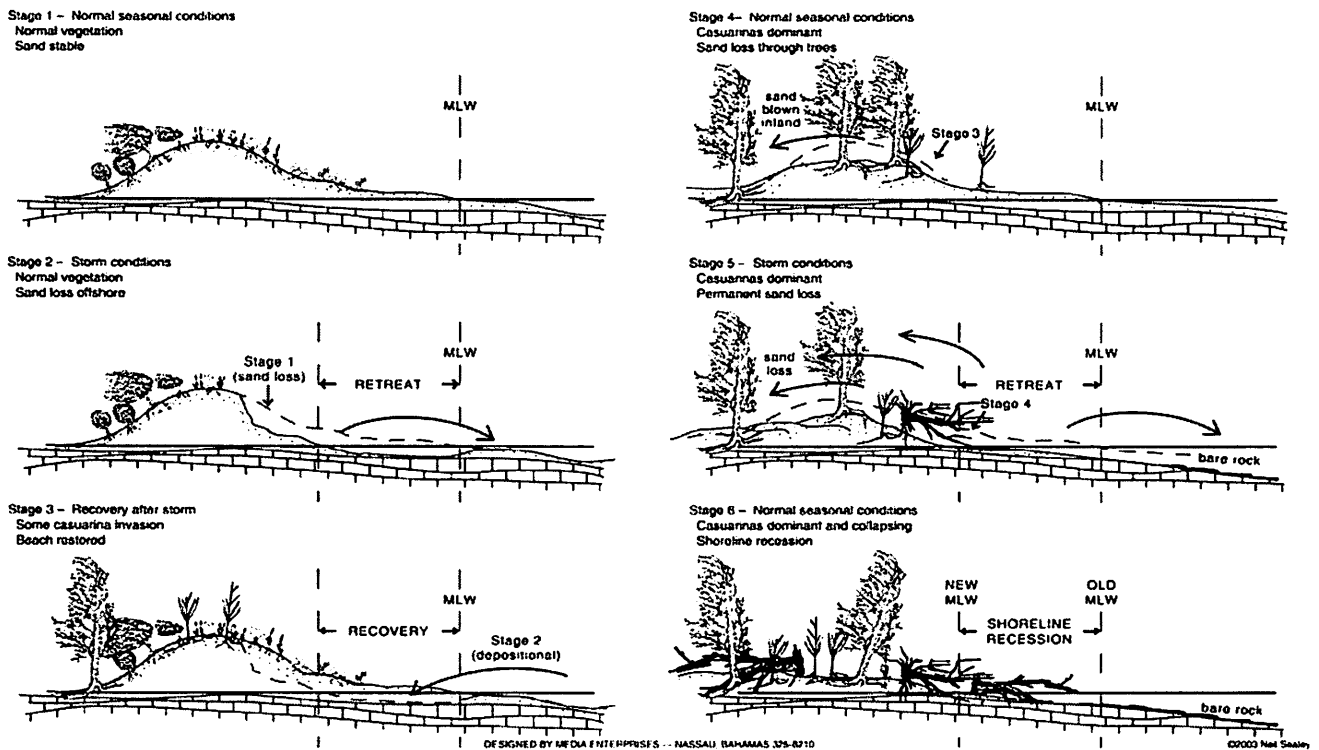


Figure 7. The six stages of the Casuarina-Induced cycle of beach erosion ending in the perpetual state of continued beach recession.

Stage 3

With the introduction of casuarinas after recovery from storm damage some of the dune vegetation is lost due to competition for nutrients in this nutrient poor environment, and from being shaded out by the tall trees. In addition the litter of branchlets further inhibits the growth of young plants by smothering them (Hammerston 2001). There is also some evidence of a toxic effect from the root system and/or the decaying plant litter (Craig, 1978). Whatever the exact cause, the result is that casuarinas start to dominate the beach vegetation. With severe beach erosion during a storm the dune is now less able to recover its natural vegetation and the casuarinas rapidly gain a commanding foothold.

Stage 4

This is a quiet stage as far as beach devel-

opment is concerned. Normal seasonal weather will not impact the beach adversely, but the stage is being set for later destruction. Casuarinas now rapidly take over the dunes and suppress the natural vegetation, completely covering the floor with their twiglets, and leaving only a fringe of native pioneer plants along the exposed foreshore. The dune is now somewhat flattened and dominated by casuarinas. Sand blown up from the beach between tides tends to be carried through the casuarinas instead of building up vertically, hence the flattened effect (Figure 9).

Stage 5

Stage five results from the first severe storm after the takeover by casuarinas. Waves strip down the beach and pound the dune but the dune is now lower and consists of bare sand dominated casuarina trees. As well as sand being washed offshore, and there will be much more of



Figure 8. East Beach and dune on San Salvador, July 1990. Note absence of casuarinas.



Figure 9. Northern beach with absence of ground cover and generally flattened profile.

it exposed to wave action than when covered by native plants, the sand will also be washed through the trees and end up behind them. The result is the total removal of the dune system and the familiar exposure of casuarina roots. This is the situation all along the southern section of

beach at Small Hope Bay, and also why the sand was washed through the buildings and access road during Michelle. Inspection of the casuarina stand north of the resort showed masses of sand carried through the trees and dumped in the swamp (Figure 10).

#### Stage 6

The critical stage six has now been reached for continued beach destruction. The sand from the dune has been taken out of the system and dumped behind the trees, in this case in the swamp. With the return of normal weather conditions there is a deficiency of sand to rebuild the beach to its former extent, and the beach retreats landward, threatening all behind it. This is the stage now existing at Small Hope Bay in most areas, with no dunes, and a retreating beach dominated by casuarinas. This can be a prolonged stage lasting as long as there is land left to be eroded. With each successive storm the beach shrinks until the casuarina tree line is reached, and fallen casuarinas lying in the sea are the hallmark of this stage, represented at Small Hope Bay by the area immediately south of the resort. Erosion does not stop at the tree line, but continues as the front trees are uprooted and washed away, only to be replaced by more sacrificial casuarinas (Figure 11).



Figure 10. Beach sand piled up at rear of belt of casuarinas on north beach.



## CONCLUSIONS

Contrary to some opinions, the casuarinas are not protecting the beach, and it is unfortunate that many people think so, including professional agencies. In recent years I have noticed a report recommending their planting on Windermere Island, Eleuthera (Anonymous report), and a further report for Stocking Island, Exuma, stating: "It should be noted that if the area was not planted with Australian pine trees the erosion would be must (sic) more severe." (Ocean Carabes, 2002).



*Figure 12. Detail of shoreline erosion in same area as Figure 11.*

casuarinas which will be quick to invade the disturbed areas.

Beach erosion is always due to sand loss in some form and can only be reversed by restoring or replacing the sand supply. Offshore dredging and beach sand stealing are clear causes for concern. Shoreline structures may cause beach erosion by redistributing sand, such as groynes which trap it on one side, or sea walls which deflect it offshore, or roads that truncate the dune system. Casuarinas and any other form of sand dune destruction will also cause sand to be lost from the system as described. This is widely recognized throughout the region, and reported particularly in south Florida and the Florida Keys (Craig et al, 1978). Casuarina-induced erosion is unfortunately endemic on many islands, and has been observed by the author on Abaco, Andros, Eleuthera, Grand Bahama and New Providence in particular, and gaining hold on most other islands, especially the more northern and wetter ones.



*Figure 11. Accelerated erosion with collapse of casuarinas and rapid shoreline regression, 2004.*

The Small Hope site was revisited in 2003 and 2004. Continued loss of the shoreline was evident, most notably to the south. In the space of 18 months there was evidence of as much as six metres of shoreline retreat judged by the position of trees now in the sea that were previously on the beach. (Figures 11, 12) This is despite the absence of abnormal weather conditions over the last two years. At the far end of the northern beach conditions were similar but less extreme. Mitigation had been achieved in two areas, the section of rebuilt dune and the area of north beach closest to the resort. In the latter area the proprietor had begun bulldozing the casuarinas and already native species were colonizing the exposed sand. Nevertheless vigilance will be required to uproot young

## ACKNOWLEDGMENTS

Much of the background to a study such as this owes a debt to many people over several years. I hope they will recognise their contribution and appreciate it. More specifically the study was prompted and aided by Mr. Jeff Birch the proprietor of Small Hope Bay Resort,

and while he did not always accept my reasoning he has been a willing collaborator in trying to understand the underlying causes for the damage at Small Hope Bay, and has undertaken a variety of measures that will be monitored over the next few years. My wife Dr. Kathleen Sealey contributed to the fieldwork and is responsible with Mr. Alex Alamo and Mr. Keith Bradley for starting a programme of beach profiling and monitoring. Drs. Paul Godfrey and Craig Edwards, long time research geologists on San Salvador, discussed the theory and added their considerable knowledge of beach processes to the study. Drs. Doug Gamble and R. Laurence Davis provided comments leading to a much improved text.

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