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C. John Burk
Smith College

H. Allen Curran
Smith College, acurran@smith.edu

Teresa M. Czerniak
Smith College

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Dunes and Vegetation: Natural Recovery on a Damaged Barrier Island

BY C. JOHN BURK, H. ALLEN CURRAN, AND TERESA M. CZERNIAK
Smith College
Northampton, Massachusetts

INTRODUCTION

THE VARYING CAPACITIES of natural systems to recover following man-imposed stress are topics of much recent concern. Barrier islands are believed to support ecosystems with extremely limited potential for direct restoration.[3] We have recently documented the natural development of two discrete dune systems on Portsmouth Island, North Carolina, after grazing animals were removed and human activities decreased.

The study area, Portsmouth Island, is approximately 10 km long and 2–3 km wide and is located on the Outer Banks of North Carolina at approximately 35° 04′ N latitude and 76° 03′ 30″ W longitude (Fig. 1). The Outer Banks are typical examples of the chain of barrier spits and islands which line the Atlantic coast of the United States from Massachusetts southward. While the origin and development of these structures has long been a matter of dispute, most coastal workers now recognize multiple causality for barrier islands, with the processes of spit elongation and segmentation and the submergence of mainland coastal ridges being most important.[7,8,14,17] Portsmouth Island may represent a primary Pleistocene-Holocene barrier (landward side of island) to which a prograding sand flat-beach zone has been added.[15] However, it has recently been suggested[13] that Portsmouth has widened soundward during Holocene time by progressive incorporation of flood tidal delta sediments onto the island. The exceptionally wide (up to 2 km) sand flat on the oceanward side of the island is subject to the effects of frequent oceanic overwash and tidal flooding.[9,10]

The Outer Banks north of Portsmouth Island have been managed by the National Park Service with extensive shoreline erosion control programs since the 1930's. A major part of the control programs was the construction of a continuous line of artificial dunes at the landward edge of the backshore zone.[4,5] Little artificial dune construction has been carried out from Portsmouth Island south, and on the lower portions of Core Banks workers have stressed the ability of grasslands to withstand and recover from perturbation, particularly oceanic overwash.[9,10]

Portsmouth has been characterized as the only unmanaged island on the Outer Banks presently "washing away".[9,10] A village was laid out on the island in 1753; through the 1850's this was the largest settlement on the Outer Banks with a human population of over 500.[1,2,6,18] Damage from over-grazing was observed as early as 1810 when a single inhabitant reportedly "of his own mark, Sheared 700 head of Sheep—had between two hundred and fifty, and three thousand head of cattle and near as many horses."[6] Heavy grazing continued until the 1950's.[10] Human population declined abruptly during and immediately after the Civil War, with the last year-round inhabitants moving from the island in the early 1970's.

ANALYSIS OF PHOTOGRAPHS

Analysis of aerial photographs shows adjacent to the Portsmouth Village area (Fig. 2) a series of vegetated linear dune ridges which have formed since 1945. In this year, a zone of unstabilized sand was present between the sand flat and the first vegetated ridge. Within a decade (Fig. 3a) this zone of unstabilized sand increased to a width of 126 m and in 1960 supported clumped rhizomatous perennial grasses, either salt meadow cord grass (*Spartina patens*) or sea oats, (*Uniola paniculata*)[1,16] By 1962 the area was characterized by a band of well-defined vegetated ridges (Fig. 3b) then 178 m wide. During the period 1962–68, development of the ridge series continued, extending a total of 232 m onto the sand flat from the 1945 vegetated ridge (Fig. 3b-c). A 1974 aerial photo (Fig. 3d) shows continued stabilization and enlargement of the ridges to a width of 282 m.

A second system of dunes has developed at the seaward (eastern) edge of the sand flat since 1962. Aerial photos through 1962 indicate only a single large dune, reportedly formed around a shipwreck,[20] which is evident on charts as early as 1890[19] and a band of smaller dunes intermittently present since at least 1945 along the edge of Ocracoke Inlet to the North. By 1968, a group of small separate dunes had developed between the shipwreck dune and the inlet and a single small dune had formed south of the shipwreck dune. By 1974, more extensive formation of small dunes had occurred both south of the shipwreck dune and north between that dune and the inlet, where a number of previously separate dunes had consolidated. Half (fifteen) of these dunes formed during the period 1962–68 and the rest between 1968 and 1974.

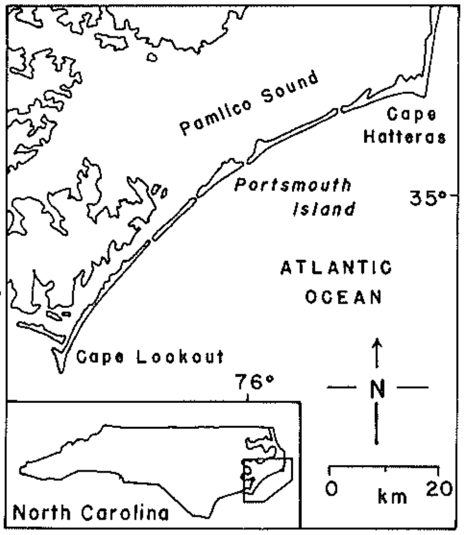

Fig. 1. Location of Portsmouth Island, northeast end of Core Banks on the North Carolina Outer Banks.

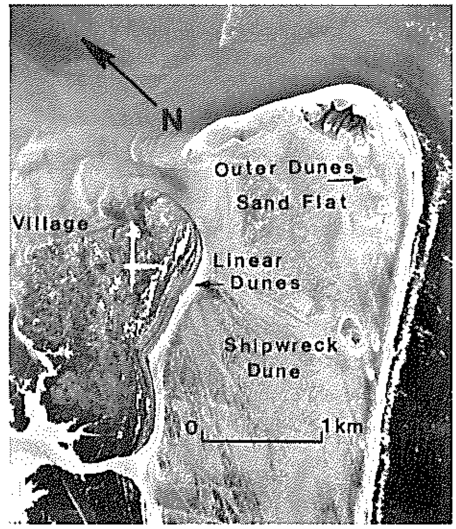

Fig. 2. North end of Portsmouth Island, significant features of the study area are labelled.

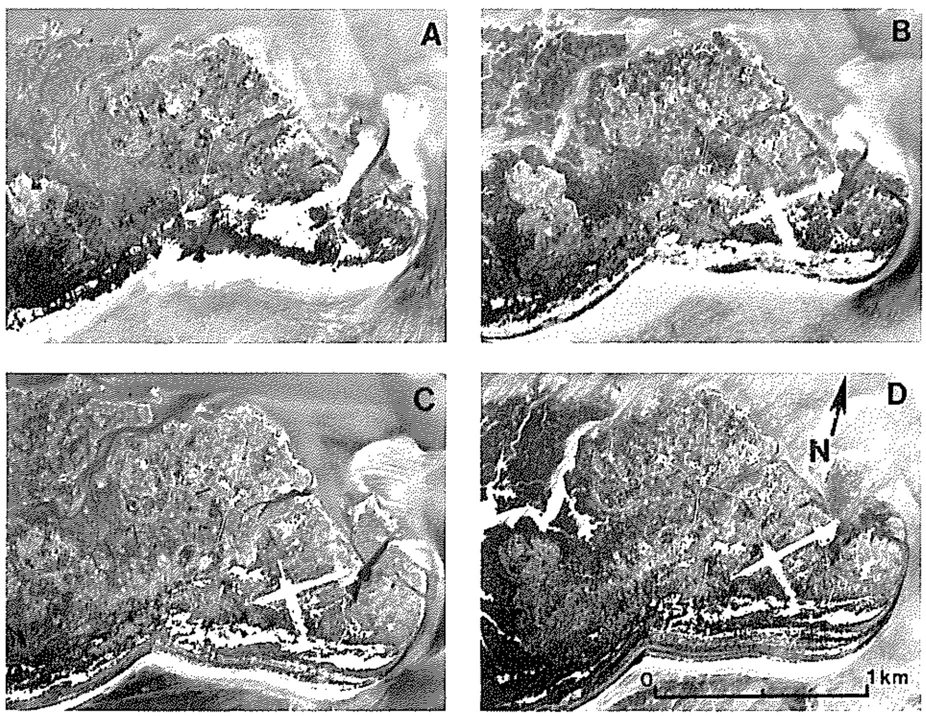

Fig. 3. Aerial photographs portraying development of the linear dune ridge system between 1955 and 1974; (A) 1955, (B) 1962, (C) 1968, (D) 1974.

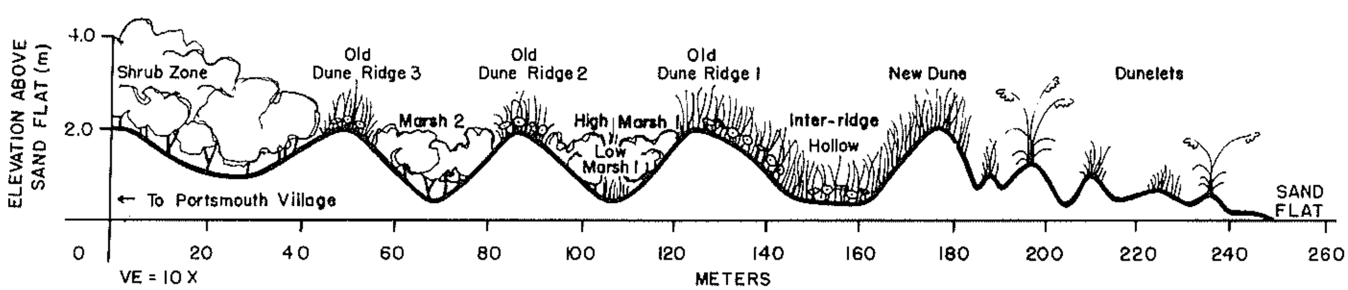

Fig. 4. Generalized transect across the linear dune ridge system to show vegetational succession that has accompanied development of the system between 1945 and the present. Plant species are identified in the text.

FIELD STUDIES

Linear Dune Ridge System

By summer, 1976, the vegetation of the series of linear dune ridges consisted of alternate bands of dune and marsh vegetation running from a group of dunelets, supporting clumped *Spartina patens* or *Uniola paniculata*, inland for over 200 m (Fig. 4). The vegetation forms a successional sequence in which a *Spartina patens* seaside pennywort (*Hydrocotyle bonariensis*) community develops and is replaced by shrubs with time and increasing distance of the community from the open sand flat (Table 1). We believe that the cessation of grazing and reduced human disturbance since the 1950's have allowed this process to be initiated and to continue to the present.

The zone of dunelets is marked by loose sand obviously reworked by wind and water and shows no ridge formation. The first ridge occurs approximately 60 m inward from the sand flat. Approximately 2 m high and less than 8 years in age, it is dominated by new growth of *Spartina patens*. Three older ridges, each also approximately 2 m high, occur between the first ridge and the area of shrub vegetation present in 1945. Ridges are separated by zones of marsh. *Spartina patens* and the rhizomatous sand-binding perennial herb *Hydrocotyle bonariensis* are dominant on all three older ridges, *H. bonariensis* reaching maximum coverage (42%) on the first older ridge and *S. patens* reaching maximum coverage (44%) on the second. These species are tightly associated, appearing together in 114 of the 180 quadrats sampled; indeed 87.6% of the quadrates containing *H. bonariensis* also contained *S. patens*. Diversity of vascular plant species increases from the zone of dunelets through Old Dune Ridge 2 and then declines. Total coverage parallels diversity, increasing from the dunelets to Ridge 2 and then declining (Table 1).

Spartina patens and *Hydrocotyle bonariensis* are also prominent in the marshes between the ridges. However, the shrub wax myrtle (*Myrica cerifera*) dominates two zones of high marsh on either side of a low marsh zone in the 8–14 year old interdune marsh and dominates the entire 14–21 year old interdune marsh. The oldest section of the transect is dominated by shrubs, *Myrica cerifera* and silverling (*Baccharis halimifolia*). The linear dune system has advanced seaward across the sand flat at an average rate of 8.1 m per year since 1955 and succession on the landward side of this, if uninterrupted, will advance to a forest type of vegetation. Various tree species including red cedar (*Juniperus virginiana*) and loblolly pine (*Pinus tadea*) are already well established in the Portsmouth Village area.

Seaward Free-standing Dune System

Regardless of their ages, dunes here less than 1 m high, with one exception, support one of the two rhizomatous grasses, *Spartina patens* or *Uniola paniculata*, which are also dominant in the zone of dunelets in the linear dune system. The exception, an anomalously large (796.7 m^2) dune while only 0.5 m high, supports both of these grasses, the halophytic forb sea-rocket (*Cakile edentula*) and a third grass, American beach grass, (*Ammophila breviligulata*). *A. breviligulata* reaches its southern limit of natural distribution near Nags Head in the upper portion of the Outer Banks but is widely planted within the Cape Hatteras National Seashore. To our knowledge, its occurrence on Portsmouth Island is not a direct result of human activity; *A. breviligulata* has been utilized in experimental plantings farther south on Core Banks.[20]

Formation of ridges has not occurred in this area. Diversity of vascular plant species increases on dunes higher than 1 m with increased age and basal area (Table 2). A clear pattern of invasion by plant species is evident. Either *Uniola paniculata* or *Spartina patens* plus *Cakile edentula* occur on all dunes which support 2 species, while 3-species dunes invariably support two rhizomatous grasses (*Uniola paniculata/Spartina patens* or in one instance *Uniola paniculata/Ammophila breviligulata*) and *Cakile edentula*. Dunes with more than three species support at least two

TABLE 1

APPROXIMATE AGE, AVERAGE PERCENT PLANT COVER, TOTAL NUMBER OF VASCULAR PLANT SPECIES SAMPLED, MEAN PLANT SPECIES PER QUADRAT, AND DOMINANT PLANT SPECIES OF 9 ZONES OF VEGETATION IDENTIFIED ALONG A TRANSECT (FIG. 4) CROSSING THE LINEAR DUNE SYSTEM ON PORTSMOUTH ISLAND, NORTH CAROLINA. AGES OF EACH ZONE OF VEGETATION WERE DETERMINED FROM AERIAL PHOTOGRAPHS. IN EACH ZONE, FIELD DATA ARE BASED ON TWENTY 0.25 m^2 QUADRATS PLACED AT INTERVALS OF 2 m PERPENDICULAR TO THE TRANSECT. COVER WAS DETERMINED BY A VISUAL ESTIMATE IN EACH QUADRAT.

Zone	Age (years)	Percent Cover	No. Species Sampled	Mean Species/Quadrat (±SE)	Dominant Species
Old Ridge III	14–21	54	10	2.9 (±.2)	*Spartina patens, Hydrocotyle bonariensis*
Marsh II	14–21	53	11	4.9 (±.3)	*Myrica cerifera, Spartina patens*
Old Ridge II	8–14	67	10	3.5 (±.3)	*Spartina patens, Hydrocotyle bonariensis*
Marsh I high zone	8–14	86	10	4.4 (±.2)	*Myrica cerifera, Spartina patens*
Marsh II low zone	8–14	77	8	5.0 (±.2)	*Hydrocotyle bonariensis, Spartina patens*
Old Ridge I	8	72	3	2.1 (±.1)	*Spartina patens, Hydrocotyle bonariensis*
New Inter-ridge Hollow	8	38	3	1.3 (±.2)	*Spartina patens, Hydrocotyle bonariensis*
New Dune Ridge	8	37	4	1.3 (±.2)	*Spartina patens*
Dunelets	8	7	2	.6 (±.1)	*Spartina patens, Uniola paniculata*

TABLE 2

AREA AND NUMBER OF VASCULAR PLANT SPECIES COMPRISING THE FLORA OF INDIVIDUAL DUNES GROUPED INTO HEIGHT AND AGE CLASSES ON THE OUTER DUNE SYSTEM OF PORTSMOUTH ISLAND, NORTH CAROLINA. APPROXIMATE AGE CLASSES WERE DETERMINED FROM AERIAL PHOTOGRAPHS. GROUND MEASUREMENTS AND FLORISTIC LISTS WERE COMPILED IN THE FIELD.

Height Class (m)	Age (years)	N	Area (m^2) Range	Area (m^2) Mean	Vascular Plant Species Present Range	Vascular Plant Species Present Mean (±SE)
<1	<8	7*	0.8–5.5	2.5	1	1(±0.0)
	8–16	4	3.5–24.2	9.7	1	1(±0.0)
1.0–1.9	<8	2	94.2–112.3	103.3	2	2(±0.0)
	8–16	4	43.2–345.6	145.8	2–3	2.5(±.3)
2.0–2.9	<8	4	84.8–589.0	334.8	3	3(±0.0)
	8–16	6	104.5–6662.2	1,495.5	2–18	7(±2.3)
3.0–3.9	<8	1	392.7	392.7	1	1
	8–16	1	3,771.1	3,771.1	11	11
4.0–4.9	86+	1	35,427.7	35,427.7	28	28

*Excluding one anomaly; see text.

rhizomatous grasses, *Cakile edentula,* and various salt-spray tolerant grasses and forbs or the shrub *Baccharis halimifolia.*

Three small dunes present in 1968 had fused by 1974 to form a single large dune (2.9 m high, basal area 6662 m^2) which supports 18 vascular plant species. This dune acts as a foredune protecting the shipwreck dune which has double peaks, 4.7 m high on the ocean side and 4.8 m high landward and includes marsh as well as dune vegetation. Although the elevations of the higher zones of vegetation on the shipwreck dune are more than double those of the ridges in the linear dune sequence, intermittent ridges and blow-out areas show no clear successional patterns. *Unola paniculata,* excluded from the linear dune system on ridges older than eight years, dominates the higher ridges of the shipwreck dune. The development and relationships of the shipwreck dune and its foredune suggest that an active dune-field with partial coalescence of the now scattered separate dunes may evolve with time in the outer dune sequence.

SUMMARY AND CONCLUSIONS

A system of linear dunes accompanied by an ordered pattern of vegetational succession has developed rapidly on Portsmouth Island, North Carolina, following removal of grazing animals and lessening of human activity on the island. Dunes also are developing rapidly at the seaward edge of the island, and increasing plant diversity on these dunes can be related to increasing dune height, age, and area.

The influence of storms on the recovery process is difficult to assess. The first half of the period 1945–1976 was marked by intense hurricane activity on the Outer Banks, the second half by very little. The destructive extratropical "Ash Wednesday" storm[21] occurred in March, 1962, shortly after the period of major hurricanes. Since the early 1960's, the duration and frequency of extratropical storms which produce high waves have increased, as well as the length of the winter storm wave season.[12]

Nonetheless the rate of growth of both dune systems and the degree to which vegetation has become re-established without human intervention suggest that Portsmouth Island possesses a greater natural capacity for recovery than previously thought. The appearance of "fragility" here and possibly on other barrier islands which are not subject to high rates of shoreline erosion may be a misleading artifact of intense disturbance related to overgrazing and human occupation.

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THE AUTHORS

C. JOHN BURK

Dr. Burk is a professor in the Department of the Biological Sciences, Smith College, Northampton, Massachusetts. His doctoral thesis, *A Floristic Study of the Outer Banks of North Carolina* was completed in 1961 at the University of North Carolina-Chapel Hill. Since that time he has conducted and directed research in various aspects of the ecology and floristics of wetlands and coastal areas of eastern North America. At Smith College he teaches courses in conservation of natural resources, plant ecology, plant systematics, and biogeography. He is author of numerous scientific publications and co-author with Marjorie Holland of the recently published book *Stonewalls and Sugar Maples: an Ecology for Northeasterners*.

H. ALLEN CURRAN

Dr. Curran is an associate professor of geology at Smith College where he teaches courses in oceanography, historical geology, and invertebrate paleontology. His interests in the geology of the Outer Banks began while he was a graduate student at the University of North Carolina-Chapel Hill, although his research has centered principally on Coastal Plain stratigraphy and paleontology and the effects of burrowing organisms in modern shallow marine environments. Dr. Curran also has participated in a number of oceanographic cruises to study the marine geology of the Carolinas Continental Margin and the Hatteras Abyssal Plain. He is the senior co-author of the *Atlas of Landforms* published by John Wiley.

TERESA M. CZERNIAK

Ms. Czerniak is presently a Ph.D. candidate in biological oceanography at Scripps Institution of Oceanography. She graduated from Smith College in 1977 with highest honors in biological sciences. Her thesis research was conducted on Portsmouth Island, North Carolina during the summer of 1976.