Vegetative Study at the Duck Field Research Facility, Duck, North Carolina

by

Gerald F. Levy

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A vegetative study of the Duck Field Research Facility of the U.S. Army Coastal Engineering Research Center, at Duck, North Carolina, was conducted from March 1974 through June 1975. A vegetation map of this area was prepared using aerial infrared photographs and ground-truth surveys. Eleven different plant communities were delimited. Adequate stratified random sampling of these communities produced frequency and biomass data for 10 of the communities and frequency and density data for the eleventh community.

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20. Abstract. (Continued)

Biomass data were obtained using the clip quadrat method. Ordination techniques confirmed the distinctiveness of the foredune, wetland, oceanside shrub, sound-side shrub, and sound-side disturbed communities. The remaining six communities were floristically similar but quantitatively distinct. Two of these latter communities appear natural while the remaining four are manmade. The natural communities were designated low dune grass and oceanside intershrub communities. The beachgrass and bitter panicum communities were deliberately established. The spurge-sandgrass and sandgrass-buttonweed communities were affected by sandgrass planting and fertilization. Permanent plots were located and mapped in each of the designated community types. Floristic collections made throughout the study period revealed a flora of approximately 178 species in 132 genera representing 58 families.

PREFACE

This report is published to provide coastal engineers with a vegetative study of the Duck Field Research Facility at Duck, North Carolina. The work was carried out under the coastal ecology research program of the U.S. Army Coastal Engineering Research Center (CERC).

The report was prepared by Gerald F. Levy, Associate Professor of Biological Sciences, Old Dominion University, Norfolk, Virginia, under CERC Contract No. DACW72-74-C-0019.

The author expresses appreciation to Drs. Paul W. Kirk and Lytton J. Musselman, Department of Biological Sciences, Old Dominion University, for assistance in designing the research program and in species identification, respectively, and to R.W. Tyndall and J.W. Usher, graduate students in the Department of Biological Sciences, for their assistance in the field. The assistance of Dr. Donald W. Woodard, formerly of CERC, is gratefully acknowledged.

Mr. Robert M. Yancey, Chief, Ecology Branch, was the CERC contract monitor for the report, under the general supervision of R.P. Savage, Chief, Research Division.

Comments on this publication are invited.

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JAMES L. TRAYERS
Colonel, Corps of Engineers
Commander and Director

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VEGETATIVE STUDY AT THE DUCK FIELD RESEARCH FACILITY, DUCK, NORTH CAROLINA

by

Gerald F. Levy

I. INTRODUCTION

1. General.

The Duck Field Research Facility is located on the Outer Banks of North Carolina, a series of offshore sandbars extending from the Virginia-North Carolina border southward about 200 miles to Bogue Inlet, North Carolina. These bars lie almost parallel to the mainland and are separated from it by shallow sounds of varying widths.

The study area is included in Currituck Bank (North Bank), which extends from the Virginia-North Carolina boundary southward to the town of Nags Head, a distance of about 45 miles (Fig. 1). The bank was originally demarcated by two inlets; Old Currituck Inlet, which was located just south of the Virginia-North Carolina line until it closed around 1730, and Nags Head Inlet, which was located just south of the present town of Nags Head until it closed sometime between 1780 and 1810 (Stick, 1958).

2. Origin.

Most investigators cite a theory developed by Johnson (1919) for the origin of this barrier island system. Johnson postulated that on a gradually shallowing sea bottom, "...small waves break at the initial shoreline and excavate a marine cliff and beach while large waves break further out and proceed to excavate the same forms in the offshore bottom." Excavated material was deposited landward of the breaking waves, eventually forming a submarine bar of significant height and indefinite length. Continuing growth irregularly raised the bar above water, forming a chain of islands separated by inlets.

The longshore current causes both shifting and closing of inlets. Deposition on one side of an inlet is succeeded by erosion on the other side, producing inlet migration. If deposition exceeds erosion the inlets eventually close unless tidal currents and outflowing fresh-waters are sufficient to dominate shoaling (Johnson, 1919).

Stick (1958) cited testimony from inhabitants which suggests that hurricane winds raise the water level in the sound several feet above normal. After storm passage, winds shift to the southwest and force the impounded waters back over the banks, sometimes forming inlets.

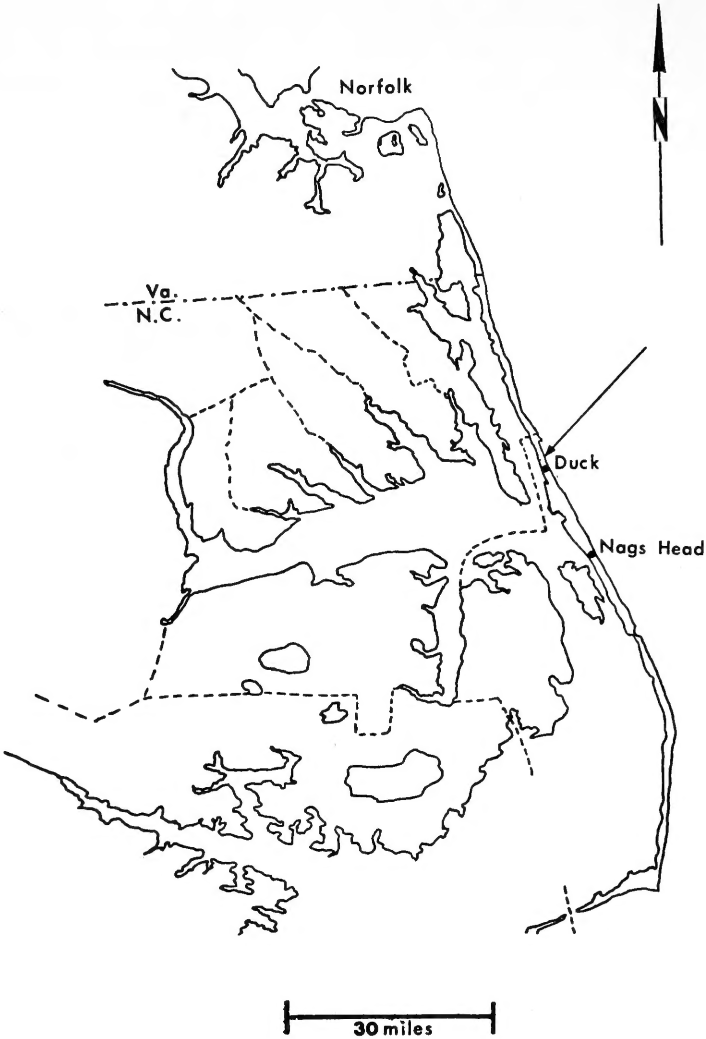


Figure 1. Location of the Duck Field Research Facility.

3. Climate.

The area has a moderately temperate maritime climate (Engels, 1952). Climatic data were collected at Hatteras, which is more under the influence of the Gulf Stream than the Duck area. These data represent maxima, but differences are probably not significant.

At Hatteras, the normal mean temperature during the 6 consecutive hottest weeks of summer is 78.6° Fahrenheit. The coldest month, January, has a mean temperature of 45.7° Fahrenheit, while July, the warmest, has a mean of 77.9° Fahrenheit. The average daily temperature range is greatest in March, 12.9° Fahrenheit, and least in August, 9.2° Fahrenheit.

The absolute maximum temperature recorded was 102° Fahrenheit, in June, and the minimum, 8° Fahrenheit, in December. The average date of earliest killing frost is December 13. February 27 is the latest date of killing frost (Burk, 1968). The mean annual percent of sunshine, 54 percent, is typical for the southeastern states. The mean annual humidity, 81.4 percent, is higher than any other continental station in the United States with the exception of Puget Sound. Monthly differences in humidity vary no more than 5 percent.

Mean annual precipitation is 62.76 inches, with July (6.06), August (5.98) and September (6.06) having the most. Periods of drought are rare.

The average annual maximum wind velocity, 13.3 miles per hour, is relatively high, with average maximum velocities greatest from December through April. The prevailing winds are northerly in the winter and southwesterly in the summer.

4. History.

The first permanent English community on the Outer Banks was established in 1664 (Stick, 1958). Soon after settlement, cattle, horses, hogs, and sheep were turned free to graze. Around 1773 settlers were reportedly converting Currituck Banks to stock range and attempting to prevent the Indians from hunting there. Grazing continued, to some extent, into the 1900's. Guild (1947) reported finding pigs feeding on mole crabs in the surf near False Cape; recent observations have confirmed that a viable "wild" hog population still exists.

The vegetation and topography of this region were drastically changed after settlement. Stratton (1943) reported that grass and shrubs were uprooted by hogs, and forests were cut for fuel, building, and ship construction. Once vegetation was disrupted, the sandy soils became susceptible to wind and storm tides. The blowouts and sand dunes seen today behind the foredune are the results of these forces. Blowouts almost reach the water table and dunes rise to over 100 feet just north and south of the Duck Field Research Facility. Unstable dunes migrate southwesterly across the banks, toward the sound, burying everything in their paths.

Gradually rising sea levels (Marmer, 1951) have caused the beaches to recede landward. The Cape Hatteras Lighthouse, constructed in the late 1860's about 3,200 feet from the beach, is today approximately 350 feet from the water's edge (Dolan, Godfrey, and Odum, 1973). In 1935 the Works Progress Administration (WPA) and the Civilian Conservation Corps (CCC) began stabilizing the foredune from the Virginia border to approximately the middle of Ocracoke Island (Stratton and Hollowell, 1940). Some foredunes now exceed 25 feet in height. Foredune stabilization has narrowed beach width, and increased the oceanside slope of the foredune and beach. Eventually the stabilized dunes will be destroyed by natural oceanic processes (Dolan, 1972; Dolan, Godfrey, and Odum, 1973).

The ocean beach, foredune, arborescent zone, and sound side marsh are the most characteristic features of the Outer Banks profile, although the widths and elevations have changed significantly in the past 300 years. The most variable area is between the foredune and the arborescent zone. This area possesses either large migrating dunes, intertidal salt marshes, and sandflats, or a narrow heterogeneous transitional zone.

During World War II, Duck field was used as a gunnery range (personal communication, D. Woodard, Marine biologist, CERC, 1974). The area was subsequently decontaminated, which leveled considerable parts of it. Effects of bombing are still apparent; the area remains littered with bomb fragments and some cratering is still evident.

A series of planting experiments were recently conducted on the study area. Extensive sandflats were planted with *Ammophila breviligulata* (American beachgrass) or *Panicum amarum* (bitter panicum), and other areas were treated with fertilizer applications. Some areas were disturbed by construction and the use of heavy equipment, both during and after the experiments.

5. Floristic Composition.

Burk's (1968) study of the Outer Banks flora reported 462 native species comprising 277 genera, 106 families, and 43 orders. He reported the largest families to be Poaceae, Asteracea, and Cyperaceae. The native plants included 14.7 percent Poaceae, 13.4 percent Asteraceae and 8.0 percent Cyperaceae. Included in his lists were 95 exotic species comprising 55 genera and 33 families, which made up 17.1 percent of the total flora.

a. Ocean Beach Community. Little or no vegetation exists between the dunes and the ocean. This is in contrast to the *Physalis viscosa-Croton maritimus* community reported for Ocracoke Island by Kearney (1900). Engels (1942, 1952) reported no sea beach vegetation on either Ocracoke Island or Shackleford Banks; however, neither of these study areas had stabilized dunes.

b. Foredune Community. *Uniola paniculata* (sea oats) is the most abundant plant in this community. Although not always dominant (Wagner, 1964), it is found throughout the Banks. Next in abundance is usually *A. breviligulata* which occurs as far south as Hatteras (Brown, 1959) and is most abundant toward the Virginia border. Eventually it replaces *U. paniculata* farther north. The abundance of these two species is partly due to WPA and CCC planting activities.

The distributions of *Andropogon glomeratus* (bushy beachgrass) and *Andropogon littoralis* are variously cited in the literature. Brown (1959) reported *A. littoralis* was absent from Outer Banks dunes. Burk (1962) stated that *A. littoralis* is dominant in the dune grass community, and *A. glomeratus* is rarely a dominant dune species. Johnson (1900) noted that *A. maritimus* (most likely *A. glomeratus*) was the dominant foredune species on Bogue Bank.

Panicum amarum is a widespread subdominant from Virginia to Ocracoke Island, North Carolina (Brown, 1959; Kearney, 1900). *Panicum amarulum* is most abundant from Bodie Island, North Carolina to Virginia (Brown, 1959). Both are considered poor sand binders.

Other plants of less ecological significance reported include: *Croton punctatus* (croton), *Cenchrus pauciflorus* (field sandbur), *Cenchrus tribuloides* (dune sandbur), *Eragrostis spectabilis* (purple lovegrass), *Triplasis purpurea* (purple sandgrass), *Cakile edentula* (sea rocket), *Erigeron canadensis* (horse weed), *Euphorbia polygonifolia* (seaside spurge), *Oenothera humifusa* (seabeach evening primrose), *Physalis viscosa* (maritime ground cherry), *Solidago sempervirens* (seaside goldenrod), *Heterotheca subaxillaris* (camphorweed), *Heterotheca gossypina* (camphorweed), *Hudsonia tomentosa* (beach heath), *Yucca gloriosa* (Spanish bayonet), *Spartina patens* (saltmeadow cordgrass), and *Opuntia compressa* (prickly pear), (Brown, 1959; Burk, 1961; Johnson, 1900; and Kearney, 1900).

c. Migrating Dune Community. No plants are found in areas of excessive sand drift. In areas of only moderate drift fast growing species (e.g., *U. paniculata* and *A. breviligulata*) occur throughout the year. During the less windy summer months, in areas of low drift, annuals such as *E. polygonifolia*, *T. purpurea*, and *Diodia teres* (buttonweed) are found along with *S. patens* and *C. tribuloides* (Brown, 1959).

d. Sandflat Communities. On flat sandy areas various community types occur depending upon moisture availability and salinity. Brown (1959) found *Typha latifolia* (cattail), *Spartina alterniflora* (smooth cordgrass), *Juncus roemerianus* (spike rush), *Cladium jamaicensis* (saw grass), *Pluchea* sp. (marsh fleabane), *Centella repanda*, *Scirpus americana* (three square), and an occasional *S. patens* growing on a wet sandflat south of the Cape Hatteras Lighthouse.

Burk (1961) found the one-quarter-mile-long dry sandflats on Portsmouth Island, North Carolina, totally barren. Johnson (1900) reported similar areas on Bogue and Shackleford Banks, North Carolina shifting wastes of windblown sand with only *E. polygonifolia* and *Andropogon* sp.

Brown (1959) described the sandflat vegetation on Hatteras Island near Rodanthe, North Carolina as dwarf, sparse, and composed of mixed grasses and sedges. However, a sandflat near Hatteras Village possessed a thick growth of *S. patens*, *Fimbristylis castanea*, and *S. sempervirens*. Sandflats north of Corolla on Currituck Bank had a good growth of *S. patens* while some flats on Hatteras Island had only a fringe of vegetation, with a center of packed sand coated with salt crystals.

e. Arborescent Communities. These communities include those dominated by shrubs as well as trees. An open canopied mesic forest dominated by *Pinus taeda* (loblolly pine), *Carya* spp. (hickories), *Quercus falcata* (Spanish oak), *Quercus nigra* (water oak), and *Liquidambar styraciflua* (sweet gum) is described by Burk (1962) as existing behind the active dunes near Nags Head, Kitty Hawk, and Duck. *P. taeda* was the dominant species (37 percent of the total). *Carya* spp., *L. styraciflua*, and *Q. falcata* with values of 16, 15, and 14 percent respectively were next in importance. Burk (1962) found 2 percent *Q. virginiana* but Brown (1959) found none.

Brown (1959) reported *Q. virginiana* and *P. taeda* as the major species in Buxton Woods on Hatteras Island. He found 55-year-old pines and an oak with a 3-foot diameter. Burk (1962) reported that 98 percent of the trees were *P. taeda*, with *Q. nigra*, *Q. virginiana*, and *L. styraciflua*; *Sabal minor* (stemless palmetto) was abundant. Other woody species reported by Brown (1959) included: *Callicarpa americana* (French mulberry), *Carpinus caroliniana* (ironwood), *Cornus florida* (flowering dogwood), *Ilex opaca* (American holly), *Ilex vomitoria* (yaupon), *Juniperus virginiana* (red cedar), *Myrica cerifera* (wax myrtle), *Myrica pensylvanica* (bayberry), *Persea borbonia* (red bay), *Q. nigra*, *Q. phellos* (willow oak), *Rhus copallina* (winged sumac), and *Zanthoxylum clavaherculis* (Hercules'-club).

Kearney (1900) concluded that *I. vomitoria* was the most abundant woody species on Ocracoke Island, followed by *Q. virginiana*, *M. cerifera*, *Z. clava-herculis*, and *J. virginiana*.

Engels (1952) listed *Q. virginiana*, *J. virginiana*, and *I. vomitoria* as the dominant trees in a wooded area west of Whale Creek Bay on Shackleford Bank. Other trees of less abundance included: *P. taeda*, *P. borbonia*, and *I. opaca*.

On the basis of relative shrub-tree importance, Lewis (1917) divided the arborescent zone on Shackleford Bank into three areas: (a) thicket formation, (b) thicket woodland formation, and (c) woodland formation. The thicket formation was dominated by *I. vomitoria*, with *I. opaca*, *J. virginiana*, *M. cenifera*, and others. The thicket woodland was characterized by *P. borbonia*, *Osmanthus americanus* (devilwood), *Q. nigra*, *P. taeda*, and *J. virginiana*. Shrubs included: *I. vomitoria*, *M. cerifera*, *C. americana*, *I. glabra*, and *Sabal glabra* (*S. minor*?).

Johnson (1900) described the Bogue Bank arborescent zone as located about 100 yards behind an advancing dune. *Q. nigra*, with *I. opaca*, *Morus rubra* (red mulberry), *Persea carolinensis* (?), *C. caroliniana*, *J. virginiana*, and *P. taeda* were reported by him. *Myrica gale* (?), *I. glabra*, and *I. cassine* (*I. vomitoria*), were noted as important shrubs with the latter being most important. Apparently this area was subsequently logged, or otherwise drastically altered as Burk (1962) found 58 percent of the trees to be *P. taeda*, 15 percent *Q. falcata*, and 12 percent *Q. virginiana*. The previously important water oak was no longer present and the pines increased to major importance.

6. Plant Succession and Climax.

Wells (1928), the only investigator to describe the plant successional pattern on the Outer Banks, suggested the following pattern for the xeric dune community: *Salsola* (upper beach) dune formation, *Uniola-Iva* dune recession, *Oenothera-Panicum* soil improvement, and *Quercus-Myrica*. He characterized this habitat as having a short hydroperiod, little humus, strong winds, and little shade. His pattern for the xeric maritime forest was: *Ilex-vomitoria-Juniperus-Myrica*, *Q. virginiana*, and oak-hickory associes. The habitat was described as having a very short hydroperiod, perennial winds, and older landward-lying dunes.

Wells (1938) reported an extensive forest of live oaks on Smith Island, previously recorded in 1805. He concluded that live oak (*Q. virginiana*) was the dominant tree of the climax maritime forest, citing as the reason the natural elimination of competitive hardwoods which are not as tolerant of salt spray. He called this community a Salt Spray Climax. Wells felt succession would be: *U. paniculata*, *M. cerifera*, *I. vomitoria*, *J. virginiana*, and *Q. virginiana*. Bordeau and Oosting (1959) concluded that the normal components of the oak-hickory association are excluded by their intolerance to salt, thus only live oak will dominate. This supports Wells' earlier conclusions.

7. Environmental Factors Governing Floristic Composition and Distribution.

a. Salt. Viewing storm effects on plants in England, Salisbury (1805) noted that greater damage resulted when rain did not accompany high winds. Beck (1819) noted that storms on the northeast U.S. coast had little effect on plants protected from the wind. These observations precipitated a controversy over the importance of wind effects versus salt spray effects on plants. Coulter, Barnes, and Cowles (1911) summarized this controversy as follows: "One maintains that the stronger transpiration on the seaward or windward side causes the branches to die earliest there, while the other theory maintains that salt particles carried in the spray account for branch destruction." They speculated that both points of view were valid because the two phenomena supplemented one another.

Boodle (1920) considered salt spray to be the less important factor. Weaver and Clements (1938) and Martin and Clements (1939) supported the contention of Boodle (1920). Doutt (1941) and Davis (1942) found evidence to support the contention that salt spray was of minor importance.

Wells and Shunk (1937) observed the injury of young windward side shoots of *M. cerifera*, *I. vomitoria*, and *Q. virginiana* on the lower Cape Fear Peninsula following 19 hours of 30-mile-per-hour winds. Shrubs farther from the ocean exposed to the same wind velocity and time periods were not damaged. They concluded that salt was the primary cause of deformed coastal shrubs and proposed that these shrubs be called "spray forms" rather than "wind forms".

Oosting and Billings (1942) concluded that Bogue Bank vegetational plant zonation patterns were not due to (a) soil moisture, temperature, pH or salt content, (b) air moisture, temperature, or (c) evaporation. They also concluded that salt spray was the only significant factor governing zonation. Oosting (1945) stated that salt spray effects were most damaging when storms produced insufficient rain to wash salt from leaves.

The amount of salt collected from the windward side of the foredune on Bogue Bank was twice as great as at any other side (Oosting and Billings, 1942). The crest of the foredune had the second largest amount followed by the crest of the hind dune. The leeward side of the foredune and the base of the hind dune received successively less amounts of salt spray.

Boyce (1951) showed that significant amounts of salt spray are not derived from the surf because the drops formed are too large to be windborne. Most salt spray particles are from the bursting bubbles in the swash and white caps of small waves (Boyce, 1954).

Boyce's (1954) study of the coastal vegetation of Brunswick County, North Carolina, found *Iva imbricata* (marsh elder) was subjected to an average of 1,900 droplets of salt spray per square centimeter per minute on the windward side and only 490 droplets per square centimeter per minute on the leeward side. The droplets averaged 51 micrometer in diameter windward and 22 micrometer leeward.

Wells and Shunk (1938) concluded that the concentration of chlorides in salt spray deposited on plant leaves was higher than that for seawater because of evaporation, and leaf death was due to cell plasmolysis. However, Boyce (1954) demonstrated that chloride ion toxicity caused leaf death. He discovered other ions were seldom present in high enough concentrations to produce necrosis. Since necrosis always occurred first at the tip regardless of where the chlorides entered the leaf, Boyce concluded that damage occurred after salt translocation. Salt entrance was increased through wind-induced leaf lacerations, which explained why plants with sessile leaves or leaves densely covered by hair are damaged less by wind action than plants with long petioles and smooth surfaces. He also discovered that increased soil nitrates resulted in decreased cuticular thickness and number of epidermal hairs allowing more frequent lacerations, increased chloride uptake, and reduced salt spray tolerance.

Wagner (1964) found that salt spray decreased the growth rate of *U. paniculata* but did not kill the plant. This he attributed to the thick cuticle and other xeromorphic characters of its leaves which reduce surface chloride ion uptake.

Numerous investigators have classified strand plants according to salt spray tolerance (Wagner, 1964; Oosting and Billings, 1942; Wells, 1939; and Wells and Shunk, 1938). Oosting (1945) studied the salt spray tolerance of 14 species. He found *S. patens* and *Atriplex arenaria* (seabeach orack) unaffected by salt spray, *U. paniculata* the next most tolerant, and *S. sempervirens* and *C. punctatus* slightly less tolerant. *Iva imbricata*, *I. frutescens* (marsh elder), and *Borrichia frutescens* (sea-ox-eye) were moderately tolerant. *E. polygonifolia*, *Chenopodium anbrosioides* (Mexican tea), and *Cynodon dactylon* (Bermuda grass) had some tolerance, while *Strophostyles helvolva* (wild bean) and *H. subaxillaris* were less tolerant. *Leptilon canadensis* (*E. candensis*) showed virtually no tolerance to salt spray.

Other species rated as highly or moderately salt tolerant include *A. littoralis* (Oosting and Billings, 1942), *Baccharis halimifolia* (groundsel-tree), *I. vomitoria*, and *M. cerifera* (Wells and Shunk, 1938).

Seneca (1969) found that maximum germination tolerance to salt (NaCl) for *A. breviligulata* and *U. paniculata* was between 1 and 1.5 percent. *Panicum amarulum* had an upper tolerance limit between 1.5 and 2 percent, while *S. patens* was about 4 percent. The latter had an average of 53.3-percent germination in 3-percent NaCl. Decrease in germination was attributed not to salt toxicity but to the osmotic differential. Based upon their germination experiments the order of tolerance (from most to least) was *S. patens*, *P. amarulum*, *U. paniculata*, and *A. breviligulata*.

All the above species showed stress in the seedling state but at different levels (Seneca, 1972). Symptoms included an initial twisting and rolling of leaves, followed by chlorosis on the outer older leaves with leaf tips becoming yellowish. Necrosis later proceeded from the tips downward, affecting the newest leaves last. *Ammophila breviligulata* and *U. paniculata* grew moderately well in salinities up to 1 percent while *P. amarulum* showed no signs of salinity stress until subjected to 2-percent NaCl. Seedlings of *S. patens* showed salinity stress only at the 4-percent level. It was the only species to actively secrete what was thought to be NaCl from its leaves. All species lived for at least 10 days when exposed to 4-percent NaCl.

b. Nutrients. Willis, et al. (1959) reported a low level of nitrogen in the sandy soil of the coastal dune system of Braunton Burrows, North Devon, England. After further studies Willis (1963) attributed the sparse vegetation on this dune system to low levels of nitrogen and phosphorus, which appeared to be due to the high leachability of the coarse sandy soils.

Wave deposition of organic detritus has been suggested as the source of nutrients for the lower beach (Ranwell, 1972). Wagner (1964) cited the freshly deposited beach sands as a source of nitrogen, while Morris, et al. (1974) suggested ocean spray-carried neuston as a possible source.

Hassouna and Warling (1964) isolated bacteria from the root soil and roots of *A. arenaria* and found that *Azotobactor*, a nitrogen-fixing bacterium, constituted a large proportion of these organisms. Their studies indicated that the root surface micro-organisms in the dune sand could stimulate significantly higher plant growth in the absence of added nitrogen when root exudates (a carbon source) was added. They concluded, "there seems little doubt that the fixation of atmospheric nitrogen is an important factor in the nutrition of *A. arenaria*."

Stewart (1967) showed that nitrogen fixed by blue-green algae in soil was utilized by higher plants. Most fixed nitrogen remained in the first centimeter of the soil unless leached.

Morris, et al. (1974) have shown that root nodules on *M. pensylvanica* contain a bacterial endophyte. They found large numbers of nodules on main and adventitious roots. Nitrogen fixation was vigorous. They concluded that the success of *M. pensylvanica* as an early successional species on dunes and other impoverished soils was due, at least in part, to the nitrogen-fixing capacity of their nodular bacteria.

Gorham (1958) found the mobile dunes in Norfolk, England, richer in soluble calcium, nitrate and silica and the stable phase dunes richer in soluble carbon and phosphate due to humus accumulation. The oldest stabilized dunes were richest in potassium, sulfate, and phosphate. Magnesium, sodium, and chlorine were always highest in the embryo dunes due to salt spray. Potassium was least in the embryo dunes, and greatest in the stabilized dunes. Calcium and bicarbonate concentrations were greatest in the youngest dunes where shell fragments were abundant. Willis and Yeamon (1961) stated that there is a sufficient supply of micronutrients (boron, iron, manganese, zinc, copper, and molybdenum) in coastal soils to support vigorous plant growth.

c. Soil Moisture and Water Table. Oosting and Billings (1942) found no significant difference between soil water moisture at depths of 10 and 20 centimeters, except in moist depressions. They could not correlate moisture factors between the surface and 20 centimeters with vegetational zonation. Kelley (1925) found that the beach was not salty, because the movement of ground water maintained unmixed fresh-water up to a few centimeters from the ocean's edge. Ranwell (1972) found the water table below dunes convexed and unaffected by tidal fluctuations, suggesting that the ground water table is independent of the sea's influences.

d. Other Factors. Oosting and Billings (1942) reported that temperature, relative humidity, and evaporation varied in different topographic and vegetational zones of the coastal system. However, no relation between these factors and vegetational zonation was found.

e. Conclusions. Many of the factors thought to affect species behavior in the coastal dune system have been studied, but several aspects of this complex ecosystem are still controversial. Careful studies must be conducted before these contradictory points of view can be resolved.

II. PROCEDURE

1. Floristics.

Plant collections were made frequently throughout the period March 1974 through May 1975. Diagnostically mature specimens were collected in duplicate, identified, mounted, and labeled.. Labeling information included collection location, date, collectors, common associated species, and a brief habitat description (Radford, Ahles, and Bell, 1968). The duplicate collection has been deposited in the Old Dominion University Herbarium.

2. Vegetational Studies.

The objectives of these studies were to (a) delimit and characterize the number and diversity of plant communities that occurred on the study area, (b) determine various phytosociological parameters of these communities through randomized sampling procedures, (c) produce an accurate vegetational map of the study area, (d) characterize the relationships between the delimited communities, and (e) locate and map a representative series of permanent quadrats.

a. Plant Community Identifications. Initially, the study area was traversed extensively to gain a general overall impression of its vegetational diversity. An east-west base line was then established along the southern boundary of the study area, using a transit and stadia rod (elevations were not determined). Nine north-south line transects were than run from the base line at 300-foot intervals. Vegetational descriptions were made along these transects, and nine distinct community types were defined; two additional community types were later added.

b. Community Sampling. The subjective community identifications verified observations made prior to the initiation of this investigation. Only two physiognomically distinct vegetational were identified: (a) Areas dominated by grasses and forbs, and (b) areas dominated by shrubs (some with trees associated).

Previous experience with similar vegetational types has demonstrated that 0.2- by 0.2-meter-square quadrats arranged in a stratified random manner will produce statistically valid results in grass-dominated and forb-dominated vegetation (Levy, 1970). Good results can be obtained using 1- by 1-meter-square quadrats in shrubby vegetation and 4- by 4-meter-square quadrats in areas dominated by shrubs and small trees.

Several techniques were used to determine the number of plots required for a statistically adequate sample. A running mean was determined for important species in each community by plotting the value obtained for a dominant species in the first sample quadrat and the mean of plots 1 and 2, 1, 2, and 3, etc. A sample was judged adequate when the regression line generated by this procedure no longer varied more than 10 percent from previously obtained mean values for the population. Five plots were sampled in shrub-dominated communities and 20 in grass-dominated communities prior to running mean analyses; this procedure was conducted for two or three dominant species in each community. Enough samples were obtained to ensure adequate sampling of all dominant species. In all cases, rarer species (those with low frequency of occurrence in the sample plots) were inadequately sampled. Results were verified by examining variance, mean, and standard error of the populations. All methods indicated that adequate data had been collected for a reliable quantitative description of the various vegetational types.

The sound-side shrub community appeared to require only five quadrats for an adequate sample. Frequency data were collected from five additional random plots to ensure sampling adequacy. The results of the five initial plots were compared to the data collected for all ten plots, using a chi-square test. The value obtained was less than the 0.05 level of confidence, demonstrating that no significant difference occurred between these two sets of data. Therefore, the first five samples were used to represent this community.

Quadrat frequency and species' standing crop data were collected for all communities except the sound-side shrub community. For the latter type, frequency for all species and rooted stem density were determined. Standing crop was determined in grams of aboveground oven-dried tissue. Each quadrat was clipped, separated by species, and individual species oven-dried to constant weight at 105° Celsius. Five 1- by 1-meter plots and 330, 0.2- by 0.2-meter plots were examined and clipped.

c. Vegetational Mapping. Three overflights of the study area were made at different seasons. Infrared aerial photos obtained were used with the ground truth from the nine previously described transects and the quadrat data to produce a scale vegetative map of the study area. The accuracy of this map is better than 90 percent.

d. Ordination of Stands. The 11 community types were arranged in an ordination model according to the method of Bray and Curtis (1957). In this method each community's frequency values were summed. Each individual species frequency in the community was divided by the total for all species and the result multiplied by 100 to yield relative frequency expressed as a percentage. The relative frequency values were then used to compare the species composition of each community with the other communities, using the Index of Similarity (IS), IS = 2w/(a + b) (Bray and Curtis, 1957). The IS values were then subtracted from 100 to yield an Index of Dissimilarity (ID), ID = 100 - IS, and used to locate the communities along an axis by means of Beals' (1960) adaptation of the Pythagorean Theorem,

$$x = \frac{L^2 + (dA)^2 - (db)^2}{2L},$$ and the technique of Bray and Curtis (1957).

The usual procedure for axis extraction is to sum the ID values for each vegetational unit. The stand with the highest sum is deemed the end of an axis; the opposite end of this axis is the stand least like it (i.e., having the highest ID in relation to it). The units are represented as points separated by a scale distance equal to the ID value. All other points are then located between the end points.

In this study, however, one stand had ID values of 100 with five other stands, and a second stand had the same relationship with four other stands. To produce a model of acceptable geometry it was necessary to modify the standard axis extraction technique in the following manner. The first end point of the X axis was the community having the highest ID sum. The second end point was the stand with the highest ID value in relation to it, excluding those stands with values of 100. The Y axis was selected in a similar fashion from a matrix of ID values composed of the remaining nine communities. The Z axis was selected using a matrix from the remaining seven stands.

e. Permanent Quadrats. Three permanent 5- by 5-meter quadrats were located in each of the nine defined community types and three were located in the barren dune areas. Only one quadrat was located in both the wetlands community and the spurge-sandgrass community due to their small extent and uniformity. The quadrats were laid out diagonally north and south and oriented with a permanent survey marker in the east corner. Locations of the permanent quadrat markers were determined by measuring direction and distance to the nearest geographic monument marker. Vegetative pattern, gross composition, and percent ground cover for each permanent quadrat were determined and mapped on graph paper.

III. RESULTS

1. Floristics.

The flora is composed of approximately 178 species and 132 genera, representing 58 families. The list of species collected (with their common names when applicable) is presented in Table 1.

2. Vegetational Studies.

a. Phytosociology. Studies indicate that 11 different community types can be delimited. Some of the community types are very distinct, i.e., foredune, oceanside shrub, sound-side shrub, and wetlands. The sound-side disturbed community is relatively distinct, but the remaining six community types are qualitatively, and in some cases, quantitatively similar. The phytosociological data for these stands are presented in Tables 2 through 12.

The sound-side shrub community (Table 8) has the greatest number of species (28), followed by the sound-side disturbed community (24) (Table 10), and the wetlands community (22) (Table 11). The oceanside intershrub community (Table 3) had 16, while the planted American beachgrass (Table 5) and low dune grass (Table 7) communities each had 10; the remaining communities had 7 species each except for the planted bitter panicum community (Table 9), which had only 6.

The oceanside shrub community (Table 4) had the greatest biomass with 2779.3 grams per square meter dry weight. Though biomass data were not obtained for the sound-side shrub community (Table 8) due to the impracticality of cutting down the few trees and large shrubs, its density of 36.9 individuals per square meter for all species, and especially its density of *M. pensylvanica* (15), *Prunus serotina* (black cherry) (8), *Sassafras albidum* (sassafras) (2.4), and *Drospyros virginiana* (persimmon) (4.4) suggest that the standing crop biomass of this community is of the same magnitude as that of the oceanside shrub community. The wetland community (Table 11), which had the second highest measured biomass, had only 104.9 grams per square meter. The remaining values ranged from 68.8 grams per square meter for the sandgrass-buttonweed community (Table 6) to 5.6 grams per square meter

Table 1. Duck Field Research Facility floristics list.

Family and Species	Common Name
Family Aceraceae	
Acer rubrum L.	Red maple
Family Aizoaceae	
Mollugo verticillata L.	Carpet weed
Family Alismataceae	
Sagitaria graminea var. *weatherbiana* (Fernald) Bogin	Arrowhead
Family Amaranthaceae	
Alternanthera philoxeroides (Martins) Grisebach	Alligator weed
Family Anacardinaceae	
Rhus copallina L.	Winged sumac
R. radicans L.	Poison ivy
Family Apiaceae	
Centella asiatica (L.) Urban	
Eryngium aquaticum L.	Eryngo
Hydrocotyle umbellata L.	Marsh pennywort
Lilaeopsis carolinensis C. & R.	
Ptilimnium capillaceum (Michaux) Ref.	
Sium suave Walter	Water parsnip
Family Aquifoliaceae	
Ilex opaca Aiton	American holly
I. vomitoria Aiton	Yaupon
Family Asclepiadaceae	
Asclepias lanceolata Walter	Milkweed
Family Aspleniaceae	
Asplenium platyneuron (L.) Oakes	Ebony spleenwort
Family Asteraceae	
Achillea millefolium L.	Yarrow
Ambrosia artemisiifolia L.	Ragweed
Aster tenuifolius L.	Aster
Baccharis halimifolia L.	Groundsel tree
Bidens mitis (Michaux) Sherff	Beggar ticks
Carduus spinosissimus Walter	Yellow thistle
Crepis vesicaria ssp *taraxifolia* (Thuillier) Thellung	Hawk's beard
Eclipta alba (L.) Hasskar	Yerba-de-tago

Table 1. Duck Field Research Facility floristics list-Continued.

Family and Species	Common Name
Family Asteraceae (concl'd.)	
Erigeron canadensis var. *canadensis* L.	Horseweed
E. candensis var. *pusillus* (Nuttall) Ahles	Horseweed
Eupatorium capillifolium var. *capillifolium* (Lam.) Small	Dog fennel
E. serotinum Michaux	Thoroughwort
Gaillardia pulchella Foug.	Blanket flower
Gnaphalium obtusifolium L.	Rabbit tobacco
Hieracium gronovii L.	Hawk weed
Heterotheca adenolepis (Fernald) Ahles	
H. gossypina (Michaux) Shinners	
Iva frutescens L.	Marsh elder
I. imbricata Walter	Seashore elder
Krigia virginica (L.) Willd.	Dwarf dandelion
Lactuca canadensis L.	Wild lettuce
Mikania scandens (L.) Willd.	Climbing hempweed
Pluchea foetida (L.) D.C.	Marsh fleabane
P. purpurascens (Swartz) D.C.	Salt marsh fleabane
Pyrrhopappus carolinianus var. *carolinianus* (Walter) D.C.	False dandelion
Solidago rugosa var. *rugosa* Miller	Goldenrod
S. sempervirens L.	Goldenrod
S. tenuifolia Pursh	Goldenrod
Xanthium strumarium var. *strumarium* L.	Cocklebur
Family Bignoniaceae	
Campsis radicans (L.) Seemann	Trumpet vine
Family Brassicaceae	
Cakile edentula (Bigelow) Hooker	Sea rocket
Lepidium virginicum L.	Peppergrass
Family Cactaceae	
Opuntia compressa (Salisbury) Macbride	Prickley pear
O. drummondii Graham	Fragile prickley pear
Family Campanulaceae	
Lobelia elongata Small	Marsh lobelia
Specularia perfoliata (L.) A. D.C.	Venus' looking glass
Family Caprifoliaceae	
Lonicera japonica Thunberg	Japanese honeysuckle
L. sempervirens L.	Coral honeysuckle

Table 1. Duck Field Research Facility floristics list-Continued.

Family and Species	Common Name
Family Chenopodiaceae	
Chenopodium ambrosioides L.	Mexican tea
Family Cornaceae	
Cornus florida L.	Dogwood
Family Convolvulaceae	
Calystegia sepium (L.) R. Brown	Hedge bindweed
Family Cucurbitaceae	
Melothria pendula L.	Creeping cucumber
Family Cyperaceae	
Carex alata Torrey	Sedge
Cyperus dentatus Torrey	Sedge
C. erythrorhizos Muhl.	
C. filicinus Vahl	
C. haspan L.	
C. ovularis (Michaux) Torrey	
C. rivularis Kunth	
C. sesquiflorus (Torrey) Mattfeld and Kukenthal	
C. strigosus L.	
C. surinamensis Rottboell	
Eleocharis tuberculosa (Michx.) R. & S.	Spike rush
Fimbristylis autumnalis (L.) R. & S.	Sand rush
F. dichotoma (L.) Vahl	
Fuirena squarrosa Michaux	Umbrella grass
Scirpus americanus Persoon	Chair maker's rush
Family Ebenaceae	
Diospyros virginiana L.	Persimmon
Family Euphorbiaceae	
Croton glandulosus var. *septentrionalis* Muell.-Arg.	Croton
C. punctatus Jacquin	Croton
Euphorbia polygonifolia L.	Beach spurge
Family Fabaceae	
Apios americana Medicus	
Cassia fasciculata Michaux	Partridge pea
Centrosema virginianum (L.) Bentham	Butterfly pea
Desmodium paniculatum (L.) D.C.	Beggar lice
D. pauciflorum (Nuttall) D.C.	Beggar lice
D. strictum (Pursh) D.C.	Beggar lice
Lespedeza capitata Michaux	Bush clover

Table 1. Duck Field Research Facility floristics list-Continued.

Family and Species	Common Name
Family Fabaceae (concl'd.)	
L. cuneata (Dumont) G. Don	
L. striata (Thunberg) H. & A.	Japanese clover
L. virginica (L.) Britton	
Strophostyles helvola (L.) Ell.	Wild bean
Family Fagaceae	
Quercus virginiana Miller	Live oak
Family Gentianaceae	
Sabatia dodecandra var. *dodecandra* (L.) B.S.P.	Sea pink
Family Hamamelidaceae	
Liquidambar styraciflua L.	Sweet gum
Family Hypericaceae	
Hypericum gentianoides (L.) B.S.P.	St. John's wort
Family Juncaceae	
Juncus coriaceus Mackenzie	Rush
J. megacephalus M.A. Curtis	Rush
J. roemerianus Scheele	Black rush
Family Juncaginaceae	
Triglochin striata R. & P.	Arrow grass
Family Lamiaceae	
Monarda punctata L.	Horsemint
Salvia lyrata L.	Sage
Stachys nuttallii Shuttlew	Hedge nettle
Family Lauraceae	
Persea borbonia (L.) Spreng.	Red bay
Family Liliaceae	
Smilax bona-nox L.	Greenbrier
Yucca filamentosa L.	Bear grass
Family Linaceae	
Linum virginianum var. *medium* Planchon	Flax
Family Loganiaceae	
Polypremum procumbens L.	

Table 1. Duck Field Research Facility floristics list-Continued.

Family and Species	Common Name
Family Lycopodiaceae	
Lycopodium appressum (Chapman) Lloyd and Underwood	Club moss
Family Lythraceae	
Lythrum lineare L.	Loosestrife
Family Malvaceae	
Hibiscus moscheutos L.	Rose mallow
Kosteletskya virginica (L.) Presl.	Sea shore mallow
Family Myricaceae	
Myrica cerifera var. *cerifera* L.	Wax myrtle
M. pensylvanica Loisel	Bayberry
Family Onagraceae	
Oenothera biennis L.	Evening primrose
O. fruticosa L.	Sundrops
O. humifusa Nuttall	Evening primrose
Family Orchidaceae	
Spiranthes cernua (L.) Richard	Nodding ladies' tresses
Family Pinaceae	
Pinus taeda L.	Loblolly pine
Family Phytolacaceae	
Phytolacca americana L.	Pokeweed
Family Plantaginaceae	
Plantago lanceolata L.	Plantain
Family Poaceae	
Andropogon elliottii Chapman	Broom straw
A. virginicus L.	Broom sedge
Ammophila breviligulata	American beachgrass
Bromus secalinus L.	Brome grass
Cenchrus tribuloides L.	Sandspurs
Cynodon dactylon (L.) Persoon	Bermuda grass
Digitaria filiformis var. *villosa* (Walter) Fernald	Crab grass
D. ischaemum (Schreber) Schreber ex Muhl.	Crab grass
D. sanguinalis (L.) Scopoli	Crab grass
Echinochloa walteri (Pursh) Heller	Walter's barnyard grass
Eleusine indica (L.) Gaertner	Goose grass
Elymus virginicus L.	Wild rye grass
Eragrostis elliottii Watson	Love grass

Table 1. Duck Field Research Facility floristics list-Continued.

Family and Species	Common Name
Family Poaceae (concl'd.)	
E. spectabilis (Pursh) Steudel	Love grass
Erianthus giganteus (Walter) Muhl.	Beard grass
Festuca sciurea Nuttall	Fescue
Leptoloma cognatum (Schultes) Chase	Witch grass
Panicum amarulum Hitchcock and Chase	Bitter panicum
P. amarum Ell.	Panic grass
P. dichotomiflorum Michaux	Fall ronieum
P. scoparium Lam.	
P. vaginatum Swartz	
P. virgatum L.	Switch grass
Polypogon monspeliensis (L.) Desf.	Rabbit foot grass
Sacciolepis striata (L.) Nash	
Setaria geniculata (Lam.) Beauvois	Fox tail grass
Sorgum halepense (L.) Persoon	Johnson grass
Spartina cynosuroides (L.) Roth	Giant cord grass
S. patens (Aiton) Muhl.	Salt meadow grass
Sphenopholis obtusata (Michaux) Scribner	Wedge grass
Triplasis purpurea (Walter) Chapman	Sand grass
Trisetum pensylvanicum (L.) Beauvois ex R. & S.	
Uniola paniculata L.	Sea oats
Zea mays L.	Corn
Family Polygonaceae	
Polygonum hydropiperoides var. *opelousanum* (Riddell ex Small) Stone	
P. pensylvanicum L.	Knot weed
P. sagittatum L.	Tear thumb
Rumex acetosella L.	Sheep sorrel
R. verticillatus L.	Swamp dock
Family Pontederiaceae	
Pontederia cordata L.	Pickerelweed
Family Primulaceae	
Samolus parviflorus Raf.	Water pimpernel
Family Ranunculaceae	
Ranunculus sardous Crantz	Buttercup
Family Rosaceae	
Amelanchier arborea var. *laevis* (Wiegard) Ahles	June berry
Prunus serotina var. *serotina* Ehrhart	Black cherry
Rubus betulifolius Small	Blackberry

Table 1. Duck Field Research Facility floristics list-Concluded.

Family and Species	Common Name
Family Rubiaceae	
Diodia teres Walter	Buttonweed
D. virginiana L.	
Family Rutaceae	
Zanthoxylum clava-herculis L.	Hercules' club
Family Salicaceae	
Salix nigra Marshall	Black willow
Family Scrophulariaceae	
Agalinis purpurea (L.) Pennel	Gerardia
Linaria canadensis (L.) Dumont	Toad flax
Verbascum thapsus L.	Mullein
Family Solanaceae	
Physalis viscosa ssp *maritima* (M.A. Curtis) Waterfall	Ground cherry
Datura stramonium L.	Jimson weed
Family Urticaceae	
Boehmeria cylindrica (L.) Swartz	False nettle
Family Verbenaceae	
Callicarpa americana L.	French mulberry
Lippia nodiflora (L.) Michaux	Frogbit
Family Vitaceae	
Parthenocissus quinquefolia (L.) Planchon	Virginia creeper
Vitis aestivalis var. *aestivalis* Michaux	Summer grape
V. rotundifolia Michaux	Muscadine
Family Xyridaceae	
Xyris jupicai Richard	Yellow-eyed grass

Table 2. Foredune community.[1]

Species	Frequency (percent)	Relative Frequency (percent)	Total Weight (grams)	Grams per Square Meter
Uniola paniculata[2]	69.2	39.6	267.5	7.3
Ammophila breviligulata	43.6	24.9	169.8	4.6
Solidago sempervirens	30.8	17.6	26.1	0.7
Erigeron canadensis	15.4	8.8	3.0	0.1
Oenothera humifusa	5.1	2.9	5.8	0.2
Cakile edentula	2.6	1.5	0.5	0.01
Euphorbia polygonifolia	2.6	1.5	0.5	0.01
Total			473.2	12.9

1 Based on 39, 0.2-meter-square quadrats.

2 *Physalis viscosa* and *Croton punctatus* were growing on the foredune but were not found in any of the 39 quadrats.

Table 3. Oceanside intershrub community.[1]

Species	Frequency (percent)	Relative Frequency (percent)	Total Weight (grams)	Grams per Square Meter
Triplasis purpurea	54.9	20.4	8.4	0.8
Heterotheca gossypina	43.1	16.1	19.3	1.9
Uniola paniculata	33.3	12.4	125.2	12.3
Ammophila breviligulata	23.5	8.8	44.9	4.4
Cenchrus tribuloides	17.6	6.6	3.6	0.4
Cyperus ovularis	19.6	7.3	5.0	0.5
Erigeron canadensis	17.6	6.6	4.4	0.4
Euphorbia polygonifolia	17.6	6.6	4.5	0.4
Panicum amarum	13.7	5.1	11.3	1.1
Solidago sempervirens	5.9	2.2	1.5	0.1
Spartina patens	5.9	2.2	6.3	0.6
Physalis viscosa	5.9	2.2	2.4	0.2
Oenothera humifusa	3.9	1.4	1.0	0.1
Diodia teres	2.0	0.7	0.5	0.05
Oenothera beinnis	2.0	0.7	0.5	0.05
Opuntia drummondii	2.0	0.7	0.5	0.05
Total			239.3	23.4

[1] Based on 51, 0.2-meter-square quadrats.

Table 4. Oceanside shrub community.[1]

Species	Frequency (percent)	Relative Frequency (percent)	Total Weight (grams)	Grams per Square Meter
Myrica pensylvanica	100.0	38.5	13,769.1	2,753.8
Phytolacca americana	40.0	15.4	23.8	4.8
Solidago sempervirens	40.0	15.4	10.4	2.1
Chenopodium ambrosioides	40.0	7.7	78.0	15.6
Prunus serotina	20.0	7.7	12.8	2.6
Smilax bona-nox	20.0	7.7	1.0	0.2
Rubus betulifolius	20.0	7.7	1.0	0.2
Total			13,896.1	2,779.3

1 Based on 5, 1.0-meter-square quadrats.

Table 5. Planted American beachgrass community.[1]

Species	Frequency (percent)	Relative Frequency (percent)	Total Weight (grams)	Grams per Square Meter
Triplasis purpurea	64.0	28.4	3.8	0.3
Ammophila breviligulata	45.2	20.4	325.5	22.3
Cenchrus tribuloides	41.1	18.5	7.1	0.5
Diodia teres	37.0	16.7	0.5	0.03
Oenothera humifusa	13.7	6.2	133.5	9.1
Euphorbia polygonifolia	11.0	5.0	4.0	0.3
Panicum amarum	6.8	3.1	4.0	2.7
Cyperus ovularis	1.4	0.6	0.5	0.03
Panicum amarulum	1.4	0.6	195.7	13.4
Cassia fasciculata	1.4	0.6	2.4	0.2
Total			677.0	48.86

1 Based on 73, 0.2-meter-square quadrats.

Table 6. Sandgrass-buttonweed community.[1]

Species	Frequency (percent)	Relative Frequency (percent)	Total Weight (grams)	Grams per Square Meter
Triplasis purpurea	86.7	40.6	320.0	53.3
Diodia teres	50.0	23.4	17.1	2.9
Cenchrus tribuloides	36.7	17.2	26.5	4.4
Panicum amarum	23.3	10.9	37.7	6.3
Oenothera humifusa	6.7	3.1	7.8	1.3
Cyperus strigosus	3.3	1.5	2.2	0.4
Euphorbia polygonifolia	6.7	3.1	1.0	0.2
Total			412.3	68.8

[1] Based on 30, 0.2-meter-square quadrats.

Table 7. Low dune grass community.[1]

Species	Frequency (percent)	Relative Frequency (percent)	Total Weight (grams)	Grams per Square Meter
Cenchrus tribuloides	33.0	31.8	6.3	0.7
Triplasis purpurea	22.3	21.4	5.0	0.6
Ammophila breviligulata	17.8	17.1	84.2	9.4
Uniola paniculata	8.9	8.6	27.8	3.1
Diodia teres	4.4	4.2	1.0	0.1
Euphorbia polygonifolia	4.4	4.2	1.0	0.1
Oenothera humifusa	4.4	4.2	1.3	0.1
Erigeron canadensis	4.4	4.2	6.4	0.7
Cyperus ovularis	2.2	2.1	0.5	0.1
Panicum amarum	2.2	2.1	2.7	0.3
Total			136.2	15.2

[1] Based on 45, 0.2-meter-square quadrats.

Table 8. Sound-side shrub community.[1]

Species	Frequency (percent)	Relative Frequency (percent)	Density
Myrica pensylvanica	100.0	7.8	15.0
Prunus serotina	100.0	7.8	8.8
Solidago tenuifolia	80.0	6.2	10.6
Smilax bona-nox	80.0	6.2	10.2
Rubus betulifolius	80.0	6.2	7.6
Ambrosia artemisiifolia	80.0	6.2	5.6
Rhus copallina	60.0	4.7	6.0
Solidago sempervirens	60.0	4.7	1.4
Melothria pendula	60.0	4.7	1.0
Rhus radicans	40.0	3.1	11.6
Chenopodium ambrosioides	40.0	3.1	5.4
Ammophila breviligulata	40.0	3.1	4.4
Diospyros virginiana	40.0	3.1	4.4
Vitis aestivalis	40.0	3.1	2.0
Parthenocissus quinquefolia	40.0	3.1	1.6
Diodia teres	20.0	1.6	20.0
Panicum amarulum	20.0	1.6	18.0
Achillea millefolium	20.0	1.6	3.2
Panicum amarum	20.0	1.6	3.2
Sassafras albidum	20.0	1.6	2.4
Triplasis purpurea	20.0	1.6	2.0
Eupatorium capillifolium	20.0	1.6	1.0
Cenchrus tribuloides	20.0	1.6	0.8
Cassia fasciculata	20.0	1.6	0.4
Zanthoxylum clava-herculis	20.0	1.6	0.2
Juncus megacephalus	20.0	1.6	0.4
Euphorbia polygonifolia	20.0	1.6	0.2
Oenothera humifusa	20.0	1.6	0.2

[1] Based on 10, 4.0-meter-square quadrats.

Table 9. Planted bitter panicum community.[1]

Species	Frequency (percent)	Relative Frequency (percent)	Total Weight (grams)	Grams per Square Meter
Panicum amarum	73.3	32.3	5.5	1.8
Triplasis purpurea	73.3	32.3	5.5	1.8
Cenchrus tribuloides	33.3	14.7	2.5	0.8
Diodia teres	33.3	14.7	2.5	0.8
Oenothera humifusa	6.7	3.0	0.5	0.2
Ammophila breviligulata	6.7	3.0	0.5	0.2
Total			17.0	5.6

1 Based on 15, 0.2-meter-square quadrats.

Table 10. Sound-side disturbed community.[1]

Species	Frequency (percent)	Relative Frequency (percent)	Total Weight (grams)	Grams per Square Meter
Triplasis purpurea	73.0	20.6	17.7	2.4
Erigeron canadensis[2]	70.3	19.8	20.4	2.8
Solidago tenuifolia[2]	--	--	--	-
Spartina patens	46.0	13.0	170.8	23.1
Panicum scoparium	21.6	6.1	3.7	0.5
Oenothera humifusa	18.9	5.3	10.2	1.4
Diodia teres	16.2	4.6	1.8	0.2
Ambrosia artemissifolia	16.2	4.6	3.0	0.4
Juncus coricious	13.5	3.8	9.9	1.3
Panicum amarum	13.5	3.8	34.4	4.6
Rubus betulifolius	10.8	3.0	2.2	0.3
Solidago sempervirens	10.8	3.0	8.8	1.2
Ammophila breviligulata	10.8	3.0	34.5	4.7
Myrica pensylvanica[3]	5.4	1.5	--	-
Euphorbia polygonifolia	2.7	0.8	0.5	0.1
Cenchrus tribuloides	2.7	0.8	0.4	0.1
Cynodon dactylon	2.7	0.8	0.6	0.1
Strophostyles helvola	2.7	0.8	0.5	0.1
Lepidium virginicum	2.7	0.8	0.5	0.1
Cassia fasciculata	2.7	0.8	0.3	0.1
Scirpus americanus	2.7	0.8	2.7	0.4
Juncus megacephalus	2.7	0.8	0.9	0.1
Lespedeza striata	2.7	0.8	12.2	1.6
Salix nigra[3]	2.7	0.8	--	-
Total			336.0	45.6

[1] Based on 37, 0.2-meter-square quadrats.

[2] Counted together because of similarity.

[3] Biomass of trees not determined.

Table 11. Wetlands community.[1]

Species	Frequency (percent)	Relative Frequency (percent)	Total Weight (grams)	Grams per Square Meter
Scirpus americanus	60.0	14.6	28.9	7.2
Aster tenuifolius	40.0	9.8	57.8	14.5
Distichlis spicata	40.0	9.8	47.2	11.8
Eleocharis sp.	40.0	9.8	10.2	2.6
Hydrocotyle umbellata	40.0	9.8	2.3	0.6
Cyperus spp.	30.0	7.3	10.7	2.7
Juncus roemerianus	20.0	4.9	93.8	23.4
Spartina patens	20.0	4.9	63.5	15.9
Bidens mitis	15.0	3.6	56.5	14.1
Lythrum lineare	15.0	3.6	12.1	3.0
Solidago sempervirens	15.0	3.6	8.6	2.2
Centella asiatica	10.0	2.4	0.9	0.2
Polygonum pensylvanicum	10.0	2.4	0.6	0.2
Sagittaria graminea var. *weatherbiana*	10.0	2.4	11.4	2.8
Fimbristylis autumnalis	5.0	1.2	3.4	0.8
Lilaeopsis carolinensis	5.0	1.2	0.1	0.02
Pontederia cordata	5.0	1.2	1.1	0.3
Oenothera fruticosa	5.0	1.2	6.2	1.6
Sacciolepsis striata	5.0	1.2	0.1	0.02
Sium suave	5.0	1.2	5.0	1.2
Solidago tenuifolia	5.0	1.2	1.1	0.3
Pontederia cordata	5.0	1.2	1.1	0.3
Total			422.6	105.74

[1] Based on 20, 0.2-meter-square quadrats.

Table 12. Spurge-sandgrass community.[1]

Species	Frequency (percent)	Relative Frequency (percent)	Total Weight (grams)	Grams per Square Meter
Euphorbia polygonifolia	75.0	30.5	8.0	2.0
Triplasis purpurea	60.0	24.5	7.4	1.8
Diodia teres	40.0	16.3	4.0	1.0
Oenothera humifusa	35.0	14.3	3.5	0.9
Spartina patens	15.0	6.1	17.2	4.3
Cenchrus tribuloides	10.0	4.1	1.0	0.2
Panicum amarum	10.0	4.1	6.5	1.6
Total			47.6	11.8

1 Based on 20, 0.2-meter-square-quadrats.

for the planted bitter panicum community (Table 9). The sand dune areas, which were devoid of vegetation, had no measurable biomass.

b. Vegetational Map. The vegetational map of the study area is presented in Figure 2. A summary of the approximate number of acres of each community, the barren sand dune areas, and roadways is presented in Table 13. The Duck Field Research Facility covers approximately 150 acres which includes 3 acres of roadways and 27 acres of barren sand dunes. The low dune grass community had the largest area of any community type, approximately 40 acres, and the planted American beachgrass community was second with 30 acres. The remaining values ranged from 14 acres for oceanside intershrub to about 1 acre for the wetlands community.

c. Community Ordination. The results of ordination techniques are presented in Figures 3, 4, and 5. The three-dimensional aspects of this model have been depicted by graphing two axes at a time. The distances between individual communities are related to the relative differences between them. It should be emphasized that ordination serves merely as a tool, which when carefully used, can yield a variety of information. By itself, however, it provides only an interesting arrangement of points and serves little purpose.

The distinctness of the foredune and wetland communities is borne out by the X-Y and X-Z perspectives (Figs. 3 and 4), which indicate the distinctness of the sound-side shrub and oceanside shrub communities. The X-Z and X-Y axes suggest that the oceanside and intershrub community is distinct, but it is closely allied with many stands on the X-Y aspect.

The sound-side shrub community is distinct on all three axes, although it shows some similarities to the large centrally located group of communities on the X-Z axis.

In contrast to the clearly distinct community types, six community types (planted American beachgrass, sandgrass-buttonweed, low dune grass, planted bitter panicum, sound-side disturbed, and spurge-sandgrass) have strong similarities to each other.

d. Permanent Quadrats. Figures 6 through 30 show most of the permanent quadrats. Low dune grass quadrat 2 has not been diagramed as it was vacant. The three permanent plots located in the oceanside shrub community were omitted as they had 100 percent *M. pensylvanica* coverage. Only one plot was located in the wetlands community (Fig. 29), and spurge-sandgrass community (Fig. 30). The three permanent quadrats which were located on barren dune sites have not been represented as figures since they are featureless. Table 14 lists separately the location of each quadrat's permanent survey marker. The usefulness of these plots will be realized as their compositional changes are mapped over the years.

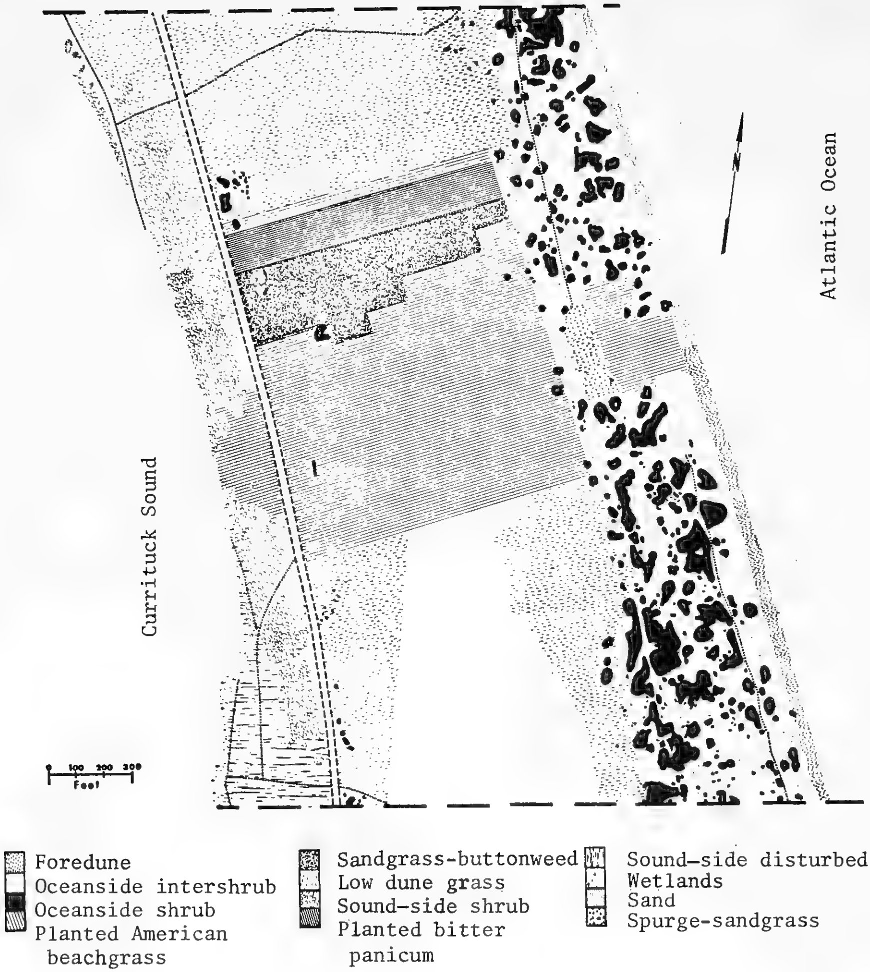


Figure 2. Vegetation map of the Duck Field Research Facility.

Table 13. Summary of community types at the Duck Field Research Facility with approximate acreages.

Community Types	Acres (approximate)
Foredune (FD)	3.5
Oceanside intershrub (OIS)	14.0
Oceanside shrub (OSS)	11.0
Planted American beachgrass (PBG)	30.0
Sandgrass-buttonweed (SG/BW)	5.0
Low dune grass (LDG)	40.0
Sound-side shrub (SSS)	7.0
Planted bitter panicum (PBP)	3.0
Sound-side disturbed (SSD)	4.0
Wetlands (WL)	1.0
Spurge-sandgrass (S/SG)	1.5
Barren sand dunes	27.0
Roads and trails	3.0
Total	150.0

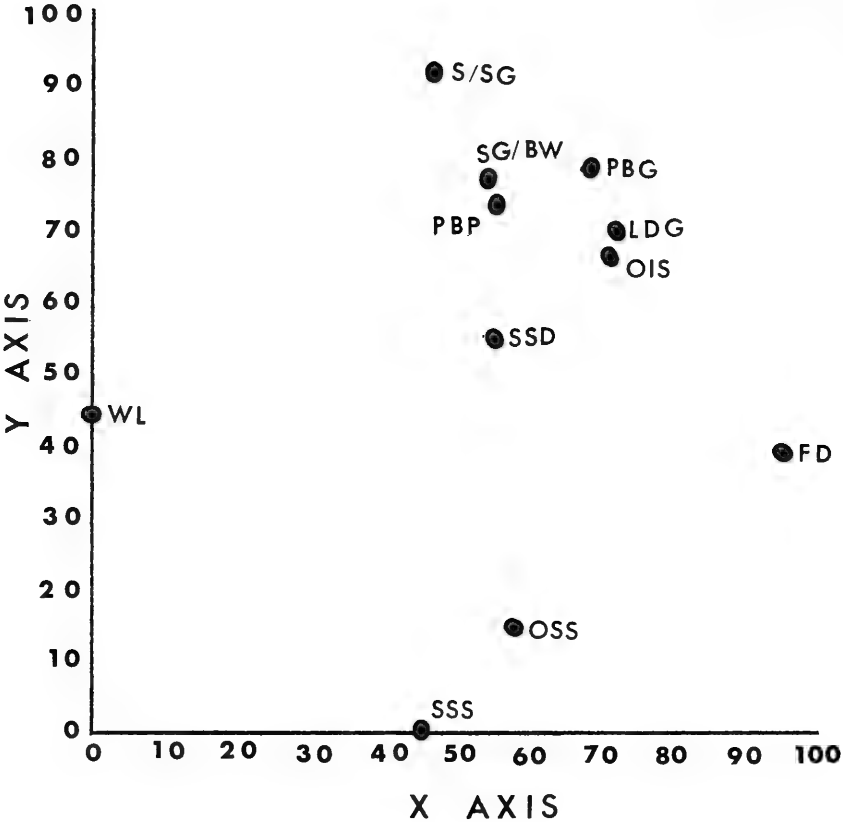


Figure 3. Ordination of plant communities at the Duck Field Research Facility, showing the X and Y axes perspective. (See Table 13 for definition of community type designation.)

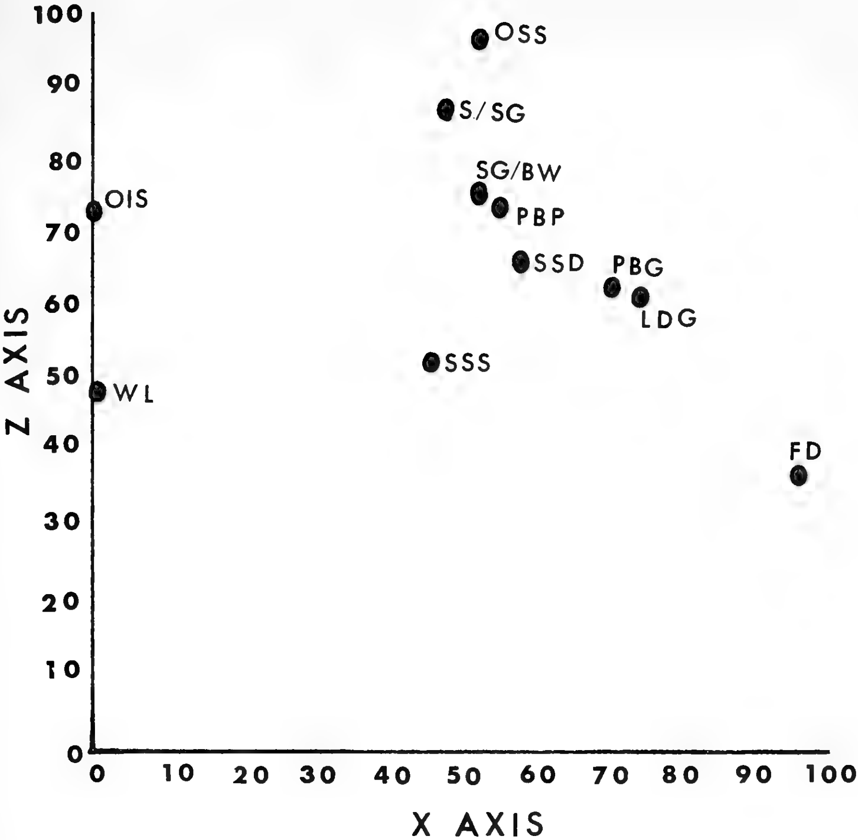


Figure 4. Ordination of plant communities at the Duck Field Research Facility showing the X and Z axes perspective. (See Table 13 for definition of community type designation.)

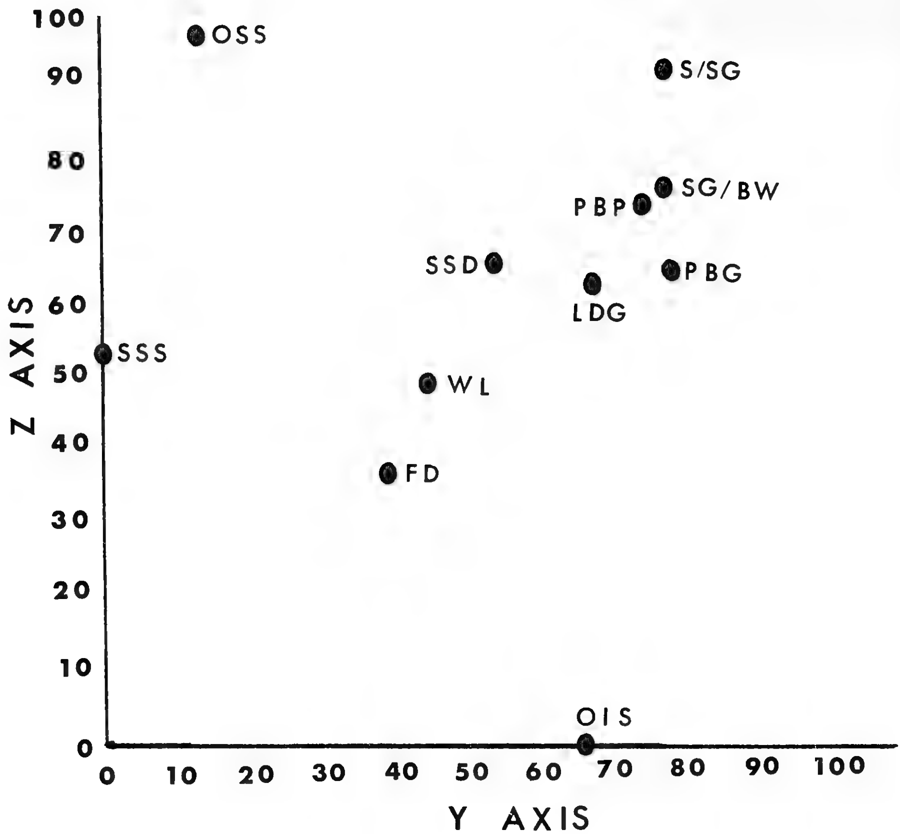
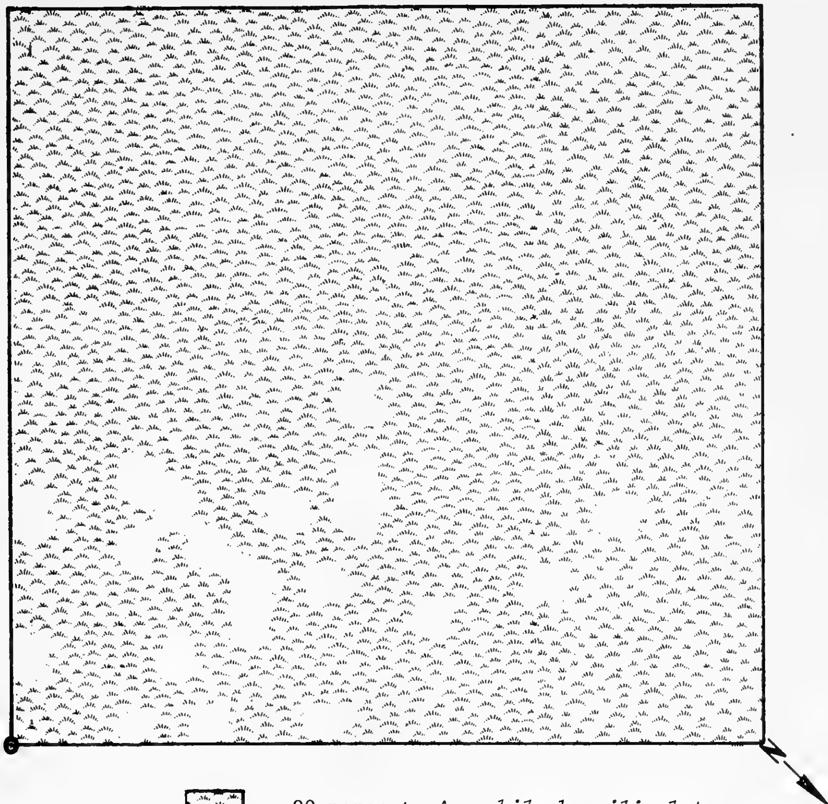


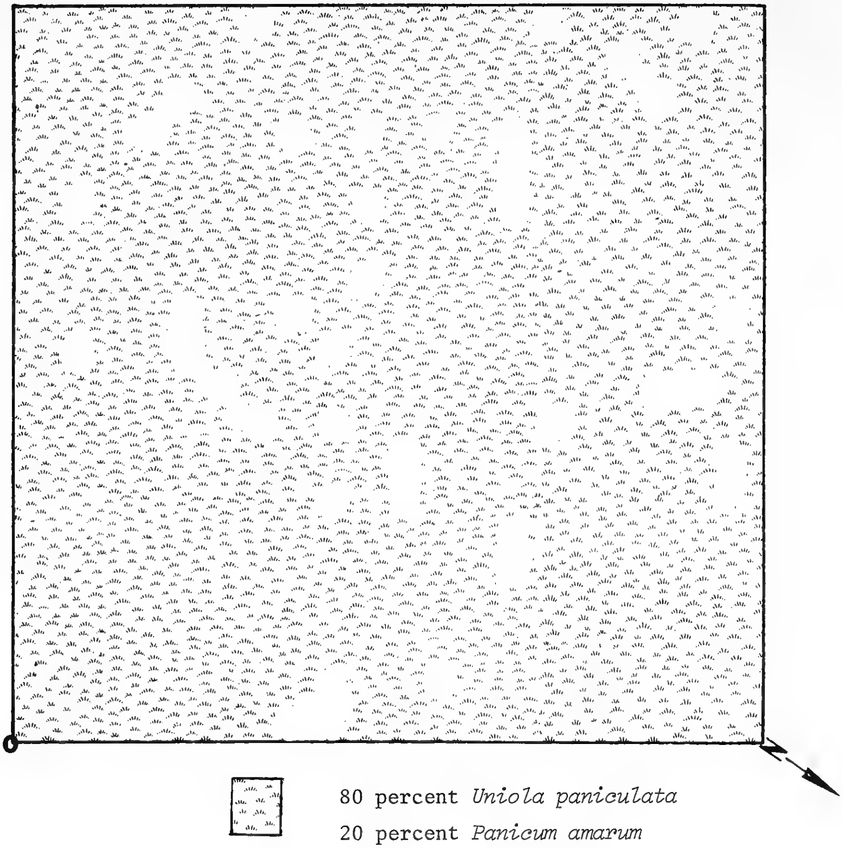
Figure 5. Ordination of plant communities at the Duck Field Research Facility showing the Y and Z axes perspective. (See Table 13 for definition of community type designation.)



90 percent *Ammophila breviligulata*
10 percent *Uniola paniculata*

Total ground cover - 95 percent

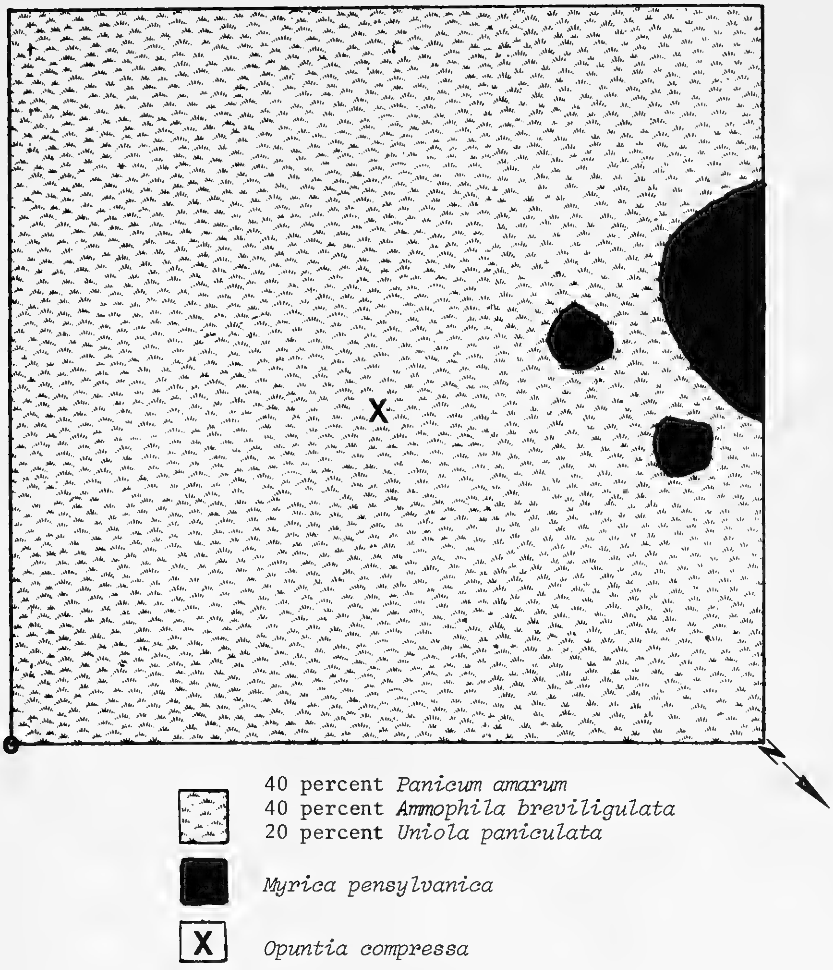
Figure 6. Foredune community permanent quadrat 1.



80 percent *Uniola paniculata*
20 percent *Panicum amarum*

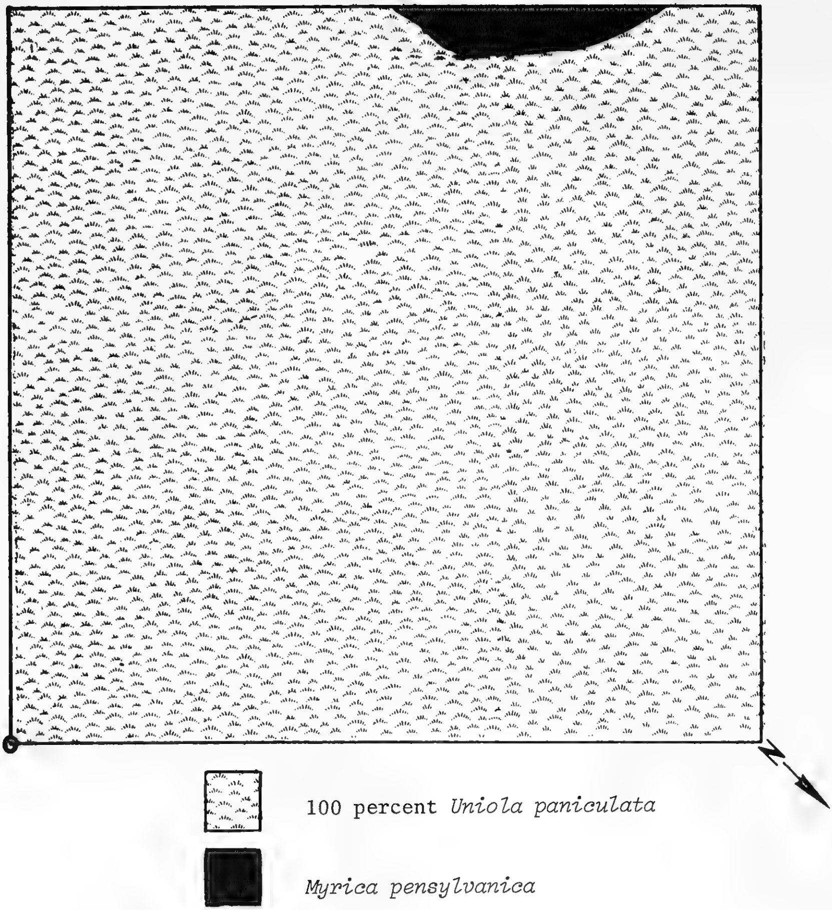
Total ground cover - 90 percent

Figure 7. Foredune community permanent quadrat 2.



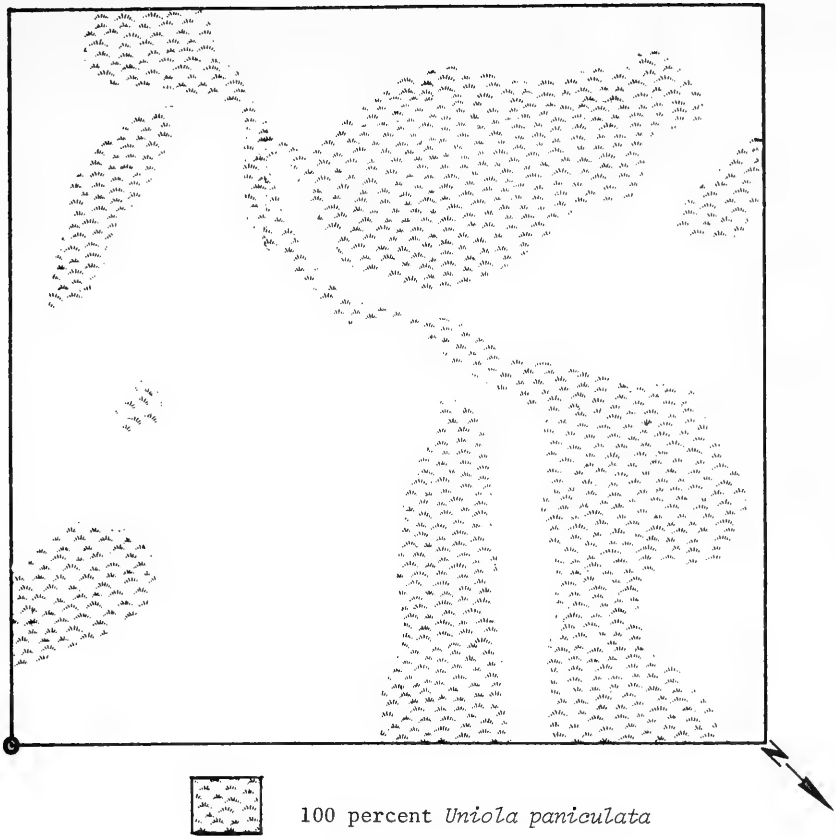
Total ground cover - 90 percent

Figure 8. Foredune community permanent quadrat 3.



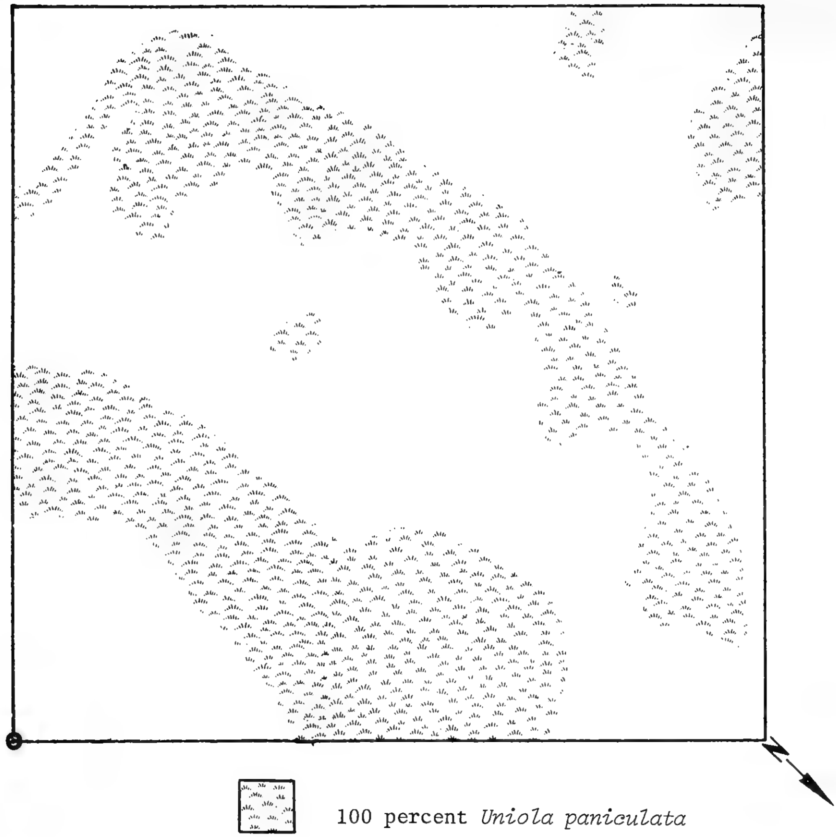
Total ground cover - 90 percent

Figure 9. Oceanside intershrub community permanent quadrat 1.



Total ground cover - 40 percent

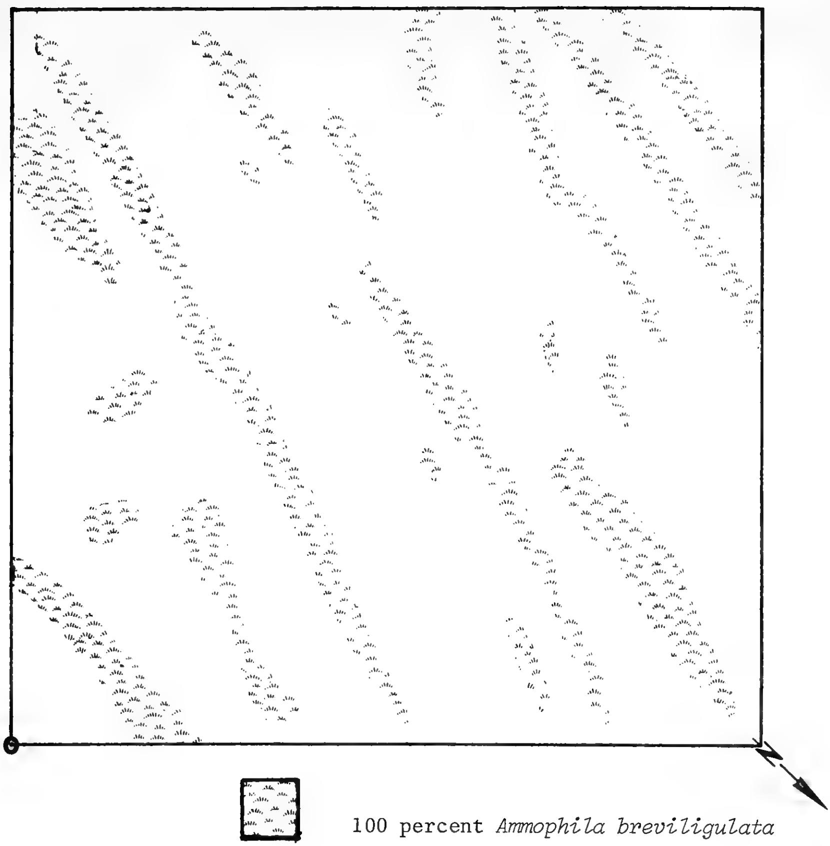
Figure 10. Oceanside intershrub community permanent quadrat 2.



100 percent *Uniola paniculata*

Total ground cover - 40 percent

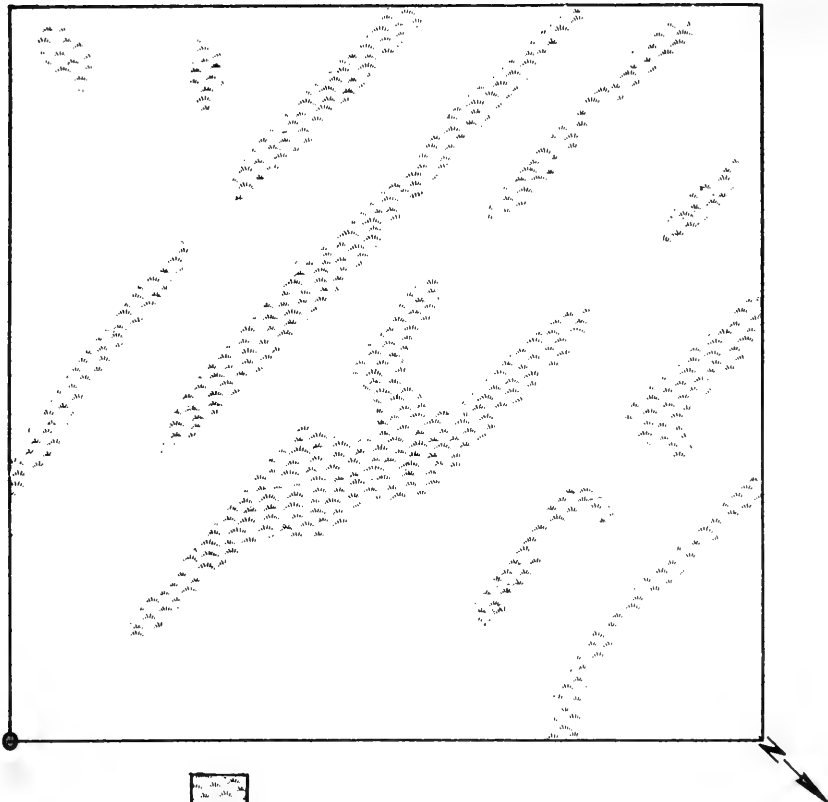
Figure 11. Oceanside intershrub community permanent quadrat 3.



100 percent *Ammophila breviligulata*

Total ground cover - 30 percent

Figure 12. Planted American beachgrass community permanent quadrat 1.



100 percent *Ammophila breviligulata*

Total ground cover - 30 percent

Figure 13. Planted American beachgrass community permanent quadrat 2.

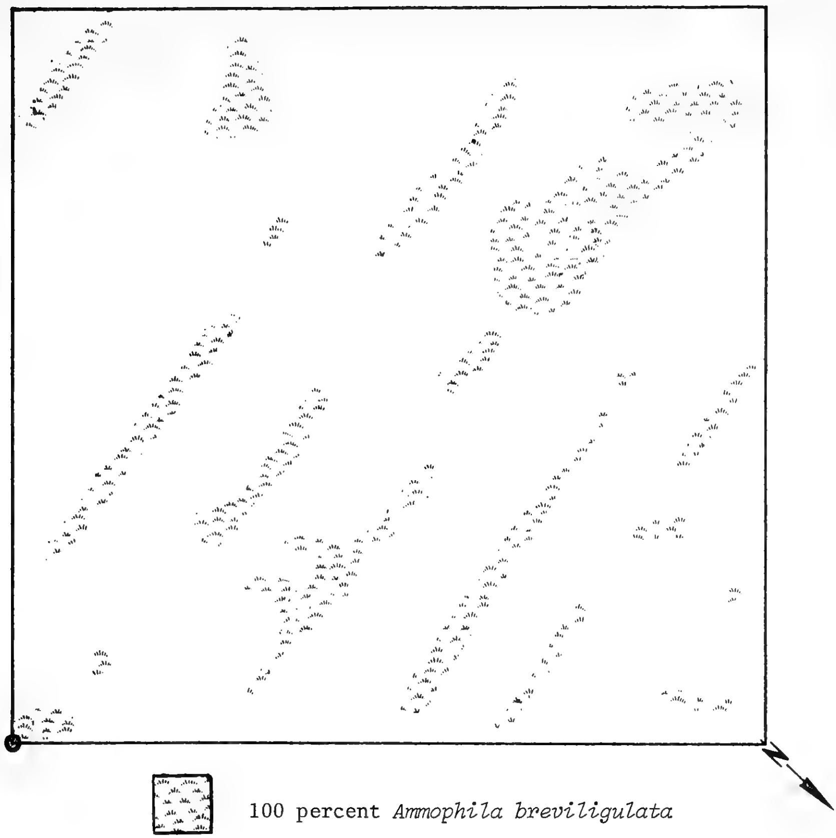
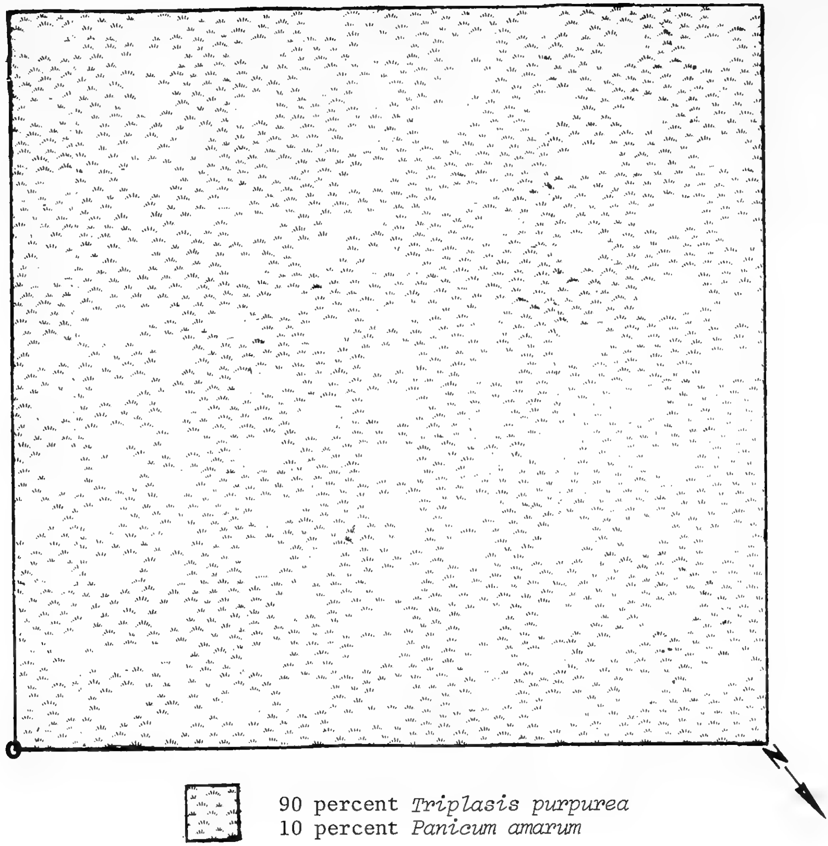
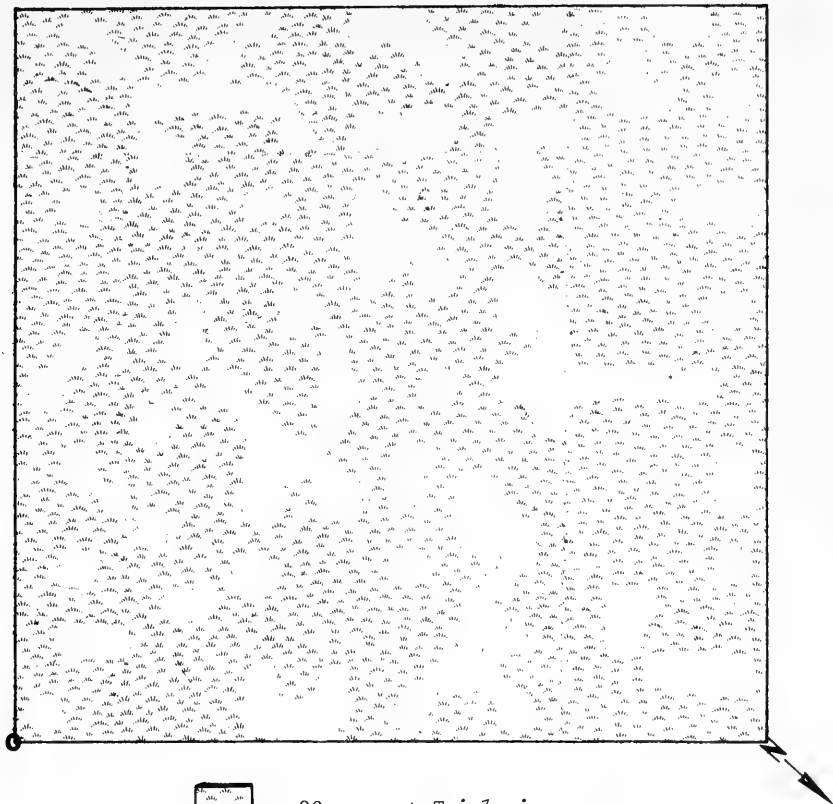


Figure 14. Planted American beachgrass community permanent quadrat 3.



Total ground cover - 70 percent

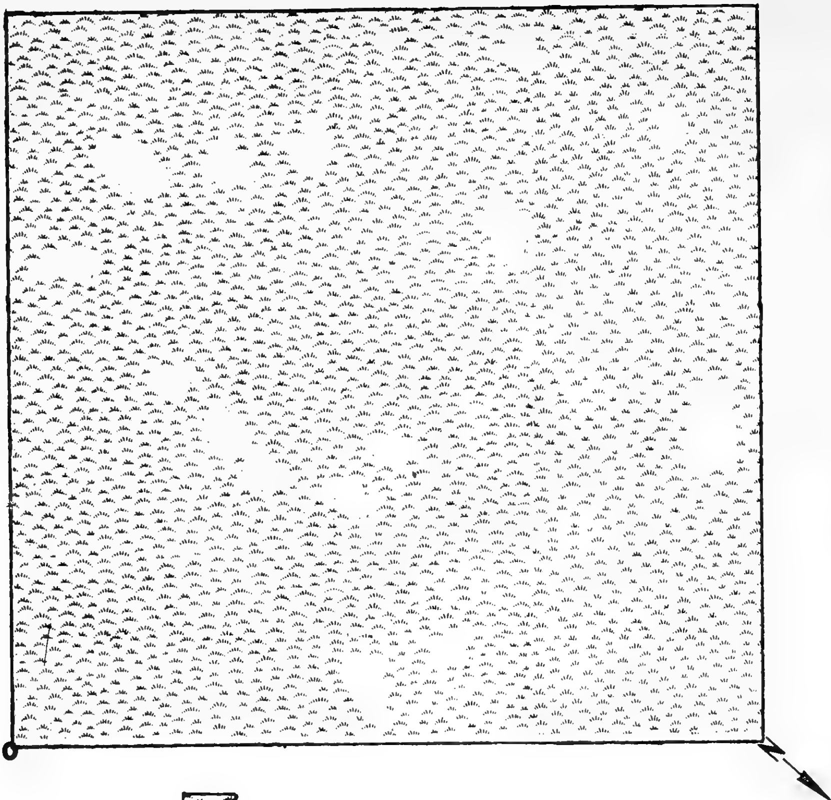
Figure 15. Sandgrass-buttonweed community permanent quadrat 1.



90 percent *Triplasis purpurea*
10 percent *Panicum amarum*

Total ground cover - 75 percent

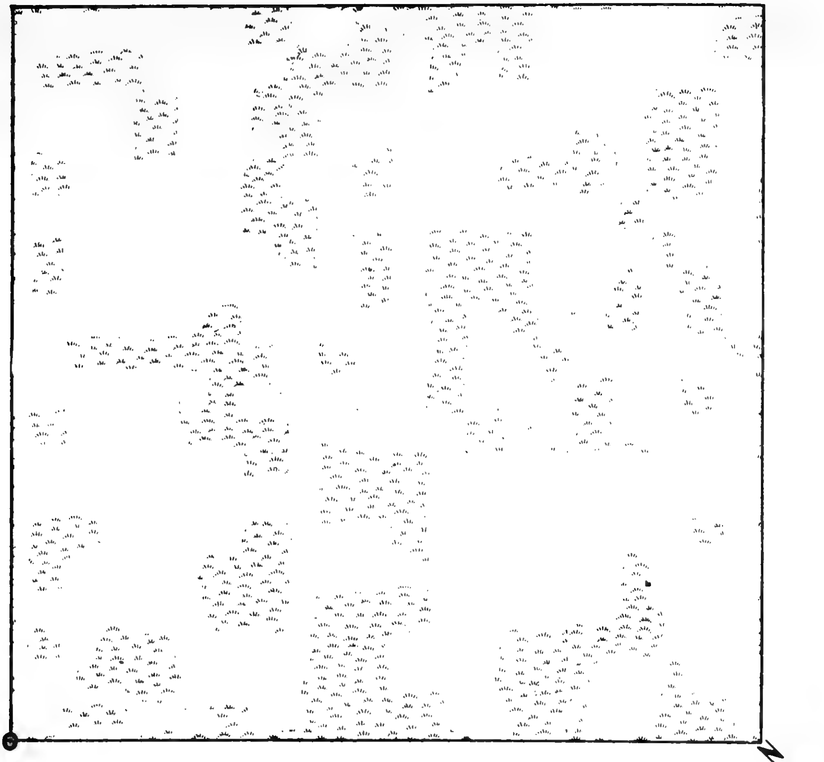
Figure 16. Sandgrass-buttonweed community permanent quadrat 2.



95 percent *Triplasis purpurea*
5 percent *Ammophila breviligulata*

Total ground cover - 95 percent

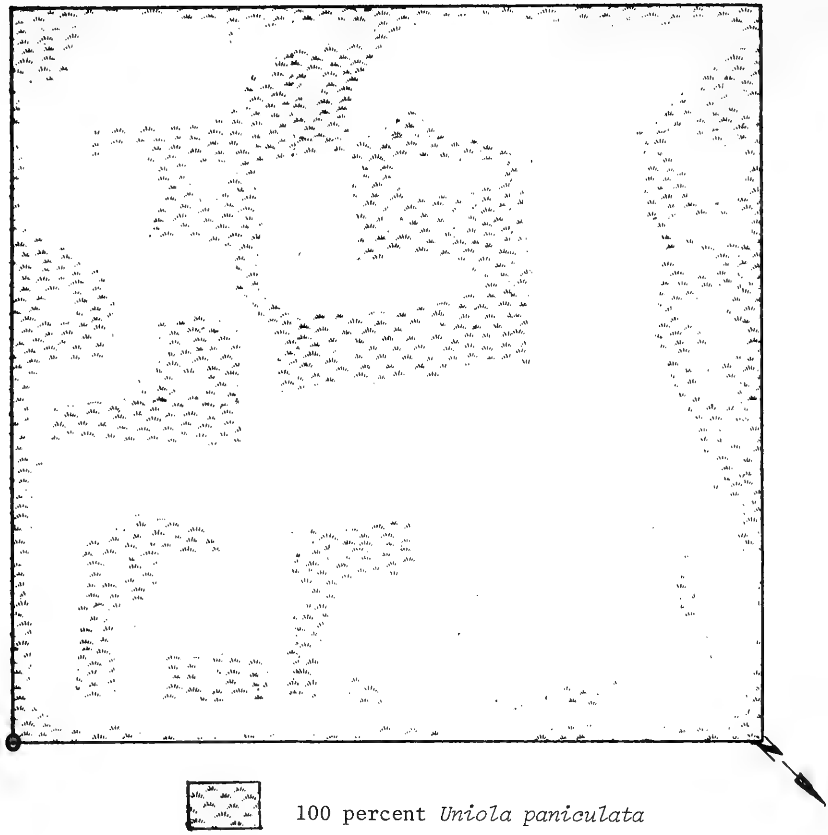
Figure 17. Sandgrass-buttonweed community permanent quadrat 3.



100 percent *Uniola paniculata*

Total ground cover - 35 percent

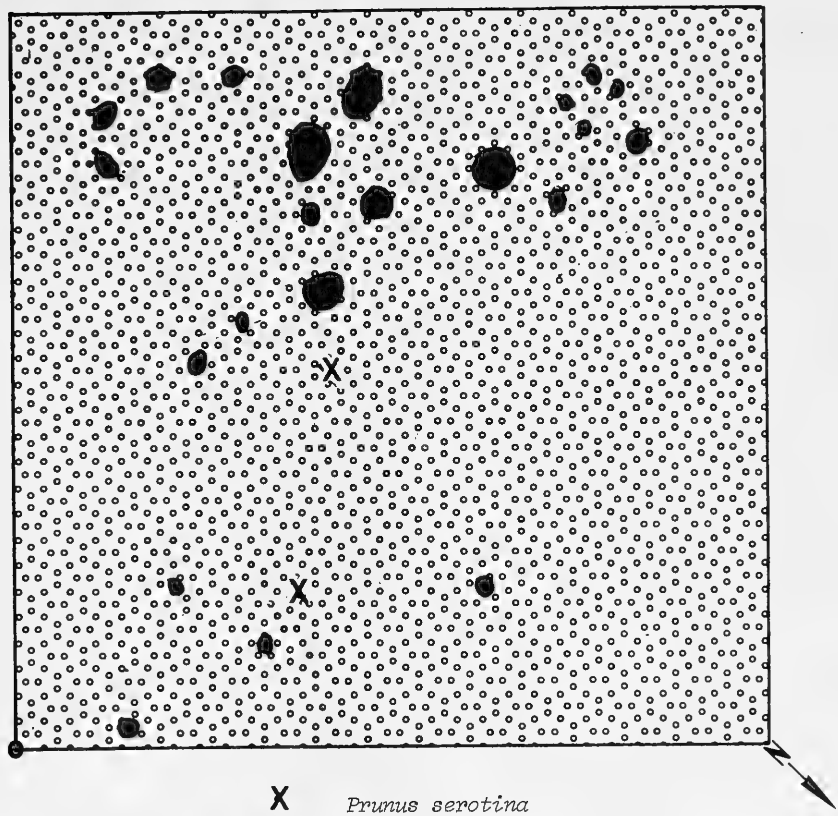
Figure 18. Low dune grass community permanent quadrat 1.



100 percent *Uniola paniculata*

Total ground cover - 35 percent

Figure 19. Low dune grass community permanent quadrat 3.



X *Prunus serotina*

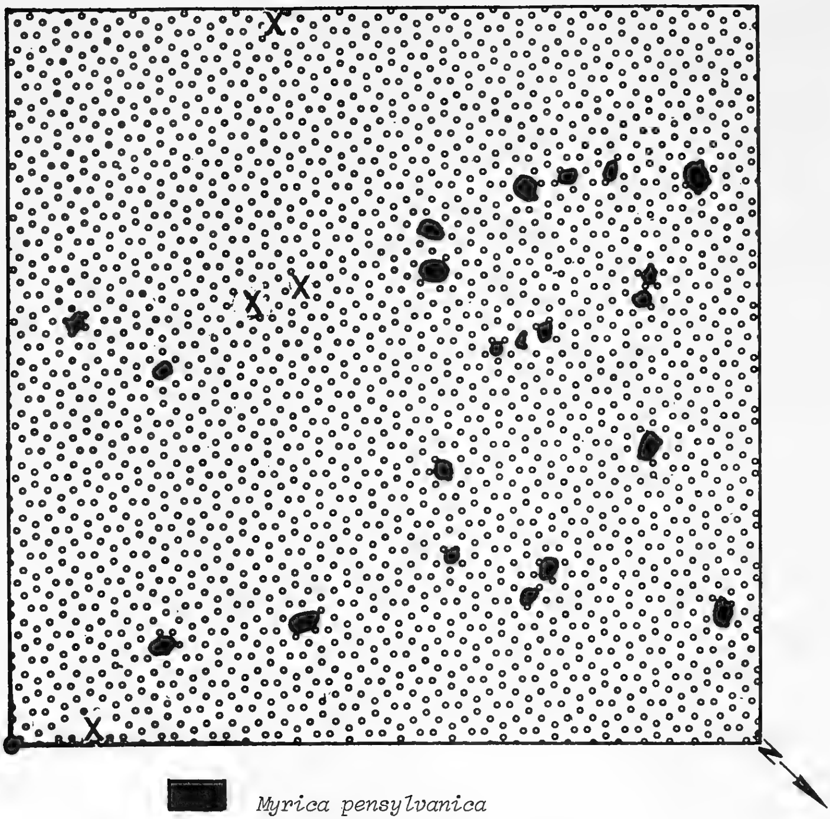
Myrica pensylvanica

Rubus betulifolius
Smilax bona-nox

Total crown cover - 95 percent

Total ground cover - 15 percent

Figure 20. Sound-side shrub community permanent quadrat 1.



Myrica pensylvanica

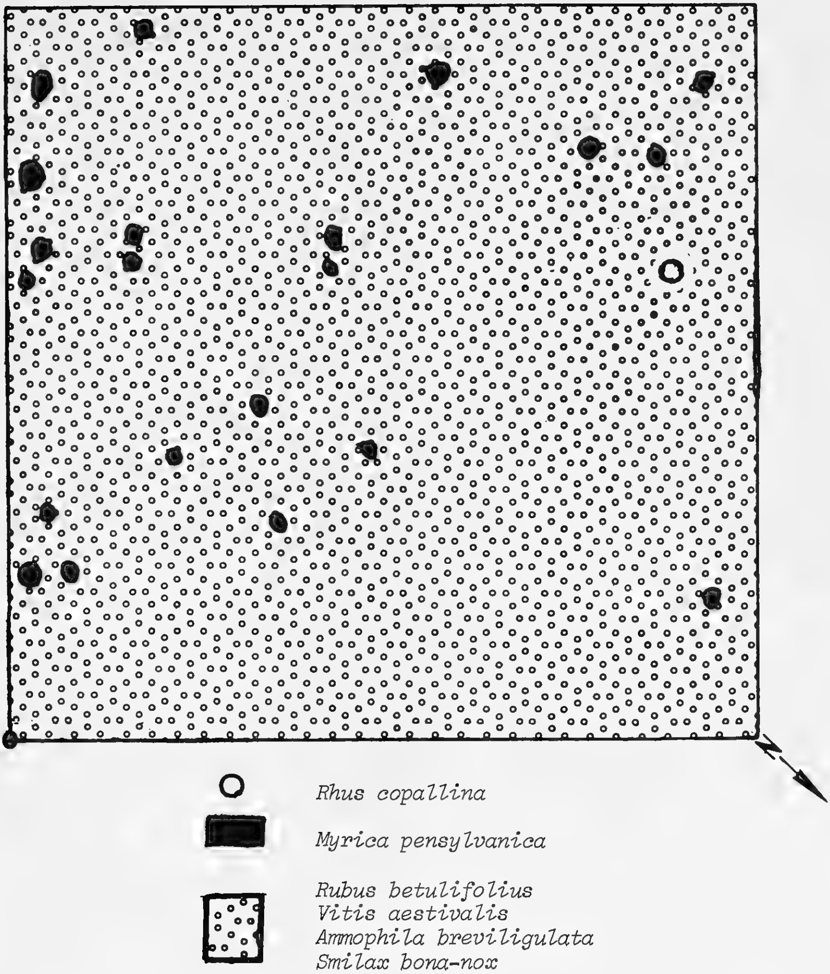
X *Prunus serotina*

Rubus betulifolius
Ammophila breviligulata
Smilax bona-nox
Parthenocissus quinquefolia

Total crown cover - 95 percent

Total ground cover - 10 percent

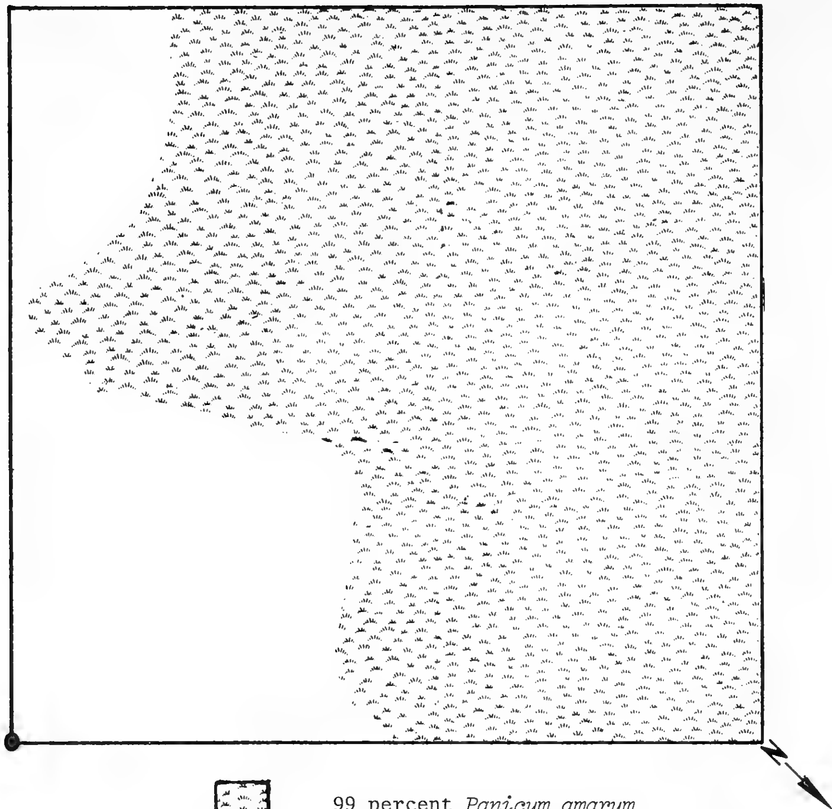
Figure 21. Sound-side shrub community permanent quadrat 2.



Total crown cover - 70 percent

Total ground cover - 10 percent

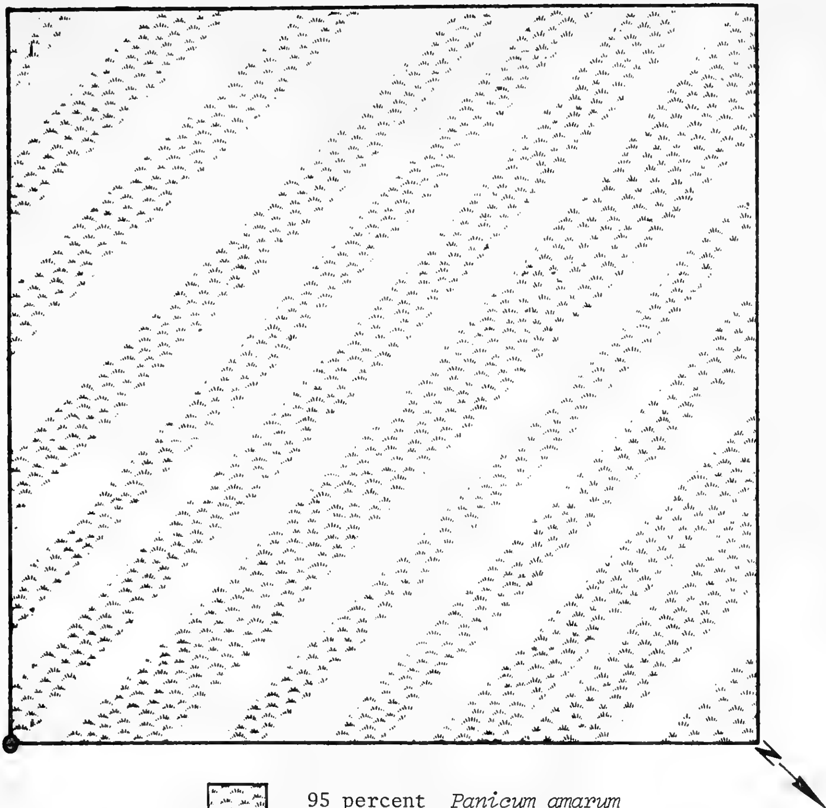
Figure 22. Sound-side shrub community permanent quadrat 3.



99 percent *Panicum amarum*
1 percent *Ammophila breviligulata*

Total ground cover - 45 percent

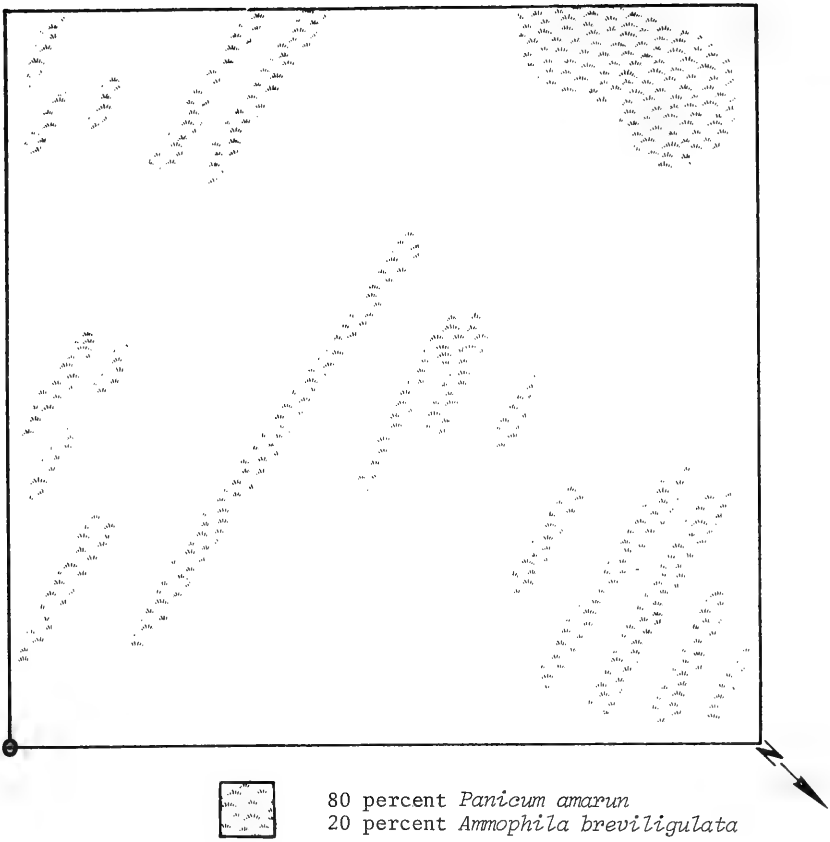
Figure 23. Planted bitter panicum community permanent quadrat 1.



95 percent *Panicum amarum*
5 percent *Ammophila breviligulata*

Total ground cover - 35 percent

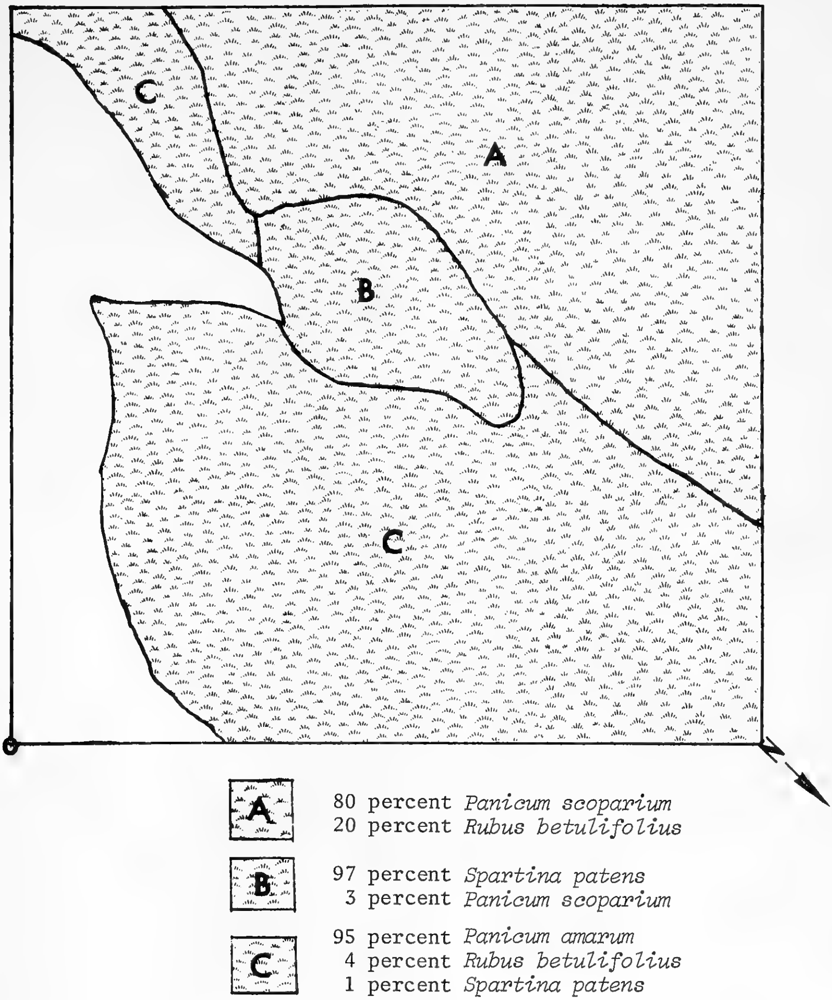
Figure 24. Planted bitter panicum community permanent quadrat 2.



80 percent *Panicum amarun*
20 percent *Ammophila breviligulata*

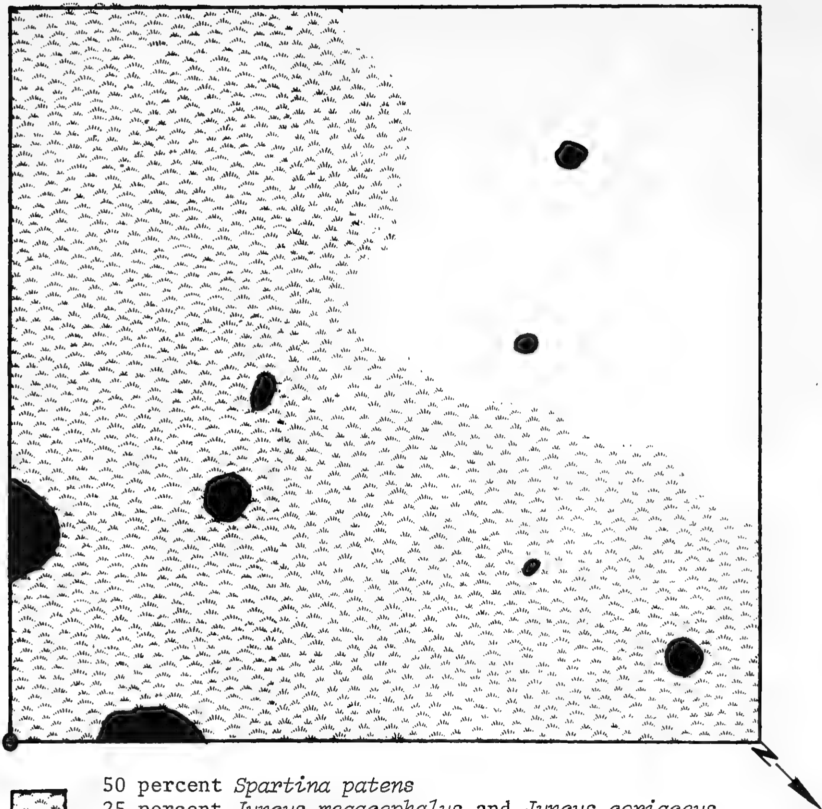
Total ground cover - 10 percent

Figure 25. Planted bitter panicum community permanent quadrat 3.



Total ground cover - 80 percent

Figure 26. Sound-side disturbed community permanent quadrat 1.

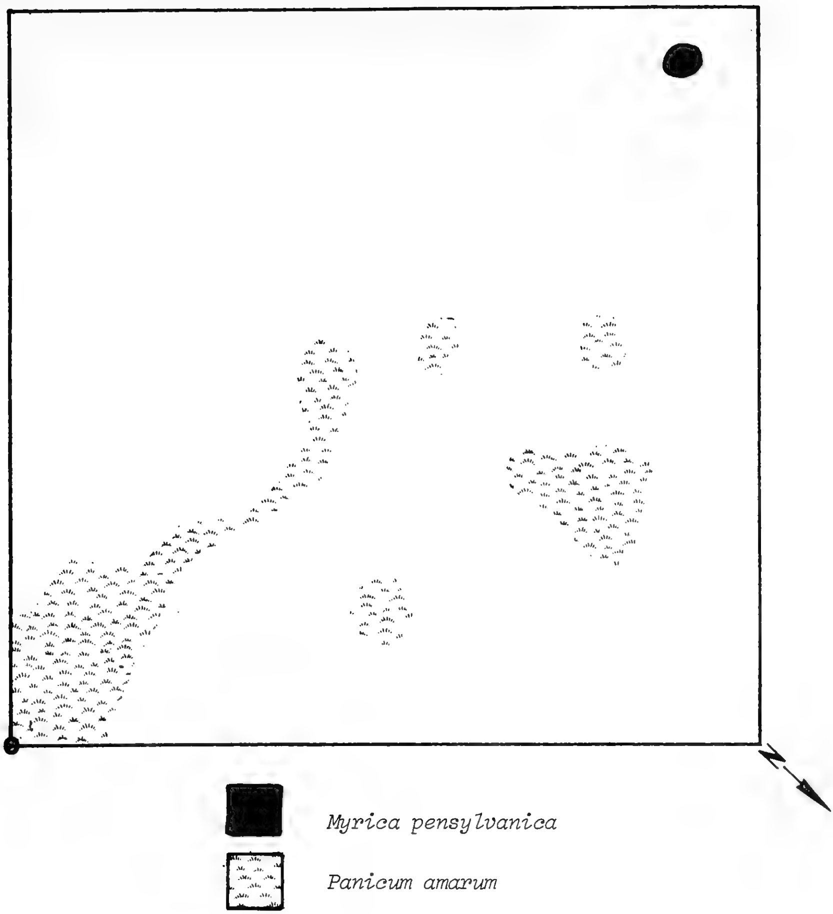


50 percent *Spartina patens*
25 percent *Juncus megacephalus* and *Juncus coriaceus*
25 percent *Cynodon dactylon* and *Panicum scoparium*

Myrica pensylvanica

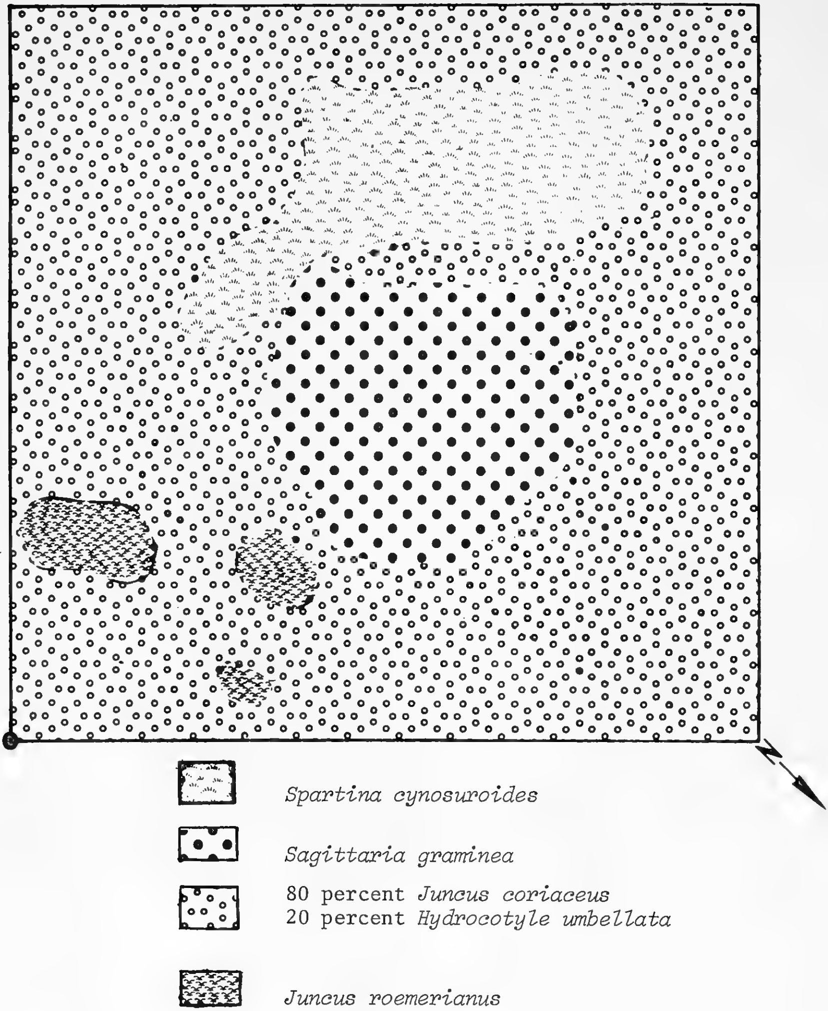
Total ground cover - 75 percent

Figure 27. Sound-side disturbed community permanent quadrat 2.



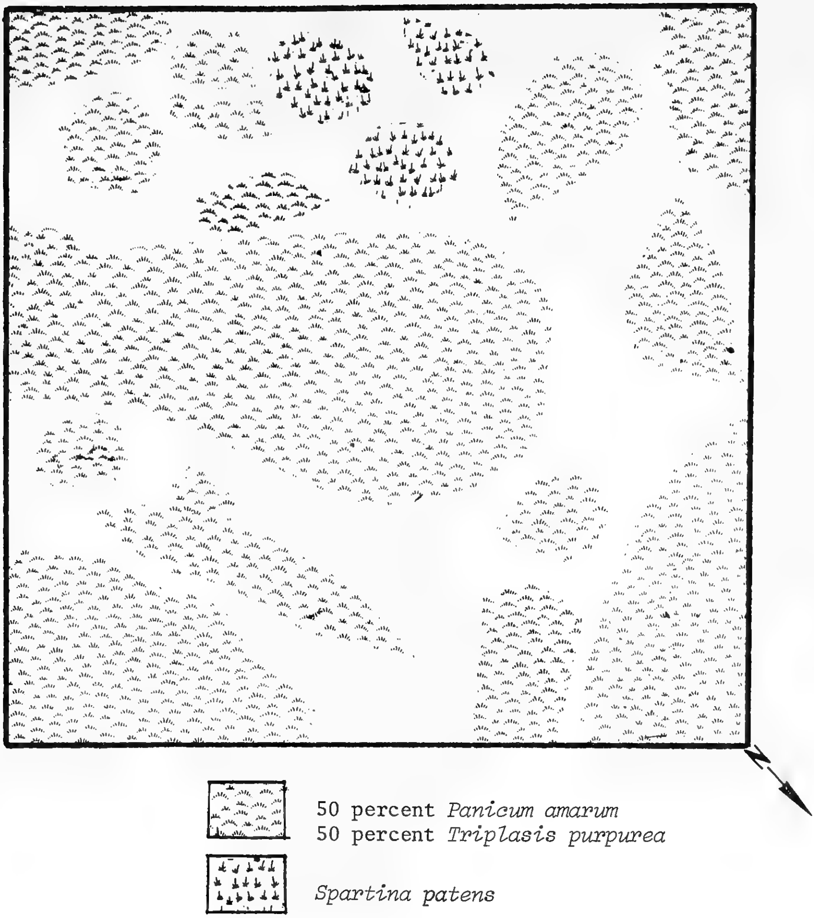
Total ground cover - 10 percent

Figure 28. Sound-side disturbed community permanent quadrat 3.



Total ground cover - 95 percent

Figure 29. Wetlands community permanent quadrat.



Total ground cover - 70 percent

Figure 30. Spurge-sandgrass community permanent quadrat.

Table 14. Location of permanent quadrat stakes at the Duck Field Research Facility (DFRF). Readings are magnetic.

Quadrat Designation	Location
Foredune 1	137°, 97 feet from U.S. Army, Corps of Engineers (USACE) survey marker 16.
Foredune 2	12°30', 696 feet from USACE survey marker located in the southeast corner of the Duck Field Research Facility (DFRF).
Foredune 3	45°, 224 feet from USACE survey marker located in the southeast corner of the DFRF.
Oceanside intershrub 1	350°10', 335 feet from USACE survey marker 11.
Oceanside intershrub 2	350°, 209.2 feet from a point located 290°, 242.5 feet from USACE survey marker in the southeast corner of the DFRF.
Oceanside intershrub 3	330°, 181 feet from USACE survey marker in the southeast corner of the DFRF.
Oceanside shrub 1	320°, 220 feet from USACE survey marker located in the southeast corner of the DFRF.
Oceanside shrub 2	345°, 230 feet from USACE survey marker located in the southeast corner of the DFRF.
Oceanside shrub 3	137°, 293.5 feet from USACE survey marker 16.
Planted American beachgrass 1	278°, 864 feet from USACE survey marker 11.
Planted American beachgrass 2	192°, 781 feet from planted American beachgrass survey marker 1.

Table 14. Location of permanent quadrat stakes at the Duck Field Research Facility - Continued.

Quadrat Designation	Location
Planted American beachgrass 3	148°, 408 feet from planted American beachgrass survey marker 2.
Sandgrass-buttonweed 1	349°, 233 feet from planted American beachgrass survey marker 1.
Sandgrass-buttonweed 2	301°, 332 feet from planted American beachgrass survey marker 1.
Sandgrass-buttonweed 3	277°, 545 feet from planted American beachgrass survey marker 1.
Low dune grass 1	349°, 759 feet from planted American beachgrass survey marker 1.
Low dune grass 2	320°, 691 feet from planted American beachgrass survey marker 1.
Low dune grass 3	326°, 807 feet from planted American beachgrass survey marker 1.
Sound-side shrub 1	280°, 1004 feet from planted American beachgrass survey marker 1.
Sound-side shrub 2	272°, 813 feet from planted American beachgrass survey marker 1.
Sound-side shrub 3	92°, 240 feet from sound side disturbed survey marker 1.
Planted bitter panicum 1	349°, 374 feet from planted American beachgrass survey marker 1.

Table 14. Location of permanent quadrat stakes at the Duck Field Research Facility - Concluded.

Quadrat Designation	Location
Planted bitter panicum 2	320°, 405 feet from planted American beachgrass survey marker 1.
Planted bitter panicum 3	301°, 567 feet from planted American beachgrass survey marker 1.
Sound-side disturbed 1	180°, 545 feet from USACE survey marker 64.
Sound-side disturbed 2	143°, 274 feet from sound side disturbed survey marker 1.
Sound-side disturbed 3	182°, 283 feet from sound side disturbed survey marker 1.
Wetlands	216°, 230 feet from sound side disturbed survey marker 1.
Barren sand dune 1	290°, 579 feet from a point 290°, 242.5 feet from USACE survey marker in the southeast corner of the DFRF.
Barren sand dune 2	290°, 890 feet from a point 290°, 242.5 feet from USACE survey marker in the southeast corner of the DFRF.
Barren sand dune 3	347°, 569 feet from barren sand dune survey marker 2.
Spurge-sandgrass	255°, 210 feet from USACE survey marker 13.

IV. DISCUSSION

1. Floristics.

a. General. Poaceae (grass family) was represented by the most species, making up 19 percent of the total flora. The Asteraceae (daisy family) made up 16 percent and Cyperaceae (sedge family) 8 percent. The remaining families represent 2 percent or less of the total flora. This compares with Burk's (1968) figures for the total Outer Banks of 14.7 percent for the Poaceae and 13.5 percent for the Asteraceae.

Among the species collected, Radford, Ahles, and Bell (1964) cited five as infrequent, three as rare, and one as very rare. The infrequent plants were *Lilaeopsis carolinensis*, *Eupatorium serotinum* (throughwort), *Heterotheca adenolepis*, *Desmodium pauciflorum* (beggar lice), and *Stachys nuttallii* (hedge nettle). The rare species were *Eragrostis elliottii* (love grass), *P. amarulum*, and *A. breviligulata*. The *A. breviligulata* is locally very abundant at Duck due to plantings. *Cyperus surinamensis* was noted as very rare. This species was represented by a large clump of individuals near the edge of the sound in the extreme southeastern part of the study area.

b. *Triplasis purpurea*. This species was the most frequent plant in areas of moderate sand drift which suggests that it may have importance as a secondary soil stabilizer. If this is the case, this species, an annual, must show salt-spray tolerance and function as a soil binder even during the winter when it is dead.

Seed and seedling tolerance to salt and the effect of cold treatment on seed germination was studied. The seedlings exhibited a high tolerance to both a salty substratum and to salt spray. Seed tolerance was as great as that of *U. paniculata* and *A. breviligulata*, the two most important primary dune stabilizers on the Outer Banks (Seneca, 1969).

Observations made during the winter of 1974-75 indicate that when this species occurs in abundance, as in the sandgrass-buttonweed community, it acts to stabilize sandy areas during the winter months. The usefulness of this species as a sand binder should be carefully evaluated with appropriate test plantings.

2. Vegetational Studies.

The plant communities at the Duck Field Research Facility exist because of the natural environmental forces characteristic of the Outer Banks and a long history of disturbance. Some types of disturbance are common to the Outer Banks in general, others are unique to this site, e.g., its use as a gunnery range.

As shown by the ordination (Figs. 3, 4, and 5), some plant communities are strongly delimited while others are similar. The distinct communities include the foredune community, which has been established on the artificially stabilized foredune and enriched by a series of plantings. This community, though quantitatively unique, has its component species represented in almost half of the other communities (49 percent). Hence, the species growing on the foredune are not restricted there, but represent those species able to resist the harsh environmental conditions of this habitat. The selecting factors appear to be strong winds, the accompanying salt spray, sand abrasion, and evaporative stress, as well as low nutrient levels and extreme temperatures.

The wetlands community on the sound side of the study area was the most unique community. There were 21 species in this community, of which 16 were found nowhere else, and 3 others in only one additional community. The aquatic nature of these sites has produced the environmental factors so extremely different from those generally found at Duck, which easily explains its uniqueness as well as its species abundance.

Two shrub-dominated communities, the oceanside shrub and sound side shrub communities, occur at Duck. In the X-Y aspect of the ordination (Fig. 3), these two communities occur close to one another and widely separated from all other communities. A similar impression is given in the Y-Z aspect (Fig. 5), although they are further apart, while the X-Z aspect (Fig. 4) shows them at opposite ends of the Z axis. These communities are unique, but six of the seven species comprising the oceanside shrub community also occur in the sound-side shrub community. The seventh, though not sampled was observed growing in the sound-side shrub. The major difference between these communities is the richness of the sound-side shrub community (28 species) and the dominance of *M. pensylvanica* in the oceanside shrub community.

It appears that the oceanside shrub community exists where it does due to the sheltering effect of the foredune. Conditions here are still severe enough to exclude all but the hardiest members of the sound-side shrub community. The oceanside shrub, which appears to be an early successional stage of what could become like the sound-side shrub community, is likely to remain in an arrested condition until it is destroyed by prevailing shoreline dynamics.

The sound-side shrub community is a middle successional stage of what could become a maritime forest (Wells, 1938). The only significant species not included in the samples was *Quercus virginiana* (live oak) which was represented in the community with a small number of scattered saplings.

The sound-side disturbed community's samples included 24 species, of which 14 were also found in the sound-side shrub community. Six of the species exclusive to the sound-side disturbed community were those often associated with highly disturbed locations. This community was once the site of military housing which was demolished and the site bulldozed. Prior to the establishment of these buildings the site may have been partly covered by sound-side shrub and partly by a wetlands community. At the present time it appears to be almost an ecotone between sound-side shrub and low dune grass, with the weedy component relatively stable. As long as these species are not overtopped by heavy shade-casting competitors they will remain important. *M. pensylvanica* is beginning to slowly expand into this area (frequency 5.4 percent).

The two shrub-dominated communities and to some extent the sound side disturbed community are being enriched by nitrogen-fixing bacteria on the nodules of legumes and on the roots of *M. pensylvanica*. Several excavations revealed the presence of such nodes on *M. pensylvanica* at Duck, supporting the results of Morris, et al. (1974).

Growing behind the foredune, in front of, between, and immediately behind the stands of *M. pensylvanica* which compose the oceanside shrub community is the oceanside intershrub community. Figures 4 and 5 show this community to be quite distinct. Of the 16 species included in the samples of this community, 4 were exclusive; however, the other species occurred in 43.6 percent of the other communities. The components of this community are not shade tolerant and the oceanside shrub community seems to be expanding to its detriment.

Two of the remaining six communities appear basically natural while the other four are manmade. The low dune grass community resembles the moderate drifting dune community of Brown (1959). The harsh conditions of these exposed, unstable sand dunes result in either a sparse plant community or no vegetation. There was no vegetation on about 27 acres at Duck (Table 13). Eleven different species were included in the samples of the community; however, the biomass was only 15.2 grams per square meter (Table 7). The annual nature of many of the low dune dominants suggests great variability in its extent and productivity from year to year.

As indicated by their names the planted American beachgrass and the planted bitter panicum communities were artificially established on the most heavily bombed part of the study area. Decontamination and extensive preparation prior to planting greatly modified the area's topography (personal communication, D. Woodard, 1974).

Though *A. breviligulata* has the highest biomass in the planted American beachgrass community, *T. purpurea* is the more widely distributed species (Table 5). The composition of this community, as shown by the ordination, is not very unique. In fact, the planted American beachgrass, planted bitter panicum, sandgrass-buttonweed, and low dune grass communities are all phytosociologically similar. The major differences between these communities relate to their physiognomy, which is a reflection of the biomass of one or two key dominants in each community, not the presence of any unique plant assemblages.

The planted bitter panicum community had one of the most depauperate floras of any of the community types and its biomass (5.6 grams per square meter) was the lowest measured in this study (Table 9). This community appears to have been a generally unsuccessful planting experiment.

The sandgrass-buttonweed and the spurge-sandgrass communities differ in the relatively high biomass of the former (68.7 grams per square meter) and the low biomass of the latter (11.8 grams). The species composition of the two communities agrees for six out of the seven species sampled. The major differences between them however was quantitative (Tables 6 and 12). *Euphorbia polygonifolia* (frequency 75 percent) was the most frequent species in the spurge-sandgrass community while it ranked next to last (6.7 percent) in the sandgrass-buttonweed community. *Triplasis purpurea* and *D. teres* were, however, well distributed in both types. Whether these two types are separable into two distinct communities is open to argument. Woodard (1974) has indicated that the sandgrass community was experimentally fertilized. This could be the reason for the measured biomass differences. All six communities repeatedly occur near each other on all axes of the ordination, and two probably belong to a continuation of types which show local variation due to environmental or historical variability.

It is felt, however, that for an intensive study on a relatively small area such as the Duck Field Research Facility it is better to draw out differences which might seem minor than to lose detail in overgeneralization. For this reason, each of the 11 defined communities has been kept separate.

The results of these studies have raised many interesting questions. Our observations suggest that the successional theories of Wells (1928 and 1938) be closely examined and perhaps reformulated. Questions have also been raised as to the future development of each of the delimited communities. Which species are likely to increase in importance, and which will decline? Especially interesting is the future of the planted and the sound-side disturbed communities.

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