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Time And Tide

RESOURCE CONSERVATION & DEVELOPMENT PROJECT

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BEACH VEGETATION AND OCEANIC PROCESSES STUDY OF POPHAM STATE PARK BEACH, REID STATE PARK BEACH, AND SMALL PT. BEACH

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Introduction

This project covers three of Maine's northern barrier beach systems. Two of these beaches, Popham State Park and Reid State Park, are owned by the State of Maine and used as recreational beaches. Section three of this report, suggestions for long-term management, will focus on these beaches. The third beach system, Small Pt. Beach, is privately owned by the St. John family; this beach was used as a control to the state beaches, as it is in an undeveloped, natural condition. In the areas of human impact, dune succession, and aeolian transport, Small Pt. Beach has been especially useful as a comparison to the state beaches.

Three areas of botanical investigation are reported: First, plant community research; second, oceanic processes research; and third, suggestions for long-term management. The plant community research deals with the plants present, their organization and successional patterns, their sensitivity to human and natural impact, and their production; the oceanic processes research deals with climatic and sea level trends, dune dynamics, sand transport, and year around observation of beach processes. When it was relevant, portions of the investigation were examined from both a historical and current perspective.

The following eight study objectives have been fulfilled. First, plant communities are described in terms of their dominants and sub-dominants, along with any factors which relate the plants or communities to the coastal environment. Second, plant community succession from the coast inland and within dune blowouts is documented. Third, large scale (1/6,000) vegetation maps are presented for all three beach systems.

Fourth, quantification of human impact on different plant communities was obtained. Fifth, summer salt-marsh production was determined. Sixth, a historical and current analysis of erosional problems is examined. Seventh, beach and dune processes, including aeolian sand transport, overwash, erosion, and barrier beach retreat are discussed. And eighth, management recommendations based on all compiled information are presented. They pertain to long-term use for recreation and preservation; they deal with specific problems as detected during the study or problems which might arise or become more serious in the future if not controlled now.

Plant Community Research

Floristics

During the summers of 1975 and 1976, plant specimens were collected in the dune, dune-shrub, dune-forest, fresh-water marsh and salt-water marsh communities. Plants were identified by the investigator and verified by the curator of the University of Massachusetts Herbarium, Mr. Harry Ahles. Sampling in all communities was complete with the exception of some herbaceous species in the fresh-water marshes. From two-hundred-and-sixty collections, one-hundred and seventy different lichens, mosses, ferns, gymnosperms and angiosperms were identified; voucher specimens will be placed in the herbaria of the University of Massachusetts and the University of Maine.

Species are organized into three lists (Appendices A, B and C). Appendix A is arranged according to the correct family position in the botanical Englerian Sequence, with genera and species alphabetized within each higher taxonomic category. In appendix B, genera are alphabetized, and common names, if available, are alphabetized in in appendix C. Species in all lists have cross referencing information. Plants were identified by the following keys: Gymnosperms and angiosperms (Fernald, 1950), lichens (Hale, 1969), ferns (Cobb, 1963) and mosses (Conard, 1958).

Plant Community Descriptions

Introduction

A list of the important coastal plant communities, sub-associations and dominants appears in Table 1. The descriptions presented in this section are based on percent cover data, quantitative point sampling data, and visual inspection of unsampled areas. For the sake of brevity, the quantitative information has been eliminated from this section, although percent cover data for three of eight profiles surveyed is presented in the next section of the report (fig. 9, 10, and 11); likewise, a small amount of the quantitative point sampling data is presented in the impact section (Tables 2, 3, and 4). Only descriptions of plant communities and their important dominants in relation to the coastal environment will be presented here.

Descriptions of the Communities

Foredune Community:

Common and botanical names of foredune plants, along with their life cycles, are listed below. The order of the list is the sequence in which they colonize from the ocean inland.

Sea rocket	*Cakile edentula*	annual
Saltwort	*Salsola Kali*	annual
American beachgrass	*Ammophila breviligulata*	perennial
Beach pea	*Lathyrus japonicus*	perennial
Dusty miller	*Artemesia Stelleriana*	perennial

Table 1 Plant Communities, Dominant Species, and Sub-Associations

	Community Type	Dominants	Sub-Associations
1)	Fore dune	Sea rocket (*Cakile edentula*) Saltwort (*Salsola Kali*) American beachgrass (*Ammophila breviligulata*)	
2)	Dunegrass	American beachgrass	a) American beachgrass - beach pea (*Lathyrus japonicus*) b) American beachgrass - raspberry (*Rubus idaeus*) c) American beachgrass - gooseberry (*Ribes hirtellum*)
3)	Beach-heather	Beach-heather (*Hudsonia tomentosa*)	a) Beach-heather - *Cladonia* b) Beach-heather - *Cladonia* - pinweed (*Lechea intermedia*) - aster (*Aster linariifolius*)
4)	Shrub	Bayberry (*Myrica pensylvanica*) Virginian rose (*Rosa virginiana*) Meadow sweet (*Spirea latifolia*) Raspberry	
5)	Dune forest	Pitch-pine (Pinus rigida)	a) Pitch-pine beach-heather - *Cladonia* b) Pitch-pine - shrub spp. c) Pitch-pine - red maple (*Acer rubrum*) - red oak (*Quercus rubra*) - white birch (*Betula papyrifera*) - Serviceberry (*Amelanchier spp.*) d) Speckled alnus (*Alnus rugcsa*) - winterberry (*Ilex verticillata*) - serviceberry - quaking aspen (*Populus tremuloides*) - with some pitch-pine
6)	Brackish to Fresh-Water Marsh	Narrow-leaved Cat-tail (*Typha angustifolia*)	a) Narrow-leaved Cat-tail b) Narrow-leaved Cat-tail - sedge - rush
7)	Salt-Water Marshes Highmarsh:	Salt-meadow grass (*Spartina patens*)	a) Salt-meadow grass - alkali-grass b) Salt-meadow grass - alkali grass - rushes - sea lavendar (*Limmonium Nashii*) - sea milkwort (*Glaux maritima*)
	Lowmarsh:	Salt-water cord-grass (*Spartina alterniflora*)	

Occasionals: Orach (Atriplex patula); Seabeach sandwort (Arenaria peploides); Sea-burdock (Xanthium echinatum)

American beachgrass is the community dominant at Popham and Reid, but is subdominant to sea rocket and saltwort in the more natural condition at Small Point (Fig. 2). Both sea rocket and saltwort can colonize further out on the beach than American beachgrass. Beach pea and dusty miller are restricted to the upper aeolian ramp or behind the fore dune ridge in the dunegrass community.

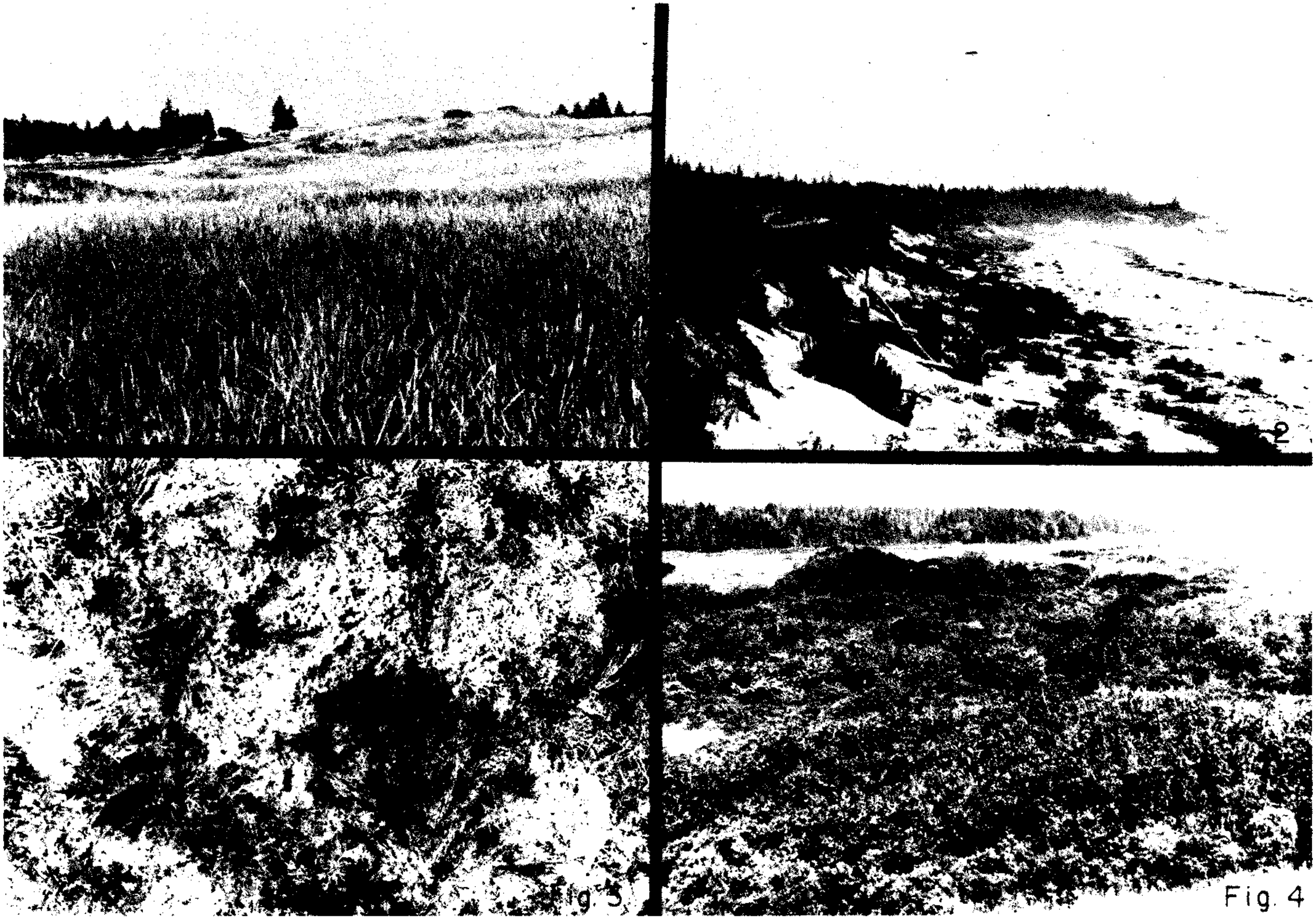
Sea rocket and saltwort have heavily branching stems which help catch and stabilize sand from early summer to early winter; small dunelets form around these plants and act as the basis for dune formation. If the level of the sand around the plants reaches a height sufficiently above mean high water, American beachgrass can colonize. During the summer of 1976, this occurred at Popham along the wide beach just west of the wooded picnic area. The last spring storm deposited on the beach backside a four-foot-wide drift line. Thousands of sea rocket seeds germinated in late spring, and sand began to collect around the plants as they grew. Within a few months, approximately one foot of sand was deposited; by the end of summer, American beachgrass and other plants were beginning to colonize and stabilize the dunelet. If the level of sand around the early colonizers is not sufficiently high, American beachgrass cannot invade, and most of the above ground portions of these annuals break off during the winter months. The storm waves and winds flatten the dunelet and redistribute the sand. The perennial root stocks and more persistent aerial shoots of American beachgrass, beach pea and dusty miller are needed to stabilize the dune started by the colonizing annuals.

Figure 1 - Dunegrass plant community, Reid State Park. Dense growth of American beachgrass.

Figure 2 - Foredune colonizing community, Small Point Beach. Sea rocket, saltwort, and American beachgrass comprising a 22% plant cover. Note salt spray in the air above the beach.

Figure 3 - Beach-heather - pinweed - aster - lichen community, Small Point Beach. Picture taken directly toward the ground to show extremely high plant cover. All light colored plants are lichens.

Figure 4 - Shrub community, Small Point Beach. Shorter shrubs: Virginian rose, meadow sweet, raspberry, and bayberry. Taller shrubs: Winterberry, serviceberry, blueberry, and others.


2
Fig. 3
Fig. 4

Dunegrass Community:

The dunegrass community (Fig. 1), dominated by American beachgrass, begins at the fore dune ridge and continues inland until a heath, swale or shrub community gains dominance. The innermost dunegrass penetration depends on the topography of the dunes (i.e., depth of the water table) and the distance from the ocean (i.e., salt-spray effect). The low species diversity in the dunegrass community attests to the severity of the environment. There is no soil development and few nutrients are held in the sand. The salt-spray, which supplies only salt cations, is heavy and eliminates all but the most specialized plants. The mist, seen as a haze over the beach in figure 2, is heaviest on hot summer days when the plants are under the most drought stress.

In some areas, American beachgrass grows in thick luxuriant stands, forming a monotypic community. In other areas, additional species enter the community as occasionals, or they acquire the status of sub-dominant. Raspberry (Rubus idaeus) often forms a sub-association with American beachgrass at Reid State Park and Small Point; the plant's proximity to the ocean appears to keep it in a short form, as is often induced by salt spray, with little flowering and fruiting. Gooseberry (Ribes hirtellum) also forms a sub-association with American beachgrass at Reid State Park, but it does not appear to be affected by salt spray as much as raspberry. American beachgrass and beach pea compose another important dunegrass sub-association; beach pea mixes with American beachgrass abundantly in some areas, climbing up the grass stalks with its tendrils or growing robustly to the same height as the beachgrass. Beach pea, raspberry and gooseberry are all found in areas where the density of American beachgrass is not too high (i.e., less than 40%); as the density of American beach-

grass increases, these other plants are excluded and a monospecific community results.

As a sand-stabilizer, American beachgrass is most important in both the dunegrass and foredune-colonizing communities, due to its tremendous underground rhizome and root system. A rhizome is a horizontally growing, underground stem with the capacity to form new aerial shoots at any of its closely spaced nodes (approximately 10 cm. apart). Secondary roots grow profusely from the rhizomes and vertical root stalks leading to the sand surface. This combination of rhizomes and secondary roots may reach a depth of approximately six feet along the foredune ridge, forming a tremendous sand binding network. In more stabilized backdune areas the roots only grow to a depth of a foot.

Another demonstration of the specialization of beachgrass for growth along the fore dune, which will be discussed more fully in another section, is its ability to produce new shoots to grow vertically through a fresh sand supply. If the grass is buried by wind or water transported sand (Fig. 34), it will push up new growth during the next growing season (Fig. 35). Although a permanent marker was not placed in this area until after the winter deposition, examination of the previous year's root system (Fig. 8) shows growth through deposits of 30 to 40 cm. in some areas. Very few plants are specialized enough to withstand this burial and survive.

Beach-Heather Community:

The beach heather community is found in drier spots inland from the dunegrass community. Beach-heather, <u>Hudsonia tomentosa</u>, is the dominant plant of the community, and the only plant of the community in more

heavily trodden areas. In some areas of Popham and Reid State Parks, a few species of the lichen genus *Cladonia* are found along with beach-heather, but the fullest development of the community is found in undisturbed areas of Small Point Beach. Here, beach-heather, pinweed (*Lechea intermedia*), aster (*Aster linariifolius*), and up to seven species of lichens are found growing in a dense carpet, leaving no exposed sand (Fig. 3). Because the short growth-form allows easy access to pedestrians and because some of the plants are very sensitive, the beach-heather plant community can be easily destroyed.

Shrub Community:

The shrub community (Fig. 4) found on the sand dunes is usually a dense tangle of impenetrable bushes approximately two to five feet in height. Four shrubs, each dominant in different areas, are the most important plants; they are bayberry (*Myrica penslyvanica*), virginian rose (*Rosa virginiana*), meadow sweet (*Spirea latifolia*), and raspberry (*Rubus idaeus*). In some areas, one shrub forms a monospecific community, while two, three or even four grow densely together in other places. The relative importance of any of the dominants changes continuously. Poison ivy (*Rhus radicans*) and gooseberry are sometimes found as sub-dominants. Because of the dense growth and prickly spines on some of the plants, this community is seldom impacted by park visitors.

Dune Forest Community:

The dune forest (Fig. 5) can have many variations in growth form or composition, but one tree, pitch-pine (*Pinus rigida*), is always present. Because of its moderate tolerance to salt-spray and its ability to live

on a sandy substrate, pitch-pine can grow closer to the ocean than any other tree on the dunes. In some areas, the dune forest is very open; the pitch-pine trees are ten to fifteen feet apart and beach-heather and Cladonia lichens grow in between the trees. In other places, the pitch-pine grows in a dense mono-specific community. Both of these situations are present on Small Point Beach, where balsam-fir (Abies balsamea), red spruce (Picea rubens), and white spruce (Picea glauca) can also be found in small numbers in this immature forest. At Popham State Park, two other situations exist.

First, an open pitch-pine shrub association is sometimes found, where the trees are widely spaced and a thick shrub community grows between the pine trees. The second situation (Fig. 5) occurs when pitch-pine, red maple (Acer rubrum), red oak (Quercus rubra), white birth (Betula papyrifera), and serviceberry (Amelanchier spp.) grow together. This is the best development of the dune forest. The forest is rather short in stature, usually 25 to 40 feet high, but relatively old. Some of the larger pitch-pine trees at Popham have been determined by corings to be one-hundred years old. The understory is rather open with herbaceous forest floor species such as wild sarsaporilla (Aralia nudicaulis), Canadian star-flower (Trientalis borealis), bunchberry (Cornus canadensis), and trailing blackberry (Rubus hispidus) scattered under the trees. There is no dune forest at Reid State Park.

One other forest-like association should be mentioned. In some low, moist localities, a highshrub thicket is often found. Speckled alnus (Alnus rugosa), winterberry (Ilex verticillata), serviceberry and quaking aspen (Populus tremuloides) are the most important plants; if the habitat is not extremely wet, then pitch-pine is also encountered. The understory

Figure 5 - Dune forest, Popham Beach. Most mature development of dune forest on all the beach systems. Pitch-pine, red maple, red oak, white birch, and serviceberry all present.

Figure 6 - High salt marsh, Reid State Park. Salt-meadow and alkali grass, dominant species; rushes, sea lavender, and sea-milkwort, sub-dominant species.

Figure 7 - Low salt marsh, Small Point Beach. Salt-water Cord-grass growing robustly and flowering along Sprague River.

Figure 8 - Overwash revegetation plot, Popham Beach. Hole dug alongside a grass culm. Bottom of meter tape at level of previous year's root system; root system for present year budding from culm node at 28 cm (i.e., 28 cm of overwash deposition). Change in grass culm color at 42 cm indicates sand level before excavation.


Fig. 5
Fig. 8

is composed of meadow sweet and virginian rose. This Shrub thicket association, growing to a height of ten to twenty feet, may be found to a limited extent on all three beach systems.

Fresh to Brackish-Water Marsh:

Although only examined cursorily, this type of marsh is present at both Popham and Reid. Narrow-leaved cat-tail (Typha augustifolia) is the most important plant. Behind Mile Beach road at Reid State Park, cat-tail grows in a thick, monospecific stand; the ground water is brackish and the plants are occasionally reached by high tides. At Popham, sedges and rushes mix with narrow-leaved cat-tail in a more open marsh.

Salt Marsh Communities:

The salt marshes, present on all three beach systems, take two forms; highmarsh (Fig. 6) and lowmarsh (Fig. 7). The species composition is distinctly different in the two marshes; composition is controlled by marsh elevation and hence, by the amount of tidal inundation per day. Since salt marshes are extremely important to the estuarine-ocean ecosystem, summer grass production was examined and is reported in a later section.

The highmarsh (Fig. 6) is dominated by two short grasses; salt-meadow grass (Spartina patens) and alkali-grass (Puccinellia maritima). In some areas, they grow quite thickly together, eliminating any other plants; in other localities, sub-dominant rushes (Juncus spp.), sea-lavender (Limmonium Nashii), and sea-milkwort (Glaux maritima) become prominent members of the community. The highmarshes are inundated several times in each monthly tidal cycle.

The lowmarsh (Fig. 7), characterized by salt-water cord-grass (*Spartina alterniflora*), is flooded twice daily. Salt-water cord-grass is practically the only plant found in this community, often growing six feet in height along the tidal creeks. These robust plants flower in September; after their death, they decay, break up, and float out into the estuarine system, thus helping to nourish the complex estuarine food web.

PLANT COMMUNITY ORGANIZATION AND SUCCESSION

INTRODUCTION

To determine plant community organization and succession on the beach system, three methods (vegetation-topographical transects, serial-photographic mapping, and a blowout comparison series) were employed. The vegetation-topographical transects provide information on species composition in relation to elevation across the dune system and distance from the ocean, while vegetation mapping gives a more complete picture of plant community organization in relation to the whole beach system, tidal rivers and rocky uplands. Both methods show community changes as a function of salt spray and water inundation.

As mentioned above, plant community succession may be studied by vegetation transects from the beach inland; it may also be studied by an analysis of a series of disturbed areas. Sand dune blowouts in various stages of revegetation can be examined to determine the successional pattern, and once determined, the vegetation in other disturbed areas may be compared to the pattern in order to establish its stage of revegetation.

Materials and Methods

After sites were selected for topographical transects, which represented the diversity of communities present, steel poles were placed behind the fore dune as permanent markers for future vegetational surveys and erosional changes. Starting from the swash line and surveying into either the back dune forest or marsh, transects were surveyed perpendicular to the beach. At every ten meter intervals, or less if community composition was changing rapidly, the presence and percent cover of all species in square meter quadrats were analysed. The presence and percent cover

data are bar-graphed as a function of topographical distance from the permanent pole and height from mean sea level (Figs. 9, 10, & 11). The vertical axis has been exaggerated for more detailed examination of specie composition vs. the elevation.

During the middle of August 1966, when dune vegetation was in full flush, vertical infrared aerial slides (35 mm.) were taken through a plexiglass covered hole located in the bottom of a small plane. Flight lines were flown at 2000 and 5000 feet over all three beach systems. The control for the base maps was taken from U.S.G.S. maps (1/24,000), and the scale was enlarged four times to produce 1/6000 final maps. To type the first-draft maps, infrared slides were projected onto base maps; the maps were attached to a movable vertical projection board, so that scale changes associated with tip or tilt and elevational variations could be minimized. The vegetation types were then transferred to Mylar over a light table and the final maps (Figs. 12, 13, & 14) copied by a large blueprint reproducer.

The infrared slides were received in October 1976 and the first draft maps were completed by the first week of December 1976. The investigator travelled to Maine the following weekend to ground truth the maps, only to encounter a snow storm. Because of the onset of winter after that visit and the necessity of making and reproducing the final maps during the winter, these maps have not been ground truthed.

In order to investigate dune successional patterns, six blowouts in the active northwest area of Small Point were analysed. The blowouts in various stages of revegetation from an almost bare, completely active blowout to a very mature forested one were examined tophgraphically and vegetatively. Four numbered poles, one for each cardinal direction, were

placed on the rim of each blowout. Topographical transects, by the stadia method, were run from north to south and east to west. The transects were surveyed in this criss-cross pattern to show the concentric rings of vegetation occupied by each community type within the blowout. The vegetation along these transects was examined by presence and percent cover data at one or two meter intervals with square meter quadrats.

The blowout data has been simplified into a series of revegetation diagrams (Figs. 15, 16, & 17). The plant communities represented by this data are given designations, and the community types are extrapolated between the transect lines to better represent the vegetation within the blowout. Viewing toward the center of every blowout, photographs were also taken from each cardinal pole for visual documentation.

Results:

The series of profiles for Popham (Fig. 9), Reid (Fig. 10), and Small Point (Fig. 11) show the effect of elevation on vegetational change. The high marsh species such as salt-meadow grass (Spartina patens) and alkali-grass (Puccinellia maritima) along with the low marsh species salt-water cord-grass (Spartina alterniflora) are only encountered on the protective, back side of the barrier beaches. The dunegrass community as seen on all three profiles and the beach-heather community as seen on the Reid and Small Point profiles are only found at the higher and drier elevations.

The successional series from the coast inland can also be visualized with these profiles; the Small Point profile (Fig. 11) exhibits most of the community types and their topographical positions. Starting from the beach berm and moving across the profile to the tidal creek, the plant

Figure 9 - Morse River Profile, Popham Beach. Topographic and vegetational profile. Percent cover of sand dune and salt marsh species bar-graphed every ten meters. Original profile - 8/15/75. On 4/19/77, the profile was checked, and 56 meters (184 feet) had eroded.

MORSE RIVER PROFILE - POPHAM BEACH STATE PARK

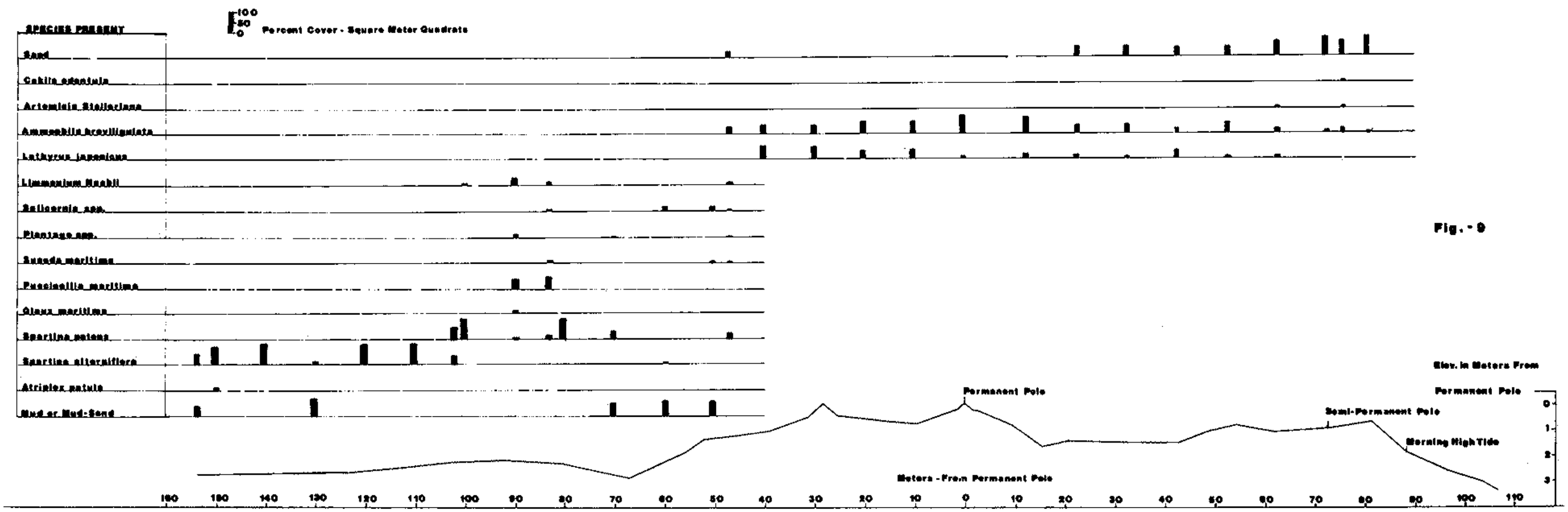


Fig. - 9

Figure 10 - Profile-P2, Reid State Park. Topographic and vegetational profile. Elevations determined from mean sea level (msl). Percent cover of sand dune and salt marsh plants bar-graphed every ten meters. Note high (6 meters) foredune ridge.

PROFILE - P2: REID STATE PARK

Fig. - 10

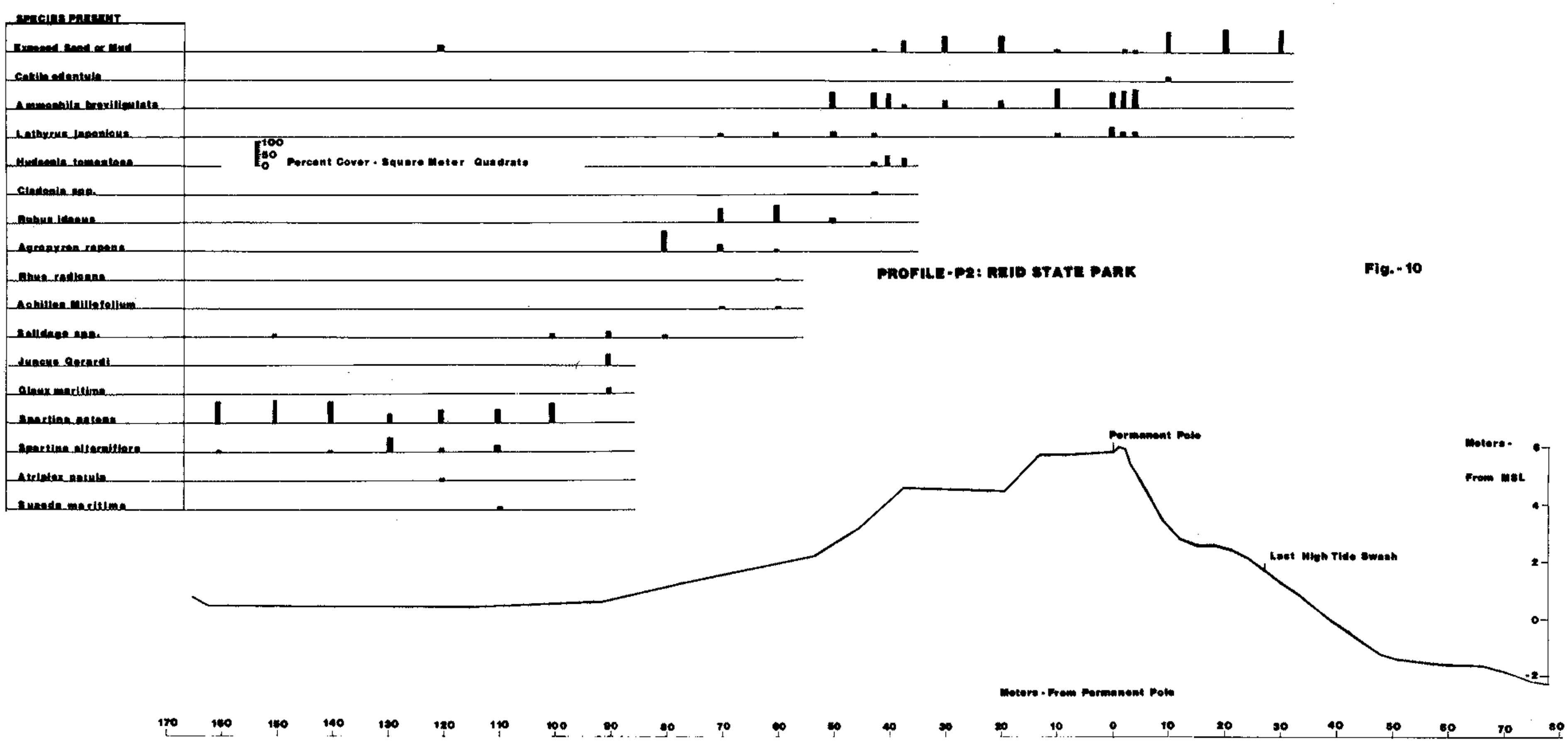
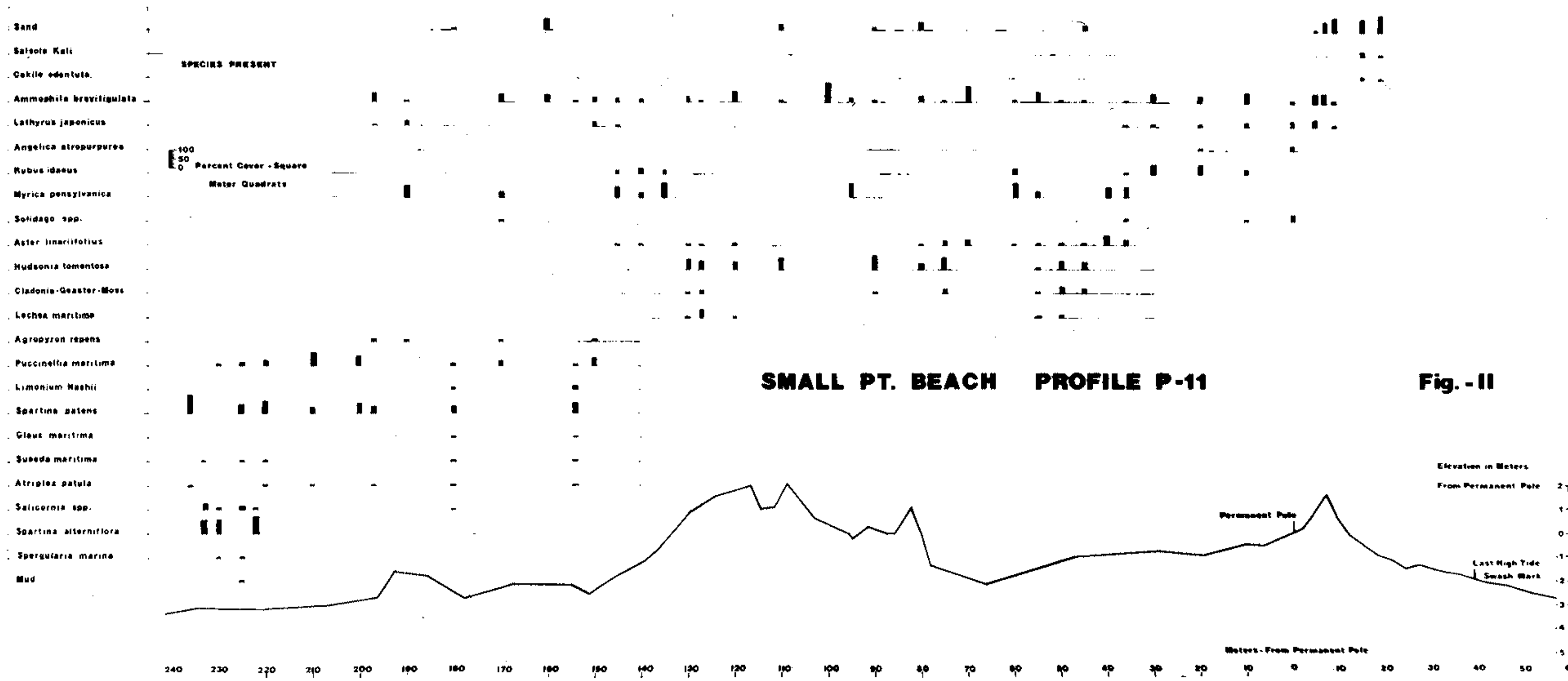


Figure 11 - Profile P-11, Small Point Beach. Topographic and vegetational profile. Percent cover of sand dune and salt marsh plants bar-graphed every ten meters.



SMALL PT. BEACH PROFILE P-11

Fig. - II

communities have the following organization and widths (beginning 20 meters seaward of the permanent pole): Foredune, 10 meters; dunegrass, 45 meters; shrub, 5 meters, beach-heather, 80 meters; shrub, 10 meters; beach-heather, 60 meters; shrub, 20 meters; high marsh, 70 meters; and low marsh, 20 meters. With some variation, this is the basic organizational and successional pattern on all the beach systems. The Reid profile (Fig. 10) depicts an almost non-existent foredune community, followed by dunegrass, beach-heather, small shrub, and high marsh communities.

The Morse River profile (Fig. 9), a much younger area geologically, has not had the time to develop the plant community diversity seen on the other profiles. Since this part of the beach is erosional, there is no foredune community. The dunegrass community extends from 80 meters before the permanent pole to 40 meters after it. The high and low marshes are located from 50 meters to the edge of the creek at 155 meters. Neither a beach-heather nor shrub community has had time to develop here.

One other part of the normal successional series is not shown by the profiles. If given enough time on a stable or accreting beach system, the successional pattern after the shrub community would be to form a shrub thicket and then a dune forest. This series has been documented on other profiles which are not presented here.

The vegetation maps (Figs. 12, 13, and 14) made from infrared aerial photographs give a better but less detailed overview of these vegetation patterns. The map legends furnish short descriptions of the vegetation types. A more complete description of all types can be found in Appendix E; the types used were slightly modified from a system employed by the University of Massachusetts Forestry Department.

Although the relative positions of the communities described by the profiles remain the same, the overall pattern becomes a mosaic when mapped. The dunegrass community (D) is the first one inland from the sand beaches. (The foredune community cannot be seen on aerial photographs.) In both the heavily used state parks and the privately owned Small Point Beach, disturbed dunegrass communities (DD) could also be detected and mapped from the aerial slides because of their low plant cover.

The community organization depicted by the maps depends on three factors: The topography of the dunes in relation to the water table, the salinity of the water, and the amount of salt spray in the air. Low areas in the dune system will be occupied by marshes. If the water is fresh or brackish, a cat-tail -sedge -rush marsh (SMB) such as those behind Reid's Mile Beach will develop. If the water is saline from tidal inundation, high or low salt marshes will develop, depending on the amount of tidal flooding per day. In the areas along the tidal rivers or creeks, low marsh (TSM) has formed; high marshes or irregularly flooded salt marshes (ISM) form away from the creeks in slightly higher areas.

The successional pattern of the non-marsh communities depends mostly on their salt spray specialization. The salt spray is constantly brought inland by onshore breezes (Fig. 2), notably during the summer growing season. The plants of the foredune and dunegrass communities have the highest tolerance to this aerosol. The plants of each succeeding community inland in the order of beach-heather, shrub, shrub-thicket and dune forest have less and less tolerance to the spray. One other factor of note is that each preceding community stabilizes and builds up soil organic layers

Figure 12 - Vegetation Map, Popham Beach State Park. Full description of types in Appendix E. Imagery: Vertical infrared slides, 35 mm. See pocket insert.

Figure 13 - Vegetation Map, Reid State Park. Full description of types in Appendix E. Imagery: Vertical infrared slides, 35 mm. See pocket insert.

Figure 14 - Vegetation Map, Small Point Beach. Full description of types in Appendix E. Imagery: Vertical infrared slides, 35 mm. See pocket insert.

for the next succeeding community.

In localities where erosion is occurring rapidly, a community type which would not normally be found close to the ocean may be seen on or near the foredune ridge. Both the Reid map (Fig. 13) and the Small Point map (Fig. 14) show shrub communities abutting the beach.

The wind also acts as an agent to change the vegetational composition in back dune areas. Possibly by itself or with the help of animals or people, a strong wind can rip a hole through the plant cover and begin to form a blowout bowl. The bowl deepens and enlarges as the sand rips around its interior; the process usually continues until the bottom of the blowout nears the water table. Soil pits dug in the centers of six blowouts reveal that the lowest point of most blowouts was only 30 to 40 cm. above the water table. This damp, heavy sand is difficult to move, even by a strong wind.

Afterwards, the process of revegetation begins. This process has been investigated on Small Point Beach where a series of six blowouts in various stages of revegetation were examined. The plant presence and percent cover data have been summarized in revegetation diagrams (Figs. 15, 16, & 17). Transects were run from north to south and east to west and the information collected along these transects extrapolated in between.

Blowout number 0 (Fig. 15, diagram; Fig. 18, picture) was the youngest; sand movement inside it is still proceeding. American beachgrass is attempting to colonize on the north side of the blowout, but plant cover is probably under two percent. Blowout number 1(Figs. 15 & 19) is still slightly active with a large band of sand around the outside. The center of the blowout has been stabilized by American beachgrass and

beach-heather. Distinct community separation had not yet occurred, so the center of the blowout in Figure 15 is typed for both plants. Demarcation between community types and succession to one more stage had occurred in blowout number 2. Concentric rings of sand, beach-heather, dunegrass, and shrub are encountered from the outside to the center. Viewing from the south side pole toward the center of the blowout, the photograph of blowout number 2 (Fig. 20) likewise shows these changes. The shrub clump in the center is composed mostly of bayberry. As seen in Figure 16, a shrub community is invading the western side of the blowout. The strong west wind, prevailing for most of the year, has blown down the western wall of the blowout; a shrub community is beginning to colonize this area. Some of the blowouts have also been elongated along their west-east axis by this same prevailing westerly wind.

Blowouts Nos. 4 & 5 (Figs. 16 & 17) have reached one more level of succession: the shrub-thicket. Winterberry, black highbush-blueberry (Vaccinium strococcum), serviceberry, quaking aspen, and speckled alnus are present, along with a partial understory of the lower shrubs. The final stage of this blowout series is presented in the diagram for the sixth blowout (Fig. 17). Pitch-pine has begun to move into the shrub thicket, shading out most of the understory shrubs. The bands of vegetation can still be detected (Fig. 21). A ring of sand is located around the outside of the blowout. The sparce (20-30% cover) beach-heather community is situated further toward the center, but cannot be seen clearly. The dunegrass level is inside the beach-heather. The first dark shrub band seen in Figure 21 is bayberry and the center of the blowout is covered with a young dune forest of pitch-pine and speckled alnus.

Figure 15 - Successional Blowout Series, Small Point Beach.

Top, blowout number 0; bottom, blowout number 1.

Types: ...... - Uncolonized sand

a a a - American beachgrass

h h h - Beach-heather

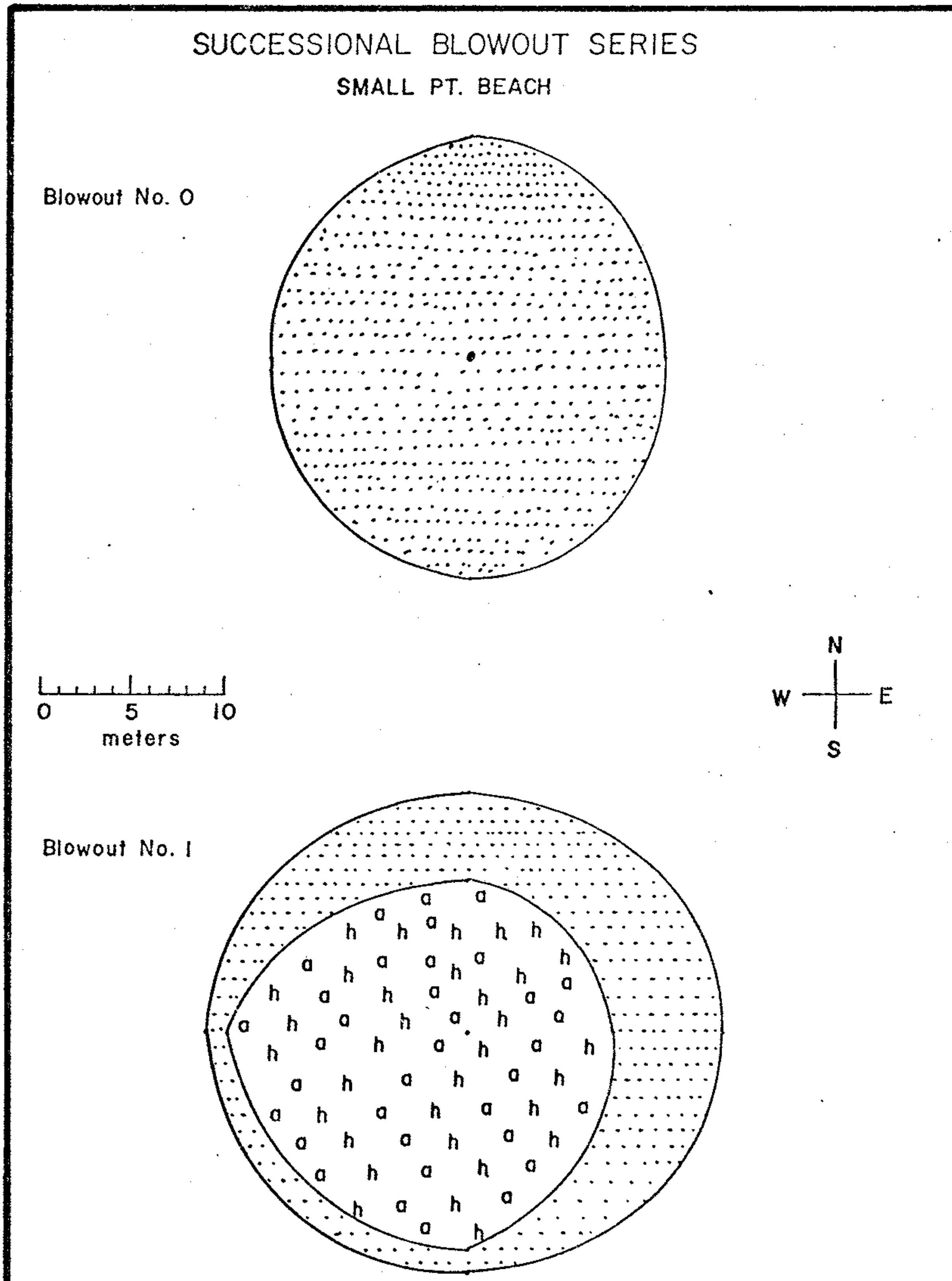


FIG. 15

See Figure Legend for Types

Figure 16 - Successional Blowout Series, Small Point Beach.

Top, blowout number 2; bottom, blowout number 4.

Types:

......	- Uncolonized sand
a a a	- American beachgrass
h h h	- Beach-heather
s s s	- Shrub community
st st	- Shrub thicket

SUCCESSIONAL BLOWOUT SERIES

SMALL PT. BEACH

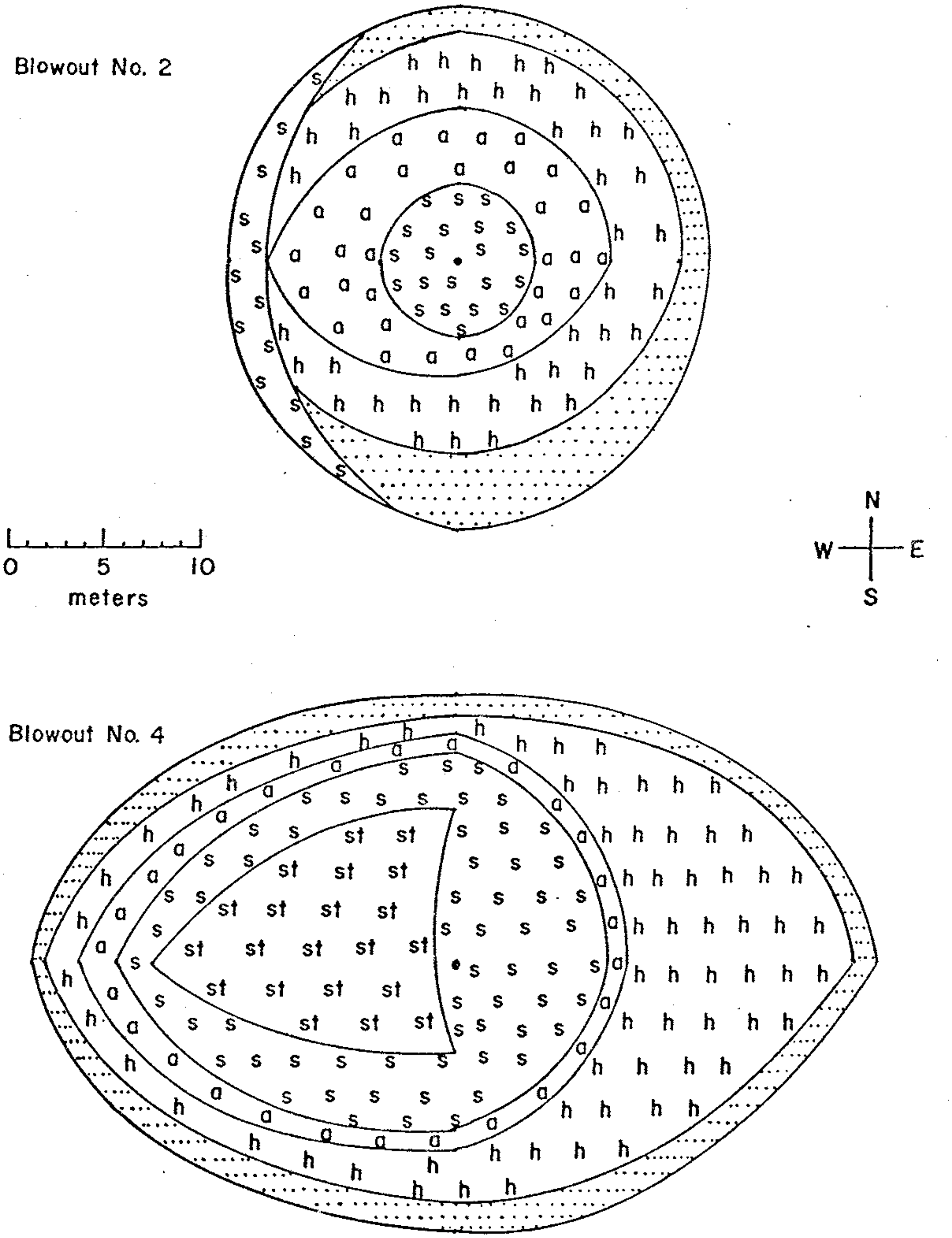


FIG. 16

See Figure Legend for Types

Figure 17 - Successional Blowout Series, Small Point Beach.

Top, blowout number 5; bottom, blowout number 6.

Types:	......	- Uncolonized sand
	a a a	- American beachgrass
	h h h	- Beach-heather
	s s s	- Shrub community
	st st	- Shrub thicket
	df df	- Dune forest

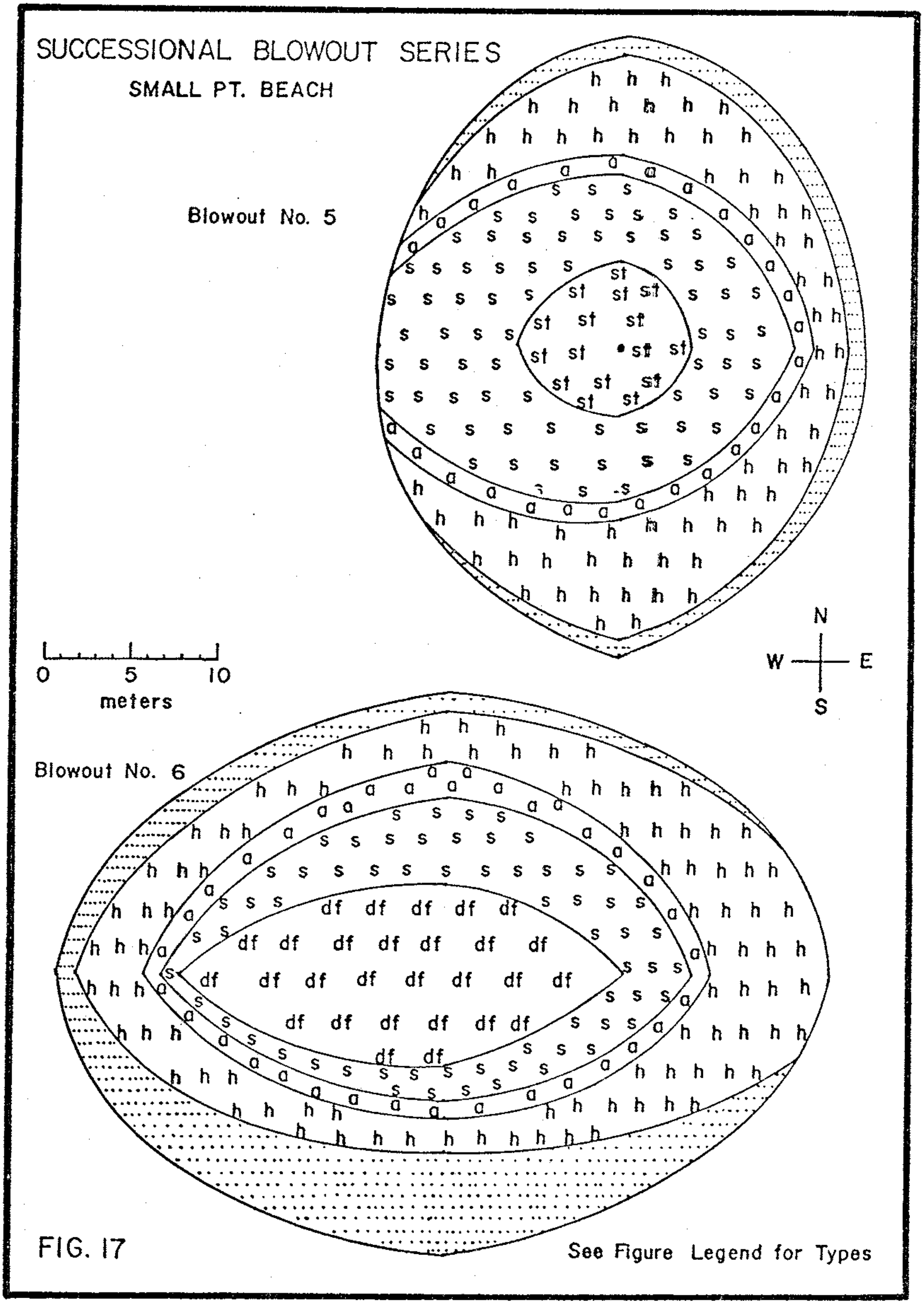

SUCCESSIONAL BLOWOUT SERIES
SMALL PT. BEACH
Blowout No. 5
Blowout No. 6
0 5 10
meters
N
W
E
S
See Figure Legend for Types

FIG. 17

Figure 18 - Blowout Number 0, Small Point Beach. Blowout almost completely devegetated. Stakes monitoring active sand movement.

Figure 19 - Blowout Number 1, Small Point Beach. American beachgrass and beach-heather sharing center of blowout. Ring of uncolonized sand around outside.

Figure 20 - Blowout Number 2, Small Point Beach. Center of blowout succeeding to bayberry shrub, with American beachgrass and beach-heather vegetation rings to the outside.

Figure 21 - Blowout Number 6, Small Point Beach. Dune forest (pitch-pine, quaking aspen, and speckled alnus) occupying blowout center. Shrub, American beachgrass, and beach-heather vegetation rings outside.


Fig. 18


Fig. 19

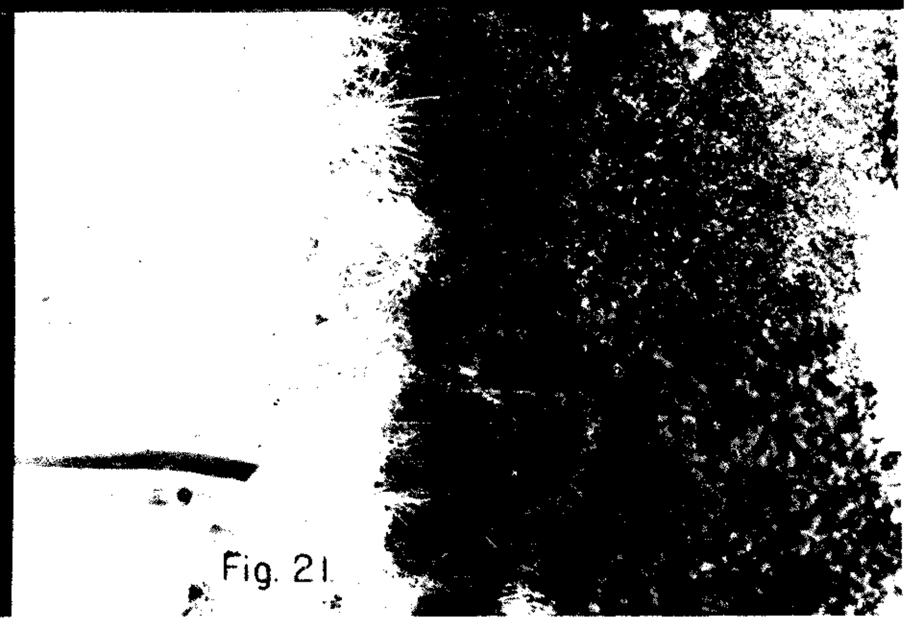


Fig. 21

The successional pattern shown by the blowout series diagrams is quite similar to that presented by the three profiles and vegetation maps. Few plants can tolerate the severities encountered on sand dunes and salt marshes, such as water stress, nutrient inavailability, water inundation, water salinity, and salt aerosols. Those plants which can live in these habitats have tolerances to each one of these factors. Those tolerances set the limits of distribution for each plant; and these distributions form the organization for the plants and plant communities on both the sand dunes and in the salt marshes.

Impact on Plant Communities

Introduction

State parks, as part of their function, must sustain a considerable amount of visitor pressure each year. This necessitates servicing as many prople as possible with the smallest amount of damage to the environment. To give the visitors a convenient but sound ecological access to the beach is quite an important problem. Three communities, the foredune, dunegrass and beach-heather, are the most severely affected. At Popham (Fig. 22) a large section of the beach-heather community is so impacted during all seasons of the year that it is difficult to determine what should be growing there. Other dunegrass sites at Popham (Figs. 23 &25) and Reid (Fig. 24) resemble little the vegetation type they should. Furthermore, the foredune plants (Fig. 2) which are essential in catching and holding sand are highly affected in many places.

A comparative study of the effects of visitors on the beach vegetation has been conducted over the past two summers. These three dune vegetation types were examined quantitatively by the point-quadrat method to determine the range and nature of these effects. The presence or absence, density per area, and percent cover of all the plants in these communities, along with the percentage of exposed sand, were all measured; disturbed sites were investigated at both Reid and Popham State Parks. Control areas in a more natural, undisturbed condition were examined on the same beach systems and also at Small Point beach, where visitor pressure is minimal. The forested picnic area at Popham was also examined; tree cores were extracted from pitch-pine and red oak in order to check for changes in growth since the opening of the park.

Figure 22 - Disturbed beach-heather association, Popham Beach State Park. During all seasons of the year, visitors were seen walking through this area of the park. On this particular visit the fence was broken.

Figure 23 - Disturbed forest picnic area, Popham Beach. Secondary dune ridge mostly devegetated, tree roots exposed, and tree growth decreased. Many trees dying and some already dead. Park visitors have to be funneled in and out of this heavily used area.

Figure 24 - Disturbed foredune ridge, Reid State Park. Path on ridge sometimes used by park visitors. In many places the path winds up to the edge of the ridge, causing more instability and erosion.

Figure 25 - Disturbed foredune and dunegrass community, Popham Beach. Plants completely destroyed. One disturbed dunegrass transect from impact analysis conducted on opposite side of fence.

Fig. 22

Fig. 23

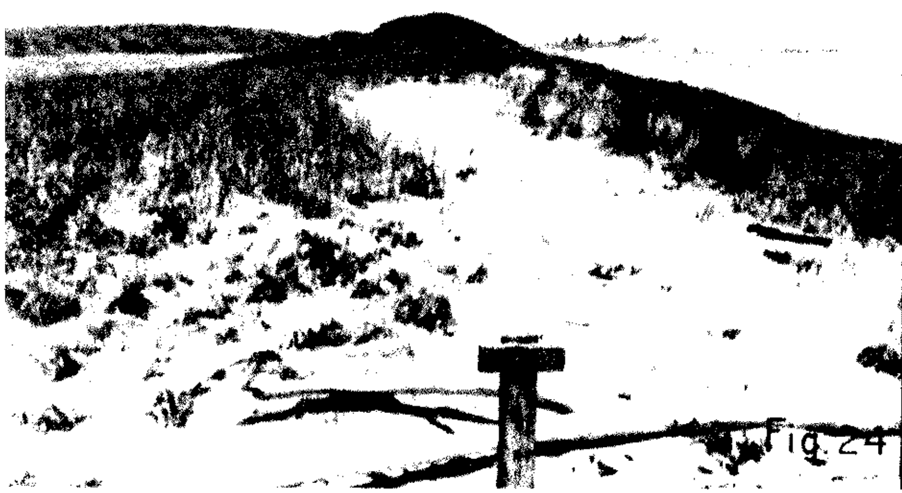


Fig. 24

Fig. 25

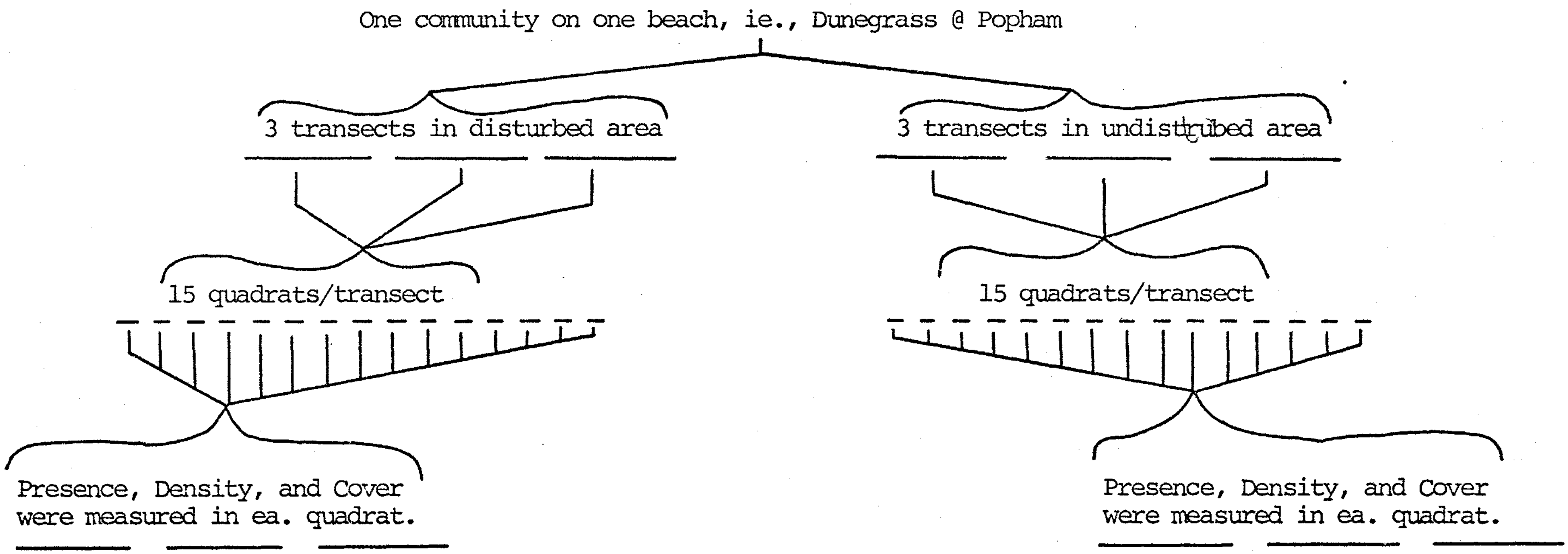
Materials and Methods

In order to have proper sampling size and sufficient data to work with, the analyses were designed as shown in Fig. 25a. Three transects were selected in disturbed and undisturbed community sites at each beach. Each transect randomly sampled a rectangular area 30 meters by 5 meters. Fifteen quadrats were sampled in each experimental area. A thirty meter tape was extended across the site; nine numbers between one and thirty were chosen from a random numbers table. Quadrats were placed at the meter numbers designated by the values chosen, and the sampling conducted. A five meter tape was placed perpendicular to the thirty meter tape at three more randomly chosen values. Along each of these five meter tapes, two more quadrats were randomly placed. Fifteen quadrats in total, nine on the thirty meter tape and two each on three five meter tapes, were examined on each transect. Three transects were run in different disturbed and undisturbed areas along the length of each beach system.

In order to conduct the sampling, a wooden point-sampler was constructed and placed on adjustable legs. The frame was made 25cm. on each side and thirteen small holes were drilled through the wood to allow the sampling pins to be dropped through the frame to the vegetation below. The sampler acted as a 25cm. square quadrat. The presence of all species within this area was then noted; the number of each species inside the quadrat, density per area, was likewise recorded. The percent cover of each species was determined by dropping thirteen very long, thin pins (2mm wide x 1m long) through the holes in the frame and recording what plants were contacted by the pins. Pins hitting exposed sand were also recorded.

DESIGN OF THE HUMAN IMPACT ANALYSIS

This analysis was conducted in the foredune, dunegrass, and beach-heather communities. So that differences within the State parks could be ascertained, both disturbed and undisturbed communities were examined at Reid and Popham; only undisturbed community sites to be used as a comparison were examined at Small Pt. The study design used within one community on one beach is shown below:



The massive amount of raw quadrat data has been simplified to values for each species along each transect, and a small amount of it has been placed in Tables 2, 3, & 4. The density and percent cover of each species for the fifteen quadrats were calculated; subsequently, all fifteen density and cover values for each species were averaged for the whole transect. The percent frequency per transect, which represents the number of quadrats out of fifteen that a particular species was encountered, was also calculated. Values were determined for each species, but only the most important species in each community are shown. In addition, the average percent cover of exposed sand was determined and recorded in the tables; and as a measure of species diversity, the total number of species found on each transect is also tabulated in the last table column. Finally, composite averages of the previous calculated values are given for all three transects in the disturbed and undisturbed sites. These composite averages will be discussed in the results.

The transects are listed as either disturbed (D) or undisturbed (U) for each of the three beach systems; Popham State Park (P), Reid State Park (R), and Small Point (S). The data for the foredune (Table 2), the dunegrass (Table 3), and the beach-heather (Table 4) communities are tabulated separately so that the impact on each vegetation type can be accessed. Although there was not sufficient time to calculate statistics, some important trends can be seen.

Results

Foredune Community:

Five species are tabulated for the foredune community (Table 2): beachgrass (Ammophila breviligulata), sea rocket (Cakile edentula), dusty miller (Artemesia Stellerianna), beach pea (Lathyrus japonicus), and saltwort (Salsola Kali). At Popham Beach the percent frequency, average density and average percent cover are lower for almost every species in the disturbed sites. For example, the percent frequency of American beachgrass for all transects decreased from 22% to 13%. Concurrently, the average density decreased from 0.29 individuals per transect to 0.13, and the average percent cover diminished from 2.7% to 2.1%. Similar decreases can be seen for most of the species. The amount of exposed sand increased from 92.3% in undisturbed sites to 96.6% in disturbed sites. This may not appear to be much, but the total plant cover halved from 7.7% (100% - 92.3%) to 3.4% (100% - 96.6%). The average number of different species, often a measure of diversity or stability in a plant community, decreased from 4.33 species in the undisturbed transects to 1.67 species in the disturbed transects.

It might also be informative at this point to compare the foredune area at Popham to the well-developed foredune at Small Point (Fig. 2). The frequency, density, and cover values show even a greater difference between the disturbed foredune at Popham and the undisturbed foredune at Small Point. But the most consequential difference is seen in the average percent cover of sand. Along the wind swept foredune, it is extremely important to have the highest plant cover possible. Higher cover implies that more branches will be present to catch wind blown sand. The average percent cover of sand increased from 78.4% at Small Point to 96.6% at

Popham, indicating that the plant cover decreased from 21.6% to 3.4%. This represents a more than six-fold decrease in plant cover.

At Reid State Park the percent frequency, the average density, and average percent cover per transect were lower in the disturbed sites for both American beachgrass and sea rocket. But beach pea values were higher in the disturbed sites — high enough to make the average percent cover of sand, and hence the total plant cover, almost equal. The disturbed foredune transects at Reid can also be compared to those at Small Point. Large differences are apparent; for instance, the percent frequency of sea rocket decreases from 35% at Small Point to 4% at Reid, while the average density decreases from 12.3% to 1.5%. In addition, the sand cover increased from 78.4% at Small Point to 89.7% at Reid, denoting that plant cover halved from 21.6% to 10.3%. Overall, the differences between the disturbed sites in the state parks and the control sites at Small Point are even greater. The most outstanding and noteworthy difference is the percent sand cover because this is, in fact, representative of the total plant cover.

Dunegrass:

Only the three most important dunegrass species are summarized in Table 3. At Popham there are large differences between impacted and unaffected sites. For American beachgrass, both the frequency and density decreased considerably from the impacted to the unaffected sites, and the average cover decreased three-fold from higher in the state parks. This, however, was expected: the control sites in the state parks and at Small Point should be similar.

TABLE 2 Foredune Community Data[1] - Human Impact Analysis

Beach System P-Pop. R-Reid S-S.P.	Comm. D-Disturbed U-Undisturbed	*Ammophila breviligulata*			*Cakile edentula*			*Artemisia Stellerianna*			Table continued on next page
		%f/t[2]	ad/t[3]	a%c/t[4]	%f/t	ad/t	a%c/t	%f/t	ad/t	a%c/t	
P	U	27	.40	4.6	7	.07	0.0				
P	U	7	.07	0.0							
P	U	33	.40	3.6	40	.40	6.2	7.0	.07	4.6	
AVERAGES		22	.29	2.7	16	.16	2.1	2.3	.02	1.5	
P	D	0	.00	0.0							
P	D	13	.13	2.1	7	.07	1.0				
P	D							7.0	.07	3.1	
AVERAGES		4.3	.04	0.7	2.3	.02	0.3	2.3	.02	1.0	
R	U	33	.53	12.8							
R	U				7	.07	1.0				
R	U	27	.87	10.3	20	.27	1.5				
AVERAGES		20	.47	7.7	9	.11	.8				
R	D	7	.07	2.6							
R	D				13	.27	4.6				
R	D	0	0.00	0.0							
AVERAGES		2	.02	0.9	4	.09	1.5				
S	U	7	.13	2.6	47	.47	20.5				
S	U	27	.33	6.2	7	.07	0.0				
S	U	20	.40	4.1	33	.53	10.8				
S	U				53	1.27	17.9				
AVERAGES		13.5	.22	3.2	35	.59	12.3				

1 - During the sampling, eight species were encountered in the foredune community, but only the five most important species have been summarized on this and the following page. The number of species for any given transect is shown in the last column, even though all the information for each species is not shown; 2 - %f/t - Percent Frequency/Transect; 3 - ad/t - Average Density/Transect; 4 - a%c/t - Average Percent Cover/Transect.

TABLE 2 (continued) Foredune Community Data - Human Impact Analysis

Beach System P-Pop. R-Reid S-S.P.	Comm. D-Disturbed U-Undisturbed	*Lathyrus japonicus*			*Salsola Kali*			Sand	No. of Different Species on the Transect
		%f/t	ad/t	a%c/t	%f/t	ad/t	a%c/t	a%c/t	
P	U				20	.20	1.5	94.4	4
P	U							98.5	2
P	U	20	.33	0.0	40	.73	1.0	84.1	7
AVERAGES		7	.11	0.0	20	.31	0.8	92.3	4.33
P	D							100.0	0
P	D							96.9	2
P	D	7	.13	1.5	7	.07	2.6	92.8	3
AVERAGES		2.3	.04	0.5	2.3	.02	0.9	96.6	1.67
R	U							87.2	1
R	U	33	.60	8.2				91.8	2
R	U	7	.07	0.0				88.2	3
AVERAGES		13	.22	2.7				89.1	2.00
R	D							97.4	1
R	D	20	.33	6.2				90.3	2
R	D	47	1.00	18.5				81.5	1
AVERAGES		22	.44	8.2				89.7	1.33
S	U				47	.60	19.5	58.5	4
S	U				7	.07	5.1	87.7	3
S	U				7	.07	0.0	85.1	3
S	U				20	.27	0.0	82.1	2
AVERAGES					20	.25	6.1	78.4	3.00

Beach-heather — Lichen Community

The beach-heather community reaches its best development on the Small Point beach system. Here, beach-heather, pinweed (Lechea intermedia), and aster (Aster linariifolius) form a complex community with about seven species of lichens, most of them from the genus Cladonia. Pinweed and aster are not even seen in the beach-heather at either Popham or Reid (Table 4). In fact, Popham did not have a beach-heather site which could be considered undisturbed. The lichens, a symbiotic relationship of a fungus and an alga, are the most sensitive members in the association. When moist, the lichens are like soft sponges; but when dry, they are frail and brittle. If they are stepped on, they can be crushed completely. Although they are quite sensitive to human pressures, they can withstand great environmental stress, such as lack of water and nutrients, because their plant requirements are extracted from the air.

At Reid the undisturbed beach-heather sites had good total plant cover. The average sand cover was only 36.9%, while it was 77.9% in the disturbed areas. On the three disturbed transects three lichens (Cladonia cristatella, Cladonia rangiferina, & Cladonia uncialis) had very low per-cent frequencies. Even beach-heather was down from 100% to 60% frequency. However, the number of different species per cent transect (Table 4, last column) was practically the same, because the plant cover was so low; occasional species not normally encountered in beach-heather areas had sparsely colonized these disturbed sites. The percent sand cover of undisturbed sites at Reid (36.9%) was almost as low as that measured for Small Point (26.8%), indicating that some healthy and vigorously growing beach-heather associations are present at Reid.

The beach-heather community at Popham State Park is almost complete

TABLE 4 *Hudsonia-Cladonia* Community Data[1] - Human Analysis

Beach System P-Pop. R-Reid S-S.P.	Comm. D-Disturbed U-Undisturbed	*Hudsonia tomentosa* %f/t[2]	ad/t[3]	a%c/t[4]	*Lechea intermedia* %f/t	ad/t	a%c/t	*Aster linariifolius* %f/t	ad/t	a%c/t	Table continued on next page.
R	U	100	2.07	36.9							
R	U	100	1.93	35.9							
R	U	100	2.00	42.1							
AVERAGES		100	2.00	38.3							
R	D	60	.87	14.4							
R	D	80	1.27	22.6							
R	D	47	.73	13.3							
AVERAGES		62	.96	16.8							
P[5]	D	67	1.07	25.1							
P	D	80	.87	23.6							
P	D	60	.73	16.4							
AVERAGES		69	.89	21.7							
S	U	100	1.87	32.3	33	.47	1.5	40	2.73	5.6	
S	U	87	2.00	32.8	67	3.07	11.8	80	5.67	7.2	
S	U	100	2.33	41.2	40	3.87	8.2	40	.87	1.5	
AVERAGES		96	2.07	35.4	47	2.47	7.2	53	3.09	4.8	

1 - During the sampling, fifteen species were encountered in the *Hudsonia-Cladonia* community, but only the nine most important species have been summarized on this and the following two pages. The number of species for any given transect is shown in the last column, even though all the information for each species is not shown; 2 - %f/t - Percent Frequency/Transect; 3 - ad/t - Average Density/Transect; 4 - a%c/t - Average Percent Cover/Transect; 5 - Since no undisturbed *Hudsonia-Cladonia* community sites could be found at Popham, only the disturbed sites were investigated, and these can be compared to Small Pt.

TABLE 4 (continued) Hudsonia-Cladonia Community Data - Human Impact Analysis

Table continued on next page.

Beach System P-Pop. R-Reid S-S.P.	Comm. D-Disturbed U-Undisturbed	Cladonia cristatella			Cladonia tenius			Cladonia rangiferina		
		%f/t	ad/t	a%c/t	%f/t	ad/t	a%c/t	%f/t	ad/t	a%c/t
R	U	40	.40	2.1	67	1.20	92.0			
R	U	7	.07	0.0	100	2.27	24.6			
R	U	27	.40	0.0	87	3.13	31.3	27	.27	0.0
AVERAGES		25	.29	0.7	85	2.20	21.7	9	.09	0.0
R	D				67	1.13	6.2	27	.33	1.0
R	D									
R	D	7	.07	0.0	7	.07	0.5			
AVERAGES		2.3	.02	0.0	25	.40	2.2	9	.11	0.3
P	D									
P	D									
P	D									
AVERAGES										
S	U	53	.67	1.0	53	1.27	26.2			
S	U	33	.33	1.0	40	1.00	11.3	13	.13	1.5
S	U	40	.47	0.5	33	.33	2.1			
AVERAGES		42	.49	0.8	42	.87	13.2	4.3	.04	0.5

TABLE 4 (continued) Hudsonia-Cladonia Community Data - Human Impact Analysis

Beach System P-Pop. R-Reid S-S.P.	Comm. D-Disturbed U-Undisturbed	Cladonia uncialis			Hypocymnia physodes			Ammophila breviligulata			Sand	No. of Different Species on the Transect
		%f/t	ad/t	a%c/t	%f/t	ad/t	a%c/t	%f/t	ad/t	a%c/t	a%c/t	
R	U				93	1.40	13.3	13	.13	0.5	37.9	6
R	U				73	.73	1.5	13	.13	0.0	40.0	5
R	U				80	1.00	2.1	20	.20	0.5	32.8	6
AVERAGES					82	1.04	5.6	15	.15	0.3	36.9	5.67
R	D	20	.40	1.0	13	.13	0.0	60	.93	1.5	75.4	9
R	D				33	.40	2.1	40	.40	2.1	73.3	3
R	D				7	.07	0.0	20	.20	1.0	85.1	6
AVERAGES		7	.13	0.3	18	.20	.7	40	.51	1.5	77.9	6.00
P	D				47	.47	0.0	7	.07	0.0	74.9	3
P	D							7	.20	2.1	74.4	3
P	D				7	.07	0.0				83.6	2
AVERAGES					18	.18	0.0	5	.09	0.7	77.6	2.67
S	U	20	.27	4.1	60	1.07	11.3				26.7	8
S	U	67	2.80	31.3	60	1.07	5.1				17.9	8
S	U				93	1.27	6.7	27	.27	1.5	35.9	7
AVERAGES		29	1.02	11.8	71	1.14	7.7	9	.09	0.5	26.8	7.67

decimated (Fig. 22). Beach-heather is practically the only species present. Pinweed, aster, and four species of Cladonia were not even encountered on three transects (45 quadrats). The only lichen sampled was Hypogymnia physodes, apparently an early colonizer here after a disturbance. American beachgrass was seen in sparce populations throughout the area, and it is hard to determine whether beach-heather or dunegrass will gain dominance if visitor pressure is relieved from the area. The average number of species per transect at Popham (2.67) is much lower than that at Small Point (7.67). The lack of six important species, the high percent sand cover, and the lower values encountered for beach-heather itself all demonstrate the poor condition of this association at Popham.

Discussion:

Several indicators of plant growth have been used for a good assessment of human impact on the vegetation. Unaffected sites within the state parks and on Small Point were sampled for comparison. In almost all species, the frequency, density and cover values were lower in the disturbed sites. The density of the individual plants and the surface area they cover are extremely important indicators for the sand dune environment. Sand dunes with higher plant density and more covered surface will be better stablized. With decreasing densities and covers, the sand begins to blow. Sand particles pelt the nearby plants, and if the process continues, dune blowouts may form (Fig. 18).

Another indicator, the average percent sand cover, gives a useful representation of the total plant cover. Any areas not covered by plants are covered by sand. As the sand cover decreases, the total plant cover increases. The total plant cover was usually between two and six times

lower in the disturbed areas. And the capacity of the plants to catch and to stabilize sand is quite reduced with lower plant cover.

Because of their topographical position, the foredune and dunegrass communities are probably the most important for sand stabilization. During hard winters, good plant cover is essential. Areas hit by occasional storm waves or high winds will better take this natural impact if plants and plant roots are present. Areas under extreme erosional conditions will be helped less, but accretional sites such as the wide beach southwest of Popham's forested picnic site are presently being stabilized by dune plants. Dune building is beginning at this site. As the dune builds, the plants grow through the sand, this helping to continue the process.

Good plant densities and covers are also important in the beach-heather association. Unstable beach-heather communities in backdunes, which are exposed to the west wind, can be easily blown out. This has happened many times, in fact, in the active northwest portion of the Small Point dune system and appears to have occurred at several places behind mile beach at Reid, although Reid's blowouts are now mostly revegetated.

The plants which live on sand dunes are highly specialized for water, nutrient, and salt stress. American beachgrass is even capable of growing through a new sand supply. The plants living in this environment have had plenty of time to evolve and cope with these stresses; however, they cannot tolerate the stress of people walking or vehicles riding on them. Once the grass culms or plant branches are broken, they die and have to be replaced by either new plant organs or by entirely new plants. If large areas are impacted and are partially to totally decimated, the

wind becomes an important factor, moving the sand around and making it even harder for the injured plants to stabilize the area. Only with healthy, solid plant cover can environments as harsh as coastal sand dunes be kept in a balanced and stable condition.

Salt Marsh Production

Introduction

The fishing, clamming and bloodworm industries are all very important to the economy of Maine. These industries are intricately tied to the salt marsh, sand flat, and mud flat estuarine system. Some of the commercially important fish species spawn in the marshes; others come daily into the marshes with the tides to forage for food. The salt marshes directly feed these species, while indirectly, by tidal flushing, the marshes help to feed many important oceanic fish and invertebrates. Detritus, dead organic material, leaves the marsh daily with the tides to help feed this complex estuarine-oceanic food web, and many of the coastal industries ultimately depend on this ecosystem. Because of its economic importance, salt marsh production was examined for two summers on three marshes; Popham State Park marsh, Reid State Park marsh, and Small Pt. marsh.

During the summer of 1975, both high marsh and low marsh were examined, while only the low marsh was examined in 1976. Even though the high marsh produces as much as or more than the low marsh, it was not sampled the second season because most of the grass dies in place and eventually becomes peat. The elevation of the high marsh prevents a large portion of the dead grass from being flushed out into the estuary and ocean.

Materials and Methods

A 30 m tape was laid out in the type of marsh to be sampled. Numbers, corresponding to the numbers on the meter tape, were selected from a random numbers table. Three numbers were selected for all high marshes, and six and eight numbers were selected for the Popham and Small Pt. low marshes, respectively, during 1975. (Reid Marsh was not sampled in 1975, because the grass was too immature to obtain a good measurement of the summer's growth). Square meter quadrats were placed alongside of the tape at the points corresponding to the selected random numbers, and all the salt-marsh cord-grass, Spartina alterniflora, was clipped with grass shears at ground level. The marshes were sampled on Sept. 6 and 7, 1975; subsequently, the grass was placed in paper bags and dried in an 85 C oven for 48 hours. After the grass was weighed, it was replaced in the oven for 24 hours, reweighed and replaced in the oven for one more drying and weighing cycle. All bags of grass had consistent dry weights by the third weighing.

The sampling procedures were basically the same during the summer of 1976 with the following changes: 1, the number of samples per transect was always six; 2, the number of transects sampled increased from one to two for each marsh; 3, all marshes were sampled almost two weeks later, Sept. 18-19 during 1976, in order to conduct the sampling when summer biomass was peaking; 4, and only the low marsh was sampled. The values of all the samples on each marsh were averaged.

Table 5 Salt Marsh Grass Dry Weights

Marsh System	Type of Marsh	No. of Samples	Average Dry Weight g/m^2	Average Dry Wt. for all 3 Marshes
Sampling Conducted Sept. 6-7, 1975				
Small Pt.	Low	8	454	530
Popham	Low	6	607	
Reid	Low	0	(1)	
Small Pt.	High	3	763	
Popham	High	3	575	584
Reid	High	3	413	
Sampling Conducted Sept. 18-19, 1976				
Small Pt.	Low	12	723	
Popham	Low	12	679	680
Reid	Low	12	638	

1- Too early to sample this marsh, grass only 2 cm high.

Results

The average dry weight results are presented in Table 5. The data are separated into year of sampling, marsh locality, and type of marsh; within each of these subclasses, the number of samples and their average dry weight are reported.

During 1975 the three high marshes (584 g/m^2) had on the average more than the low marshes (530 g/m^2). Most of this grass dies in place and will ultimately form high marsh peat, but a small amount of the grass probably flushes into the detritus cycle during high tides. Also, the high marsh serves as a home for many of the insects and animals in the estuarine food web.

The low marsh, which more directly supplies the detritus system, showed considerably more dry weight biomass (approx. 150 g/m^2 more) during 1976 than during 1975. Although many factors like rainfall or the amount of sunshine would affect the growth, most of the difference is probably a result of the two week later sampling time. On Sept. 6-7, 1975, the marshes had not reached full development. The following year they were sampled 12 days later.

One other interesting result can be seen. The Reid marsh always had lower dry weights than the other two marshes, even though all three marshes are within five miles of each other geographically. The marshes are also very similar in that they are all located behind barrier beach headlands and connected to the ocean by tidal streams approximately 60 to 100 feet wide at the mouth. All through the growing season, the Reid marsh appeared to be behind the other two marshes in respect to the height of salt-marsh cord-grass. The only possible suggestion for the

slower development and the lower average biomass might be the amount of daily sunshine. The Reid marsh behind One-Half Mile Beach is so situated with a forest to its southwest that it might receive one or two hours less of sun a day, possibly enough of a decrease in sunlight to cause the lower production.

Discussion and Management

The low marsh average dry weight of 680 g/m^2 for 1976 compares favorably with other areas along the east coast. Hatcher and Mann (1975) reported a low marsh average of 558 g/m^2 for Nova Scotia which is near the northern extension of salt-marsh cord-grass. South of Maine on Long Island, Udell et al (1969) reported dry weight values of 827 g/m^2 for low marsh. The summer on Long Island is mych longer and hotter than Maine, and the total dry weight production would be expected to be higher. The marshes along the Coast of Maine have a luxuriant and productive low and high marsh growth; they also fall into the spectrum of decreased production from south to north along the east coast.

The majority of the marsh area is in a healthy and undisturbed condition. Some truck tracks, motorcycle tracks, and foot paths were detected in the marshes close to the sandy beach areas. The vehicles should be kept off the marsh. The weight of the vehicle compacts the peat and forms a ditch; the ditch then fills with water, and even the salt marsh plants can not colonize standing water. The gullies persist for years (Godfrey, pers. comm.). In the more remote areas of the marshes, only foot tracks of bird watchers were seen. No traces of oil were detected anywhere in the marshes. Since the turn of the century, after these marshes were hayed, they received very little impact. They should

be kept in this condition. To manage marshes the owners need only keep vehicles and large numbers of people out of the area. In general, any vehicle access roads to the marshes should be blocked off and large paths through the marsh fenced. Undisturbed marshes from the most productive terrestrial-aquatic ecosystem for Maine's climate, and ultimately help support the people who depend on the sand and mud flats, estuaries, and oceans for their livelihood.

Oceanic Processes

Introduction

To obtain a significant understanding of ocean-beach processes, several factors dealing with coastal ecosystems were examined. Investigations were conducted in coastal climate regarding temperature, precipitation, fog, and wind; sea level trends concerning the recent past through analysis of tide gauge information, and the distant past by researching the literature for salt marsh coring data; historical analysis of barrier beach movement and erosion through an examination of a map time series for shoreline changes, and sand dune and salt marsh coring evidence for barrier beach retreat; and dune dynamics with respect to factual and descriptive documentation of aeolian transport, overwash, and erosion. Discussion within each section utilized and built on evidence obtained from earlier portions of the report; in addition, whenever it was relevant, information was collected from the present, recent past, and distant past. Hopefully, in this manner, an integrated view of the complicated processes operating along the coast was ascertained.

Coastal Climate

Maine has three climatic divisions, the northern, southern interior and coastal (Lautzenheiser, 1959). These divisions are variously affected by air masses from three predominant directions: 1) Cold, dry air from Canada mostly during the winter; 2) Warm, moist air streaming overland from the Gulf of Mexico during the summer; and 3) cool, damp air from the North Atlantic. Coastal weather characteristics are significantly affected by the marine influence. Temperatures are lower in the summer and higher in winter. Similarly, precipitation decreases slightly during the summer months and increases during the winter. Partial to complete foggy days have a much higher incidence on the coast than they do inland. And the presence of the cool ocean water causes continuous onshore-offshore breezes, particularly during the summer.

Since the coastal division may be affected by three potential air masses, it has other annual characteristics. The weather patterns are generally of a short duration; they change twice weekly on the average. Large seasonal differences from year to year are not uncommon. Likewise, several Northeasters are expected to blow in off the Atlantic Ocean every winter while occasional summer hurricanes, often partially abated, travel up the Atlantic coast.

Temperature:

The coastal breezes off the cool water influence the temperature up to ten miles inland. Summer temperatures are lower while winter temperatures are higher than more inland locations. The annual mean temperature for the Brunswick Naval Air Station is 45 degrees F. The highest monthly mean (Table 6) occurs during July, with August quite

similar, while the lowest monthly means occur during January and February. The spring and fall months exhibit successive mean monthly changes of approximately nine degrees from the July-August high. Average maximum and minimum temperatures (Table 6) attest to the marine temperature modification. Maximum temperatures in the high 90's and minimum temperatures in the low -20's have been recorded, but are not common. Due to this marine influence, springs and falls occur later than inland sites, and the frost-free growing season of 140-160 days is comparable to inland localities 200 miles farther south (Lautzenheiser, 1959).

Precipitation:

Coastal precipitation falls in two forms, as rain throughout the year and as appreciable snow from November to April. The average monthly precipitation (Table 6) is reasonably equitable during the year, although it is slightly higher in winter and lower in summer; the total yearly precipitation is approximately 43 inches. Higher amounts during the winter are caused by coastal storms-"Northeasters." Summer averages are slightly lower due to a decrease in thunderstorms along the coast, a decrease caused by lower summer temperatures and less convective lifting than occurs in more inland sites.

Winter storms bring rain, freezing rain or snow. The total snow accumulation is approximately 84 inches per year. Most of this snow falls between December and March; however, intermittent rain storms and thaws seldom permit a continuous winter snow pack. Winter Northeasters cause the largest accumulations of up to 20 inches and are often mixed with rain. These same storms cause wind driven waves to flood or erode low coastal areas. Furthermore, if these storms crest during

TABLE 6 Seventeen Year Weather Summary for Coastal Maine[1]

	Temperature Degrees F.			Precipitation - Inches		Fog Days
Month	Average Maximum	Monthly Mean	Average Minimum	Average Monthly Precip.	Average Monthly Snowfall	Average Occurrence of Fog
Jan.	30.0	21.1	11.7	3.50	19.6	11.5
Feb.	32.2	22.9	13.0	4.10	22.2	4.0
Mar.	40.2	32.4	24.2	3.80	16.1	12.0
April	51.4	43.1	34.3	3.54	3.2	13.0
May	62.6	53.0	43.1	3.15	.3	16.0
June	71.3	62.8	53.2	3.03	--	18.0
July	77.2	68.3	--	2.55	--	19.0
Aug.	76.0	67.2	--	2.85	--	22.0
Sept.	68.2	59.2	49.6	3.18	--	19.0
Oct.	58.2	49.3	40.2	3.41	.4	18.0
Nov.	46.2	39.0	31.1	4.95	3.7	16.0
Dec.	33.6	25.7	17.4	4.61	18.4	12.9
Revelant Totals				42.67	83.9	181.4

1 - Information obtained from an unpublished summary (1945-1972), Brunswick Naval Air Station. The station is located a few miles inalnd.

spring tides, normal eleven-foot high tides can elevate to fourteen or more feet, thus increasing the damage to sandy beaches and other low areas.

Fog:

Fog is an important weather feature on the coast. It lowers the amount of sunshine plants receive during the summer while simultaneously diminishing the drought stress. Fog may temporarily occur at night or in the morning and then burn off with the noon day sun; it also blows in off the ocean for periods of up to seven days in length. Furthermore, some fog occurs during one of every two days a year (Table 6). It reaches its peak occurence from June to October when there are more than 18 days of fog per month. February, the month with the lowest incidence of fog, averages only four fog days. At this time of the year, even the coastal climate is dominated by the northwest Canadian winds.

The increase in fog and concomitant decrease in sunshine most likely account for the larger density of lichen species and lichen plant cover as opposed to the more southerly sand dune areas such as Cape Cod. The lichen, old man's beard (Usnea trichodea), was found hanging from the spruce and fir trees at Reid State Park; its presence there can probably be correlated with that of the fog. Likewise, it is suspected-but untested-that the fog which is carried onshore brings with it cations, making the aerosol load on the plants even greater than if salt spray alone blew in.

Wind:

The wind speed and direction have been summarized in monthly wind diagrams and wind speed histograms (figs. 26, 27, 28, & 29). The data are from the Brunswick Naval Air Station located several miles inland. Although micro wind data from the shoreline would have been preferable, it could not be obtained. This weather factor, more than any other, undergoes considerable alterations along the shore. Nevertheless, significant trends may be seen.

During the summer months (May - September), wind comes predominantly from the southwest. July and August have the highest percentages of southwest wind, 48% and 43%, respectively. The wind gradually swings into the northern quadrants in the fall. A southwest wind is still prevailing in October, but more combined wind approaches from the northwest and the northeast. By November, thirty percent of the wind comes from the northeast off the ocean, while the southwest and northwest quadrants are still approximately equal with 23% of the wind. Predominantly northeast or northwest from December through March, the cold damp Atlantic winds or the cold dry Canadian winds prevail. In April a more southerly continental influence begins to bring in the southwest winds, thus lessening the effects from the northern quadrants. At no time are the southeast winds of considerable importance; the highest month, May, only claims 13% of the wind from this direction. Thus, in summary, there are two prevailing wind trends: 1) Southwest from May through September, and 2) Northwest-Northeast from November through March. April and October are transition months; winds approach from all quadrants almost equally, with the exception of the southeast wind

which is normally much lower.

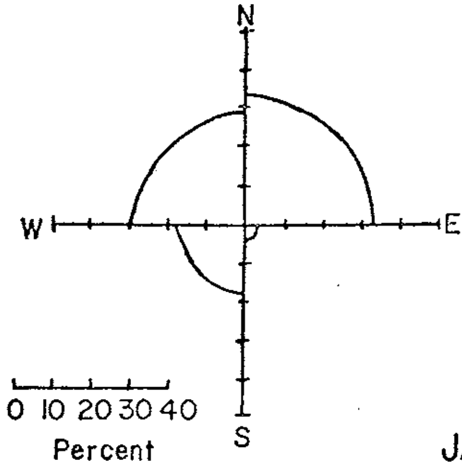
The wind speed histograms (Fig. 26, 27, 28, & 29) appear to be similar; however, some trends are noticeable. No wind, graphed as calm, occurs between 10% and 16% of the time. Between 45% and 56% of all wind for the year falls within the two ranges of 4.5 - 7.0 mph and 8.0 - 11.5 mph. The months of May through September have a larger percentage of wind than the winter months within the lower wind speed ranges (4.5 - 11.5 mph), while the winter months have a larger percentage than the summer months within the higher speed ranges (12.5 - 25 plus mph).

The higher wind speeds, 12.5 - 18.5 mph, 19.5 -24.0 mph, and 25 plus mph are a significant factor in sand movement. Aeolian sand transport is a function of sand grain size, sand moisture, and wind speed. The months of January - April have the highest wind speeds. When the percentages of wind occurring in the three highest ranges are summed, these winter months have more than 26% of their total wind above 12.5 miles per hour. The month with the lowest amount of wind in these high ranges is August, with only 12.7%. If only the higher two speed ranges are considered, 19.5 - 24.0 mph and 25 plus mph, the same trend holds true. January, February, March and April all receive more than 6.5% of their wind within these two high categories. February is the highest, with 8.6% of the wind occuring above 19.5 mph. The weather data presented in Figures 26, 27, 28 & 29 has one deficiency. It does not demonstrate what percent of the wind at any particular speed approaches from each quadrant. For example, during February, 8.6% of the wind is in the two highest wind speed categories. It is not known, however, whether these high velocities are out of the southwest, northwest or northeast. For this reason, true wind roses, which are vectors with magnitude and direction, could not be constructed.

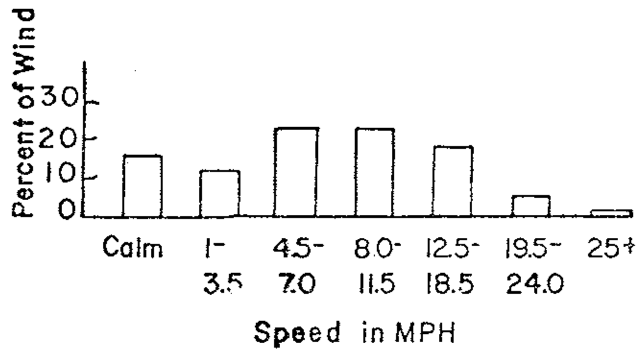
Figure 26 - Monthly prevailing wind diagrams and wind speed histograms, Brunswick Naval Air Station Weather Summary (1945-1972). Months: January, February, and March. Wind speeds converted from knots to miles per hour (mph).

MONTHLY PREVAILING WIND DIAGRAMS AND WIND SPEED HISTOGRAMS

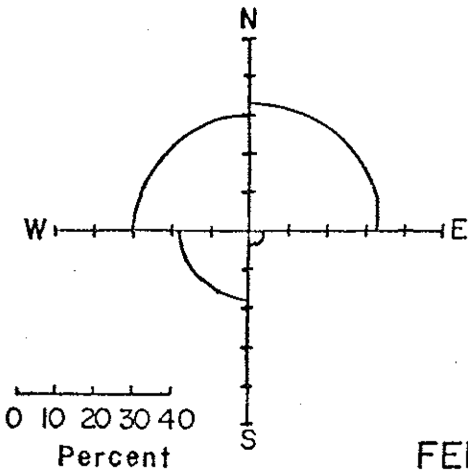
Percent of Wind From Each Quadrant

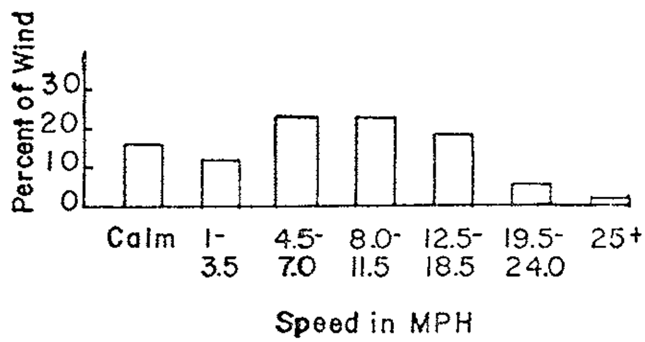


Percent of All Wind vs. Speed Range in MPH

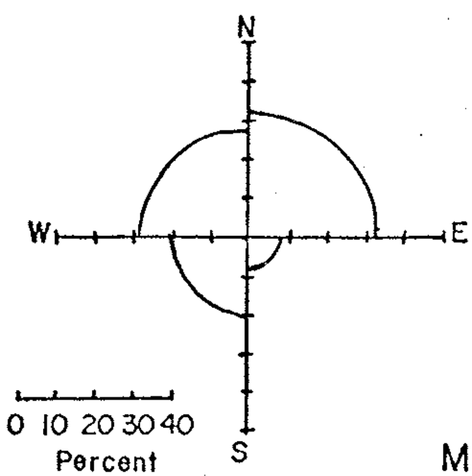


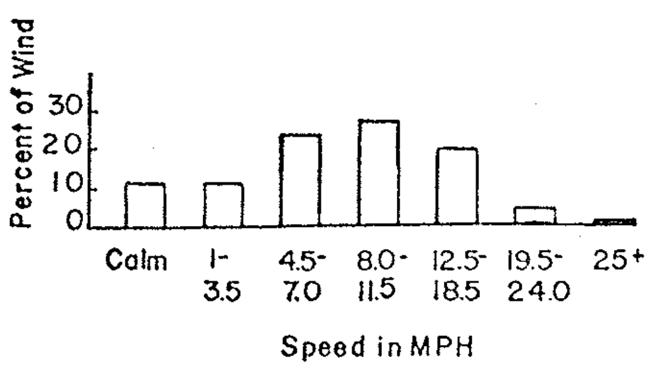
JANUARY: 1945-1972





FEBRUARY: 1945-1972





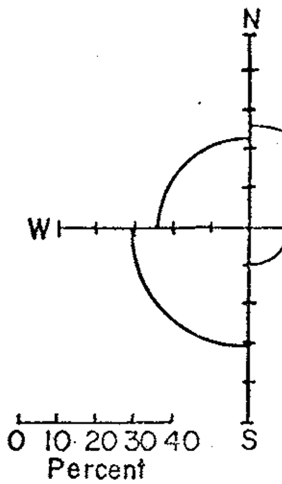
MARCH: 1945-1972

FIG. 26

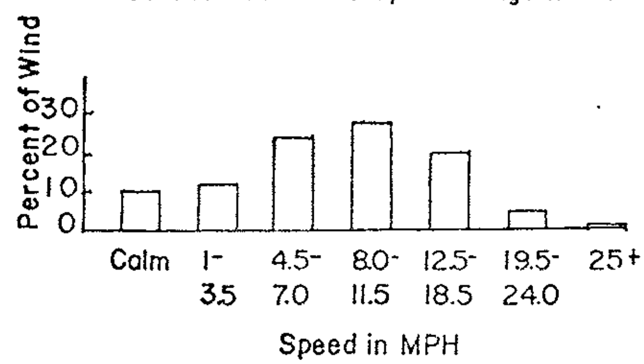
Figure 27 - Monthly prevailing wind diagrams and wind speed histograms, Brunswick Naval Air Station Weather Summary (1945-1972). Months: April, May, and June. Wind speeds converted from knots to miles per hour (mph).

MONTHLY PREVAILING WIND DIAGRAMS AND WIND SPEED HISTOGRAMS

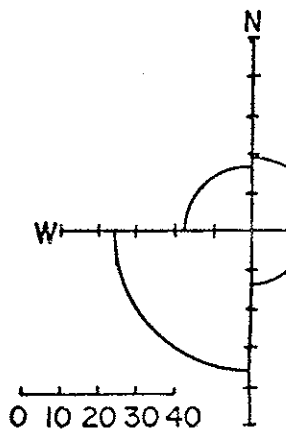
Percent of Wind From Each Quadrant

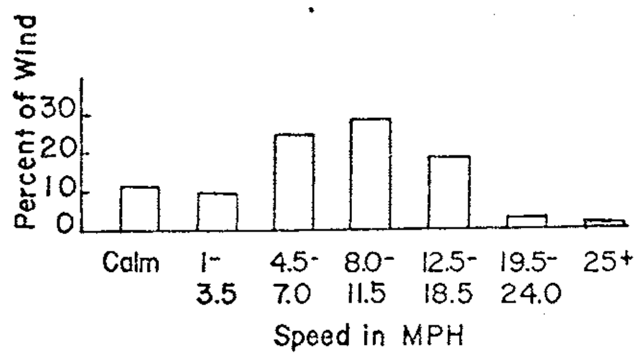


Percent of All Wind vs. Speed Range in MPH

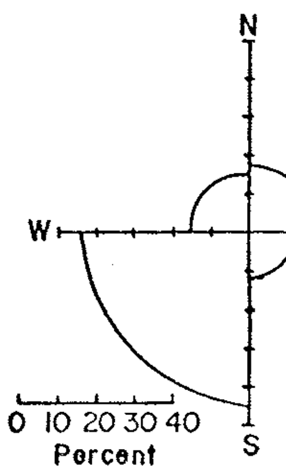


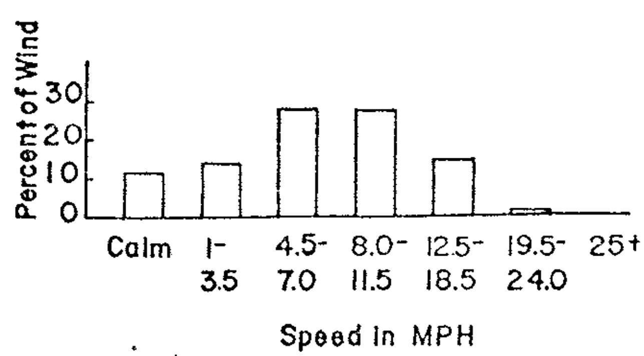
APRIL: 1945-1972





MAY: 1945-1972





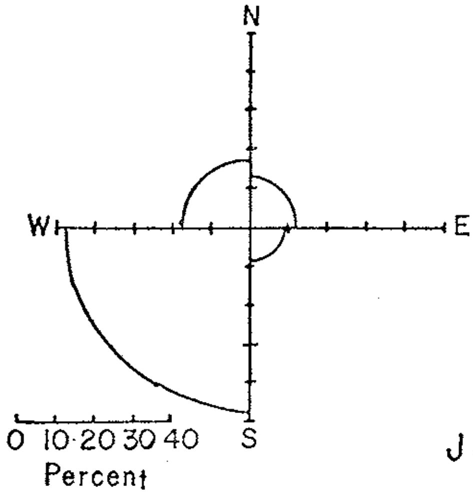
JUNE: 1945-1972

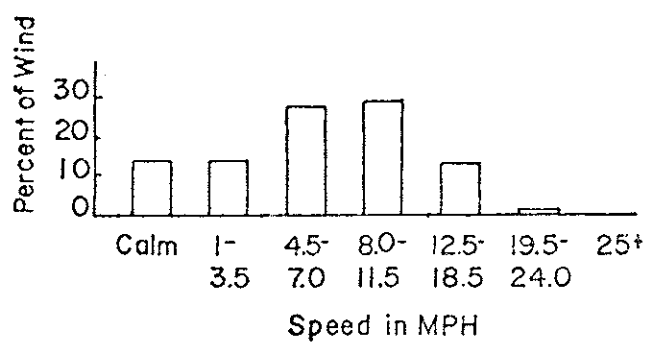
FIG. 27

Figure 28 - Monthly prevailing wind diagrams and wind speed histograms, Brunswick Naval Air Station Weather Summary (1945-1972). Months: July, August, and September. Wind speeds converted from knots to miles per hour (mph).

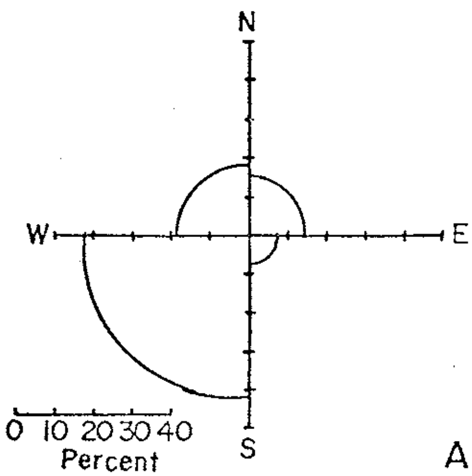
MONTHLY PREVAILING WIND DIAGRAMS AND WIND SPEED HISTOGRAMS

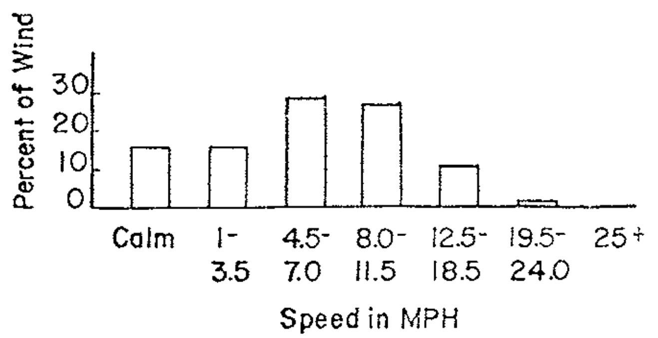
Percent of Wind From Each Quadrant | Percent of All Wind vs. Speed Range in MPH



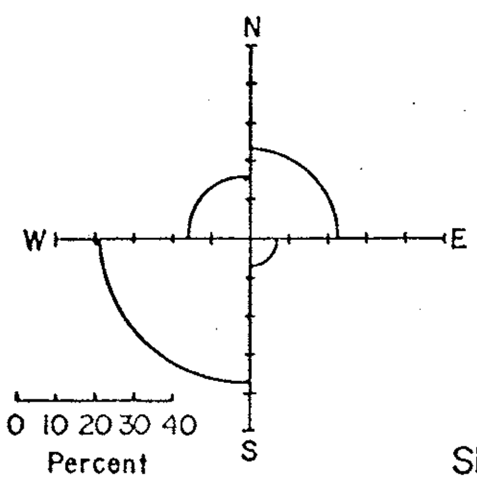


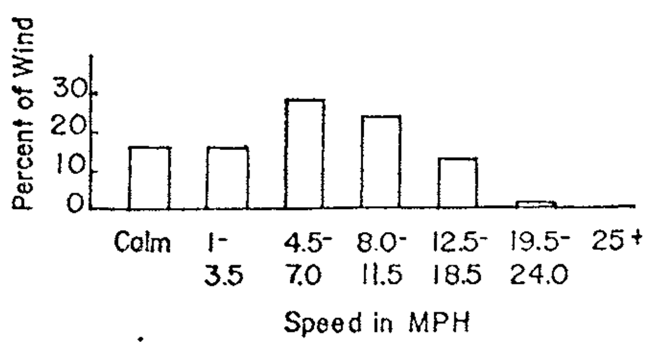
JULY: 1945-1972





AUGUST: 1945-1972





SEPTEMBER: 1945-1972

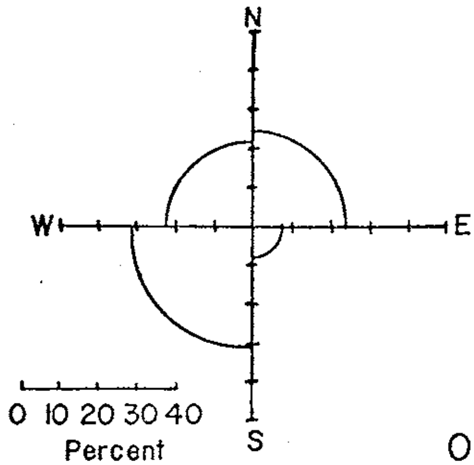
FIG. 28

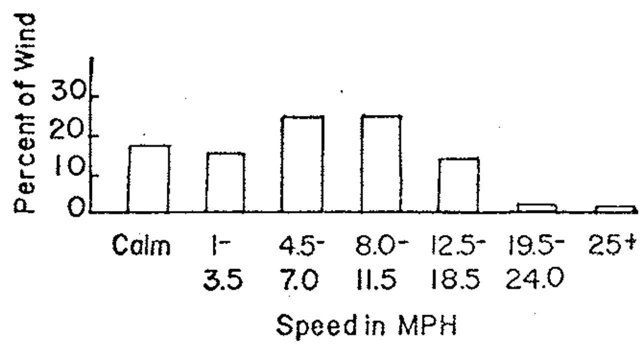
Figure 29 - Monthly prevailing wind diagrams and wind speed histograms, Brunswick Naval Air Station Weather Summary (1945-1972). Months: October, November, and December. Wind speeds converted from knots to miles per hour (mph).

MONTHLY PREVAILING WIND DIAGRAMS AND WIND SPEED HISTGRAMS

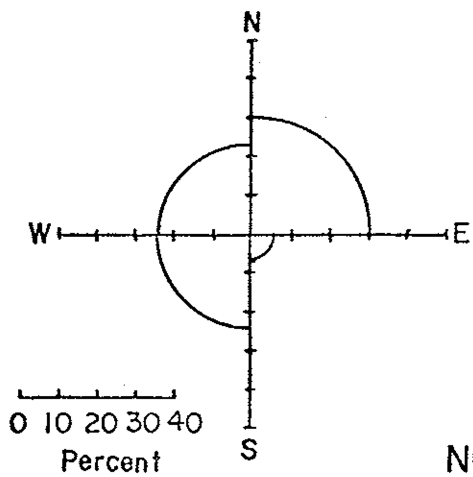
Percent of Wind From Each Quadrant

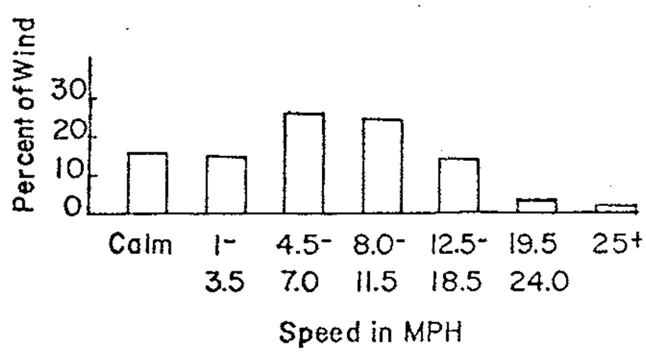
Percent of All Wind vs. Speed Range in MPH



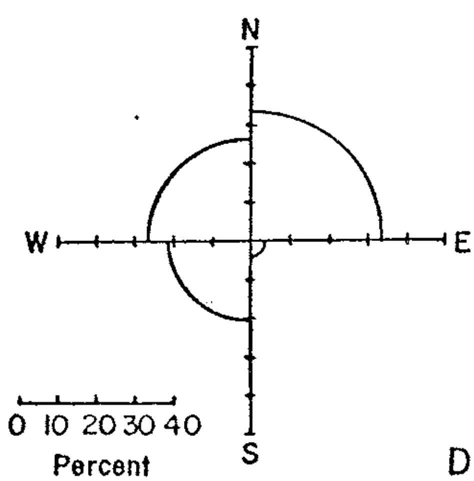


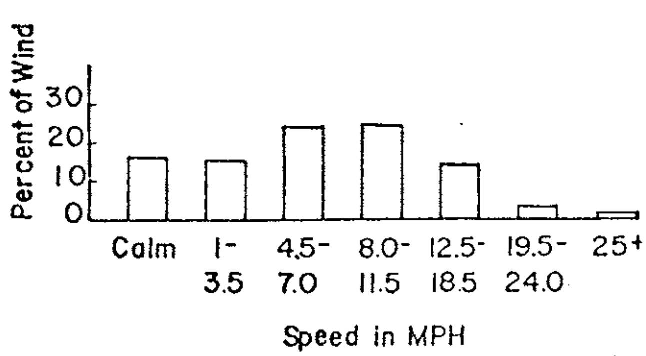
OCTOBER: 1945-1972





NOVEMBER: 1945-1972





DECEMBER: 1945-1972

FIG. 29

Sea Level Trends

Both land and sea levels have been changing since the last Pleistocene glaciation. Bloom (1963) states that coastal, southwestern Maine deglaciated around 12,000 B.P. (before present); this was also the time of maximum submergence of the land, still weighted down from the preceding burden of ice. At that time Portland, Maine was one-hundred and sixty feet below water. Between 9000-7000 B.P., the crust rebounded very quickly from the weight of the ice (Bloom, 1963), and it has experienced other more moderate fluctuations since then.

In tectonically stable locations, sea level can be examined separately from land movements. Shepard (1960) reporting on investigations in the Gulf of Mexico found that from 14,000 B.P. to 7,000 B.P., sea level rose quickly; from 7000 B.P. to the present, it continued to rise but at a decreasing rate.

Investigations on Cape Cod and Plum Island, Massachusetts and one in Hampton, New Hampshire have revealed that land and sea movements have produced a continuously drowning northeast shoreline over the last 7000 years. Two different rates, first fast and then slow, have been determined:

McIntire & Morgan (1964)	6300-3000 B.P.	1.00f/c[1] sea level rise
Plum Island, Mass.	3000-Present	0.25 f/c sea level rise
Keene (1971)	6850-4000 B.P.	0.75 f/c sea level rise
Hampton, N.H.	4000-Present	0.36 f/c sea level rise
Redfield & Rubin (1962)	3700-2100 B.P.	1.00 f/c sea level rise
Cape Cod, Mass.	2100-Present	0.33 f/c sea level rise

---

1 - Feet per century

These rates and time intervals vary slightly, probably a result of

differential peat compaction and differential crustal movement.

Over a shorter interval, sea level trends can also be examined by analysis of tide gauge data. Hicks and Crosby (1972) published an average change of approximately a foot per century in Maine:

Portland	1912-1972	2.30 mm/yr	0.75 feet/century
Eastport	1930-1972	3.60 nn/yr	1.18 feet/century

The northeast coast of Maine has been subsiding faster than the south-west.

Tide gauge rates of approximately one foot per century are much faster than rates (0.25 - 0.36 feet/century) determined by previously mentioned investigations dealing with the last three thousand years. If rates have changed in the very recent past, then experimental techniques dealing with long time intervals (ie., thousands of years) will not be sensitive enough to demonstrate these changes. Nevertheless, two methods of analysis have shown that sea level has been increasing for at least 7000 years and continues to do so.

Historical Analysis of Barrier Beach Movement and Erosion

Introduction

Two important questions should be addressed in a historical analysis of a barrier beach system. First, has there been severe erosion or accretion of the beach in the very recent past (i.e., 100 years)? And second, has there been movement forward toward the ocean or inland toward more upland sites of the whole barrier beach over a much longer period (i.e., 2000 years)?

The more recent past may be analyzed by an examination of old maps. The first reliable map of this locality was made in 1859 by the U.S.C. & G.S. Reid State Park beach was not included, presumably because the map dealt with the mouth of the Kennebec River. The second map edition appeared in 1862, and it included Reid. Subsequently, new map editions, partially revised, were released every fifteen or twenty years. The coast line was not revised with each new edition; therefore, selected editions have been chosen for comparison with a more recent coastline (1965-Ed. 11).

To analyze the more distant past of the barrier system, other methods have been employed. If the barrier beach is retreating toward more inland sites and if a salt marsh has always been present behind the barrier (here, an assumption), then a retreating barrier beach system would move over and cover the salt marsh. Barrier beach retreat has been documented in many places along the east coast (Godfrey and Godfrey, 1974; Fisher et al, 1974; Kraft, 1971;McIntire and Morgan, 1964). If the sand dunes are cored on the backside of the barrier, it is possible to detect barrier beach retreat via the presence of underlying salt marsh strata. Two sand dune profiles, one at Reid State Park

and the other at Small Point beach, were cored in order to examine this problem.

Materials and Methods

Maps:

Old United States Coast and Geodetic Survey maps of the Phippsburg and Georgetown peninsulas were purchased from the National Archives in Washington, D. C. Photostatic negative copies of the years 1859, 1862, 1920, and 1962 were obtained and a more recent map from 1965 was borrowed from the Geology Map Library at the University of Massachusetts. Employed as a base map, the 1965 coastline (Ed. 11) was traced onto an opaque plastic. Control points farther inland were also placed on the base map so that an overlay could be made. Photostatic negative copies of previous editions, which were supposed to be reproduced to scale, were not made exactly to scale. Hence the old maps were placed in a Sketch-Master in order to adjust the scale, and through the use of extra control points and triangulation, the 1862 (Ed. 2) and 1920 (Ed. 5) shorelines were traced onto the base map.

Coring:

The coring method is basically the one used by Dr. Paul Godfrey in previous research for the National Park Service. Sites were selected for coring profiles at Reid State Park behind Mile Beach and at Small Point beach. Permanent poles were placed in the dunes for a datum point and for future reference; a topographical profile was surveyed from the beach inland to the salt marsh. Three or four coring sites were selected along each topographical profile.

Plastic PVC sewer pipes 3 1/4 inches in diameter and ten feet long

were used for cores, their ends filed to reduce friction. A steel pipe, slightly larger in diameter than the cores and approximately three feet long, was utilized as the manner to drive the core into the sand dunes or salt marsh. Half of the steel pipe was hollow; the other half was filed with lead. The top of the core was then inserted into the hollow bottom half of the steel pipe; finally, the steel pipe was repeatedly lifted and dropped on the core to push it into the ground.

When the core was almost at ground level, a plumber's expanding pipe plug was placed in the top of the core. A strong vacuum seal was thus formed by expanding the pipe plug inside the core. After the seal was secured, the core could be removed from the ground. Before removal, measurements were made from the top of the plastic core to the ground, and from the top of the plastic core to the top of the top of the core strata inside the core so that any compaction of the strata due to pounding could be taken into account. Extracting the cores was accomplished with a truck jack and a heavy-duty chain.

The cores were subsequently cut open in order to analyze the strata. Both sides of the core pipe were cut lengthwise on a table saw without disturbing the internal strata. A thin piece of wire was then pulled through the length of the core, thus facilitating the splitting of the core material. Upon opening, each core half contained one half of the core strata. Finally, analysis of the core strata was conducted, and each layer was measured in relation to the top of the core.

Compaction due to pounding occurred in approximately half of the cores. In cases in which the vacuum had not been sufficiently strong, stratal layers separated from each other. Core compaction was accounted for by placing the top stratal layer even with the known ground level on

the core diagram (Figs. 31b & 31d), and then adjusting the remaining strata. Separations caused by the lack of vacuum were accounted for by placing the strata below the separation at a level with the top of the separation in the coring diagrams.

Results

Maps:

The final mapping product (Coastal Changes for Popham, Reid, and Small Point beaches) is presented in Figures 30a and 30b. Reid State Park has not undergone extreme shoreline changes, as detected by these 1:40,000 scale maps, although a small amount of erosion occurred on Mile Beach between 1862 and 1965. The barrier dune next to Little River, Todds Point, has been quite active during this period (Fig. 30b). This small barrier spit has had three different configurations. In 1862 it was much wider than it was in 1965. By 1920, the back side of the barrier had been heavily eroded up to the 1965 position, and the barrier point was elongated almost across the mouth of Little River. After 1920 the frontside of Todd's Point was eroded up to the 1965 position and the tip of the barrier was shortened by the changing course of Little River.

Popham and Small Point beaches have undergone much larger changes. Only changes from 1862 to 1965 can be ascertained as no coastline revisions were made on the 1920 map (Ed. 5). In 1865 at Popham, the Kennebec River beach was built out almost 50 yards farther into the river. South beach's shoreline was located approximately 100 yards (300 feet) farther inland than its 1965 location. Since 1965, the duneline has eroded farther than its 1862 position (Barry Timson, pers. comm.).

The largest shoreline change appears on the map between Fox Island

and Morse River. In 1862 the shoreline was situated between 200 and 300 yards farther south of its 1965 location. Severe erosion took place on this section of the barrier during that 100 year interim. The banks of Morse River have been altered on both Popham beach and Small Point beach. At Popham, the Morse River shoreline prograded between 1862 and 1965. During the same period, 200 yards of beach accreted on the west side of Morse River, partially blocking the mouth of Morse River and deflecting the tidal river to the east. It is also interesting to note that in 1965 there were four small islands in the mouth of Morse River that are not there now.

Most of the long straight shoreline at Small Point has not changed significantly. The tip of the barrier near Sprague River has been altered; between 1862 and 1965, it increased in width and moved inland.

Figure 30a - Shoreline Changes - 103 years, Small Pt. and Popham Beach. Map scale is the same as the base map, 1:40,000. The shoreline changed between 100 and 300 yards at two Popham locations, and Sprague and Morse Rivers have altered their courses, eroded, and deposited.

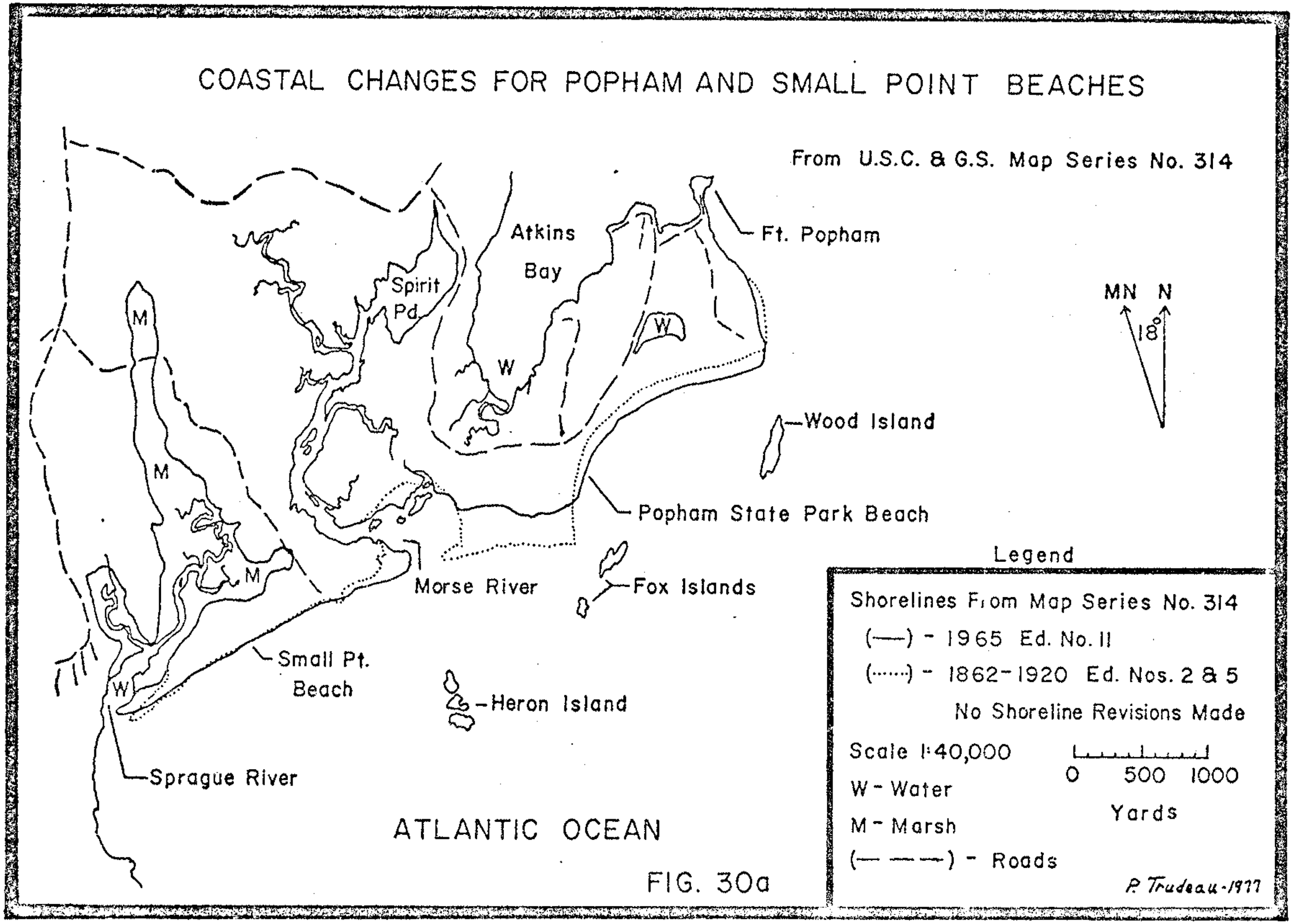

COASTAL CHANGES FOR POPHAM AND SMALL POINT BEACHES
From U.S.C. & G.S. Map Series No. 314
Ft. Popham
Atkins Bay
Spirit Pd.
MN N
18°
W
M
Wood Island
Popham State Park Beach
Morse River
Fox Islands
Small Pt. Beach
Heron Island
Sprague River
ATLANTIC OCEAN
Legend
Shorelines From Map Series No. 314
(——) - 1965 Ed. No. 11
(·····) - 1862-1920 Ed. Nos. 2 & 5
No Shoreline Revisions Made
Scale 1:40,000
0 500 1000
Yards
W - Water
M - Marsh
(— — —) - Roads
P. Trudeau - 1977

FIG. 30a

Figure 30b - Shoreline Changes - 103 Years, Reid State Park. Map scale is the same as the base map, 1:40,000. The most significant changes occurred at the mouth of Little River.

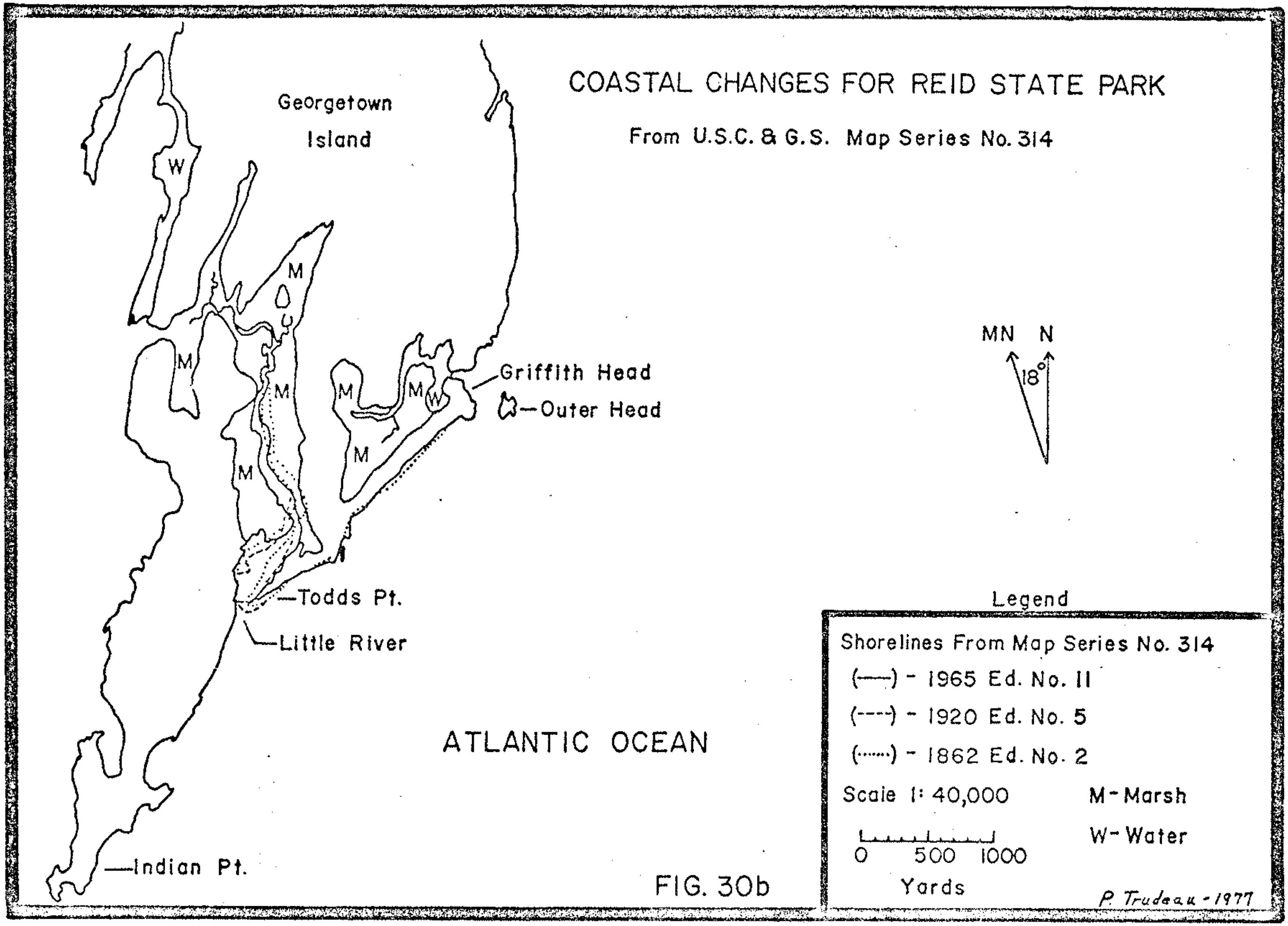

COASTAL CHANGES FOR REID STATE PARK
From U.S.C. & G.S. Map Series No. 314
Georgetown
Island
Griffith Head
Outer Head
Todds Pt.
Little River
Indian Pt.
ATLANTIC OCEAN
MN
N
18°
M
W
Legend
Shorelines From Map Series No. 314
(——) - 1965 Ed. No. 11
(----) - 1920 Ed. No. 5
(......) - 1862 Ed. No. 2
Scale 1: 40,000
M - Marsh
W - Water
0 500 1000
Yards
P. Trudeau - 1977

FIG. 30b

Coring:

Small Point coring profile (P10A) and Reid State Park coring profile (P2) are drawn to scale in figures 31a and 31c, respectively. An enlargement of the core strata was also made for Small Point (Fig. 31b) and Reid (Fig. 31d). Core strata were given designated types; if two strata intergrade, then both types were indicated on the figures, one superimposed on the other. Core information for Small Point core P10A-1 was not included as it added little information to the profile analysis.

Three cores were extracted from the back dune and salt marsh of Small Point (Fig. 31a). Cores P10A-2 and P10A-3 were removed from dry dune sites, while core P10A-4 was pulled from the salt marsh. Through examination of core strata P10A-4, P10A-3, and P10A-2 in figure 31b, it can be perceived that the dunes have retreated over the marsh at least 18 meters. Both high and low salt marsh strata were present in core P10A-3 at a depth between -1.60 and -2.00 meters. These same strata were also represented in core P10A-4 at a depth of -1.23 to -2.20 meters. During the past few thousand years, site P10A-3 was occupied by salt marsh vegetation; presently, it is covered by sand dunes and their associated plants; consequently, the dunes have been retreating over the marsh at this coring site. Retreat distance is measured from P10A-3 coring site (187 meters) to the point where salt marsh vegetation begins (205 meters), or approximately 18 meters. Actually, the amount of retreat is greater than 18 meters but less than 108 meters; core P10A-2, located 90 meters farther inland than P10A-3, did not exhibit salt marsh peat between -1.60 and -2.00 meters, thus indicating that coring site P10A-2 was never inhabited by salt marsh vegetation. Ostensibly, then, the dunes have retreated at least 18 meters, but less than 108 meters.

Reid State Park coring profile (P2) is drawn in relation to mean sea

Figure 31a - Small Pt. Coring Profile - P10A. Core P10A-1 added little to profile analysis and was not included in core strata analysis (Fig. 31b). Core P10A-2 was removed from a site vegetated by dunegrass, P10A-3 from dunegrass, and P10A-4 from salt marsh.

SMALL PT. CORING PROFILE - P10A

FIG. 31a

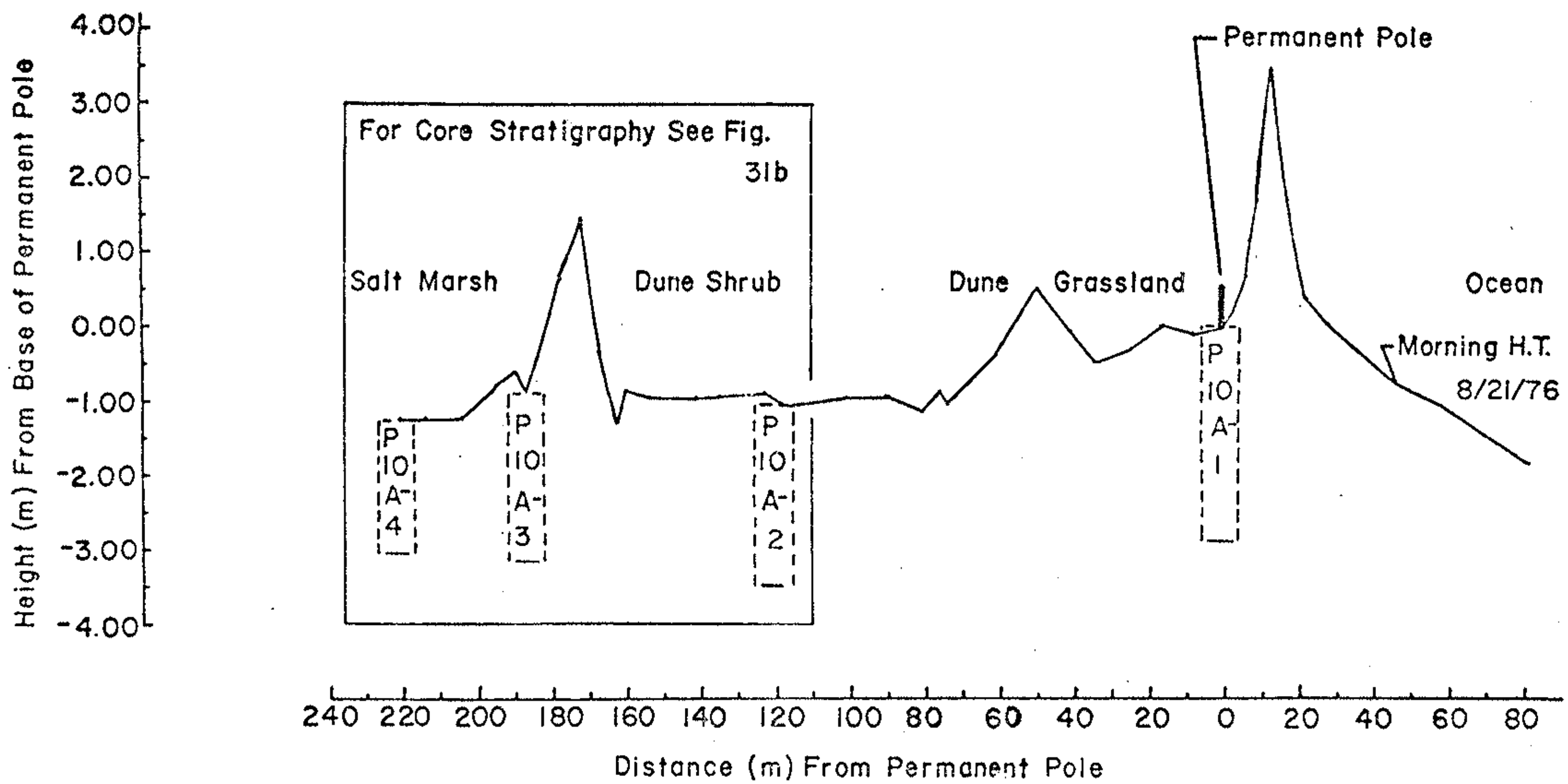
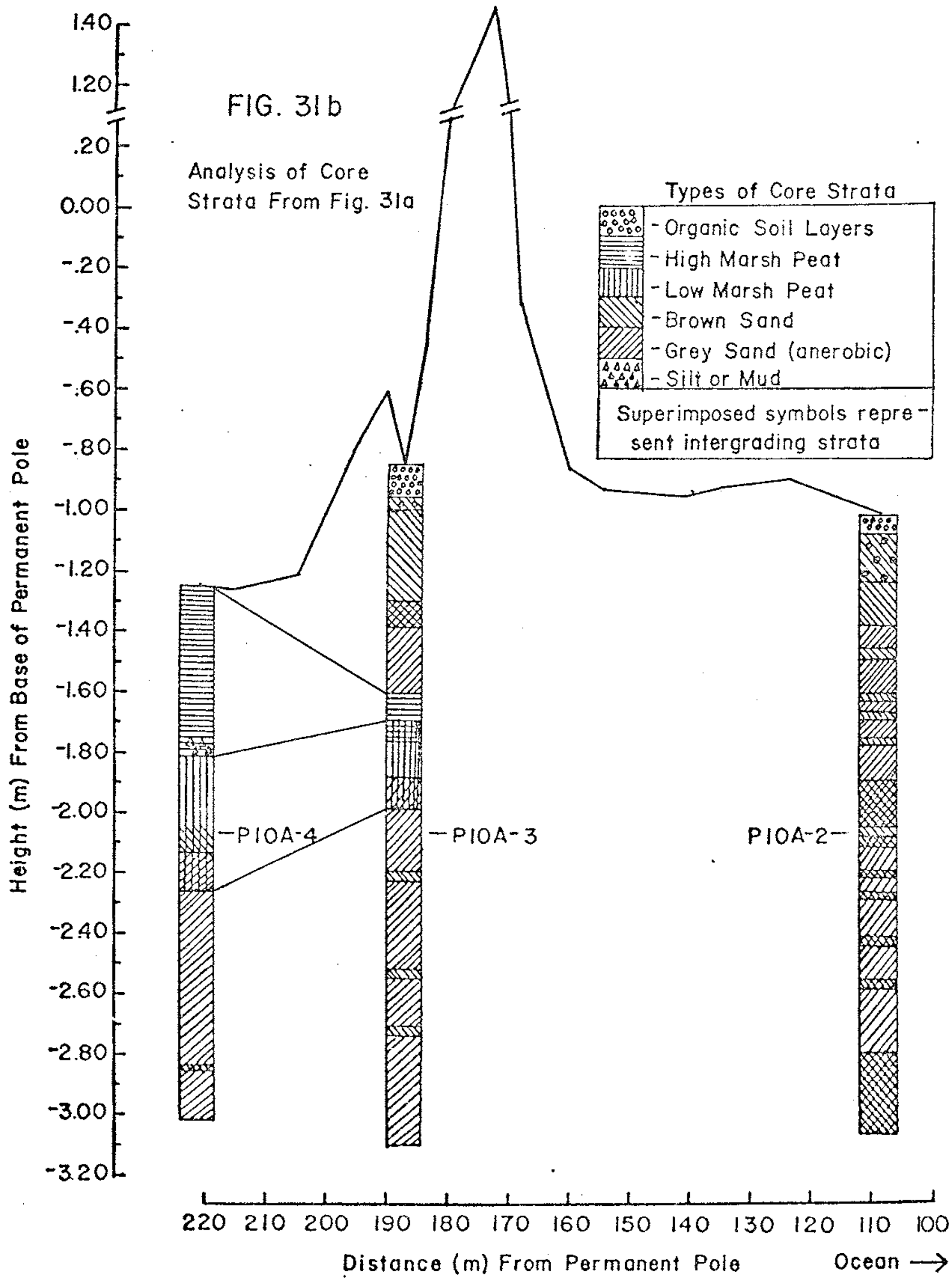


Figure 31b - Core Strata Analysis, Small Pt. Coring Profile P10a. If two layers intergrade, their symbols are superimposed, one on the other.

SMALL PT. CORING PROFILE P1OA



level (Fig. 31c), and a large scale description of core strata is presented in Figure 31d. Cores P2-1 and P2-2 were removed from sites covered with dunegrass vegetation, while core P2-3 was extracted from salt marsh. High and low salt marsh peats, located between 0.50 meters and 0.04 meters above mean sea level on core P2-3, were not observed at similar elevations on core P2-2, thus indicating that the dune has not retreated over the salt marsh at this site. Other evidence suggesting lack of retreat was the brown sand found between 0.43 meters above mean sea level (msl) and -0.43 meters below msl in core P2-2. If the sand were gray, it would indicate that it had once been in a deoxygenated, anerobic environment, such as the gray sand located under the salt marsh peats (-0.27 to -1.42 meters below msl) in core P2-3; however, there was no gray sand in core P2-2.

Old organic soil layers are extensively interspersed in sand layers (P2-2), and one is similarly present in core P2-1 (Fig. 31d). These buried soil layers are indicative of aeolian dune retreat. If portions of the dune were devegetated in the past, aeolian transported sand could have buried the soil horizons. If the dune between coring site P2-1 and the foredune ridge had been severely devegetated, sand could have been wind transported from the beach; it seems more likely, however, to have been supplied from a devegetated area between core P2-1 and the foredune ridge. Hence there are signs of aeolian dune retreat in cores P2-1 and P2-2; however, the movement has not yet encroached upon the salt marsh.

Discussion

There are three processes by which barrier beaches can retreat: overwash, inlet formation, and aeolian transport. Overwash, a storm

Figure 31c - Reid State Park Coring Profile-P2. Core P2-1 and P2-2 were removed from sites vegetated by dunegrass and P2-3 from salt marsh. Strata analysis of cores can be found in figure 31d.

REID STATE PARK CORING PROFILE - P2

FIG. 31c

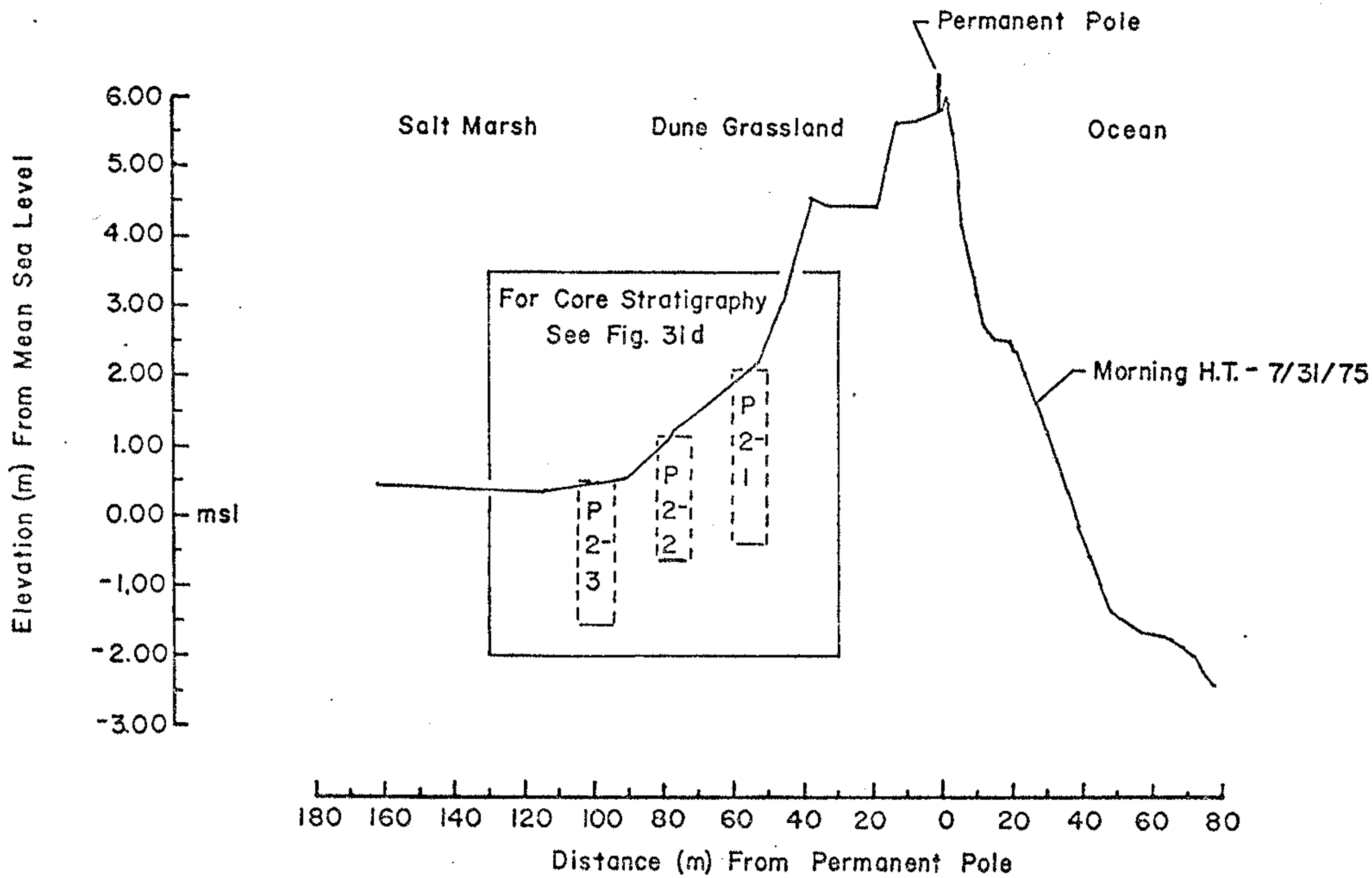
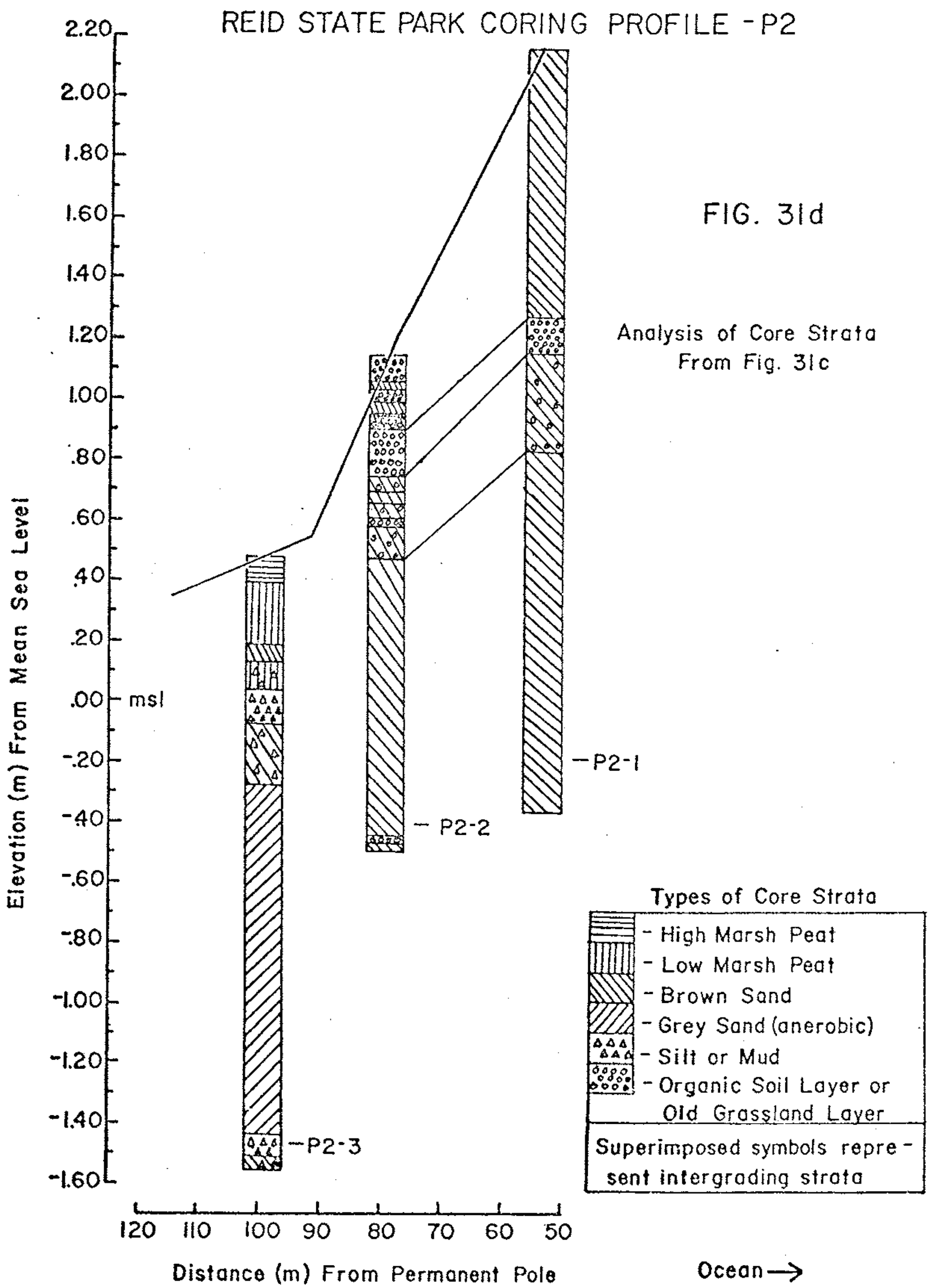


Figure 31d - Core Strata Analysis, Reid State Park Coring Profile-P2. If two layers intergrade, their symbols are superimposed, one on the other.



REID STATE PARK CORING PROFILE - P2
FIG. 31d
Analysis of Core Strata
From Fig. 31c
2.20
2.00
1.80
1.60
1.40
1.20
1.00
.80
.60
.40
.20
.00 msl
-.20
-.40
-.60
-.80
-1.00
-1.20
-1.40
-1.60
Elevation (m) From Mean Sea Level
P2-1
P2-2
P2-3
Types of Core Strata
- High Marsh Peat
- Low Marsh Peat
- Brown Sand
- Grey Sand (anerobic)
- Silt or Mud
- Organic Soil Layer or
Old Grassland Layer
Superimposed symbols represent intergrading strata
120 110 100 90 80 70 60 50
Distance (m) From Permanent Pole
Ocean →

induced surge of water and sand, and inlet formation, a storm induced breach of the dune, occur frequently farther south along the east coast. One of these, overwash, has been extensively documented for two winters at Popham Beach and to a limited extent at Small Point, but not at Reid. During a major overwash, high storm tides are driven up and over the foredune ridge; wave energy is dissipated by American beachgrass; and large loads of sand are deposited between the culms. If the barrier is flat and low, as is often the case on southern barriers, surge waters sweep across the barrier and deposit sand in a salt marsh or lagoon. By this process, the barrier beach remains a dynamic unit which retreats inland through periods of rising sea level or subsiding land.

Another possibility, aeolian dune retreat, is a process whereby active sand movement occurs in devegetated areas or from beaches into dunes. Transport of sand depends on speed, direction, and duration of wind. Section nine of this report, dune dynamics, deals with aeolian transport over the foredune ridge.

Small Point beach and Reid State Park have high foredune ridges, often ranging between 3.5 meters and 6.0 meters above mean sea level (Figs. 31a & 31c). It appears unlikely that any storm waves could surge over the ridges; hence storm damage is usually sustained as erosion. Also, there is evidence of barrier beach movement. Small Point coring profile (P10A) reveals at least 18 meters, but less than 108 meters, of sand dune retreat over the salt marsh. Since the foredune is so high, and since there are prominent secondary dunes (Fig. 31a), the backdune retreat at Small Point is most likely caused by wind.

At Reid, there is no evidence to suggest sand dune retreat over the salt marsh; however, there is evidence to account for significant sand

movement within the dunes. In one core (P2-1), an old soil horizon is buried by a meter of sand. And in another core (P2-2), there are several organic layers buried by sand up to 0.50 meters. Since the core closer to the ocean (P2-1, Fig. 31c) exhibits deeper burial of old soil horizons than core P2-2 (which is located 20 meters farther inland), it appears that the sand transport direction is from the ocean inland. The foredune at Reid State Park is even higher than that at Small Point. Consequently, movement of sand by overwash is not likely. The movement of sand at Reid is most likely caused by wind; at this time, however, the dunes have not yet begun to retreat over the salt marsh.

In the more recent past, the shoreline maps (Figs. 30a & 30b) display little change along the long, straight beaches at Reid and Small Point. At Popham, however, the maps depict quite large erosional and accretional changes. South Beach's shoreline was located much farther inland in 1862; by 1965 it had accreted 100 meters, and since then it has eroded even more than 100 meters. The area between Morse River and Fox Island at Popham has undergone the reverse process. In 1862, the shoreline was located 200 meters seaward of its 1965 position. There is also an erosional scarp as far inland as the dune forest, although the dunes are presently building seaward. This area has had the most active shoreline of all three beaches.

The dunes near the mouths of the three tidal rivers, Little River, Morse River, and Sprague River, have also been quite active. This, however, is expected; tidal rivers continally change their courses. As the river twists and turns, it erodes one bank and deposits sand on the other, or in a sand bar. Tidal creek movement, erosion, and deposition are usually of little consequence so long as no permanent structures are ever placed near such active sites.

Dune Dynamics: Overwash, Erosion, and Aeolian Sand Transport

Introduction

Sand moves by four different processes in coastal systems: Littoral drift, aeolian transport, beach erosion and storm-induced washover. Data on erosion profiles and littoral drift will be presented by Barry Timson. Aeolian transport investigated on thirty sand accretion-erosion profiles in combination with photographic and descriptive information (on overwash and erosion) will be reported here.

Sand movement over the fore dune was investigated by a series of ten accretion-erosion transects on each beach. By monitoring these stakes year round, it was possible to determine what portion of the fore dune was most active, what sections of the beach systems experienced the most transport, and when the greatest transport occurred. Because of experimental difficulties encountered by working in public parks, many data points are missing. Park visitors removed, broke, and shifted sand stakes to new locations. Erosion and overwash also claimed stakes; however, stakes were replaced when possible (i.e., when there was no ice or dune erosion).

The greatest understanding of beach processes developed from continual inspection of the beaches. I spent two summers in full-time residence setting up, photographing and monitoring experiments, but found that the most significant beach activity occurred during the winters. Consequently, every eight to ten weeks (from September to May), I visited, walked and photographed each beach. Overwash, erosion and wind transport were documented; they will be discussed in this section.

Materials and Methods

To obtain a good assessment of aeolian transport, ten accretion-erosion transects were established during June 1976 on each beach. On Small Point and Reid State Park beaches, which are relatively straight, transects were established at 140 meter and 117 meter intervals, respectively. At Popham, transects were variously spaced from 100 meters to 200 meters, depending on the curvature of the fore dune.

During the previous winter (1975-1976), an experiment was set up with stakes 40 meters into the dunes (10 meters apart); but it was quickly determined that most of the activity occurred right along the foredune ridge. Thus, for the 1976-1977 winter, four stakes were placed in each transect, one on the aeolian ramp, one on the dune ridge, and two on the backdune slope. All stakes were between two and four meters apart.

On June 22, 1976, numbered stakes with grooves at 10 cm intervals were partially buried, leaving thirty centimeters exposed. Changes in sand height were recorded in September and December of 1976 in addition to February and April of 1977. Negative values were recorded as erosion and positive values as accretion.

Erosion was monitored photographically and with a profile located at Morse River. Initially, the profile was surveyed and analyzed for plant cover on August 15, 1975; then winter erosion was checked during the summer of 1976 and the spring of 1977.

Overwash, which is only prevalent at Popham, was documented with photographs; an overwash plot was also established at Popham in order to follow the revegetation process. After a severe Northeaster during March 1976, a foredune area, approximately 30 meters by 20 meters, was staked off south of the dune privies at Popham. The site had from 20

to 40 centimeters of sand deposited on it; some of it reworked by wind. In June 1976, species presence and plant cover were recorded and analyzed in order to determine what species colonized an overwash site and how quickly they developed a stablilzing plant cover.

Results

Aeolian Transport

Small Point and Popham beaches have a south-east-south exposure while Reid's is southeast. As documented in the prevailing wind diagrams (Figs. 26, 27, 28 and 29), less than 13% of the wind approaches from the southeast quadrant. Consequently, only a small portion of wind comes directly across the beach perpendicular to the dunes. A large portion of wind originates in the southwest quadrant, however, with more in the summer (approx. 50%) than winter (approx. 20%). Blowing parallel to the beach (Fig. 42), these winds are the most effective agent in moving sand.

During the winter, a large portion of the wind approaches from the northwest and northeast quadrants, but these winds blow across vegetated backdune areas and transport little sand. There are a few devegetated areas which show northwest wind transport. For instance, in a large devegetated area of Small Point (Fig. 40), over a meter of sand is being moved by the northwest wind. A shrub community composed of bayberry and virginian rose is undergoing burial. It appears that this process has also occurred at Reid in the past (Fig. 1, background), but vegetation is now beginning to stabilize the site. It would probably be occurring at Popham (Fig. 22), but the northwest wind is blocked by the Popham dune forest.

More sand transport was recorded on Small Point (Fig. 41, Fig. 44

Figure 40 - Aeolian Transport, Small Point Beach. Active backdune, exposed to winter northwest winds. Once devegetation has occurred, there is nothing to stop sand movement. Here, a meter of sand is covering a bayberry and rose shrub community. Photo, March, 1976.

Figure 41 - Aeolian Transport over fore dune at Small Point. Viewing southwest along dune ridge. Photo, March, 1976. Wind builds a sand ramp on front of dune and then transports sand over the top. Heaviest transport during the winter months.

Figure 42 - Aeolian Transport, Small Point Beach. Photo, 1/20/76. Wind from west-south-west moving sand east-north-east along the beach and over the fore dune.

Figure 43 - Fence buried by sand, Popham Beach State Park. Fence put in after park opened, less than 10 years of sand burial.

Fig. 40

Fig. 41

and Appendix D) and Popham (Fig. 43, Fig. 45 and Appendix D) than at Reid (Fig. 46 and Appendix D) because the first two have better southwest wind exposure. Figure 44 demonstrates graphically the changes which occurred on three selected transects at Small Point. Stakes were located on the dune ramp (165, 170 and 190), and on the ridge (166, 171 and 191), and behind the ridge (167, 172 & 192 and 168, 173 and 193). Highest accretion was on the ramp and ridge; values decreased on the back stakes.

Some sand transport was detected throughout the ten-month study period, but the greatest amount of transport occurred during the fall and winter (Appendix D). At Small Point, sand transport was 5.5cm per stake between 9/18/76 and 12/5/76, and 3.8cm per stake between 12/5/76 and 2/6/77. Therefore, southwest autumn winds are the most effective sand transporters.

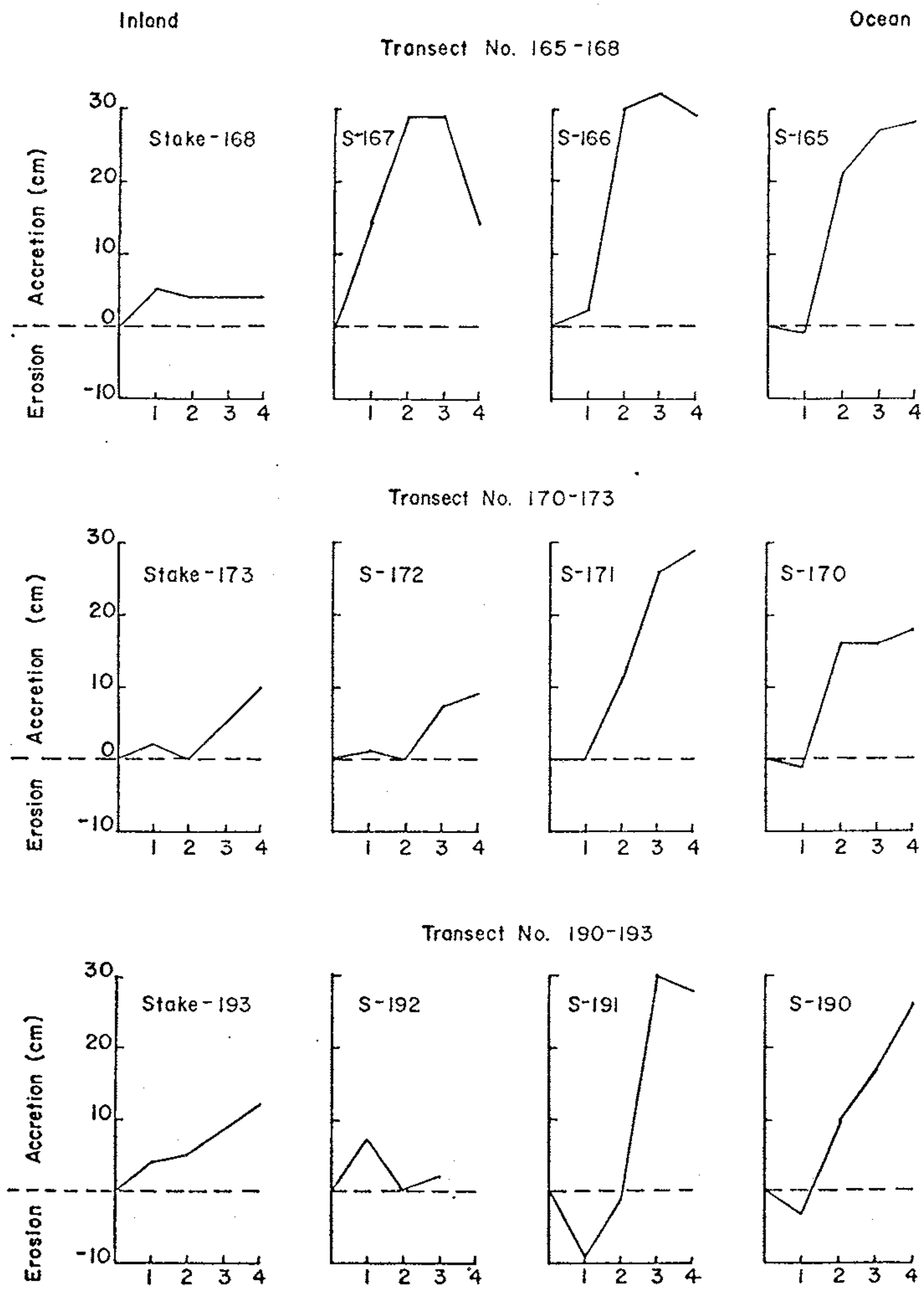
Small Point beach is relatively straight, and it has a uniform foredune exposure. Transect 150-153 was established on the northeast end of the beach and transect 195-198 on the southwest end. Those in between were located at 140-meter intervals. From northeast to southwest, averages for net transport per transect were as follows (values from four stakes averaged): 6.0, -0.5, 8.0, 18.8, 16.5, 6.0, 14.5, 6.0, 17.0 and 2.5cm. Aeolian transport along the beach fluctuated indiscriminately; consequently, no portion of Small Point beach received significantly larger inputs than any other.

Significant transport occurred from 12/5/76 to 2/6/77 (6.5cm/stake) at Popham, but many data were not recorded due to winter snow and ice. Twice as many values were recorded between 9/18/76 and 12/5/76 with an average of 4.9cm per stake. Due to limited December-February data, it is somewhat speculative as to the period of greatest movement. However, as at

Figure 44 - Three sand accretion-erosion transects, Small Point Beach. In each transect changes in sand elevation between four data collection dates are shown for each of four stakes. Three of ten beach transects were selected for graphical display, while data collection dates and elevational changes for all ten are presented in Appendix D.

THREE SAND ACCRETION-EROSION TRANSECTS FROM SMALL PT.

Amount of Change Shown During Measurement Periods for Each Stake



Four Measuring Times During a Ten Month Period

FIG. 44

Small Point, transport values at Popham were higher in the winter than in the summer.

Three transects (135-138, 140-143, & 145-148), situated between the life guard stations and the sea wall, had insignificant transport (-3.25, 5.0, & 0.25cm, respectively). Here, the beach faces southeast and does not receive any southwest wind. Seven other transects between Morse River and the Popham bath houses (100-103, 105-108, 110-113, 115-118, 120-123, 125-128, and 130-133) had much higher transport averages (eroded 5.3, 8.0, 20.3, 12.0, 23.5 and 15.3cm., respectively). All these transects were located on dune ridges facing south or southwest; therefore, the southwest winds are the most effective agents of aeolian transport.

Aeolian transport, especially on Mile Beach, was less important at Reid than at the other two beaches. Mile Beach has a southeastern exposure and Half-Mile Beach a more southerly exposure (20-30 degrees more); accordingly, Half-Mile Beach receives more southwest wind. In addition, Todds Head, which protrudes 40-70 meters into the ocean, obstructs and reduces southwest wind approaching Mile Beach. Transect averages bear out these effects. Approximately four times more sand accreted on Half-Mile Beach transects than on Mile Beach transects.

In conclusion, aeolian transport on these beach systems is characterized by the following: 1) southwest winds, which are the most effective in moving sand, 2) more sand transported in the winter than in the summer, and 3) the greatest sand accretion detected from one meter before the dune ridge to three meters behind it.

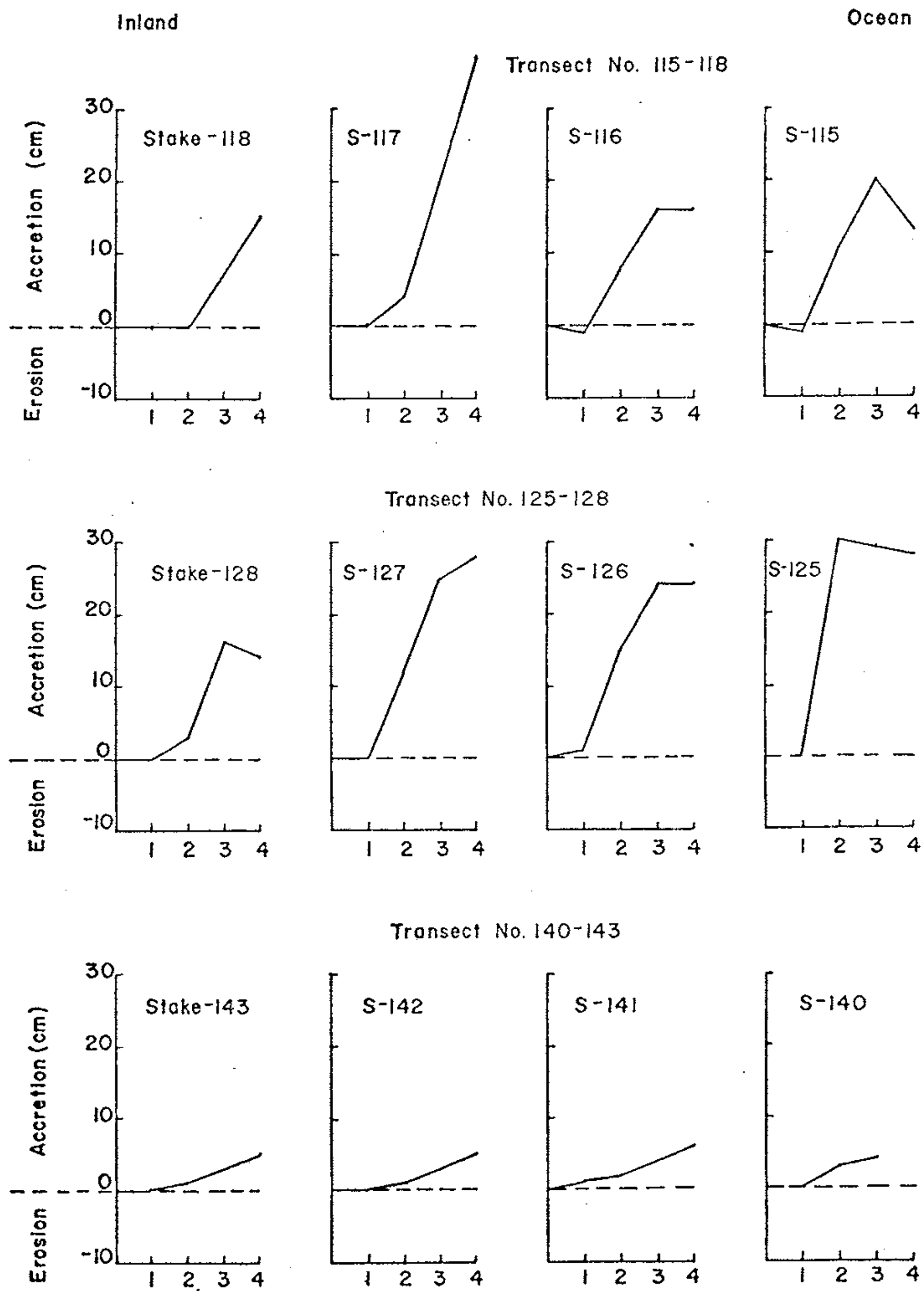
Overwash:

Overwash, storm induced surges of water and sand over the fore dune,

Figure 45 - Three sand accretion-erosion transects, Popham Beach State Park. In each transect changes in sand elevation between four data collection dates are shown for each of four stakes. Three of ten beach transects were selected for graphical display, while data collection dates and elevation changes for all ten are presented in Appendix D.

THREE SAND ACCRETION-EROSION TRANSECTS FROM POPHAM BEACH

Amount of Change Shown During Measurement Periods For Each Stake



Four Measuring Times During a Ten Mouth Period

FIG. 45

Figure 46 - Three sand accretion-erosion transects, Reid State Park. In each transect changes in sand elevation between four data collection dates are shown for each of four stakes. Three of ten beach transects were selected for graphical display, while data collection dates and elevational changes for all ten are presented in Appendix D.

THREE SAND ACCRETION-EROSION TRANSECTS FROM REID PARK

Amount of Change During Measurement Periods Shown for Each Stake

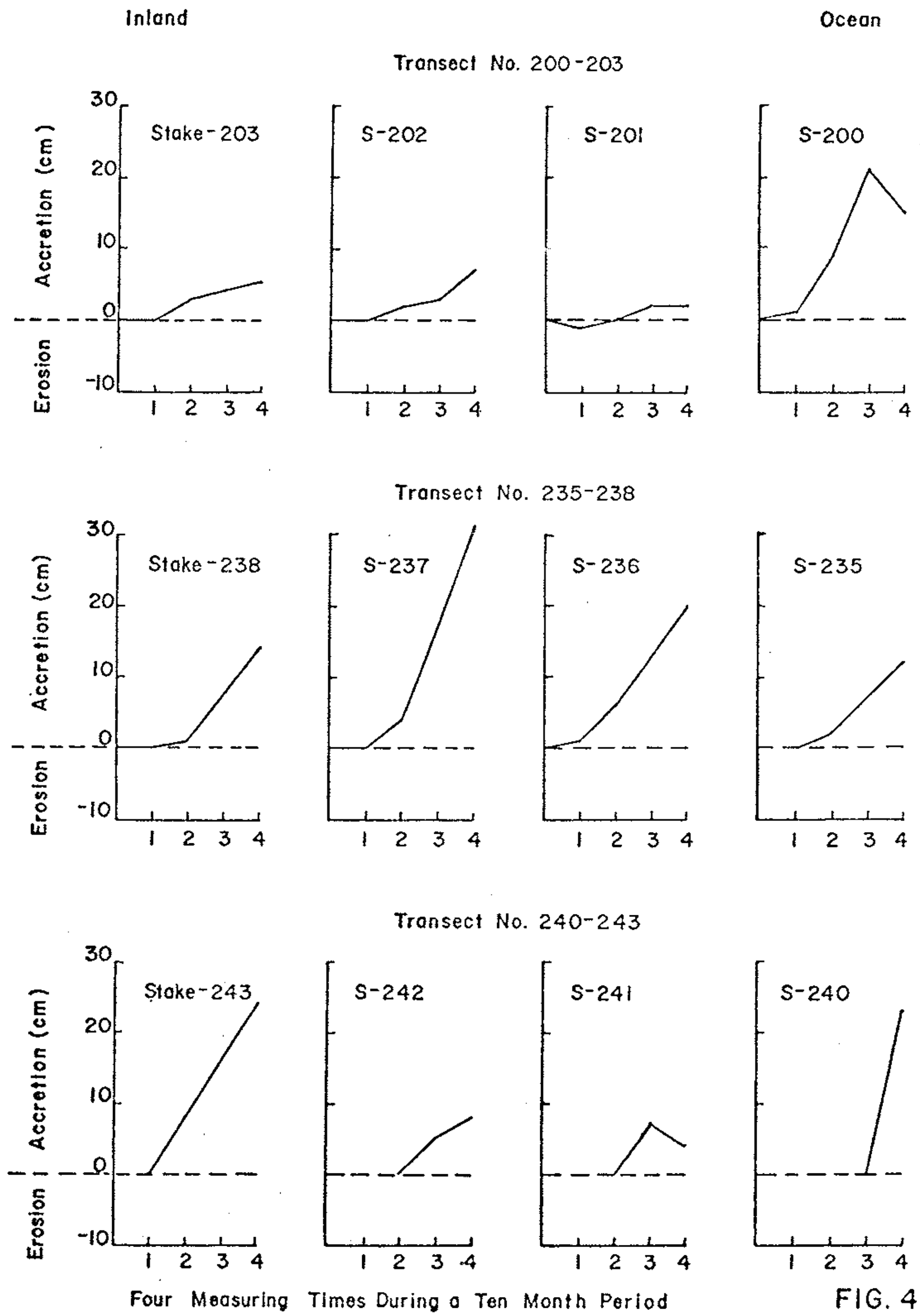


FIG. 46

is only prevalent at Popham Beach. Two or three small overwash sites were detected on Small Point, but they probably represent less than 2% of the distance along the fore dune. At Popham, however, where the foredune is much lower than at either Reid or Small Point, large overwashes were photographed both winters. On South Beach (Fig. 32) between the sea wall and Sea Acres beach entrance, overwash sediments of 10 to 30cm. were deposited from seven to twenty meters into the dunes (1975-1976 winters). Deposits along this beach were continuous for 250-300 meters. South of the Popham dune privies (Fig. 34), 30cm. depositions occurred during the 1975-1976 winter. An extensive overwash also occurred on the wide beach southwest of Popham's forested picnic area during the first winter. Water and sand swept across the wide berm, up over the low dune, and into the dormant American beachgrass. And finally, portions of the Morse River dunes overwashed several times both winters (Fig. 33).

Revegetation of one overwash site was followed south of the Popham dune privies in order to determine what species could survive thick depositions and how quickly they could establish good plant cover. On March 26, 1976, this revegetation plot was marked with stakes (Fig. 34); subsequently, on June 19, 1976, approximately seven weeks after the beginning of plant growth, the plot was sampled by two methods for composition and cover. Both methods, square-meter quadrat estimation and point sampling, revealed a total plant cover of 40-48 percent (Fig. 35). American beachgrass was essentially the only species present, except for a few beach pea plants. Within seven weeks American beachgrass had grown through 30cm. of sand, a demonstration of its highly specialized ability to live in a dynamic and unstable environment.

Figure 32 - Overwash on South Beach at Popham. November, 1975. A thick layer (10-30cm) of sand and debris washed seven to twenty meters into the dunes. Pitch-pine trees were present on the beach (background), indicating a severely eroding shoreline.

Figure 33 - Overwash on Morse River Profile, Popham Beach State Park. The photo, taken on 4/19/77, sites from the ocean toward the salt marsh; thick deposits of sand and debris were washed 35-50 meters into the dunes. During the study, 56.5 meters (186 feet) eroded on the oceanside of the profile.

Figure 34 - Overwash south of Popham Beach State Park dune privies after March, 1976 Northeaster. Some sand was reworked by wind after the overwash. The overwash site was marked with stakes to watch the revegetation process (see also Fig. 35). Approximately 30cm. of sand were deposited over most of the site and probably a meter near the fence.

Figure 35 - Overwash revegetation site (see also Fig. 34), south of Popham Beach State Park dune privies. Photo taken on 6/8/76; only three months after the overwash and only six weeks after the beginning of the growing season, American beachgrass had approximately 40% plant cover.


Fig. 32


Fig. 33

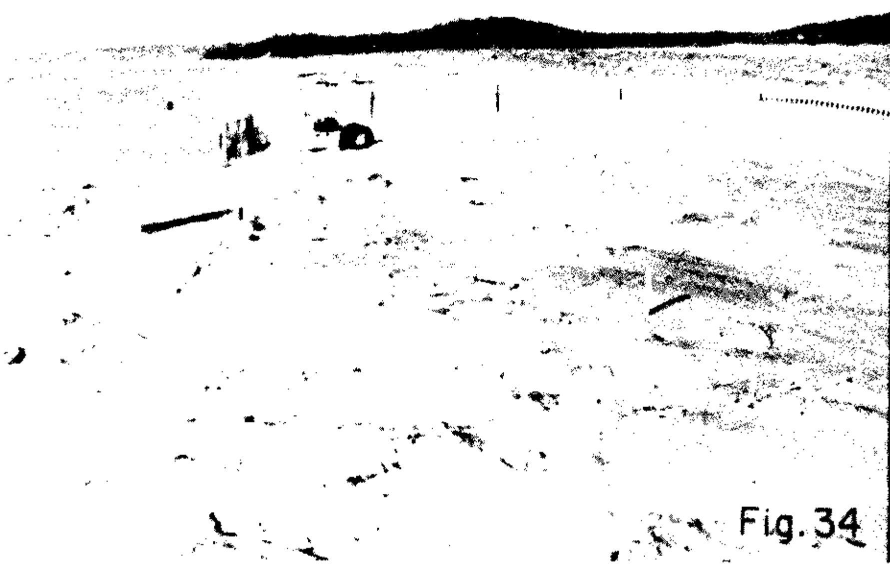


Fig. 34

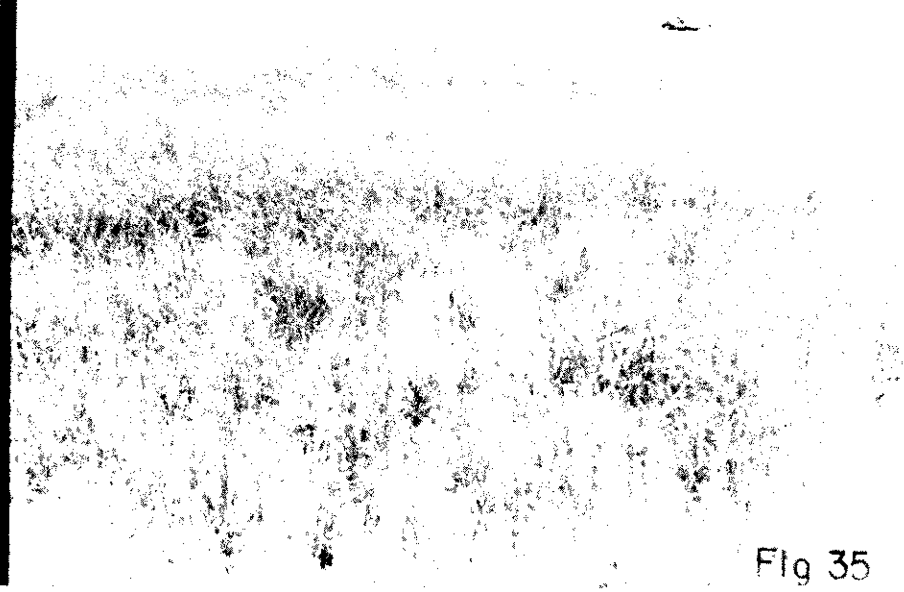


Fig 35

Erosion:

Small Point beach had the least erosion. Some occurred along the northeast portion of the beach, but less than two meters of fore dune were actually removed (determined from sand accretion-erosion transects). The aeolian ramp was partially eroded by storm waves during both winters and was replaced during summer and fall. High foredune plant cover helped reduce sand losses.

More severe erosion occurred at Popham; young dunes near Morse River were relentlessly eroded throughout the study (Fig. 36). Erosional scarps, two to eight feet high, were constantly present. A profile was established here in August 1975 (Fig. 9) and by April 19, 1977, 186 feet (56.5 meters) had eroded. This is the fastest eroding location within park boundaries, and the coastal change map (Fig. 30a) shows that a significant amount of erosion and deposition have occurred here between the shoreline dates stated on the map.

Directly south of Popham dune privies, one to two meters eroded during both winters, while slightly northeast of the bath house site, approximately seven to ten meters were removed during the 1976-1977 winter (an estimation since no permanent stakes were located here). This protruding dune between the bath houses and the life guard beach was eroded and rounded by storm waves.

No dune erosion took place along life guard beach at Popham, although a small amount of beach erosion was aggravated by the sea wall. Due to sand bar movement, this beach may widen significantly. A bar, separated from the beach by a runnel during most of the study, welded to the beach berm between February and April of 1977. The runnel filled with wind transported sand from the bar. If the process continues, the beach will

substantially widen.

Erosion at Reid was not severe during the winter of 1975-1976, but became quite critical the following winter. On Half Mile Beach, two areas were active. First, Todds Point was severely scarped throughout the study, and visitor pressure prevented any plants from colonizing and stabilizing the point (Fig. 38). Second, the beach berm immediately south of Todds Head has been repeatedly bared to rock (Fig. 39) and covered with sand. Storm waves removed the sand during the winter while gentle summer waves redeposited it.

The most crucial erosion at Reid was on Mile Beach (Fig. 37). Large dune scarps (12-15 feet high) were present for a distance of 200 meters north of Todds Head (winter, 1976-1977). Removal of the foredune ramp was followed by at least two meters and probably more of dune erosion. (Two meters of dune erosion were detected on sand accretion-erosion profile number 230-233; however, since all of the stakes were removed, the total amount of erosion could not be ascertained.) Because the barrier dune is quite narrow in this location, some critical problems may arise in the future (these are discussed in management).

Discussion of Dune Processes and Movement

The processes of erosion, overwash, and wind transport of sand operate in different combinations on these barrier beach systems. Small Point and Reid have relatively uniform processes due to their long, straight beaches, lack of islands and absence of sand bars. Popham is much more complicated. The beach and dune ridge curve continuously, several islands are situated offshore, the Kennebec River is nearby, and sand bars form and move with the currents. I will discuss the processes

Figure 36 - Eight-foot, foredune erosion scarp near Morse River profile, Popham Beach State Park. November 1975. Three-foot backpack was placed in the photograph for scale. American beachgrass roots slowed the erosion process. This area was severely eroded both winters.

Figure 37 - Foredune Erosion, Mile Beach, Reid State Park. Photo, 4/19/77. Backpack was placed in the photograph for scale. This twelve to fifteen-foot erosion scarp was located approximately 40 meters north of Todds Head; aeolian ramp and part of the fore dune were removed during the 1976-1977 winter.

Figure 38 - Foredune erosion and impact, Todds Point, Reid State Park. Photograph taken on 8/12/76, after an abated hurricane passed along the Maine coast. Foredune was not only sustaining environmental damage but also human impact; no plants can grow under these conditions. Historically, this spit has had the most active shoreline at Reid.

Figure 39 - Beach erosion south of Todds Point, Reid State Park. During the study, the rocks near this entrance were repeatedly covered with sand and exposed. Winter storm waves eroded the beach and exposed the rocks; gentle summer waves brought the sand back ashore. No dune damage was sustained here between 1975-1977.


Fig. 36


Fig. 37

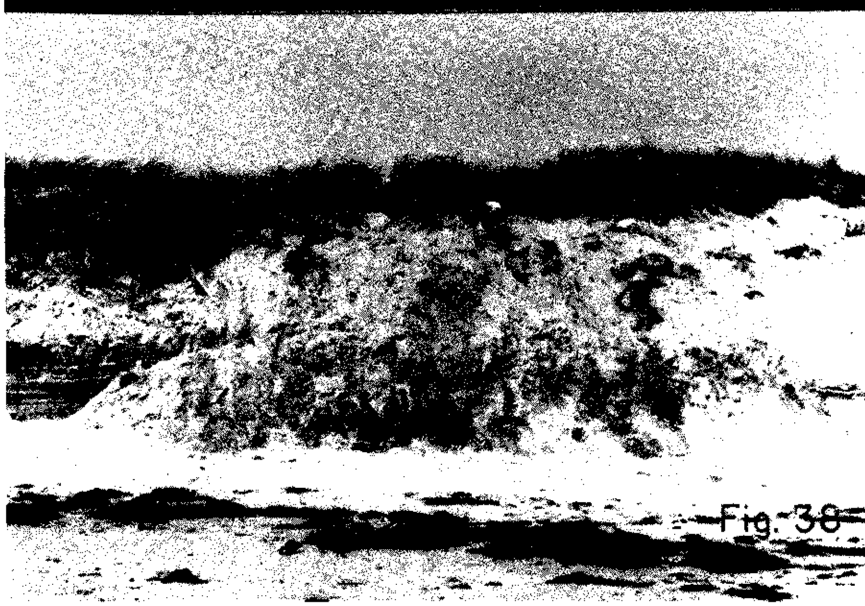


Fig. 38


Fig. 39

which have been investigated in this report as they directly relate to each beach.

Small Point Beach:

The fore dune ridge at Small Point is relatively high (3-5 meters above m.s.l. and approximately 8 meters in one location). Although a few dune sites are quite low and small overwashes have been photographed, the fore dune prevents any large overwashes. However, sand is transported over the fore dune by wind. From October to March, southwest winds move sand parallel to the beach and form an aeolian dune ramp. Once completed, sand moves up the ramp, over the ridge, and into the dormant dunegrass. Aeolian transport over the foredune helps to minimize sand losses from the beach during the winter.

Each winter several powerful storms move north along the coast. If the low pressure passes over the shore line at high tide, a considerable increase in water level occurs. During this study, many storms caused substantial damage to the dune ramp but little to the dune itself. For example, in March 1976, a strong Northeaster smashed into the coast. At Small Point, waves completely removed the dune ramp along much of the beach. Due to the presence of a ten to twelve-foot dune scarp, it appeared that the dune had severely eroded. But upon closer inspection of sand accretion-erosion transects, it was found that none of the dune itself had been removed. Only the beach berm and dune ramp had disappeared.

Between late spring and late fall, the damage incurred during winter begins to be repaired. Gentle waves bring sand up onto the beach berm; winds transport the sand to the base of the dune, thus building the ramp. Plants colonize, grow, and stabilize this sand, and if they develop a

sufficiently thick cover, help to lessen the effect of winter storms.

At Small Point, plant cover on the fore dune was greatest in August 1975. By the end of the following winter, plant parts were spread all over the beach; the aeolian ramp was almost completely destroyed. Partial rebuilding of the foredune ramp occurred throughout the summer and fall of 1976. During the winter of 1976-1977, erosion was not as severe. Presently, the ramp is continuing to rebuild.

From 1862-1965, Small Point's shoreline changed imperceptively. An equilibrium might have momentarily developed whereby erosional losses were equated with aeolian depositions. If this were the case, the foredune ramp would be removed in years when harsh storms occurred and replaced in subsequent years. But short and long-term sea level trends indicate that if any equilibrium exists, it will be transient. Sea level is rising between 0.30 feet per century (peat dating - 3000 years) and 1.0 feet per century (60 years of tide gauge data). If the barrier beaches do not retreat, they will erode. Evidence from Small Point coring profile P10A indicates that there has been between 18-108 meters of dune retreat. Since the fore-and secondary dunes are notably high, overwash has probably not been effective, and any backdune retreat has been caused by the wind.

Aeolian transport over the foredune ridge is also part of the system. If sand is transported to the backside of the primary dune and the same amount is eroded from the front side, the dune will maintain its integrity, but move slightly inland. Therefore, if this process were to continue for many years, it could result in barrier island retreat.

Reid State Park:

The foredune at Reid State Park is quite high, usually between five and eight meters above m.s.l. As might be expected, there were no indications of storm-induced washovers, but erosion has been occurring, particularly on the southern third of Mile Beach. Here, the barrier is only 70-100 meters wide.

If erosion continues, it may become critical. The problem is accentuated as aeolian transport into Mile Beach dunes is minimal, partly a consequence of poor wind exposure to the beach and partly obstruction of wind by Todds Head. Also, coring profile P-2 revealed that there has not been any retreat of Mile Beach dune over the salt marsh. However, old soil horizons have been buried on the profile (probably aeolian movement of sand within the dunes and not from the beach into the dunes). If this narrow barrier continues to erode and if the barrier is not retreating, it may breach and form an inlet. Inlet formation and movement of sand into shoals behind barrier beaches has been documented as a natural mechanism of salt marsh formation and barrier island retreat (Godfrey and Godfrey, 1974). But in a state park in which there has been a considerable investment of money, beach nourishment may be necessary (see management).

Half Mile Beach is somewhat different than Mile Beach. Most of the barrier, except for Todds Point, remained stable during the study. In addition, a better exposure on Half Mile Beach resulted in four times more aeolian transport into the dunes than on Mile Beach. Todds Point has been and will most likely continue to be the most active area of the park. Little River, which flows behind this spit, continually changes its course, erodes the fore shore and back shore, and deposits sand in

bars. This activity will be insignificant to park management as long as permanent structures are not placed on the barrier. As no cores were removed, retreat of the barrier will not be discussed.

Popham Beach State Park:

Processes operating at Popham Beach State Park are different from the other two beaches; both overwash and wind transport move sand into the dunes. The foredune at Popham is much lower than at either Small Point or Reid. Consequently, overwashes were detected on five of six winter beach surveys. Significant overwashes were encountered near Morse River, south of the dune forest, south of the dune privies, and on South Beach. In total, one third to one half of the beach sustained overwash during the study.

Substantial aeolian sand transport also occurred from the Popham dune privies southwest to Morse River. As a consequence of a southeastern exposure, much less aeolian transport was detected on the life guard beach.

During the past few years, there has been severe erosion northeast of the state park; park property, however, has not been affected. Within the park boundaries, seven to ten meters of erosion occurred between life guard beach and the bath houses in addition to nearly fifty-six meters near Morse River. The Morse River dunes have been extremely mobile in the past; four small islands were once located in the river mouth Fig. 30a). A small island may reform in the next few years as an overwash fan has almost cut through the dune to the high marsh. Similar to the active dunes near Sprague and Little Rivers, erosion near Morse River will be inconsequential if left undeveloped.

No cores were removed from Popham; therefore, discussion of long-term retreat would be speculative. However, the shore line has been both accretional and erosional during the last one-hundred years. Shore lines south of the dune forest and along South Beach have fluctuated more than 200 and 100 meters, respectively. Presently, the former is stable while the latter is intensely erosional (specifically, northeast of park property).

Suggestions for Long-Term Management

Introduction

Public accessibility and sound ecological principles have been considered in writing these proposals which, hopefully, will maintain and preserve these parks in the immediate and distant future with the least amount of environmental deterioration. The proposals are a result of information collected by the authors concerning coastal vegetation, coastal processes, and their interactions. Ten management suggestions, developed in conjunction with the natural processes, are herein presented; they deal with fences, picnic areas, planting and fertilizing, boardwalks, fore dunes, park accessibility, beach erosion, beach nourishment, park enlargement, education, and other problems.

Proposals

1) Use of fences to control visitor pressure:

To control visitor impact on the beach system, fences must be employed in three areas: First, along fore dunes; second, along all beach paths leading from parking lots to the ocean; and third, along route 209 near Popham Beach State Park. (Some of these suggestions have been partially implemented during the past two years and should be completed and continued in the future.

Foredune snow fences should be a permanent modification of coastal park management. Fencing should be installed prior to the heavy tourist season (i.e., between April 15 and May 15) and removed subsequent to it

(i.e., October 1-October 15). Elimination of the snow fence during the winter is essential; if it is not exposed to harsh winter conditions (i.e., snow, ice, salt aerosol, dessicating winds, and storm waves), the fence will have a longer life.

Even more important, in an attempt to work with the natural beach processes, fencing should be removed during the winter to allow wind and water transported sand to move into the dunes; highest transport occurs between October and April, coinciding with the dates mentioned above. Aeolian sand transport is an integral part of dune building and retreat, and it is important that these natural processes be allowed to operate, thus ensuring long-term beach stability. In addition, the natural overwash process at Popham, which deposits sand behind the foredune, would destroy any fence not removed before winter. Therefore, sand, which is blown or washed into the fore dunes from the beach, will not be eroded during severe winter storms.

Fence should be installed on the beach approximately five or ten feet from the base of the fore dune. Consequently, foredune plants could colonize the foredune ramp and several feet of beach during the summer; and subsequently, wind transported sand would be caught by their branches and erosion diminished by their roots during the winter. In a more natural condition, such as at Small Point Beach, foredune plants colonize approximately thirty feet of beach, depending on backshore inclination. At the state parks, beach space is of utmost importance for servicing visitors; therefore, placing the fence five or ten feet out from the base of the fore dune is a compromise between visitor needs and park conservation. Regardless, in heavily eroded localities, the fence will have to be placed at the base of the dune scarp to ensure

ample space for beach visitors.

In an attempt to examine the regeneration capacity of the foredune plants, Ben Kreiton, the ranger at Popham Beach State Park, moved a section of fence approximately twenty-five feet out onto the beach on about July 1, 1976. Prior to the move, no plants were present on the beach due to the heavy visitor pressure. Within six weeks, foredune plants had colonized the area, even though it was late in the growing season. Rhizomes and seeds were always present; they only needed a chance to germinate and grow without being down-trodden.

Experiments conducted on visitor impact indicate that the frequency, density, and cover of plants were lower in disturbed dune communities than in undisturbed sites. Substantial impact was detected in the foredune, dunegrass, and beach-heather communities close to beach access paths and life guard areas. Consequently, to rectify this situation, all access paths leading from the parking lots to the beach should be lined with fences and prickly shrubs. The fences will protect the shrubs until they can establish themselves and form a natural barrier; then they can be removed.

Salt-spray rose (Rose rugosa), virginian rose (Rose virginiana), and raspberry (Rubus idaeus) all have spines and inhabit coastal sand dunes; virginian rose and raspberry are found much more frequently than salt-spray rose. However, salt-spray rose has much longer and thicker spines which form a more impenetrable barrier, and it also grows twice as high as the other two shrubs. Consequently, if available, salt-spray rose would be a better natural barrier.

In the summer of 1976, thousands of rose bushes were planted at

both Popham and Reid, but insufficient care and maintenance caused many of them to die; suggestions for increasing their survival are noted below. The shrubs should be planted approximately two and one-half feet apart along the outisde of each fence. Last year, a large number were planted along the inside of the fences and most of these bushes were trampled. By establishing the shrubs outside of the fence, they will not be crushed, and there will be an ample walkway after they grow to full stature. The bushes should not be planted any closer than twenty feet from the fore-dune; a high incidence of salt-spray kills them. (Rose bushes and other shrubs are present along the fore dune on a few erosional sites, but these bushes were established inland before the dune eroded.) Most of the shrubs planted along the ridge of the Mile Beach foredune last year were dead within six weeks. A small amount of peat should be mixed with the sand when the bushes are planted and watered to ensure better moisture retention, and they should be watered every ten days from June 15 to August 15, unless a large rainfall occurs (more than .75 inches). And finally, they should be fertilized for the first five years with a high nitrogen fertilizer.

Popham Beach State Park is easily accessible from route 209; on days when the parking lot is filled to capacity or closed, visitors walk over the dunes to the beach and destroy the vegetation (Fig. 22). A permanent fence lined with prickly shrubs should be placed along route 209, starting about 50 meters east of the park gate and proceeding to the east park boundary. Pedestrian traffic through these dunes has caused almost complete devegetation of herbaceous plants; consequently, moving sand has buried and killed pitch-pine trees and prevented revegetation of the area.

If left unimpacted, these back dunes will probably revegetate in four to seven years, slower than sites along fore dunes (1-3 years). Since the vegetation is completely decimated, it is difficult to determine whether an American beachgrass community will recolonize or whether a beach-heather community, the natural vegetation of the site, will revegetate the site. If these dunes have not sufficiently revegetated in six years, or if park supervisors wish to have the area covered with vegetation more swiftly, the site could be planted with American beachgrass.

2) Picnic areas at Popham:

Picnic areas at Popham Beach State Park are in more unstable areas than at Reid State Park, due to their locations. At Reid, picnic areas were rightly established on rocky headlands and present few problems, while at Popham, no rocky headlands existed. Consequently, the picnic areas were placed on the dunes and required more management.

Presently, the Popham forested picnic area is quite disrupted (Fig. 23); the situation necessitates pedestrian traffic control out of the picnic area and onto the beach by fencing and boardwalks. Two paths, lined with fences, prickly shrubs and boardwalks, should funnel the visitors out of the area. The dune ridge immediately oceanward of the picnic area should be fenced and lined with shrubs at its base in order to discourage visitors from walking directly to the beach. If so manipulated, the shrubs should form natural barriers to control pedestrian traffic, and then the fences could be removed.

Many trees have died in the forested picnic area; others have shown decreases in growth (detected on tree corings). Many of the dead trees have had their roots exposed by visitor induced erosion along the picnic

area foredune; others at the site have had their roots compacted or abrased by trucks and visitors driving or walking on them. To lessen this impact, a thick layer of mulch (1½-2 inches) could be spread through the picnic area and around the trees, and it would have to be maintained each year by replenishing any losses due to compaction. Also, pitch-pine trees could be planted in the forested picnic area to replace dead trees, and around the open dune picnic area to offer shade to park visitors. They should likewise be fertilized for five years and watered for three to better ensure their chances of survival.

3) Fertilization and replanting of disturbed sites:

The solution to disturbed dune sites does not reside in the ability of dune plants to live in this harsh environment; instead, it remains a management problem of keeping park visitors out of these fragile areas, while at the same time, allowing them proper access to the beaches. In time, the disturbed dune areas will revegetate, those along the fore dune more quickly due to the aerosol nutrient supply and those in the back dunes more slowly. However, the process may be accelerated by replanting with American beachgrass and fertilization, or by fertilization alone.

Foredune areas north of the life guard stations at Popham have shown approximately a thirty percent increase in plant cover after only one year of fenced enclosure (estimated by visual detection). It is anticipated that this foredune and other fenced locations should develop a 50-60% plant cover within a few years, while back dune areas may take two to three times as long.

If deemed necessary for aesthetic reasons or if the disturbed backdune sites are not revegetating after five years due to sand movement, they

should be planted with American beachgrass, fertilized, and enclosed with fence. Regardless of what approach is taken, all the disturbed dune sites should be fertilized with hand broadcasters until an ample plant cover has developed; tractor pulled fertilizers should not be used since they cause more damage by crushing plants than they relieve by fertilizing them. High nitrogen fertilizers would be most appropriate for this environment.

A natural fertilizer, high in nitrogen, could also be scattered into the dunes; seaweed is raked weekly during the summer on the life guard protected beaches. This free, highly nutritious fertilizer should be spread into the dunes, unless either of the following situations arises: The smell of the seaweed offends park visitors or it attracts too many green-headed flies, thus precluding comfortable sun-bathing. Consequently, if one of these situations arises, the seaweed should continue to be buried.

4) Use of boardwalks:

Boardwalks are a necessity in dune management; park visitors tend to stay on boardwalks in lieu of bare sand, since they are cooler than sand during the summer and much easier to walk on than sand throughout the year. In a similar manner, wooden walkways form narrower paths to the beach than unmanaged access ways and serve to keep more vegetation intact.

All access ways from parking lots to the ocean which are not presently covered with boardwalks should have them installed; also, truck approaches should have extra wide ones secured. To eliminate gaping holes and maintain foredune integrity, the height of the fore dune under the boardwalk should be similar to nearby foredune heights. In this manner, the fore-

dune would be no more susceptible to winter storm erosion or dune breaching than other areas along the ridge, which it would be if the foredune were lower at these sites. Portions of boardwalk directly over the foredune ridge should be removed during the winter; consequently, any aeolian or overwashed sand which naturally builds the dune can be deposited on the ridge; in addition, the boardwalks will not have to be extricated from the new sand supply each spring.

Elevated walkways over the foredune should also be considered on certain beach accesses. Although they are more expensive, they would allow American beachgrass to colonize underneath them, thus stabilizing the foredune more securely than by boardwalk alone. This investment should only be considered on those accesses which are not erosional and receive insubstantial aeolian or overwashed deposits each year, such as the Griffiths Head entrance at Reid and the two life guard beach entrances at Popham. The rest of the beach accesses at both parks are too unstable, and movable boardwalks would function more efficiently in these active sites.

5) Placement of logs on the foredune ramp:

In both actively eroding areas and more stable areas, logs have been placed against the foredune. In highly deteriorating sites, such as Mile Beach north of Todds Head, the logs have served to diminish the wave energy and lessen the erosion. Logs placed here with the aid of a tracked vehicle did not affect the vegetation since none was present. Logs were also placed along the foredune in more stable areas of both Reid and Popham with the aid of a bulldozer. At these sites, the logs appeared to have caught sand and aided in building up the dune ramp, but the tracked

vehicle destroyed a large portion of the vegetation. Logs placed in vegetated areas should be placed there by hand, while logs placed along erosional dunes should still be positioned with the aid of a bulldozer.

6) Salt marshes:

Management and discussion of salt marshes may be found in the section entitled Salt Marsh Production.

7) Access through the back gate at Popham:

In 1976, a gate was erected on the back entrance (Route 209) to Popham State Park; parking was eliminated, visitor use was restricted, and most likely, more revenue was received at the front gate. Its presence has curtailed most of the abuses in this unmanaged back dune area, such as random paths through the dunes and motorcycle tracks crushing the vegetation. Vehicular access for individuals with fishing permits was continued after the gate was installed, and tracks have been detected in the dunes and in the high marsh since that time. One of the following suggestions should be used to remedy the situation: Complete restriction of vehicular access through the back gate while allowing individuals with fishing permits to park in the small lot provided inside the gate, or issuance of a warning (in writing) to these individuals, stating that they must stay on the vehicle path provided; otherwise, their access into the back dunes will be restricted to the small parking lot.

8) Mile Beach Erosion and Possible Beach Nourishment:

Mile Beach, the barrier beach between Griffiths Head and Todds Head, is long and narrow. As discussed in previous sections on historical analysis of barrier beach movement and dune dynamics, Mile Beach has experienced no dune retreat over the salt marsh along profile P2, and aeolian transport into the dunes from the beach is minimal. In addition, even though the coastal change map for Reid State Park (Fig. 30b) exhibited little erosion between 1862 and 1965 on Mile Beach, severe erosion has occurred on the southern end of this beach during the last two years (Fig. 37). Although the dune scarp was fifteen feet high along portions of the fore dune and looked extremely severe, less than five meters of dune actually eroded (only an estimate due to loss of sand accretion-erosion stakes). Consequently, the severity of the situation resides not in how much has already eroded, but in how much could erode before the problem becomes unsolvable.

The beach is lowest in elevation and narrowest in width along the southern portion; profile P2 (Fig. 10) demonstrates a width of only 100 meters between the beach and the salt marsh. If erosion continues in this location and if the barrier ever breaches, then the following four consequences would arise in this order: a) the sewer system and leach field for Todds Head would become useless and the equipment would be destroyed; b) the continuity of Mile Beach would be disrupted and Todds Head would only be accessible from the Griffiths Head road; c) the *Typha*-*Myrica* brackish marsh would be entirely undermined and a new low salt marsh (*Spartina alterniflora* marsh) would form (neither a positive nor negative consequence); and d) the inlet might connect with the tidal creek behind Mile Beach (Fig. 13), subsequently altering the lagoon water

depth and dam system dynamics behind Griffiths Head via the flood and ebb tides of the new creek. This modification might render the damming system non-functional.

Admittedly, none of these consequences has yet occurred; however, if erosion continues at this rate, the first problem would be realized in the next few years while the remaining three would arise within ten to fifteen years. Since the State Park system has a considerable investment in the lagoon damming system behind Griffiths Head as well as the Todds Head sewer system (which would close down Half Mile Beach and part of Mile Beach), the park management and the Bureau of Conservation may have to consider beach nourishment along the southern 200 meters of Mile Beach. The erosion process should be monitored with permanent stakes every fifteen meters behind the fore dune for another year, and if five or more meters of dune erode, then plans should be proposed to find an external sand source with matching grain size for the southern portion of Mile Beach. The process of overwash has been shown not to be an important factor in dune maintenance or barrier beach retreat at Reid; consequently, beach nourishment to maintain foredune integrity and protect previous capital investment should not interfere with natural beach processes at this location. In the interim, the small wooden walkway and benches north of Todds Head should be removed, and all of Mile Beach's dunes should be closed off to visitors.

9) Considerations Concerning Future Park Enlargement at Popham:

Several factors should be considered regarding decisions on the future of Popham Beach State Park:

a) The Popham maritime forest should be conserved for its uniqueness and beauty; in comparison to the other beaches studied, the Popham dune forest has succeeded to and attained the most mature vegetation. The maritime forest at Small Point is small and immature in contrast to Popham, and Reid State Park has no dune forest at all. The forest at Popham has succeeded to a level beyond the pitch-pine state where red oak, red maple, white birch, aspen, white spruce, red spruce, and fir, along with pitch-pine form a complex and mature forest. The level of maturity attained by this maritime forest is probably unsurpassed in the State of Maine and quite comparable to other mature maritime forests further south on the East Coast. Consequently, for its uniqueness alone, it should be preserved.

b) Unless a considerable capital investment is made for initial and continued management, a heavily used dune forest might resemble the present forested picnic area (Fig. 23). The problems of establishing and maintaining accessways from parking lots to the beach and preventing the complete destruction of the forest undergrowth and sensitive, immature dune forest soils (which both help promote the very existence of the forest itself) must be considered.

Prior to the establishment of Popham Beach State Park, beach visitors freely used the dune forest for beach access and beach activities; the disturbance to the forest undergrowth and soils can be seen on old aerial photographs as holes opened up in the dune forest canopy in combination with bare, exposed sand. More recent photographs indicate that these areas have begun to revegetate under present park management, even though scars of previous deterioration can still be seen by walking through the

dune forest. If not managed with shrub-lined walkways, boardwalks and mulch to protect the undergrowth and soils, this sensitive vegetation type could quickly deteriorate.

c) The beach south of the dune forest is presently undergoing dune building and the shoreline appears to be stable; in the past, however, this beach has had the most active shoreline of any in the study sites (Fig. 30a). In addition, evidence of past erosion up to the dune forest, most likely by the river channel, is present as an old dune scarp just south of the pitch-pine trees. The area between the beach and the dune forest has not yet had time to succeed to beach-heather or shrub community, thus indicating that the last erosional thrust was of a recent nature. And finally, the Morse River dune area has been extremely erosional during the last two years, with losses of 56.5 meters (187 feet) recorded on one profile. If erosion continues at that end of the beach system, the river channel may begin to carve into the presently stable beach and eliminate a considerable portion of beach space. Therefore, development of a beach facility here should be proposed and constructed with great care, maybe with only temporary facilities, due to possible unforeseen erosion in the future.

d) The dune forest at Popham might be considered as a possible site for a conservation walkway, similar to the walkway through the white cedar swamp within the National Seashore on Cape Cod. In this manner the forest could be simultaneously protected and utilized. Educational signs, demonstration models, and instructive dioramas could be erected along the walkway to inform the public about dune flora and its maintenance and stabilization of coastal dunes; shore birds, dune animals, and some of their ecology and plant interactions; and finally, explanations of some of the

geologic processes which operate on the coast and preserve these barrier beaches.

These abovementioned considerations and consequences should all be examined before the future of Popham Beach State Park is determined. If this unique vegetation type is destroyed, it will take a considerable amount of time before another maritime forest of its stature could develop.

10) Public education concerning preservation of these sensitive dune systems:

The public has to be informed about the need to preserve these fragile beach systems; only with their help and intensive park management can these barrier beaches be utilized by the public to the fullest extent permitted by natural vegetation and beach processes, and still be functioning fifty years from now.

Therefore, a short, descriptive leaflet at park gates or perhaps erection of more signs along beach access paths (a few were erected last year) would be both instructive and educational. Interesting facts in conjunction with explanations of natural dune and beach processes might best enlighten them to the problems encountered in coastal state parks, such as:

a) Sea level has been rising between .25 - 1.00 feet/century for 7000 years along the coast of Maine.

b) Sand is transported by wind, storm waves and coastal currents in a very complicated and often unpredictable manner. Approximately 350 feet of erosion has occurred north of Popham Beach State Park since 1975; a portion of it has been aggravated by man-made structures.

c) Although the dune vegetation is extremely sensitive to human impact, it has evolved the capacity to live in a harsh environment constantly assaulted by salt spray, high winds, nutrient inavailability, summer drought, and fresh sand deposits. Only in the absence of man's crushing feet and vehicles can plants be expected to live and stabilize sand in such an austere environment.

Finally, a plea to park visitors might be appropriate: In the interest of continued conservation and preservation, please enjoy the beach and facilities provided, but respect signs, remain on established walkways, and stay out of the vegetation which tenaciously attempts to stabilize this dynamic environment.

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APPENDIX A

The family names in this species list are ordered according to the Englerian Sequence; the genera and the species are alphabetized within each higher taxonomic group. The name of the authority, who first described or last changed the position of the plant, is given after the specific name according to the abbreviations of *Gray's Manual of Botany*, (Fernald, 1950).

BRYOPHYTA

Polytrichaceae	*Polytrichum commune* L.
Dicraranaceae	*Dicranum scoparium* L.

FUNGI

Lycoperdaceae	*Geaster hygrometricus* Pers.
Cladoniaceae	*Cladonia cristatella* Tuck.
	Cladonia mitis Sandst.
	Cladonia rangiferina (L.) Wigg.
	Cladonia uncialis (L.) Wigg.
Usneaceae	*Usnea trichodea* Ach.
Parmeliaceae	*Cetraria islandica* (L.) Ach.
	Hypogymnia physodes (L.) Nyl.

PTERIDOPHYTA

Equisetaceae	Equisetum arvense L.
Lycopodiaceae	Lycopodium obscurum L.
Osmundaceae	Osmunda cinnamonea L.
	Osmunda regalis L.
Polypodiaceae	Anthyrium Filix-Femina (L.) Roth.
	Dryopteris Thelypteris (L.) Gray
	Onoclea sensibilis L.

Spermatophyta

Gymnospermae:	
Pinaceae	Abies balsamea (L.) Mill.
	Juniperus communis var. depressa Pursh.
	Picea glaca (Moench) Voss
	Pinus rigida Mill.
	Pinus strobus L.
Angiospermae:	
Montocotyledoneae:	
Typhaceae	Typha angustifolia L.
Juncaginaceae	Triglochin maritima L.
Gramineae	Agropyron repens (L.) Beauv.
	Agrostis alba L.
	Agrostis alba var. palustris (Huds.) Pers.
	Agrostis tenuis Sibth.
	Ammophila breviligulata L.
	Bromus tectorum L.
	Calamagrostis canadensis (Michx.) Nutt.

	Deschampsia flexuosa (L.) Trin.
	Distichlis spicata (L.) Greene
	Elymus arenarius L.
	Elymus virginicus L.
	Festuca rubra L.
	Hordium jubatum L.
	Phleum pratense L.
	Poa pratensis L.
	Puccinellia maritima (Huds.) Parl.
	Spartina alterniflora Loise.
	Spartina patens (Ait.) Muhl.
	Spartina pectinata Link
Cyperaceae	Carex scoparia Schkuhr
	Carex silicea Olney
	Cyperus filiculmis Vahl.
	Eleocharis obtusa (Willd.) Schultes
	Scirpus americanus Pers.
	Scirpus cyperinus (L.) Kunth
	Scirpus maritimus L.
	Scirpus maritimus var. Fernaldi Bickn.
Juncaceae	Juncus balticus Willd.
	Juncus effusus L.
	Juncus filiformis L.
	Juncus Gerardi Loisel.
	Juncus Greenei Oakes & Tuckerm.
Liliaceae	Lilium philadelphicum L.
	Maianthemum canadense Desf.
	Medeola virginiana L.
	Smilacina stellata (L.) Desf.

Iridaceae	Iris versicolor L.
Orchidaceae	Cypripedium acaule Ait.
Dicotyledoneae:	
Salicaceae	Populus tremuloides Michx.
	Salix Bebbianna Sarg.
	Salix discolor Muhl.
Myricaceae	Comptonia peregrina (L.) Coult.
	Myrica Gale L.
	Myrica pensylvanica Loisel.
Corylaceae	Alnus rugosa (Du Roi) Spreng.
	Betula popyrifera X populifolia Marsh.
	Betula populifolia Marsh.
Fagaceae	Quercus rubra L.
Polygonaceae	Polygonella articulata (L.) Meisn.
	Rumex Acetosella L.
	Rumex crispus L.
Chenopodiaceae	Atriplex patula var. hastata (L.) Gray
	Chenopodium album L.
	Salicornia europaea L.
	Salsola Kali L.
	Suaeda linearis (Ell.) Moq.
	Suaeda maritima (L.) Dumort.
Caryophyllaceae	Arenaria lateriflora L.
	Arenaria peploides L.
	Arenaria peploides var. robusta Fern.
	Cerastium arvense L.
	Spergularia marina (L.) Griseb.
Ranunculaceae	Thalictrum polygamum Muhl.

Berberidaceae	*Berberis* *Thunbergii*
Cruciferae	*Cakile* *edentula* (Bigel.) Hook.
Saxifragaceae	*Ribes* *glandulosum* Grauer
	Ribes *hirtellum* Michx.
Rosaceae	*Amelanchier* *laevis* Wieg.
	Amelanchier *stolonifera* Wieg.
	Amelanchier *Wiegandii* Nielson
	Crataegus sp. L.
	Potentilla *anserina* L.
	Potentilla *simplex* Michx.
	Prunus *pensylvanica* L.f.
	Prunus *serotina* Ehrh.
	Pyrus *arbutifolia* (L.) L.f.
	Pyrus *floribunda* Lindl.
	Pyrus *melanocarpa* (Michx.) Willd.
	Rosa *rugosa* Thumb.
	Rosa *virginiana* Mill.
	Rubus *allegheniensis* Porter
	Rubus *hispidus* L.
	Rubus *idaeus* var. *strigosus* (Michx.) Maxim.
	Spirea *latifolia* (Ait.) Borkh.
Leguminosae	*Lathyrus* *japonicus* Willd.
	Trifolium *repen* L.
	Vicia *Cracca* L.
Empetraceae	*Carema* *Conradii* Torr.
Anacardiaceae	*Rhus* *radicans* L.
	Rhus *typhina* L.
Aquifoliaceae	*Ilex* *verticillata* (L.) Gray
Celastraceae	*Nemopanthus* *mucronata* (L.) Trel.

Aceraceae	Acer pensylvanicum L.
	Acer rubrum L.
Guttiferae	Hypericum perforatum L.
Cistaceae	Hudsonia ericoides L.
	Hudsonia tomentosa Nutt.
	Lechea intermedia Leggett.
Lythraceae	Lythrum Salicaria L.
Onagraceae	Epilobium angustifolium L.
	Oenothera biennis L.
	Oenothera parviflora L.
Araliaceae	Aralia nudicaulis L.
Umbelliferae	Angelica atropurpurea L.
Cornaceae	Cornus canadensis L.
Ericaceae	Arctostaphylos Uva-ursi (L.) Spreng.
	Gaylussacia baccata (Wang.) K.Koch
	Kalmia angustifolia L.
	Lyonia ligustrina (L.) DC.
	Rhododendron canadense (L.) Torr.
	Vaccinium angustifolium Ait.
	Vaccinium atrococcum (Gray) Heller
	Vaccinium macrocarpon Ait.
Primulaceae	Glaux maritima L.
	Lysimachia quadrifolia L.
	Trientalis borealis Raf.
Plumbaginaceae	Limmonium Nashii Small
Oleaceae	Fraxinus pennsylvanica var. subintegerrima (Vahl.) Fern.
Apocynaceae	Apocynum androsaemifolium L.
Asclepiadaceae	Asclepias syriaca L.

Convolvulaceae	*Convolvulus sepium* L.
Labiatae	*Teucrium canadense* L.
Solanaceae	*Solanum Dulcamara* L.
Scrophulariaceae	*Melampyrum lineare* Desr.
Plantaginaceae	*Plantago juncoides* Lam.
	Plantago oliganthos R. & S.
Rubiaceae	*Galium trifidum* L.
Caprifoliaceae	*Diervilla Lonicera* Mill.
	Lonicera Morrowi Gray
	Sambucus canadensis L.
	Viburnum cassinoides L.
	Viburnum recognitum Fern.
Compositae	*Achillea lanulosa* Nutt.
	Artemisia Stelleriana Bess.
	Aster acuminatus Michx.
	Aster johannensis Fern.
	Aster linariifolius L.
	Aster novi-belgii L.
	Erigeron annuus (L.) Pers.
	Hieracium aurantiacum L.
	Hieracium pratense Tausch
	Lactuca biennis (Moench) Fern.
	Prenanthes sp. L.
	Solidago canadensis L.
	Solidago rugosa Ait.
	Solidago sempervirens L.
	Sonchus arvensis L.
	Xanthium echinatum Murr.

APPENDIX B

This species list is alphabetized by the genus and then the species within the genus; family names and common names also accompany the species names to facilitate cross reference to other lists.

Genus Species	Family	Common Name
Abies balsamea	Pinaceae	Balsam-Fir
Acer pensylvanicum	Aceraceae	Striped Maple
Acer rubrum	Aceraceae	Red Maple
Achillea lanulosa	Compositae	Woolly Yarrow
Agropyron repens	Gramineae	Quackgrass
Agrostis alba	Gramineae	Redtop
Agrostis alba var. palustris	Gramineae	Creeping Redtop
Agrostis tenuis	Gramineae	Rhode Island Bent
Alnus rugosa	Corylaceae	Speckled Alnus
Amelanchier laevis	Rosaceae	Serviceberry
Amelanchier stolonifera	Rosaceae	Serviceberry
Amelanchier Wiegandii	Rosaceae	Serviceberry
Ammophila breviligulata	Gramineae	American Beachgrass
Angelica atropurpurea	Umbelliferae	Purple-Stemmed Angelica
Apocynum androsaemifolium	Apocynaceae	Spreading Dogbane
Aralia nudicaulis	Araliaceae	Wild Sarsaparilla
Arctostaphylos Uva-ursi	Ericaceae	Common Bearberry
Arenaria lateriflora	Caryophyllaceae	Grove-Sandwort
Arenaria peploides	Caryophyllaceae	Seabeach-Sandwort
Arenaria peploides var. robusta	Caryophyllaceae	Seabeach-Sandwort
Artemisia Stelleriana	Compositae	Dusty Miller
Asclepias syriaca	Asclepiadaceae	Common Milkweed

Aster acuminatus	Compositae	Aster
Aster johannensis	Compositae	Aster
Aster linariifolius	Compositae	Aster
Aster novi-belgii	Compositae	Aster
Athyrium Filix-femina	Polypodiaceae	Lady-Fern
Atriplex patula var. hastata	Chenopodiaceae	Orach
Berberis Thunbergii	Berberidaceae	Japanese Bayberry
Betula papyrifera X populifolia	Corylaceae	White Birch
Betula populifolia	Corylaceae	Gray Birch
Bromus tectorum	Gramineae	Brome-Grass
Cakile edentula	Cruciferae	Sea-Rocket
Calamagrostis canadensis	Gramineae	Blue-joint
Carex scoparia	Cyperaceae	Sedge
Carex silicea	Cyperaceae	Sand Sedge
Cerastium arvense	Caryophyllaceae	Field-Chickweed
Cetratia islandica	Parmeliaceae	Iceland Moss
Chenopodium album	Chenopodiaceae	Lamb's Quarters
Cladonia cristatella	Cladoniaceae	British Soldiers
Cladonia gracilis	Cladoniaceae	Cladonia
Cladonia mitis	Cladoniaceae	Cladonia
Cladonia rangiferina	Cladoniaceae	Reindeer Moss
Cladonia uncialis	Cladoniaceae	Cladonia
Comptonia peregrina	Myricaceae	Sweet-Fern
Convolvulus sepium	Convolvulaceae	Hedge-Bindweed
Corema Conradii	Empetraceae	Poverty-Grass
Cornus canadensis	Cornaceae	Bunchberry
Crataegus sp.	Rosaceae	Hawthorn

Cyperus filiculmis	Cyperaceae	Sedge
Cypridedium acaule	Orchidaceae	Pink Lady's Slipper
Deschampsia flexuosa	Gramineae	Common Hairgrass
Diervilla Lonicera	Caprifoliaceae	Bush-Honeysuckle
Distichlis spicata	Gramineae	Spike-Grass
Dryopteris Thelypteris	Polypodiaceae	Marsh Fern
Eleocharis obtusa	Cyperaceae	Spike-Rush
Elymus arenarius	Gramineae	Sea-Lyme-Grass
Elymus virginicus	Gramineae	Terrell Grass
Epilobium angustifolium	Onagraceae	Fireweed
Equisetum arvense	Equisetaceae	Common Horsetail
Erigeron annuus	Compositae	Daisy-Fleabane
Festuca rubra	Gramineae	Red Fescue-Grass
Fraxinus pennsylvanica var. subintegerrima	Oleaceae	Green Ash
Galium trifidum	Rubiaceae	Three-Cleft Bedstraw
Gaylussacia bacata	Ericaceae	Black Huckleberry
Geaster hygrometricus	Lycoperdaceae	Earth-Star
Glaux maritima	Primulaceae	Sea-Milkwort
Hieracium aurantiacum	Compositae	Orange Hawkweed
Hieracium pratense	Compositae	King Devil
Hordeum jubatum	Gramineae	Squirrell-Tail Grass
Hudsonia ericoides	Cistaceae	Golden-Heather
Hudsonia tomentosa	Cistaceae	Beach-Heather
Hypericum perforatum	Guttiferae	Common St. John's-Wort
Hypogymnia physodes	Parmeliaceae	--------
Ilex verticillata	Aquifoliaceae	Winterberry
Iris versicolor	Iridaceae	Blue Flag
Juncus balticus	Juncaceae	Rush
Juncus effusus	Juncaceae	Soft Rush

Juncus filiformis	Juncaceae	Thread-Rush
Juncus Gerardi	Juncaceae	Black Grass
Juncus Greenei	Juncaceae	Rush
Juniperus communis var. depressa	Pinaceae	Ground-Juniper
Kalmia angustifolia	Ericaceae	Sheep-Laurel
Lactuca biennis	Compositae	Lettuce
Lathyrus japonicus	Leguminosae	Beach-Pea
Lechea intermedia	Cistaceae	Pinweed
Lilium philadelphicum	Liliaceae	Wood-Lily
Limmonium Nashii	Plumbaginaceae	Sea-Lavender
Lonicera Morrowi	Caprifoliaceae	Honeysuckle
Lycopodium obscurum	Lycopodiaceae	Flat-Branch Gound Pine
Lyonia ligustrina	Ericaceae	Maleberry
Lysimachia quadrifolia	Primulaceae	Whorled-Loosestrife
Lythrum Salicaria	Lythraceae	Spiked-Loosestrife
Maianthemem canadense	Liliaceae	False Lily of-the-Valley
Medeola virginiana	Liliaceae	Indian Cucumber-Root
Melampyrum lineare	Scrophulariaceae	Cow-wheat
Myrica Gale	Myricaceae	Sweet Gale
Myrica pensylvanica	Myricaceae	Bayberry
Nemopanthus mucronata	Celastraceae	Mountain-Holly
Oenothera biennis	Onagraceae	Evening-Primrose
Oenothera paryiflora	Onagraceae	Evening-Primrose
Onoclea sensibilis	Polypodiaceae	Sensitive Fern
Osmunda cinnamonea	Osmundaceae	Cinnamon-Fern
Osmunda regalis	Osmundaceae	Royal Fern
Phleum pratense	Gramineae	Timothy
Picea glauca	Pinaceae	White Spruce
Pinus rigida	Pinaceae	Pitch-Pine

Pinus strobus	Pinaceae	White Pine
Plantago juncoides	Plantaginaceae	Seaside-Plantain
Plantago oliganthos	Plantaginaceae	Seaside-Plantain
Populus tremuloides	Salicaceae	Quaking Aspen
Poa pratensis	Gramineae	Kentucky Bluegrass
Polygonella articulata	Polygonaceae	Jointweed
Potentilla anserina	Rosaceae	Silverweed
Potentilla simplex	Rosaceae	Old-Field Cinquefoil
Prenanthes sp.	Compositae	Rattlesnake-Root
Prunus pensylvanica	Rosaceae	Pin Cherry
Prunus serotina	Rosaceae	Black Cherry
Puccinellia maritima	Gramineae	Alkali-Grass
Pyrus arbutifolia	Rosaceae	Red Chokeberry
Pyrus floribunda	Rosaceae	Purple Chokeberry
Pyrus melanocarpa	Rosaceae	Black Chokeberry
Quercus rubra	Fagaceae	Red Oak
Rhododendron canadense	Ericaceae	Canadian Rhodora
Rhus radicans	Anacardiaceae	Poison Ivy
Rhus typhina	Anacardiaceae	Staghorn-Sumac
Ribes glandulosum	Saxifragaceae	Skunk-Current
Ribes hirtellum	Saxifragaceae	Gooseberry
Rosa rugosa	Rosaceae	Salt-Spray Rose
Rosa virginiana	Rosaceae	Virginian Rose
Rubus allegheniensis	Rosaceae	Sow-Teat Bramble
Rubus hispidus	Rosaceae	Trailing Blackberry
Rubus idaeus var. strigosus	Rosaceae	Raspberry
Rumex Acetosella	Polygonaceae	Sheep-Sorrel
Rumex crispus	Polygonaceae	Yellow Dock

Salicornia europaea	Chenopodiaceae	Samphire
Salix Bebbianna	Salicaceae	Long-Beaked Willow
Salix discolor	Salicaceae	Large Pussy-Willow
Salsola Kali	Chenopodiaceae	Saltwort
Sambucus Canadensis	Caprifoliaceae	Common Elderberry
Scirpus americanus	Cyperaceae	Three-Square
Scirpus cyperinus	Cyperaceae	Wool Grass
Scirpus maritimus	Cyperaceae	Salt-Marsh Bulrush
Scirpus maritimus var. Fernaldi	Cyperaceae	Salt-Marsh Bulrush
Smilacina stellata	Liliaceae	Starry False Solomn's-Seal
Solanum Dulcamara	Solanaceae	Nightshade
Solidago canadensis	Compositae	Canadian Goldenrod
Solidago rugosa	Compositae	Goldenrod
Solidago sempervirens	Compositae	Seaside Goldenrod
Sonchus arvensis	Compositae	Field-Sow-Thistle
Spartina alterniflora	Gramineae	Salt-Water Cord-Grass
Spartina patens	Gramineae	Salt-Meadow Grass
Spartina pectinata	Gramineae	Fresh-Water Cord-Grass
Spergularia marina	Caryophyllaceae	Sand-Spurrey
Spirea latifolia	Rosaceae	Meadow Sweet
Suaeda linearis	Chenopodiaceae	Sea-Blite
Suaeda maritima	Chenopodiaceae	Sea-Blite
Teucrium canadense	Labiatae	American Germander
Thalictrum polygamum	Ranumculaceae	Tall Meadow-Rue
Trientalis borealis	Primulaceae	Star-Flower
Triglochin maritima	Juncaginaceae	Arrow-Grass
Trifolium repen	Leguminosae	White Clover
Typha angustifolia	Typhaceae	Narrow-Leaved Cat-Tail

Usnea trichodea	Usneaceae	Old Man's Beard
Vaccinium angustifolium	Ericaceae	Low Sweet Blueberry
Vaccinium atrococcum	Ericaceae	Black Highbush-Blueberry
Vaccinium macrocarpon	Ericaceae	Large Cranberry
Viburnum cassinoides	Caprifoliaceae	Northern Wild-Raisin
Viburnum recognitum	Caprifoliaceae	Arrow-Wood
Vicia Cracca	Leguminosae	Canadian Pea
Xanthium echinatum	Compositae	Sea-Burdock

APPENDIX C

This species list is alphabetized by the common name of the plant. Not all plants have common names, and many times several different plants within the same genus or even in different genera will have the same name. The generic and specific name, along with the family name, accompany each common name and facilitate cross reference to other lists.

Common Name	Family	Genus species
Alkali-Grass	Gramineae	*Puccinellia maritima*
American Beachgrass	Gramineae	*Ammophila breviligulata*
American Germander	Labiatae	*Teucrium canadense*
Arrow-Grass	Juncaginaaceae	*Triglochin maritima*
Arrow-wood	Caprifoliaceae	*Viburnum recognitum*
Aster	Compositae	*Aster acuminatus*
Aster	Compositae	*Aster johannensis*
Aster	Compositae	*Aster linariifolius*
Aster	Compositae	*Aster novi-belgii*
Balsam-Fir	Pinaceae	*Abies balsamea*
Bayberry	Myricaceae	*Myrica pensylvanica*
Beach-Heath	Cistaceae	*Hudsonia tomentosa*
Beach-Pea	Leguminosae	*Lathyrus japonicus*
Black Cherry	Rosaceae	*Prunus serotina*
Black Highbush-Blueberry	Rosaceae	*Pyrus melanocarpa*
Black Huckleberry	Ericaceae	*Vaccinium atrococcum*
Blue Flag	Ericaceae	*Gaylussacia baccata*
	Iridaceae	*Iris versicolor*

Blue-Joint	Graminae	_Calamagrostis_ _canadensis_
British Soldiers	Cladoniaceae	_Cladonia_ _cristatella_
Brome-Grass	Graminae	_Bromus_ _tectorum_
Bunchberry	Cornaceae	_Cornus_ _canadensis_
Bush-Honeysuckle	Caprifoliaceae	_Diervilla_ _Lonicera_
Canadian Goldenrod	Compositae	_Solidago_ _canadensis_
Canadian Pea	Leguminosae	_Vicia_ _Cracca_
Canadian Rhodora	Ericaceae	_Rhododendron_ _canadense_
Cinnamon-Fern	Osmundaceae	_Osmunda_ _cinnamomea_
Cladonia	Cladoniaceae	_Cladonia_ _gracilis_
Cladonia	Cladoniaceae	_Cladonia_ _mitis_
Cladonia	Cladoniaceae	_Cladonia_ _uncialis_
Common Bearberry	Ericaceae	_Arctostophylos_ _Uva-ursi_
Common Elderberry	Caprifoliaceae	_Sambucus_ _canadensis_
Common Hair-Cap Moss	Polytrichaceae	_Polytrichum_ _commune_
Common Hairgrass	Gramineae	_Deschampsia_ _flexuosa_
Common Horsetail	Equisetaceae	_Equisetum_ _arvense_
Common Milkweed	Asclepiadaceae	_Asclepias_ _syriaca_
Common Saltwort	Chenopodiaceae	_Salsola_ _Kali_
Common St. John's Wort	Guttiferae	_Hypericum_ _perforatum_
Cow-Wheat	Scrophulariaceae	_Melampyrum_ _lineare_
Creeping Redtop	Gramineae	_Agrostic_ _alba_ var. _palustris_
Daisy-Fleabane	Compositae	_Erigeron_ _annuus_
Dusty Miller	Compositae	_Artemisia_ _Stelleriana_
Earth-Star	Lycoperdaceae	_Geaster_ _hygrometricus_
Evening Primrose	Onagraceae	_Oenothera_ _biennis_
Evening Primrose	Onagraceae	_Oenothera_ _parviflora_
False Lily-of-the-Valley	Liliaceae	_Maianthemum_ _canadense_
Field-Chickweed	Caryophyllaceae	_Cerastium_ _arvense_

Field-Sow-Thistle	Compositae	Sonchus arvensis
Fireweed	Onagraceae	Epilobium angustifolium
Flat-Branch Ground Pine	Lycopodiaceae	Lycopodium obscurum
Fresh-Water Cord-Grass	Gramineae	Spartina pectinata
Golden-Heather	Cistaceae	Hudsonia ericoides
Goldenrod	Compositae	Solidago rugosa
Gooseberry	Saxifragaceae	Ribes hirtellum
Gray Birch	Corylaceae	Betula populifolia
Green Ash	Oleaceae	Fraxinus pennsylvanica var. subintegerrima
Ground-Juniper	Pinaceae	Juniperus communis var. depressa
Grove-Sandwort	Caryophyllaceae	Arenaria lateriflora
Hawthorn	Rosaceae	Crataegus sp.
Hedge-Bindweed	Convolvulaceae	Convolvulus sepium
Honeysuckle	Caprifoliaceae	Lonicera Morrowi
Iceland Moss	Parmeliaceae	Cetraria islandica
Indian Cucumber-Root	Liliaceae	Medeola virginiana
Japanese Bayberry	Berberidaceae	Berberis Thunbergii
Jointweed	Polygonaceae	Polygonella articulata
Kentucky Bluegrass	Gramineae	Poa pratensis
King Devel	Compositae	Hieracium pratense
Lady-Fern	Polypodiaceae	Athyrium Filix-Femina
Lamb's Quarters	Chenopodiaceae	Chenopodium album
Large Cranberry	Ericaceae	Vaccinium macrocarpon
Large Pussy-Willow	Salicaceae	Salix discolor
Lettuce	Compositae	Lactuca biennis
Long-Beaked Willow	Salicaceae	Salix Bebbianna
Low Sweet Blueberry	Ericaceae	Vaccinium angustifolium

Maleberry	Ericaceae	*Lyonia ligustrina*
Marsh Fern	Polypodiaceae	*Dryopteris Thelypteris*
Meadow Sweet	Rosaceae	*Spirea latifolia*
Mountain-Holly	Celastraceae	*Nemopanthus mucronata*
Narrow-Leaved Cat-tail	Typhaceae	*Typha angustifolia*
Nightshade	Solanaceae	*Solanum Dulcamara*
Northern Bush-Honey-suckle	Caprifoliaceae	*Diervilla Lonicera*
Northern Wild-Raisin	Caprifoliaceae	*Viburnum cassinoides*
Old-Field Cinquefoil	Rosaceae	*Potentilla simplex*
Old Man's Beard	Usneaceae	*Usnea trichodea*
Orach	Chenopodiaceae	*Atriplex patula* var. *hastata*
Orange Hawkweed	Compositae	*Hieracium aurantiacum*
Pin Cherry	Rosaceae	*Prunus pensylvanica*
Pink Lady's Slipper	Orchidaceae	*Cypripedium acaule*
Pinweed	Cistaceae	*Lechea intermedia*
Pitch-Pine	Pinaceae	*Pinus rigida*
Poison Ivy	Anacardiaceae	*Rhus radicans*
Poverty-Grass	Empetraceae	*Corema Conradii*
Purple Chokeberry	Rosaceae	*Pyrus floribunda*
Purple-Stemmed Angelica	Umbelliferae	*Angelica atropurpurea*
Quackgrass	Gramineae	*Agropyron repens*
Quaking Aspen	Salicaceae	*Populus tremuloides*
Raspberry	Rosaceae	*Rubus idaeus* var. *strigosus*
Rattlesnake-Root	Compositae	*Prenanthes* sp.
Red Chokeberry	Rosaceae	*Pyrus arbutifolia*
Red Fescue	Gramineae	*Festuca rubra*
Red Maple	Aceraceae	*Acer rubrum*
Red Oak	Fagaceae	*Quercus rubra*

Redtop	Gramineae	Agrostis alba
Reindeer Moss	Cladoniaceae	Cladonia rangiferina
Rhode Island Bent	Gramineae	Agrostis tenuis
Rhodora	Ericaceae	Rhododendron canadense
Royal Fern	Osmundaceae	Osmunda regalis
Rush	Juncaceae	Juncus balticus
Rush	Juncaceae	Juncus Greenei
Salt-Marsh Bulrush	Cyperaceae	Scirpus maritimus
Salt-Meadow Grass	Gramineae	Spartina patens
Salt-Spray Rose	Rosaceae	Rosa rugosa
Salt-Water Cord-Grass	Gramineae	Spartina alterniflora
Saltwort	Chenopodiaceae	Salsola Kali
Samphire	Chenopodiaceae	Salicornia europaea
Sand Sedge	Cyperaceae	Carex silicea
Sand-Spurrey	Caryophyllaceae	Spergularia marina
Seabeach-Sandwort	Caryophyllaceae	Arenaria peploides
Sea-Blite	Chenopodiaceae	Suaeda linearis
Sea-Blite	Chenopodiaceae	Suaeda maritima
Sea-Burdock	Compositae	Xanthium echinatum
Sea-Lavender	Plumbaginaceae	Limonium Nashii
Sea-Lyme Grass	Gramineae	Elymus arenarius
Sea-Milkwort	Primulaceae	Glaux maritima
Sea-Rocket	Cruciferae	Cakile edentula
Seaside Goldenrod	Compositae	Solidago sempervirens
Seaside Plantain	Plantaginaceae	Plantago juncoides
Seaside Plantain	Plantaginaceae	Plantago oliganthos
Sedge	Cyperaceae	Carex scoparia
Sensitive Fern	Polypodiaceae	Onoclea sensibilis
Serviceberry	Rosaceae	Amelanchier laevis

Serviceberry	Rosaceae	Amelanchier stolonifera
Serviceberry	Rosaceae	Amelanchier Wiegandii
Sheep-Laurel	Ericaceae	Kalmia angustifolia
Sheep-Sorrel	Polygonaceae	Rumex Acetosella
Silverweed	Rosaceae	Potentilla anserina
Skunk-Current	Saxifragaceae	Ribes glandulosum
Soft Rush	Juncaceae	Juncus effusus
Sow-Teat Bramble	Rosaceae	Rubus allegheniensis
Speckled Alnus	Corylaceae	Alnus rugosa
Spike-Grass	Gramineae	Distichlis spicata
Spike-Rush	Cyperaceae	Eleocharis obtusa
Spiked Loosestrife	Lythraceae	Lythrum Salicaria
Spreading Dogbane	Apocynaceae	Apocynum androsaemifolium
Squirrel-Tail Grass	Gramineae	Hordeum jubatum
Staghorn-Sumac	Anacardiaceae	Rhus typhina
Star-Flower	Primulaceae	Trientalis borealis
Starry False Solomon's Seal	Liliaceae	Smilacina stelata
Stiff-Leaf Aster	Compositae	Aster linariifolius
Striped Maple	Aceraceae	Acer pensylvanicum
Sweet-Fern	Myricaceae	Comptonia peregrina
Sweet Gale	Myricaceae	Myrica Gale
Tall Meadow-Rue	Ranunculaceae	Thalictrum polygamum
Terrell Grass	Gramineae	Elymus virginicus
Three-Cleft Bedstraw	Rubiaceae	Galium trifidum
Three-Square	Cyperaceae	Scirpus americanus
Timothy	Gramineae	Phleum pratense
Trailing Blackberry	Rosaceae	Rubus hispidus
Thread-Rush	Juncaceae	Juncus filiformis

Umbrella-Sedge	Cyperaceae	Cyperus filiculmis
Virginian Rose	Rosaceae	Rosa virginiana
White Birch	Corylaceae	Betula papyrifera
White Clover	Leguminosae	Trifolium repen
White Pine	Pinaceae	Pinus strobus
White Spruce	Pinaceae	Picea glauca
Shorled-Loosestrife	Primulaceae	Lysimachia quadrifolia
Wild Sarsaparilla	Araliaceae	Aralia nudicaulis
Winterberry	Aquifoliaceae	Ilex verticillata
Wood-Lily	Liliaceae	Lilium philadelphicum
Wool Grass	Cyperaceae	Scirpus cyperinus
Woolly Yarrow	Compositae	Achillea lanulosa
Wrinkled Goldenrod	Compositae	Solidago rugosa
Yellow Dock	Polygonaceae	Rumex crispus

Appendix D

The results of the sand movement analysis are tabulated in this appendix. The results are separated by beach system, then by sand transect number, and then by stake number on the transect. Each stake had the following four measurement times:

T_0 - 6/22/76 - Experiment set up.

T_1 - 9/18/76 - First measurement.

T_2 - 12/5/76 - Second measurement.

T_3 - 2/6/77 - Third measurement.

T_4 - 4/19/77 - Fourth measurement.

The values listed in the table are the change in height (CH) between any two consecutive measurement dates, while the final change in height represents the net change for the whole experiment, as shown below:

CH_1 - is the change from T_0 to T_1.

CH_2 - is the change from T_1 to T_2.

CH_3 - is the change from T_2 to T_3.

CH_4 - is the change from T_3 to T_4.

CH_N - is the net change from T_0 to T_4.

The values in the table may be negative, representing an erosional surface, or positive, representing an accretional surface.

Three other symbols, depicting problems with the analysis, are also shown in the table. (E) indicated that the stake was eroded and not replaced. (*) indicated that beach visitors either broke or removed the stake. And finally, (X) indicated that natural elements, such as a washed-up log crushing a stake, caused the removal of the stake, or that snow and ice prevented taking a good measurement. Stakes were replaced, unless they were eroded.

Table 7

Sand Accretion-Erosion Data from Popham, Reid, and Small Pt. Beaches

Beach System	Transect Number	Stake Number	CH_1	CH_2	CH_3	CH_4	CH_N
POPHAM	100-103	100	1	E	E	E	
		101	-1	E	E	E	
		102	0	E	E	E	
		103	0	E	E	E	
	105-108	105	1	5	X	5	11
		106	0	0	X	11	11
		107	0	0	X	0	0
		108	1	-1	X	-1	-1
	110-113	110	*	9	X	16	25
		111	*	1	X	*	1
		112	-2	4	X	5	7
		113	0	0	X	*	0
	115-118	115	-1	12	9	-7	13
		116	-1	9	8	0	16
		117	0	4	X	33	37
		118	0	0	X	15	15
	120-123	120	*	*	*	*	
		121	0	6	X	10	16
		122	0	10	9	-1	18
		123	2	0	X	*	2
	125-128	125	*	30	-1	-1	28
		126	1	14	9	0	24
		127	0	12	13	3	28
		128	0	3	13	-2	14
	130-133	130	2	E	E	E	2
		131	2	11	9	-2	20
		132	2	4	14	-3	17
		133	1	1	17	0	19
	135-138	135	-4	-2	0	*	-6
		136	-1	-1	-1	-2	-5
		137	-1	*	*	*	-1
		138	-1	*	*	*	-1
	140-143	140	*	3	1	*	4
		141	1	1	X	4	6
		142	0	1	X	4	5
		143	0	1	X	4	5
	145-148	145	*	*	-5	0	-5
		146	*	*	3	0	3
		147	*	*	X	3	3
		148	*	*	*	X	

Table 7 (continued)

Beach System	Transect Number	Stake Number	CH_1	CH_2	CH_3	CH_4	CH_N
SMALL PT.	150-153	150	*	6	7	-1	12
		151	*	2	3	7	12
		152	*	0	X	0	0
		153	*	0	X	0	0
	155-158	155	*	6	9	-1	14
		156	-1	-1	-7	2	-7
		157	1	-3	-5	-4	-11
		158	2	2	X	-2	2
	160-163	160	*	3	14	13	30
		161	-9	8	-5	8	2
		162	-1	-3	1	0	-3
		163	0	1	X	2	3
	165-168	165	-1	22	6	1	28
		166	2	28	2	-3	29
		167	14	15	0	-15	14
		168	5	-1	X	0	4
	170-173	170	-1	17	0	2	18
		171	0	11	15	3	29
		172	1	-1	7	2	9
		173	2	-2	X	10	10
	175-178	175	0	21	X	X	21
		176	0	0	7	-2	5
		177	-8	-1	-1	2	-8
		178	2	0	X	4	6
	180-183	180	5	23	2	0	30
		181	-1	15	2	6	22
		182	-2	3	-4	2	-1
		183	0	0	X	7	7
	185-188	185	-4	4	0	12	12
		186	-7	4	3	7	7
		187	0	0	1	2	3
		188	0	3	X	-1	2
	190-193	190	-3	13	7	9	26
		191	-9	8	31	-2	28
		192	7	-7	2	*	2
		193	4	1	X	7	12
	195-198	195	-5	5	9	11	20
		196	-5	17	-4	4	12
		197	7	-3	X	0	4
		198	6	5	X	3	14

Table 7 (continued)

Beach System	Transect Number	Stake Number	CH_1	CH_2	CH_3	CH_4	CH_N
REID	200-203	200	1	8	12	-6	15
		201	-1	0	2	0	1
		202	0	2	1	4	7
		203	0	3	1	1	5
	205-208	205	0	*	X	2	2
		206	-2	2	1	-1	0
		207	0	0	0	3	3
		208	0	0	X	2	2
	210-213	210	*	1	X	-2	-1
		211	0	3	0	0	3
		212	0	0	1	0	1
		213	0	0	1	0	1
	215-218	215	*	4	0	-2	2
		216	-1	0	0	1	0
		217	0	1	X	0	1
		218	0	0	X	*	0
	220-223	220	*	*	0	X	0
		221	0	8	0	-1	7
		222	3	4	-1	0	6
		223	1	3	0	0	4
	225-228	225	0	9	E	E	9
		226	-1	1	0	E	0
		227	0	1	X	1	2
		228	0	0	0	0	0
	230-233	230	-2	9	E	E	7
		231	0	5	E	E	5
		232	0	1	E	E	1
		233	0	1	E	E	1
	235-238	235	*	2	X	10	12
		236	1	5	X	14	20
		237	0	4	X	27	31
		238	0	1	X	13	14
	240-243	240	X	*	X	23	23
		241	X	*	7	-3	4
		242	X	*	5	3	8
		243	X	8	X	16	24
	245-248	245	0	-1	12	-11	0
		246	-1	3	1	3	6
		247	2	1	X	*	3
		248	0	1	X	*	1

Appendix E

EXPLANATIONS OF TYPES

Forest Types: A complete forest type consists of three different characters in combination; forest type - forest height class - forest density class, ie., H2A - Hardwood stand- 21-40 feet in height - with high density.

Types:

H- Hardwoods at least 80% of the stand.
S- Softwoods at least 80% of the stand.
HS- Hard & Softwoods, hardwoods 50%.
SH- Soft & Hardwoods, softwoods 50%.

Forest Height Classes:

1- 1-20 feet
2- 21-40 feet
3- 41-60 feet
4- 61-80 feet
5- 81-100 feet
6- 3 or more uneven heights

Forest Density Classes:

A- High Density; 81-100% crown closure.
B- Low Density; 30-80 % crown closure.

Shrub Community:

SR- On dunes *Myrica*, *Rosa*, *Spirea*, & *Rubus* in varying compositions and densities, and in older or more upland areas *Amelanchier*, *Ilex*, *Vaccinium*, & *Kalmia* also present.

Marsh Types:

ISM- Irregularly flooded "high" saltmarsh; *S.patens* & *Puccinellia*.
TSM- Tidal "low" saltmarsh; *Spartina alterniflora*.
M- Meadow, waterlogged soil, but no surface water during the growing season. Grasses, sedges, and rushes.
SM- Usually waterlogged soil, sometimes up to six inches of water, and here often brackish water. Cattails, bulrushes, sedges, and some grasses.

Heather Community:

H- *Hudsonia*, *Aster*, *Lechea*, & *Cladonia* lichens in varying compositions and densities.

Sand and Ledge Types:

S- Open sand.
LB- Ledge, rockcliff, or sandbar.
RSB- Saltwater beach recreation, bathhouse, & parking.

Grassland Types:

D- Dune grassland. Ammophila breviligulata dominant plant. Lathyrus, Artemisia, Rubus, & Ribes sometimes present.

DD- Disturbed Dune or Heath Community. Disturbance usually caused by man, and sometimes perpetuated by the wind (possibly caused by the wind or fire).

AF- Abandon field.

Urban Types:

URH- High density residential, bldg. lots less than ¼ acre.

URM- Medium density residential, bldg. lots ¼-½ acres.

URL- Light density residential, bldg. lots ¼-1 acre.

URO- Open very light density residential, bldg. greater than 1 acre.

UE- Estate with more than three acres, extensive lawns, gardens, or orchards.

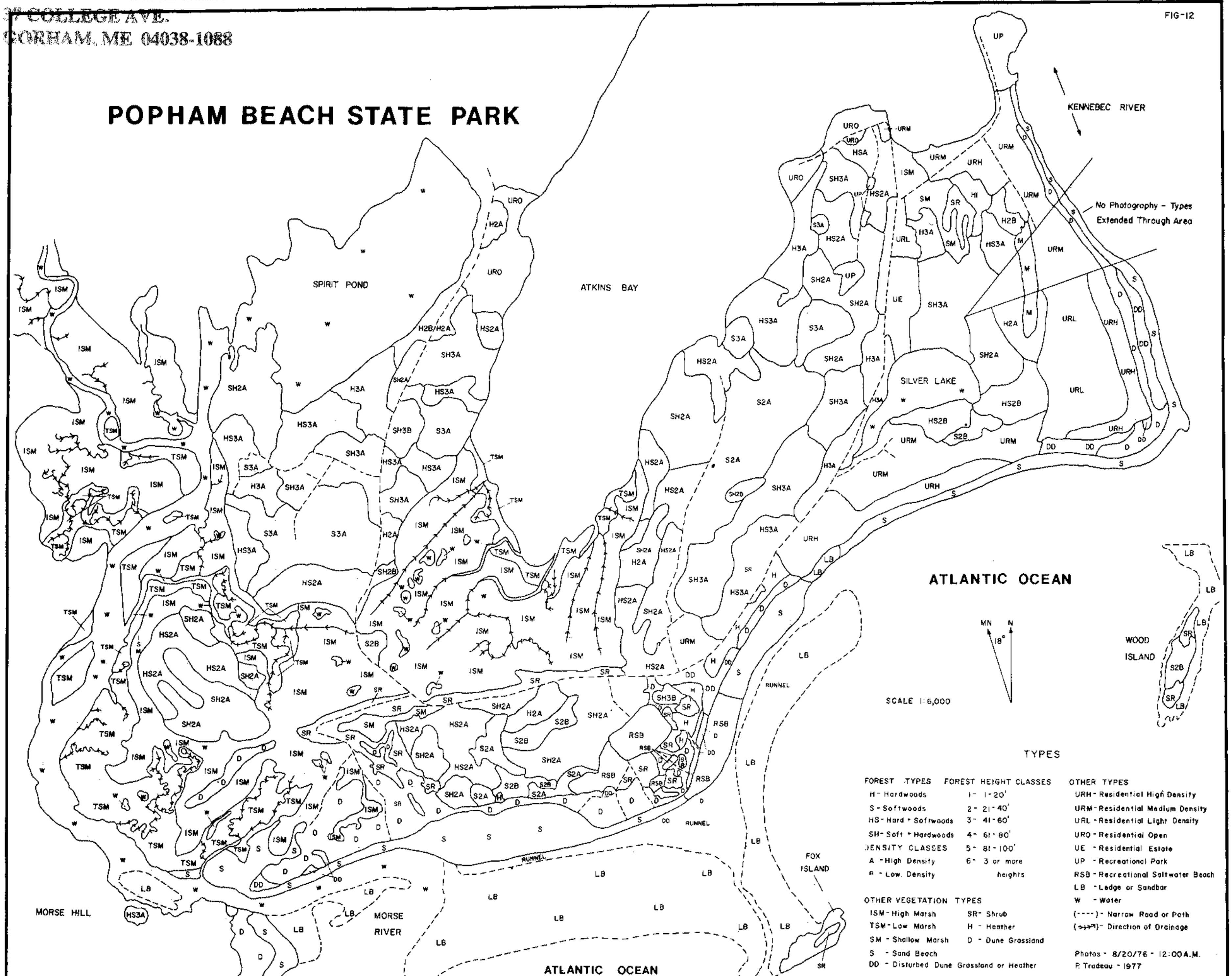
UP- Park, either recreational or historical park.

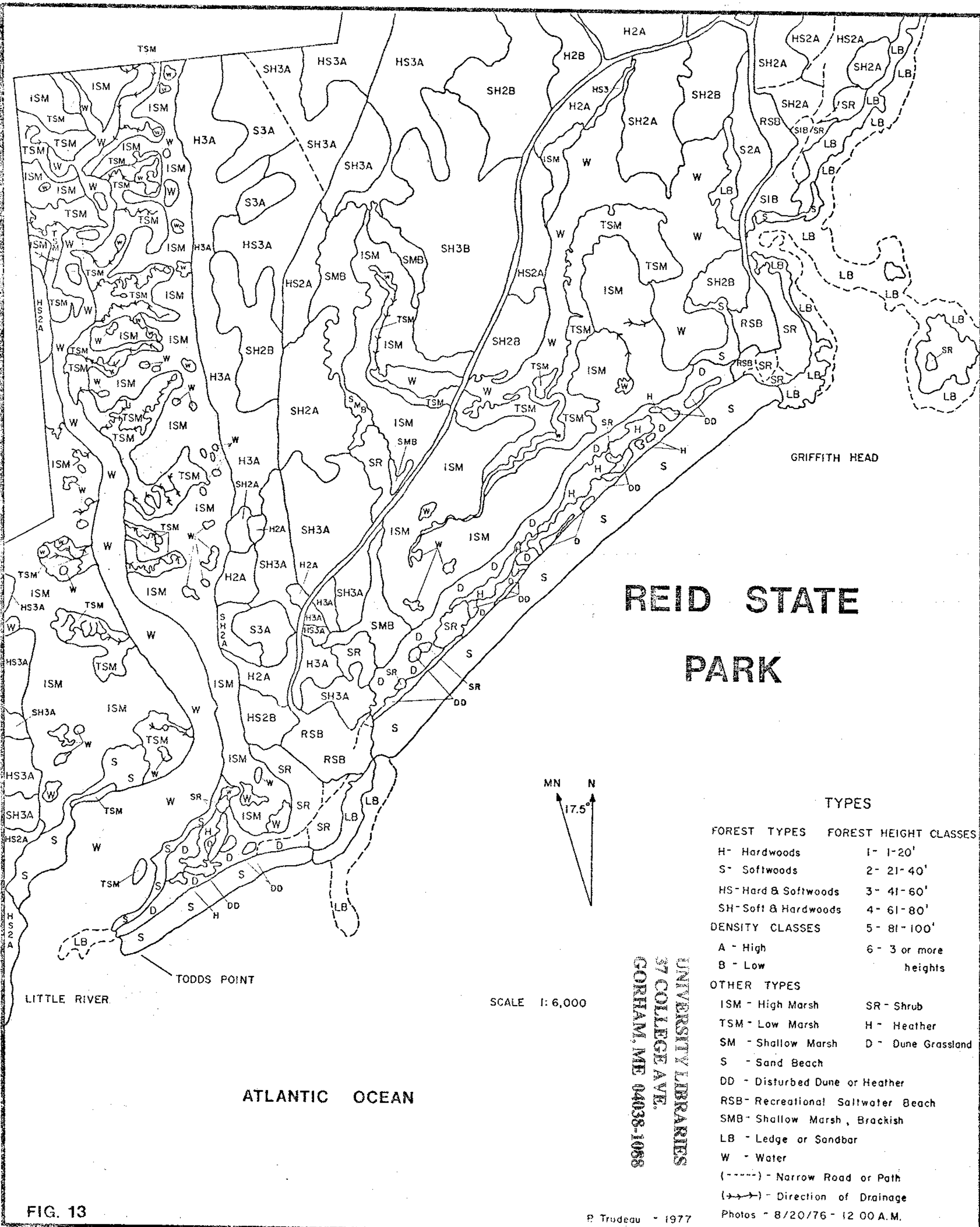
POCKET INSERTS

FIGURES 12, 13, and 14

FIG-12

POPHAM BEACH STATE PARK

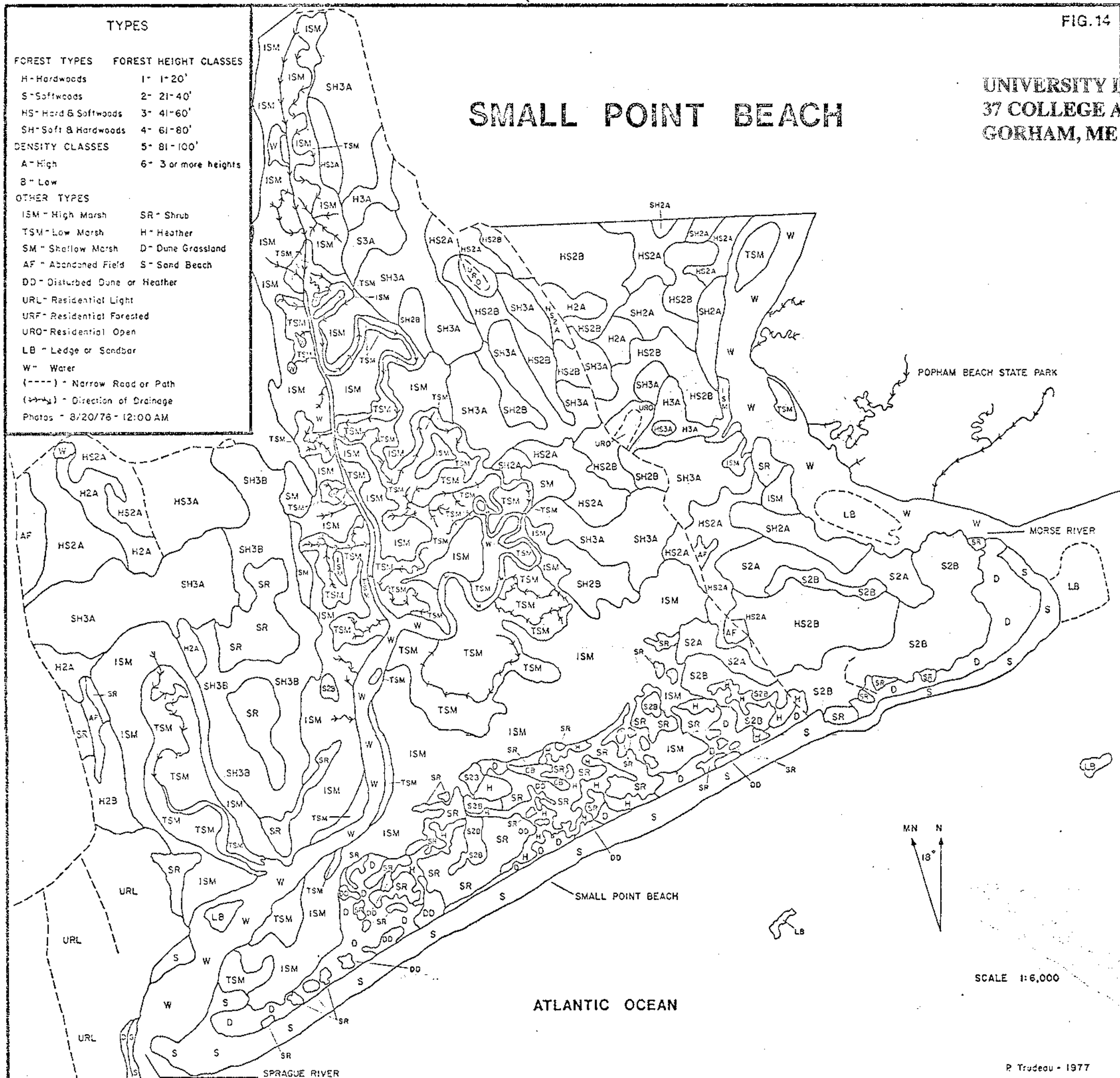




REID STATE PARK
GRIFFITH HEAD
TODDS POINT
LITTLE RIVER
ATLANTIC OCEAN
SCALE 1: 6,000
MN
N
17.5°
TYPES
FOREST TYPES
H- Hardwoods
S- Softwoods
HS- Hard & Softwoods
SH- Soft & Hardwoods
FOREST HEIGHT CLASSES
1- 1-20'
2- 21-40'
3- 41-60'
4- 61-80'
5- 81-100'
6- 3 or more heights
DENSITY CLASSES
A - High
B - Low
OTHER TYPES
ISM - High Marsh
TSM - Low Marsh
SM - Shallow Marsh
S - Sand Beach
DD - Disturbed Dune or Heather
RSB - Recreational Saltwater Beach
SMB - Shallow Marsh, Brackish
LB - Ledge or Sandbar
W - Water
(-----) - Narrow Road or Path
(→→→) - Direction of Drainage
SR - Shrub
H - Heather
D - Dune Grassland
Photos - 8/20/76 - 12 00 A.M.
P. Trudeau - 1977

FIG. 13

FIG.14


SMALL POINT BEACH
TYPES
FOREST TYPES
H - Hardwoods
S - Softwoods
HS - Hard & Softwoods
SH - Soft & Hardwoods
FOREST HEIGHT CLASSES
1 - 1-20'
2 - 21-40'
3 - 41-60'
4 - 61-80'
5 - 81-100'
6 - 3 or more heights
DENSITY CLASSES
A - High
B - Low
OTHER TYPES
ISM - High Marsh
TSM - Low Marsh
SM - Shallow Marsh
AF - Abandoned Field
SR - Shrub
H - Heather
D - Dune Grassland
S - Sand Beach
DD - Disturbed Dune or Heather
URL - Residential Light
URF - Residential Forested
URO - Residential Open
LB - Ledge or Sandbar
W - Water
(----) - Narrow Road or Path
- Direction of Drainage
Photos - 8/20/76 - 12:00 AM
POPHAM BEACH STATE PARK
MORSE RIVER
SMALL POINT BEACH
SPRAGUE RIVER
ATLANTIC OCEAN
MN
N
18°
SCALE 1:6,000
P. Trudeau - 1977