

A BRIEF HISTORY OF THE PAMET RIVER SYSTEM
WITH RECOMMENDATIONS FOR ENVIRONMENTAL STUDIES
AND ACCOMPANIED BY TWO MAPS

A Report
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TABLE OF CONTENTS

	page
Key Personnel	1
Acknowledgements	1
Introduction	2
Geological History	5
Floral History	9
Social History	14
Discussion	19
Summary	22
Conclusions	27
Bibliography	31

LIST OF FIGURES

1. Location of the Pamet River.
2. Truro population changes from 1600 to 1980.
3. Succession of vegetation in the Great Pamet within the National Seashore, from 1962 to 1979.
4. Pamet Past and Present (separate cover)

KEY PERSONNEL

Principal Investigator: Graham Giese
Co-principal Investigator: Mark J. Mello
Associate Investigator: Charles T. Westcott
Research Assistant: Gwynne Wiatrowski
Research Assistant: Amy Witter

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We dedicate this brief history to John, Lucy and Bill Worthington, and to the memory of Bob Worthington, whose love, knowledge, and efforts on behalf of the Pamet River have inspired many to follow their lead.

INTRODUCTION

This brief review of the natural and social history of the Pamet River, and their interactions resulting in the present system, has been prepared with support provided by the Truro Conservation Trust through a grant from the Massachusetts Department of Environmental Management, Scenic Rivers Program, and the National Park Service.

The purpose of the study is to take a broad overview of this single estuary and its upland valleys, their natural development and human alterations. It is intended to provide a foundation for further studies, specific to particular problems, in order to improve management of the system.

This report first reviews the geological and floral history of the Pamet River System prior to the first settlement by Europeans. It next considers the social history of these settlers with emphasis on their environmental management decisions and their consequences. This is followed by a discussion of alterations in vegetation, a summary of those alterations in specific sections of the system, and a brief set of conclusions and recommendations.

The two maps presented with this report are based on Whiting's 1848 map, the earliest detailed map of the Pamet System, and the U.S.G.S. topographic map of 1972, and were modified to reflect the Pamet System around 1620 and 1980. Comparison of these two maps therefore depicts the effects of human alterations since the landing of the Pilgrims. Man-made features were eliminated from the 1848 map and the border of the Pamet System was traced from the wetland border indicated on this map, as the only major alteration appeared to be the conversion of the upper section of Mill Creek to a pond. The distribution of the dominant forms of vegetation is hypothetical and represents a synthesis of the geological history of the area, pollen analysis

and habitat preferences of dominant vegetation based upon cores from Duck Pond in Wellfleet (Winkler, 1982) and the Pamet Cranberry Bog (Patterson, III, 1980), and literature describing the distribution of vegetation on the Sandwich Moraine (Altpeter, 1937).

The present-day map is a modification of the 1972 U.S.G.S. topographic map using the U.S.D.A. 1980 aerial photograph; MacConnell's 1963 and 1979 update vegetation maps for the National Seashore property; Koteff, Oldale and Hartshorn's 1967 and Oldale's 1968 geologic maps; and selected site visits. The distribution of vegetation is, at best, accurate for 10-acre plots and should not be expected to represent each and every backyard, but to represent the types and proportion of the dominant vegetation types in and around the Pamet System.

The following classes of vegetation are depicted on these maps:

Salt marsh. The dominant vegetation is Spartina, both cordgrass (S. alterniflora) and salt hay (S. patens), but glasswort (Salicornia spp.) and other typical marsh vegetation is included in this category.

Cattail/Rush. Cattails (Typha sp.) and reeds (Phragmites communis) predominate in most of the areas, but this habitat also includes fresh water rushes and sedges.

Scrub Swamp. The dominant plants of this area include sweet pepperbush (Clethra alnifolia), winterberry (Ilex verticillata), swamp honeysuckle (Rhododendron viscosum), leatherleaf (Chamaedaphne calyculata), highbush blueberry (Vaccinium corymbosum), and sweet gale (Myrica gale). This category includes margins of marshes and woody bogs, as well as shrub swamps.

Oak (Black and White). This area indicates habitats that are dominated by black oak (Quercus velutina) and white oak (Q. alba), but includes other species of trees, especially pitch pine (Pinus rigida).

Pitch Pine. This habitat is dominated by pitch pine, but includes a variety of other species, from oaks to blueberries.

Beech/Maple. This habitat is dominated by mesic species, particularly beech (Fagus grandifolia) and red maple (Acer rubrum). Historically, hickory (Carya) and chestnut (Castanea dentata) were probably present and birches (Betula) may have been more common.

Locust. Black locust (Robinia pseudo-acacia) is an introduced species from Virginia, planted by the early settlers. It therefore appears only on the 1980 map.

Scrub Oak. The scrub oak barrens are dominated by scrub oak (Quercus ilicifolia), but in the 1620 map includes areas possibly dominated by bearberry (Arctostaphylos uva-ursi). In the 1980 map these two species have been plotted separately.

Bearberry (1980 only). As previously mentioned, this species has been differentiated from scrub oak only in the present-day map.

Grass. The category lumps two habitats, that dominated by beach grass (Ammophila breviligulata) such as the barrier dunes, and that dominated by wavy hairgrass (Deschampsia flexuosa) and heather (Hudsonia spp.).

Upland Shrub. This habitat includes cherry (Prunus spp.), shadbush (Amelanchier spp.), beach plum (Prunus maritima), Viburnum spp., blueberry (Vaccinium spp.), huckleberry (Gaylussacia spp.), bayberry (Myrica pensylvanica) and wild rose (Rosa spp.).

Other symbols which are depicted are: water, barren areas, artificial fill, dikes/culverts, and mosquito ditches. Remaining symbols on the present-day map are those of the U.S.G.S. topographic maps.

GEOLOGICAL HISTORY

Pamet River in Truro on Cape Cod is an altered estuarine system composed of three branches(Fig. 1). The main stem, Great Pamet, extends completely across Cape Cod, from Cape Cod Bay to the ocean shore, and it is flanked by two smaller branches: Little Pamet to the north, and the south branch which forks first to Mill Creek and then continues to Bangs (=Eagle's Neck) Creek. The system is isolated from ocean waters at its eastern limit by an unbroken barrier beach, and it opens to Cape Cod Bay through a tidal inlet between barrier beaches. Pamet Harbor lies just inside these Cape Cod Bay barrier beaches, where the three branches of Pamet system join together.

To better understand how this system works, let us move back in time some 400 years, to a time before the arrival of the first European settlers when Pamet River was virtually unaltered by human activities. This estuary, like so many others to be found along the coast of Massachusetts, differed from a true "river" in several important respects. First, its water was saline, not fresh, and the water flow was driven by the force of the Cape Cod Bay tides. Second, the valleys occupied by the estuary were not cut by flow of the waters presently occupying them. Rather, they were ancient valleys which were gradually being filled by fine sediments brought in from the sea by the tides.

The valleys themselves had been cut thousands of years earlier when the surface of the sea was hundreds of feet lower than it is today. This was at the end of the last great Ice Age, and the vast continental glaciers--that had once reached as far as the present location of Long Island--were retreating northward. Pausing for a thousand years, more or less, east of the present location of outer Cape Cod, one lobe (the South Channel lobe) of the ice released the mass of clays, silts, sands, cobbles and boulders which form the body of outer Cape Cod from Orleans to High Head in North Truro. Much of this material was carried from the melting ice by streams (and at times torrents)

of melt water which also cut valleys across the newly developed "outwash" plains. These valleys, like the outwash plains they traversed and dissected, sloped downward from the east toward the west.

Later, when climatic warming produced a further retreat of the South Channel ice lobe, additional changes developed. According to Oldale (1968), heavy rains of the periglacial climate fell on soil still frozen by permafrost, and the resulting surface flows cut new valleys and modified existing ones. With yet greater warming, the permafrost melted and with it blocks of ice which had been trapped and buried by sediments in the outwash valleys. This final melting produced "collapsed structures" and kettles which added complexity to the valley forms.

This, in a general way, was the origin of the valleys that are occupied by the Pamet system today. When the melting of the ice and permafrost was complete, they were left high and dry like so many dry valleys which cross outer Cape Cod today, for the porous sediment allowed the water table, then as now, to be controlled by the level of the sea.

However, the level of the sea was on the way up, for global ice melting was producing a global sea level rise, and that rise, with some minor fluctuations and at a decreasing rate, has continued to our own time. Several thousand years ago the submergence was sufficient to allow the sea to flood the Pamet valleys. Perhaps bogs or ponds had formed first, in the deeper depressions as the ground water table rose with rising sea level. But eventually salt water flowed into the system and the development of the present estuary was underway. With it the rising sea brought two additional forces which were to play important roles in molding the system: waves and tides. Wave forces, particularly during easterly storms, were especially severe along the ocean coast and the loose glacial deposits eroded rapidly, producing a line of steep marine scarps. Today these scarps are retreating at

an average rate of about 3 feet each year. Altogether they have probably eroded back several miles since the Pamet valley submerged. How much further east that valley once extended is not known, but today the valley floor is below sea level at the ocean shore and the Pamet system is separated from ocean waters by a barrier beach--a combination beach and dune system--which moves westward at the same rate that the cliff line erodes. This westward "migration" of the dune is in part accomplished by the dual action of wind blowing sand inland and beach grass stabilizing the newly deposited sand, and in part by the occasional overwashing of the entire barrier beach system by storm waves, which suspend and carry sand with them, depositing it at the upper end of the estuary.

The rate of sand movement along the beaches of the Atlantic shore is sufficient to keep the Pamet system sealed off from the sea except for the occasional overwash episodes. On the Cape Cod Bay shore, however, wave action is considerably less, and so is the alongshore rate of sand movement. It is likely that at the time the Pamet valley was first submerged, the net direction of littoral drifting was toward the south, driven chiefly by winter northwesterly wind waves (Giese, 1963). However, as the Province Lands Hook continued to develop, (Ziegler, et al., 1965) it provided increasing shelter from these waves, and eventually the gentler southwesterly wind waves prevailed, producing a northerly net littoral drifting.

The combination of wave-driven alongshore sand movement, rising sea level, and wind-transported onshore sand movement produced a line of barrier beaches which provide shelter for Pamet Harbor. The inlet from the bay to the harbor has probably undergone several cycles of change consisting of a gradual northward migration until finally reaching the marine scarp at Corn Hill; a shoaling of the inlet in that location leading to the breaking through of a new inlet further south under storm conditions; followed by another phase of

gradual northward migration.

Through this inlet, wherever its location, the 9.5 foot tidal range of Cape Cod Bay forced the flood and ebb of salt water which flowed through the system. Increasing dilution by fresh groundwater caused a gradual decrease of salinity with distance up all three branches and at the head of each, as well as in small lateral embayments, salt marshes gave way to fresh water vegetation.

Also through the inlet, carried in suspension by the flood tidal currents, came the silt and clay particles that later settled to the bottom and added to the upward growth of the marsh surface, matching sea level rise with increasing thickness of marsh peat.

Such was the Pamet River system 400 years ago: a tidal estuary, extending from the bay to the ocean with channel size, salinity and tidal range decreasing upstream, closed from the ocean by a barrier beach which gradually migrated westward, and opened to the bay through a tidal inlet which cyclically migrated northward.

FLORAL HISTORY

Changes in vegetation associated with the Pamet System have occurred as the result of two very distinct processes: 1) gradual long-term changes due to geologic and climatic effects, and 2) rapid changes due to human alterations. Both processes have formed three major environments which support the floral communities present in the Pamet System: upland, fresh water wetland, and tidal estuary. In order to understand the effects of past human alterations on the system and to predict the effects of future alterations, each process must be discussed separately, then synthesized.

Changes over geologic time: Uplands

The early pollen history of the outer Cape is similar to much of southern New England (Davis, 1965). An open windblown tundra consisting of heather and grasses was replaced by an open low spruce forest and eventually a closed spruce forest around 10,000 years before present (B.P.). Over the next 1,000 years, jack pine gradually replaced the spruce forest. As the climate continued to warm, the frequency of jack pines decreased, replaced by white pine and pitch pine during the period from 9,000 to 7,500 B.P. Deciduous trees such as oak, maple, hickory, beech, ash, and chestnut, as well as hemlock also appeared during this time, the most dominant being the oaks. Thus, by 7,500 B.P. a "modern forest" had developed. Most of the changes from 7,500 to the arrival of the first European settlers were associated with climatic fluctuations between warm, wet, and cool, dry periods. These fluctuations generally affected the relative abundance of pines and oaks versus the more mesic species such as hemlock, hickory, beech, ash, chestnut, etc.

Around 7,500 to 5,000 B.P. there appears to be a divergence in

succession of upland vegetation on the Outer Cape from the mainland. While most of southern New England developed a typical mesophytic forest dominated by various combinations of oaks, hemlock, hickory, white pine, beech, ash, chestnut, yellow birch, and maple (Davis, 1965), Outer Cape Cod remained cloaked primarily in an oak-pitch pine forest (Deevey, 1948), Patterson, III and O'Keefe, 1980), and (Winkler, 1982). Altpeter (1937) suggests that the Cape Cod forest was nearly pure pitch pine and oak over 100 feet above mean sea level (MSL) which were maintained in an open state by semi-annual burning by Indians. A more mesic forest developed with decrease in elevation, with the typical mesophytic forest described above occurring below 75 feet (MSL). However, core samples from Duck Pond in Wellfleet collected by Winkler and from the Pamet bog collected by Patterson, III and O'Keefe contain very little pollen of these mesic species just prior to the arrival of European settlers. Thus, the scenario presented by Altpeter may be true for the Sandwich Moraine, but harsher environmental conditions persisting on the outer Cape maintained a pine barrens habitat in all but the lowest, protected valleys and kettles. Since there is no comprehensive study of the vegetation on the outer Cape at the time of arrival of the Pilgrims, the elevations where changes in communities occur are, at best, educated guesses based primarily on the work by Patterson, III and O'Keefe (1980) and Winkler (1982) and the present distribution of the pines and oaks. Although corings in some Brewster ponds show a rise in sorrel and ragweed prior to European settlement which would indicate agricultural activity (Winkler, 1982), Leatherman (1981) suggests that the slopes of the Pamet valley were probably too steep for Indian settlements, so that vegetation at the time of arrival of Europeans was basically unaltered by humans. For the purposes of defining the upland floral communities for the circa 1620 map, we have made the following assumptions: the succession of communities along the ocean cliffs and the bayside barrier

beaches in the beachgrass to bear oak communities was similar to that seen at the present time; slopes above 75 feet (MSL) were pitch pine-dominated; oaks (red, black, and white) dominated from 25 feet to 75 feet above MSL; and beech, birch, tupelo, sassafras, red maple, and/or hickory occurred in protected valleys and kettles at elevations between 25 feet (MSL) and the water table.

Changes over geologic time: Wetlands

Tidal estuary. Floral changes in the aquatic portion of the Pamet system since the retreat of the glaciers is difficult to pinpoint in the estuarine areas due to a lack of pollen analysis from coring data taken from present or past salt marsh locations. Corings taken at three sites in the Pamet River by Leatherman (1981) are somewhat confusing as presented and need further analysis. The cores at Ballston beach were comprised entirely of freshwater peat. According to Leatherman, a core at the east side of Route 6 was characterized by fresh water marsh peat from the base of the core to a meter below the surface, which would roughly correspond to 1,500 B.P. This would suggest that a fresh water bog of some sort developed in this area of the Pamet (now Route 6 to Ballston Beach) and that salt water intrusion due to rising sea level did not occur at the Route 6 site until 1,500 B.P. Although more data are required to define the history of submergence, it is clear that from 1,500 to 400 B.P. a salt marsh existed in the Pamet River well past Route 6 but probably not to Ballston Beach. Invasion by storm tides and overwash from the ocean side were probable occurrences, however. The Little Pamet and the south branch of the Pamet most likely have a similar history, but because of their size, may have been tidal for most of their entire length but not subject to storm overwash from the east. Cattails often invade salt marsh peat if salt water intrusion is prevented, therefore the present distribution

of the cattail marshes in the fresh water portions of the Pamet system has been used to map the extent of the salt marsh at the time of European settlement. An exception was made in the Ballston Beach area of the Pamet where salt water intrusion may have been too intermittent or too brackish to maintain a salt marsh. No attempt has been made to distinguish between the two Spartina species, cordgrass and salt hay, which are and were the dominant forms of vegetation of the salt marsh.

Freshwater wetlands. Historically, there is scant freshwater wetlands associated with the Pamet System, a small area north of the head of the Great Pamet and probably one at the head of Bangs Creek. The evolution of these wetlands is based on the corings done by Patterson III (1980) in the wetland north of the head of the Great Pamet, known as the Pamet Cranberry Bog.

This wetland began to form about 7000 B.P. when rising sea level (and subsequent rising of the fresh water table) resulted in the development of peat bog in this kettle north of a deeper kettle which developed into a pond. Ericaceae pollen, which includes cranberry and Sphagnum spores date back to 7000 B.P. in the cores. Wetland ferns, sedges, and sweet gale, are also present throughout the cores indicating the presence of a bog which remained relatively unchanged throughout its history prior to settlement by Europeans. The border of the bog was primarily red maple, judging by the presence of its pollen throughout the core. The relative sporadic abundance of sweet pepperbush and the change in abundance of various Ericaceous species (blueberries, leatherleaf, swamp azalea, cranberry, etc.) which have indistinguishable pollen grains) are due to the historical proximity of these shrubs to the location of the corings, since these insect-pollinated plants would have heavy pollen which would accumulate under the shrubs rather than be windblown and dispersed throughout the bog. In summary, the freshwater wetlands associated with the Pamet System were small and relatively stable throughout

the period from about 7000 to 400 B.P.

SOCIAL HISTORY

Substantial human alteration of the Pamet system began in the 18th century. The Pilgrims explored the system sufficiently in 1620 to learn that it was navigable only at the higher stages of the tide and consequently went on to settle at Plymouth. This decision foretold many of the problems that were to come some 200 years later. While the small estuary provided resources sufficient for many of the needs of a small group of rural people such as the native Indians (the Pamets), or the early European settlers, it would often be found lacking when called upon to meet the requirements of 19th century commerce and industry.

Soon after settlement of the colony at Plymouth, the resources of outer Cape Cod, especially fisheries, began attracting the attention of the settlers. According to Rich (1884), when the first group of "proprietors" moved from Eastham to their Pamet lands in 1700, they joined early settlers, many of whom had names associated with families in Barnstable. The Town of Truro was incorporated in 1709 and the community grew rapidly until hostilities began with England in the 1770's (Fig. 2). The Pamet estuary and its valleys provided these first Europeans well: an inlet and harbor for sheltered moorings and access to the sea; salt from the evaporation of water; tidal flows and channels for transportation; fish, shellfish and marsh birds for food; salt marsh grasses for winter fodder for cattle; wood for heat and for building houses and boats; upland grasses for sheep and cattle grazing; soil for farming; and home sites protected from storm winds.

The major change during this period was in the upland vegetation. Town records from 1711 include reference to the "great destruction and waste made of firewood within the Town of Truro" (Rich, 1884, p. 101). However, there was also concern about the destruction of marsh and beach grass, and in 1730

"a committee..were chosen..to prevent cattle and horses going upon the meadows and the beaches adjoining. The object was the preservation of the meadows from destruction by sands" (Rich, 1884, p. 230). Later, in "1760, on account of the great losses sustained by the town in consequence of the blowing of meadows the winter past, an abatement of the provincial tax of the town was asked" (Rich, 1884, p. 247). Direct alterations to tidal flow during the 18th century were limited to small dikes at the upper reaches of branches of the estuary (such as at Mill Pond) and the minor effects of bridges across the channels and marshes.

The conflict with England put an end to this first phase of growth and development of the Pamet valleys. When the colonial period ended, Truro was a rural settlement which depended heavily on the Pamet system, which, as an estuary had not yet been greatly altered.

The second surge of population growth came in the first half of the 19th century and reached its peak about 1850 (Fig.2). This was Truro's golden period of industry and the Pamet River was more than ever the focus of activity. While the economy of the town in the 18th century was based on farming, with whaling and fishing playing secondary roles, maritime activities now became foremost. The salt industry began in earnest around 1800 and reached its zenith around 1840 when the town had 39 salt works. At this time the Pamet could claim some 60 vessels working at the cod and mackerel industry, and to support and supply them, wharves, stores, sheds, a shipyard and a sail loft. Many of these structures are clearly shown on Henry Whiting's detailed 1848 map of Truro, as are a number of bridges crossing the three branches and many roadways which have remained unchanged to the present day.

Many factors, including the infamous "October gale" of 1841, a sudden drop in mackerel abundance, the collapse of the salt industry, and the

bankruptcy of a leading supply house coincide with the end of this brief period of prosperity, but probably the major underlying cause was simply that the demands of 19th century industry exceeded the scale of the estuary's resources. Truro's population dropped by more than 20% between 1850 and 1860, after which the Civil War and the great westward migration which followed it maintained the decline.

It is a remarkable fact that right up to the mid-nineteenth century peak in Truro's population and commercial activity, the major natural characteristics of the Pamet estuary remained essentially unaltered. The great manipulations occurred during the period from 1850 to 1930, when the town suffered a dramatic slump and the population dropped by 75% (Fig.2).

In 1854, a single wood-and-stone jetty was constructed at the inlet in the hope of stabilizing and deepening the channel, but the effort failed and does not seem to have had any significant effect on the system. On the other hand when, in 1869, the townspeople voted to replace the rotting timbers of Wilder's Bridge with solid fill, the entire eastern portion of the Great Pamet was changed from a estuarine to a fresh water environment.

Soon after, in the early 1870's, the railroad was extended across Truro. A trestle was used to cross the channel of Great Pamet, and there tidal flow was not seriously disturbed, but solid fill dikes were used to cross the mouths of Little Pamet, Mill Pond Creek and Bang's Creek. The effect of these dikes was to cut off increasingly greater areas of the Pamet River system from tidal flow and thereby to reduce the volume of water which flowed in and out of the inlet from Cape Cod Bay. With a decrease in the tidal flushing came increased sedimentation and shoaling of the channels.

Various proposals were made to improve the harbor and finally in 1919 an ambitious harbor engineering project was undertaken by the Commonwealth of Massachusetts. A new inlet was dredged through the barrier beach

approximately 2500 feet south of the natural inlet, and a 60-foot wide channel was dredged eastward from the inlet to a basin in the South Branch near Mill Creek. The dredge spoil material was deposited inside the new inlet along the northern side of this channel, creating a dike which divided the estuary into two systems. Tidal flows entered the Great Pamet through the natural inlet, which was at the time near Corn Hill, and flowed through a channel north of the dike. Flow into the South Branch entered the new inlet and ran south of the dike. Stone jetties were built out into Cape Cod Bay both north and south of the new inlet.

The already depleted system was further disturbed by this project in several respects. The volume of tidal flow through the natural inlet was further reduced and this caused the inlet to shoal even more, while the volume available to flow through the new inlet was not sufficient to maintain the channel which had been dredged. The jetty south of the new inlet interrupted the northward net littoral drifting of beach sand, causing beach accretion south of the south jetty, and erosion north of the north jetty.

The dike was reinforced with boulders in 1920, notwithstanding which the main channel soon cut its way through the dike and part of its flow was diverted through the new inlet. As a result, shoaling increased at the natural inlet until it finally closed completely during the hurricane of 1938, permitting all flow to once again pass through a single inlet.

The inlet channel was widened in 1950-1951 and new, longer jetties constructed. The increased width caused a decrease in channel depth. The average channel depth shoaled from 1.8 m (5.9 feet) in 1950 to 1.3 m (4.3 feet) by 1951 (Fitzgerald and Levin, 1981). The longer jetties increased the trapping of sand south of the inlet and beach erosion north of it. As a result, the north jetty became, and is now, completely detached from the high tide beach north of the inlet.

Despite all the problems which resulted from the dikes, the railroad was very useful to the town in several respects. First, it made available new markets for fish, and trap fishing developed as an important industry. Secondly, it supplied excellent passenger service and summer visitors. In the 1890's summer cottages were built at Ballston Beach and Corn Hill and the stage was set for the 20th century development of summer activity as Truro's chief economic asset.

One aspect of the marshes was seen as a detriment to summer life in Truro: standing pools of water that served as mosquito breeding sites. It was found that the standing water could be reduced by the dredging of a regular network of drainage ditches. These mosquito control projects produced grids of ditches in all three branches of the Pamet system. Typically, the dredge spoil material was deposited in ridges alongside the ditches. Together, the drainage produced by the ditches and the elevated ridges of rich soil produced a significant reduction in water level and conditions favoring the invasion of upland species.

Truro's population began to increase again in the mid-twentieth century and that increase still continues (Fig. 2). With the new prosperity has come a renewed interest in and concern for the Pamet River system and the resources that it provides the people of Truro.

DISCUSSION

Changes in upland vegetation

The Pilgrims found an outer Cape forest that was primarily oak and pitch pine, with mesic species (beech, maple, hickory, birch, chestnut) confined to sheltered moist hollows (Patterson III and O'Keefe, 1980; Winkler, 1982). The subsequent deforestation of the outer Cape since European settlement has been well documented (Thoreau, 1849; Rich, 1884; Strahler, 1966; Jorgenson, 1978). The long-term effects of this deforestation varied greatly, from the creation of a vast desert-like moving dune system in the Province Lands to near-mature oaks and pines surrounding some of the kettle ponds in Wellfleet. There is no evidence that the Pamet system suffered from wholesale inundation of sediment due to blowing sand as now occurs in Pilgrim Lake, since the wetland boundary of most of this system appears to be relatively stable when a comparison is made between Whiting's 1848 map and the most recent 1972 U.S.G.S. map. The marked exception to this will be discussed under the following section on changes to wetlands.

Pollen analysis from the Pamet cranberry bog reveals a disappearance of oak pollen following settlement, and it also reveals the presence of introduced species such as black locust, Scotch pine, and Scotch broom. Pitch pine rapidly increases in abundance in this century, and the percent pollen at the surface indicates that it may now be at its greatest abundance. Oaks have also regained a foothold, but are at lower densities than just prior to settlement. The trend is a return to a mature oak-pine forest, with some areas recolonized by locusts, where birches might be the expected colonizer.

The relationship of the understory species, notably the Ericaceae (bearberry, blueberry, huckleberry) cannot be accurately traced through pollen analysis because these insect-pollinated species have heavy pollen which is

not readily windborne and is, therefore not accurately represented in the core samples. There is a dramatic increase in grass, sorrel, ragweed and wormwood pollen, reflecting the change from forests to fields and barrens.

Changes in wetland vegetation

The human alterations that have had the greatest effect upon the Pamet System involve the diking associated with construction of the railway and major roads which cross its three main branches. Culverts with clapper valves (or tide gates) were installed in association with the dikes so that water only flowed seaward; thus tidal salt water was eliminated from the landward side of these dikes.

The earliest major dike was Wilder Dike constructed in 1869 at the site of the former Wilder Bridge where Castle Road crosses the Great Pamet. Dikes were constructed in the early 1870's for the railway across Mill and Bangs Creeks and the Little Pamet. The salt marsh landward of these dikes was rapidly replaced with fresh water marsh vegetation, primarily cattails. Wetland shrubs also encroached upon the marsh as the threat of lethal salt water inundation had been virtually eliminated. Additional diking for road construction across the Little Pamet at Castle Road, across Mill Creek at Mill Pond Road, and across Bangs Creek at Old County Road further accelerated the succession of cattail swamp to shrub swamp. The effects of dikes for Route 6 across the upper reaches of the Little Pamet and at Fisher Road combined with ditching or mosquito control (which will be discussed shortly) have resulted in the succession of these upper reaches of the marsh to upland vegetation. Minor alterations of this system have also occurred along a few fingers of salt marsh which had been diked for various reasons, including the development of a cranberry bog. The net result of the diking activity has been a 50-60% conversion of salt marsh to cattail marsh or shrub swamp.

Major alterations in the fresh marshes which developed after diking can be traced to ditching to control mosquito populations. Cortell (1982), Portnoy (1983), and Soukop and Portnoy (n.d.) have commented on the rapid succession of upland vegetation and degradation of water quality in the marshes due to the draining and lowering of water level which the ditching accomplishes. The raised elevation of the marsh where the material dug from the ditches is placed also is colonized by upland vegetation. The net result is a loss in acreage of wetlands which may be irreversible, and a degradation of the remaining wetlands from acidification associated with ditch maintenance. Succession from shrub swamp vegetation to upland shrubs can be seen in the upper portion of the Great Pamet by comparison of the vegetation survey done by Randall (1962) and updated and digitized by the National Park Service in 1979 (Figure 3).

Alterations in the inlet and harbor during the early part of this century have had a relatively minor effect on the salt marsh vegetation. Certainly some of the marsh was removed when the boat basin was dredged, and the boundaries of the salt marsh have changed in response to the stabilization of the location of the inlet, but the total area of salt marsh in the harbor has probably stayed about the same or even increased slightly. The major detriment to the salt marsh in recent years is the compaction of sediment from off-road vehicle and heavy foot traffic along the western boundary of the salt marsh north of the inlet. A band of glasswort is colonizing compacted areas along this stretch.

SUMMARY

Here we review the changes which have occurred in the Pamet River System since the first settlement by Europeans, which have been detailed above, in terms of specific sections of the system. It may benefit the reader to refer to the accompanying map, "Pamet River - Past and Present" to better identify and understand each section. On that map, the locations of culverts passing through man-made dikes are identified by number and listed on Table 1.

I. Inlet and Harbor

Under natural, pre-colonial conditions, this was the region of the estuary which changed most frequently. The inlet changed according to a cycle of northward migration followed by break-throughs further south. As the inlet changed position, old channels in the harbor area filled as new ones formed.

Jetties constructed at the present inlet in the 20th century have fixed its position, while the former inlet at Corn Hill has closed. The jetty south of the inlet has caused a considerable widening of the south barrier beach by interrupting the net northward littoral drifting of sand, while the barrier beach north of the inlet has eroded considerably, despite the deposition there of dredge spoil.

During the past decade, a drainage channel was dredged southward through the tidal flats from the culvert leading into the Little Pamet system. The spoil from this dredging operation was deposited parallel to and west of the channel forming a supratidal ridge.

Due to the stabilization of the present inlet and the closing of the former inlet at Corn Hill, there has been rapid sedimentation of the harbor north of the inlet with subsequent colonization by Spartina. The western

border of this area has been further modified by off-road vehicle traffic which has compacted the substrate, resulting in a wide strip of the pioneer species, glasswort. Beach grass predominates on the barrier dune, as it presumably did in the pre-colonial period, except for the regions disturbed by pedestrian traffic in the vicinity of Corn Hill Beach. Beach grass was also planted and survives on the dredge-soil ridge west of the Little Pamet drainage channel as well as on the former railway dike.

II. Little Pamet

A. Corn Hill Road to Castle Road. The northern branch of the Pamet estuary was cut off from salt water by the construction of a solid-fill dike for the railroad right-of-way in the early 1870's. The salt marsh in this lower section changed to cattail marsh, but has not changed its physical form except for sedimentation of the channels and encroachment of upland vegetation in that section east of Corn Hill which has for a long time been farmed.

B. Castle Road to Route 6. This section has succeeded from cattail swamp to shrub swamp, and upland vegetation has encroached along the borders.

C. East of Route 6. Here the upper reach of the former estuary is dominated by the upland species, goldenrod and meadowsweet, and now is only occasionally wet, with the exception of a mosquito control ditch.

III. Great Pamet

A. Former railroad right-of-way dike to Castle Road. This section has remained part of the tidal system, due to the construction of a railroad trestle, as opposed to the dikes used on the other two branches of the estuary. As a result, the vegetation has remained virtually unchanged, except for the upper reaches of several small fingers which have been diked and are

now fresh and in some cases have limited upland vegetation, and the large area of fill southwest and a smaller area northwest of Wilder Dike.

B. Castle Road to Ballston Beach. Here the tidal flow has been interrupted for over a century by the Wilder Dike and the vegetation has passed through several successional stages, similar to the Little Pamet, Section B. However, the encroachment of upland vegetation is more extensive in the eastern part of this section. At present the shrub swamp vegetation is rapidly being replaced by cherry, shadbush, and bayberry.

IV. South Branch

A. Harbor to railroad dikes. Tidal flow has not been interrupted in this section. However, there have been significant physical changes due to dredging for the boat basin, considerable artificial filling in the vicinity of the present town landing, and natural and artificial filling associated with the south barrier beach. The salt marsh vegetation that was neither buried nor removed remains virtually unchanged.

B. Railroad dike to Mill Pond Road. This portion of the Mill Creek was cut off from tidal flow by the construction of a railroad right-of-way in the early 1870's. The former salt marsh has converted to a fresh marsh dominated by cattails, but also including reeds and sedges. The border vegetation is primarily wetland shrubs.

C. Mill Creek north of Mill Pond Road. Mill Pond was probably first diked in the middle of the 18th century, but tidal access existed as late as mid-19th century to power a grist mill. The original salt marsh vegetation has been replaced by a central area of cattails and sedges surrounded by shrub swamp. There has been a minor encroachment of upland vegetation.

D. Railroad dike to Old County Road. Salt marsh occupied this area

until tidal flow was interrupted by the railroad dike in the early 1870's. At present, salt marsh occupies about one-third of the area, the remainder being primarily cattail marsh.

E. Old County Road to Head of Bangs Creek. The pre-colonial division between salt and fresh marsh in this area is not clear, nor is the date of the earliest dikes. However, at present the area is virtually all shrub swamp with a small area of cattail marsh near Old County Road. There is a pond at the head of Bangs Creek which is not shown on Whiting's map of 1848. Apparently (Mello visual observation) Sphagnum was removed from this area to create the pond.

F. South dike to Fisher Road. The former salt marsh in this area has now converted to mixed sedges and grasses, with scattered wetland shrubs.

G. South of Fisher Road. Here the upper reach of the former estuary has primarily upland vegetation, including a residential garden plot.

V. Ocean Barrier Beach

The barrier beach at the head of Great Pamet migrated westward in pre-colonial times, keeping pace with the eroding scarps north and south of it. Both storm winds and overwash contributed to the westward sand transport. Sand removal to maintain the roadway crossing this barrier resulted in its gradual narrowing. Such removal probably began when the roadway was first hardened in the early 20th century. Finally, after the storm overwash in 1978, a portion of this roadway was closed and sand removal ceased, while the southern part has remained open as a parking lot for Ballston Beach.

The barrier dune is vegetated primarily by beach grass as it has been in the past, with the exception of the footpath leading to Ballston Beach. Historicaaly, storm overwash of this barrier beach deposited sediment on the

marsh behind it. The combination of salt and sediment influx killed the fresh water vegetation which which would then be recolonized by cattails. This cycle continues today, witnessed as recently as the storm of 1978.



CONCLUSIONS

The Pamet River was a tidal harbor and not navigable at low stages of the tide when the Pilgrims arrived in 1620. It remains so today, but its inlet is shallower now than it was because the tidal prism has been reduced by dikes built across each of the three major branches of the estuary. Tidal flow has been blocked from the Little Pamet entirely and from large sections of the Great Pamet and South Branch. The former areas of salt marsh behind these dikes have converted to cattail marsh, shrub swamp, and in some cases to upland vegetation. The loss of wetland vegetation has been accelerated by the dredging of ditches for mosquito control and the deposition of dredged material on the marsh. The eastern section of the Great Pamet in particular is rapidly succeeding from shrub swamp to upland at the present time.

Truro's population increased from one hundred or so in 1700 to over 2,000 in 1850, then dropped to about 500 in 1930, and has increased again to about 1,500 in 1980. Almost all of the major alterations of the Pamet System occurred during the period of dramatic population decline. Perhaps the most desperate and misguided alterations resulted from attempted harbor improvements in 1919. Sediment transport processes are still out of equilibrium at the harbor inlet and the southern end of the barrier beach north of the inlet is rapidly eroding.

Based on our review of the history of the Pamet River, we conclude that the following aspects of the system require detailed measurement and study in order to produce sound alternative management options.

- 1) Determine the size and function, including hydraulics, of all artificial fill deposits and their associated culverts and tide gates.

2) Further define sediment transport processes and hydraulics associated with the tidal inlet. Studies by Giese and Westcott (1980) and FitzGerald and Levin (1981) provide valuable background data. These should be updated and new management alternatives devised.

3 Transects should be run periodically across selected sections of freshwater wetlands to monitor vegetation changes in areas now isolated from tidal flow.

4) Water levels, water salinity and revegetation by salt marsh species in the section of Bangs Creek between the railroad dike and Old County Road should be monitored. A leaky tide gate presently permits limited salt water access to this area. Careful monitoring of the resulting conditions would be a valuable aid in predicting future changes both here and in other regions which may regain access to tidal flow.

5) Special attention should be paid to the eastern section of the Great Pamet because of the rapidity of its vegetational changes. However, since that area is presently under study, plans for future research should await the results of that study.

6) Marsh cores from the eastern section of the Great Pamet (either those which the NPS presently has or new ones) should be analyzed to better determine the history of development of this area.

7) Pollen analysis of core samples from Duck Pond in Wellfleet and Pamet Cranberry Bog in Truro indicate that the pine barrens ecosystem of Outer Cape

Cod is a very old system, maybe over 7,000 years old. Many plants and animals associated with pine barrens are found in no other system, and therefore those species, many of which are on the state's rare or endangered species list (Harding, 1983; Sorrie, 1983) that are found here are more likely to be relict populations rather than recent introductions associated with human activities. With the pressure of development, some of these species, particularly those associated with upland habitats may face the threat of extinction. An inventory of barrens plants and animals should be undertaken so that management decisions, both for purchase of critical habitats and maintenance of barrens conditions can be addressed.

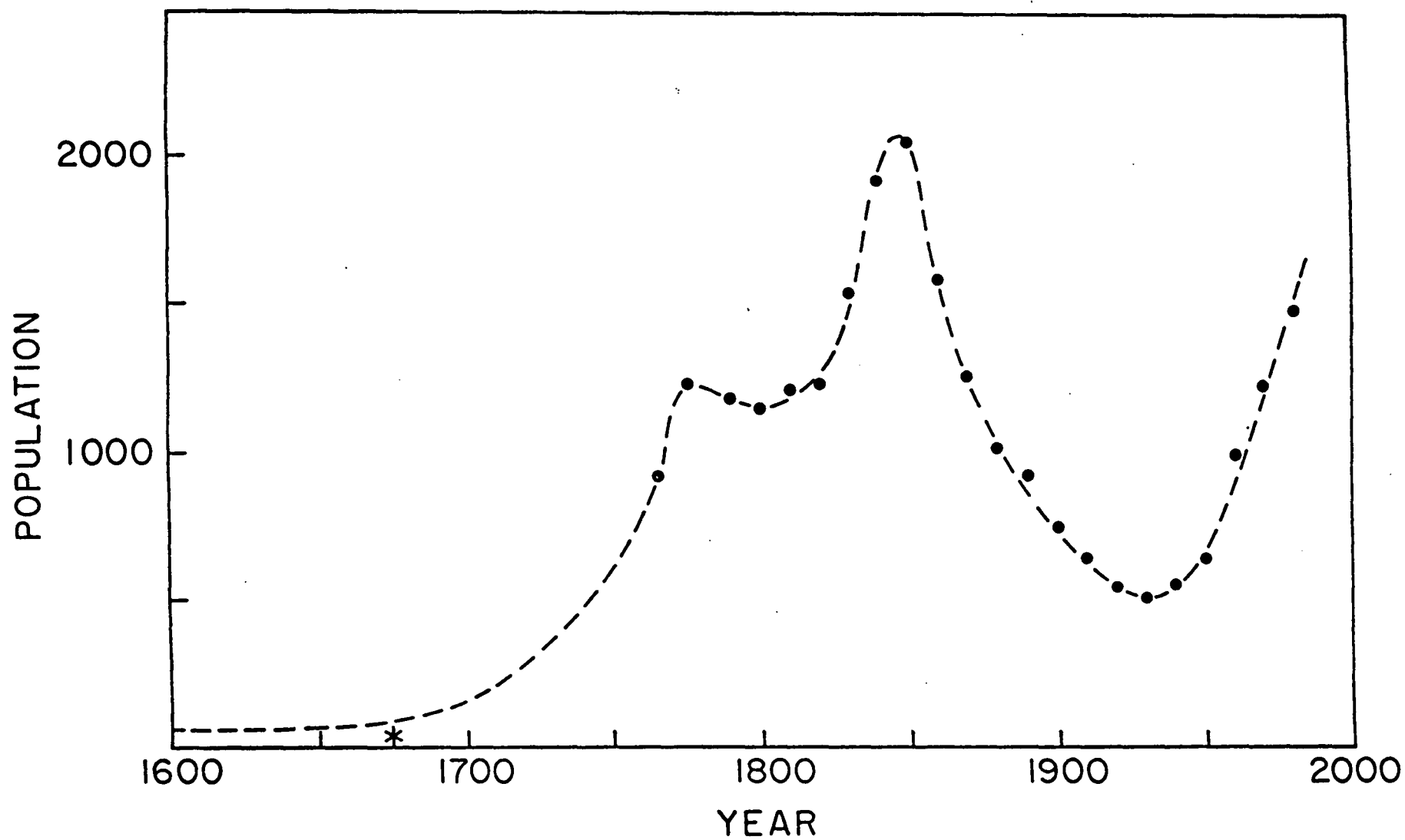


Figure 2. Truro population changes from 1600 to 1980. (* estimated Indian population in 1674)

Figure 1. Location of the Pamet River.

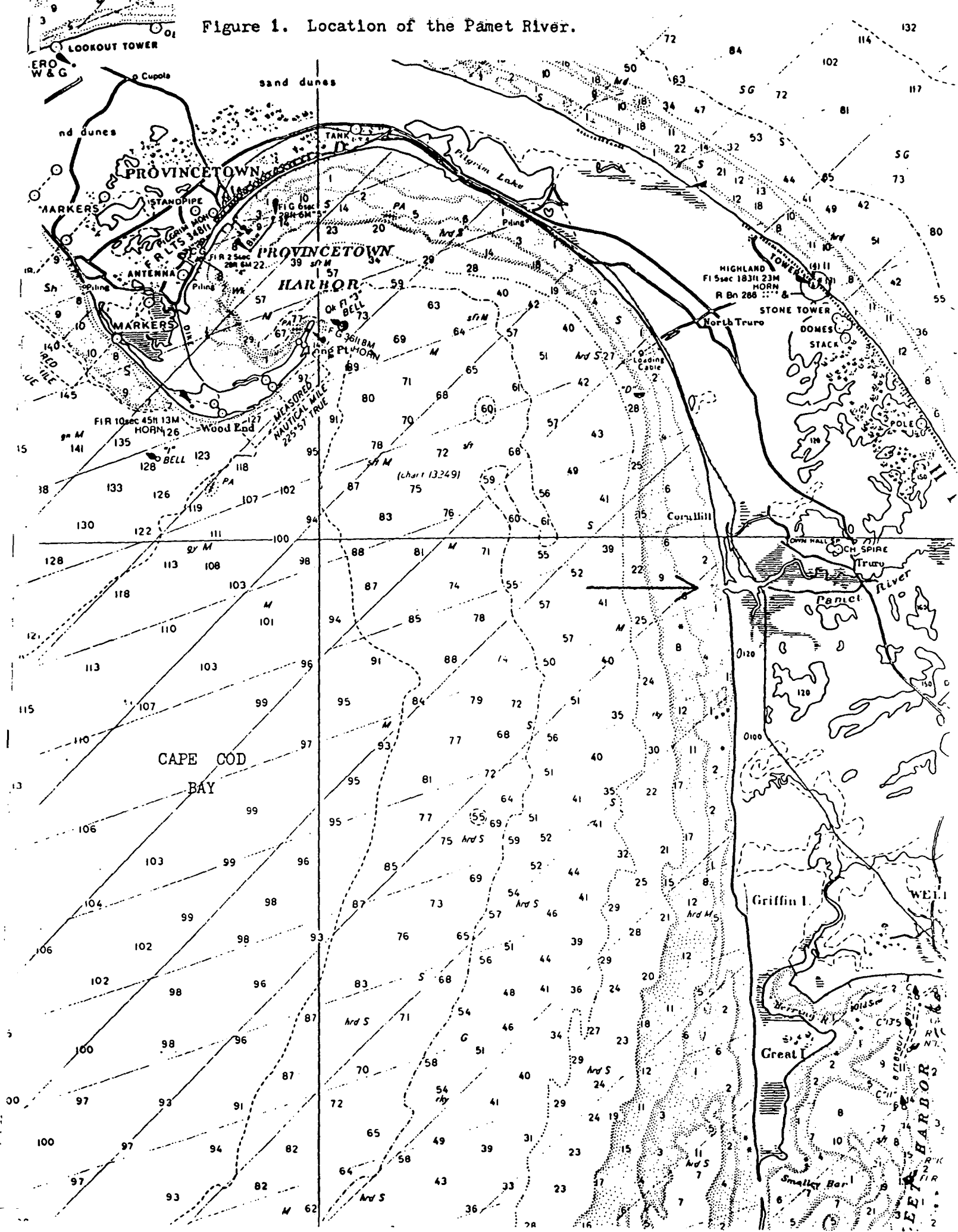
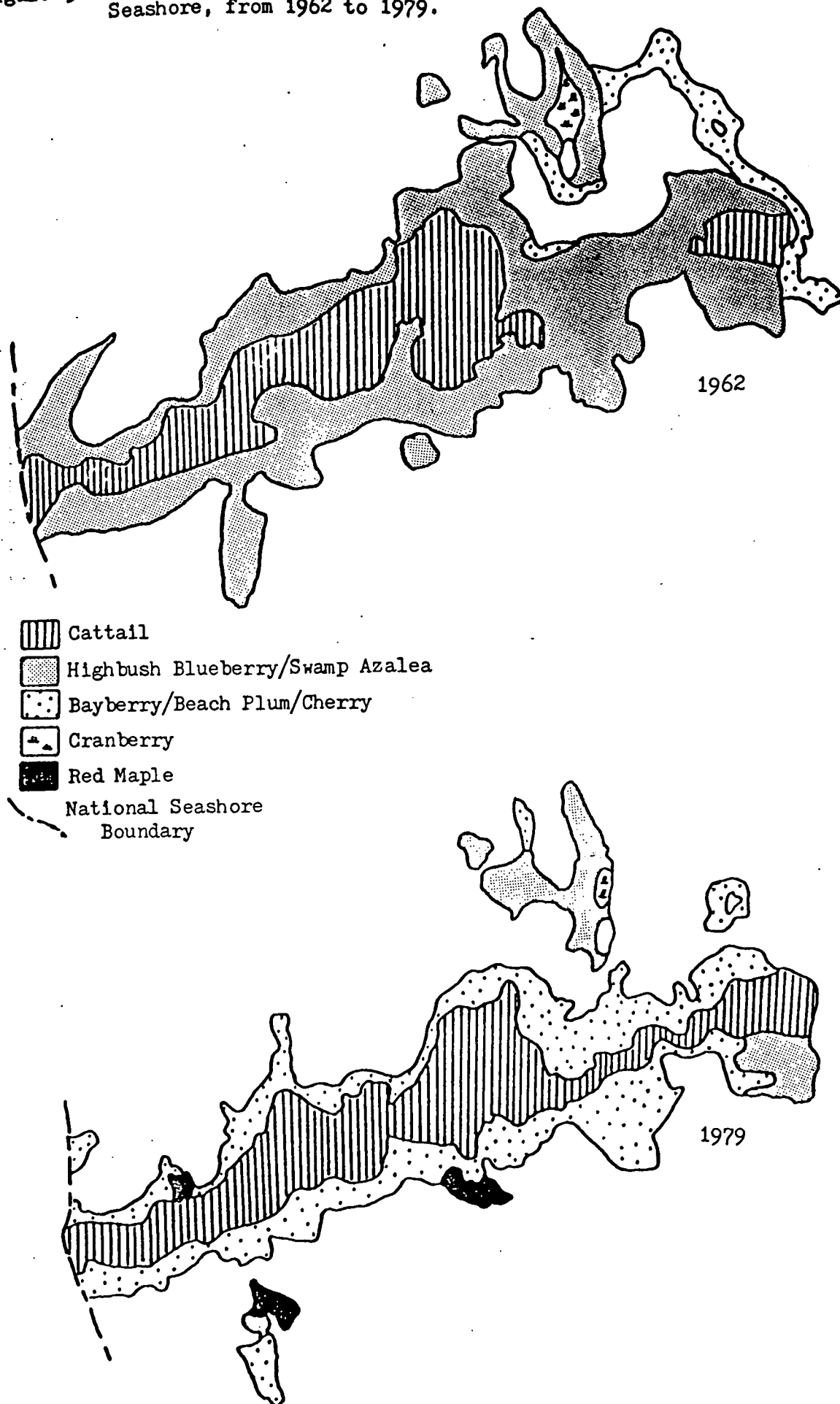
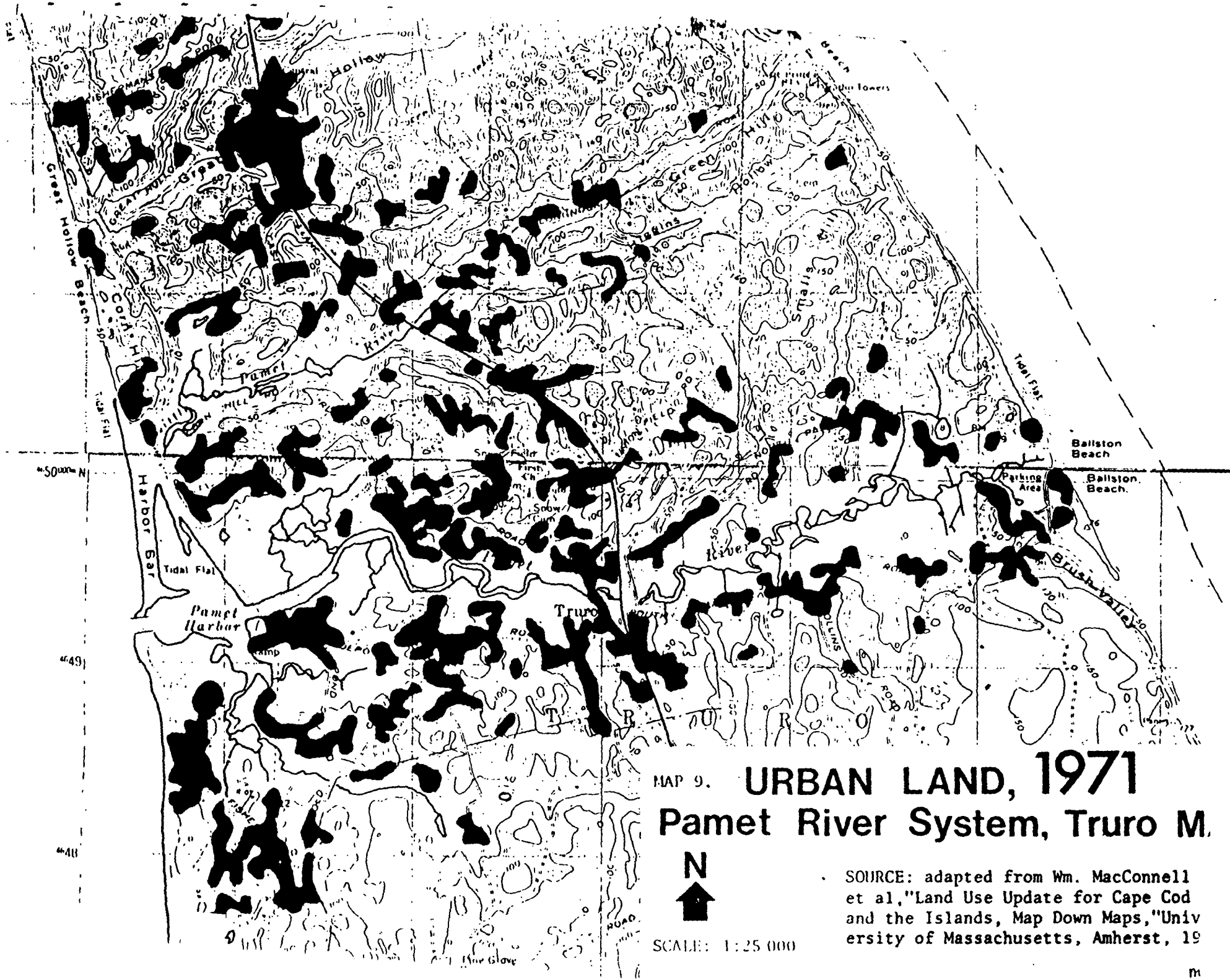


Figure 3. Succession of vegetation in the Great Pamet within the National Seashore, from 1962 to 1979.



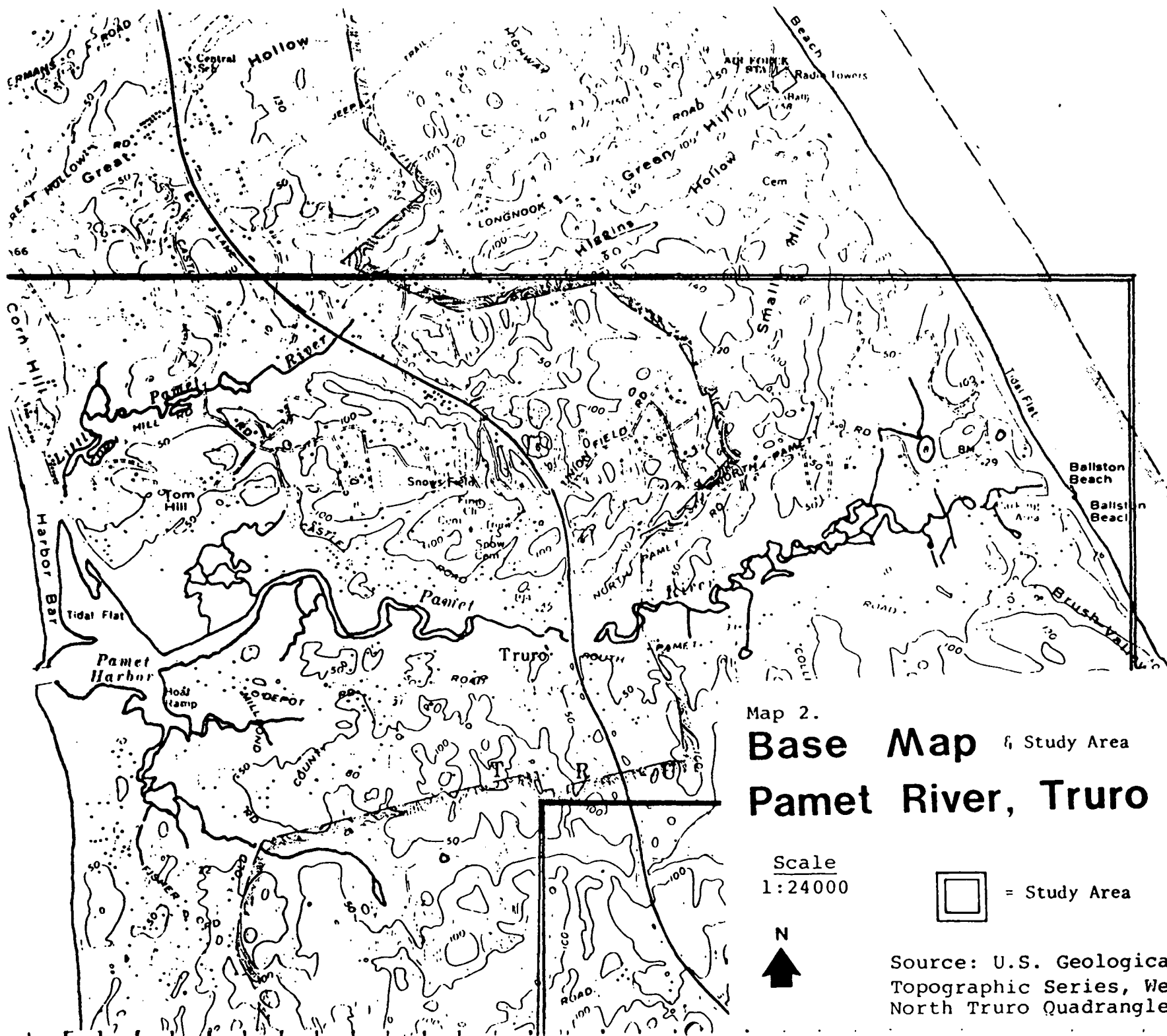


MAP 9. URBAN LAND, 1971
Pamet River System, Truro M.



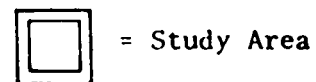
SCALE: 1:25 000

SOURCE: adapted from Wm. MacConnell et al., "Land Use Update for Cape Cod and the Islands, Map Down Maps," University of Massachusetts, Amherst, 1971



Map 2.
Base Map of Study Area
Pamet River, Truro MA

Scale
1:24000



Source: U.S. Geological Survey,
Topographic Series, Wellfleet &
North Truro Quadrangles, 1972.

