

Cultural, environmental and historical controls of vegetation patterns and the modern conservation setting on the island of Martha's Vineyard, USA

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Abstract

Aim Long-term studies of landscape dynamics in relationship to changes in cultural, environmental and disturbance factors have great potential for increasing the understanding of modern ecological conditions and improving the development of conservation plans that incorporate historically important processes. In this study we compiled archaeological, historical, palaeoecological and ecological information on Martha's Vineyard to investigate temporal and spatial variation in landscape pattern and process. Although < 250 km², this island off the Massachusetts coast embraces remarkable geographical variation and harbours uncommon plant and animal assemblages that make it a national priority for conservation.

Location The study embraces the entire island of Martha's Vineyard, which lies *c.* 8 km south of Cape Cod and the mainland of Massachusetts. The triangular-shaped island contains three major geomorphological regions: *moraine* forms a series of irregular and subparallel ridges and hills 40 to over 80 m in elevation that terminate at the western end of the island in high cliffs at Gay Head and Squibnocket; sandy glacial *outwash overlying moraine* spreads down the northeastern end of the island forming a region of low undulating hills and shallow depressions 15–30 m in elevation, and an extensive *outwash plain* stretches across the central and eastern part of the island and slopes gently from 30-m elevation in the north to < 3 m towards the southern coast where it is dissected by a series of north–south trending valleys that terminate in coastal ponds. In all areas except the southwest corner the island is underlain by >100 m of Quaternary and coastal plain sediments.

Methods Long-term records of vegetation, fire, natural disturbance and human activity were compiled over the past 2000 years and across the physiographic variation on the island. Palaeoecological interpretations of vegetation, fire, climate and land-use history are based on a series of eleven stratigraphies from ponds, lakes and wetlands; archaeological data were compiled from recent surveys; historical data were assembled from census and town records, fire records, aerial photographs and cartographic series; and ecological information was derived from forestry and conservation surveys and field sampling of vegetation, soils and site characteristics. Extensive use was made of geographical information systems and multivariate statistical analyses.

Results Spatial patterns in vegetation over the past 2000 years have varied strongly with soils and physiography, which are also associated with major differences in fire and land-use history. Mesic hardwood forests that seldom burned occupy the western moraine, open oak-pine and hardwood forests occur on the frequently burned and dissected outwash plain along the south coast, and pine-oak forests cover the central outwash plain, which extends across much of the island and displays among the highest charcoal values in New England. Although a relatively large Native American population may have been an important source of fire ignitions there is no palynological

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or archaeological evidence that this culture cleared substantial areas or directly altered the extent of forest cover. Shifts in forest composition and fire were associated with regional climate change during the pre-European period, whereas pronounced changes in forest cover and the development of extensive open-land areas of grassland, shrubland and heathland were driven by European land use.

The contrasting characteristics, land-use histories and ownerships of different regions of the island yield contrasting conservation priorities and management directions. The mesic morainal forests have changed modestly in composition during the historical period and can effectively support a distinct woodland flora if adequately protected. The large outwash plain is broken by non-native plantations but could yield an effective landscape mosaic of oak and pine forests interrupted by extensive scrub oak barrens that could be maintained through prescribed fire or cutting. In contrast, the south shore grasslands and shrublands are the product of intensive agricultural land use. These habitats and their unusual suite of plants and animals require traditional land-use practices, or their substitutes, in order to reverse the ongoing increase in woody species and to maintain these cultural landscapes.

Main Conclusion The biotic, edaphic, disturbance and historical diversity across this relatively small landscape is remarkable and yet poses many challenges to interpretation and conservation. The modern landscape can only be understood through knowledge of its long-term past and can be best managed in the context of the natural and cultural factors that have shaped it through time.

Keywords

New England, land-use history, natural disturbance, fire, conservation, pine, oak, grassland, cultural landscape.

INTRODUCTION

In all landscapes the pattern of vegetation and the distribution of dominant species are determined by interactions among soils, natural disturbance processes, human land-use and lags in vegetation responses to historical events (Grimm, 1984; Foster *et al.*, 2003). Investigations of the relative importance of these factors and the manner in which they have interacted and changed through time are critical for interpreting current ecological patterns as well as developing effective conservation and management strategies (Motzkin *et al.*, 1999; Landres *et al.*, 1999; Swetnam *et al.*, 1999). For many reasons it is likely that relationships between factors such as vegetation, disturbance and soils, which vary spatially across landscapes, may change through time as the climate or cultural environment change. However, it is seldom possible to decipher the underlying causes of landscape patterns because of an inability to sample vegetation, disturbance and environmental processes in a consistent fashion over the many hundreds of years necessary to evaluate them effectively.

Palaeoecology and related historical approaches provide among the best means for developing the temporal and spatial record required for such analyses (cf. Brubaker, 1975; McLachlan *et al.*, 2000; Parshall *et al.*, 2003). Over the many hundreds or thousands of years that can be reconstructed from sedimentary, archaeological and historical records it may be possible to characterize disturbance regimes and to

evaluate the type and rate of biotic responses generated by changes in disturbance, cultural activities and climate. The application of these approaches to a suite of vegetation and landscape features provides major insights into geographical and ecological patterns and processes (Brubaker, 1975; Grimm, 1981; Parshall *et al.*, 2002). When these studies are combined with the richness of temporal information that links the pre-historical and historical past with modern conditions, results may move from a level of general ecological interest to one having direct bearing on the interpretation and management of important conservation landscapes (McLachlan *et al.*, 2000; Motzkin & Foster, 2002).

The present study addresses ecological and conservation objectives by examining long-term variation in landscape pattern and processes for the island of Martha's Vineyard, located off the coast of Massachusetts (Fig. 1). The island supports many unusual plant and animal assemblages that are threatened by development and are a focal point of local to national conservation and restoration activity [Massachusetts Natural Heritage and Endangered Species Program (MNHESP), 2001; Goldstein 1997]. The Vineyard landmass is highly varied in geomorphology, soils and topography and, although broadly covered with Pitch pine-oak vegetation (Westveld, 1956), supports considerable variation in vegetation composition and structure. The area has experienced a wide range of disturbances including severe windstorms, fire and agricultural land use and has been identified as a likely location of intense pre-historical modification by

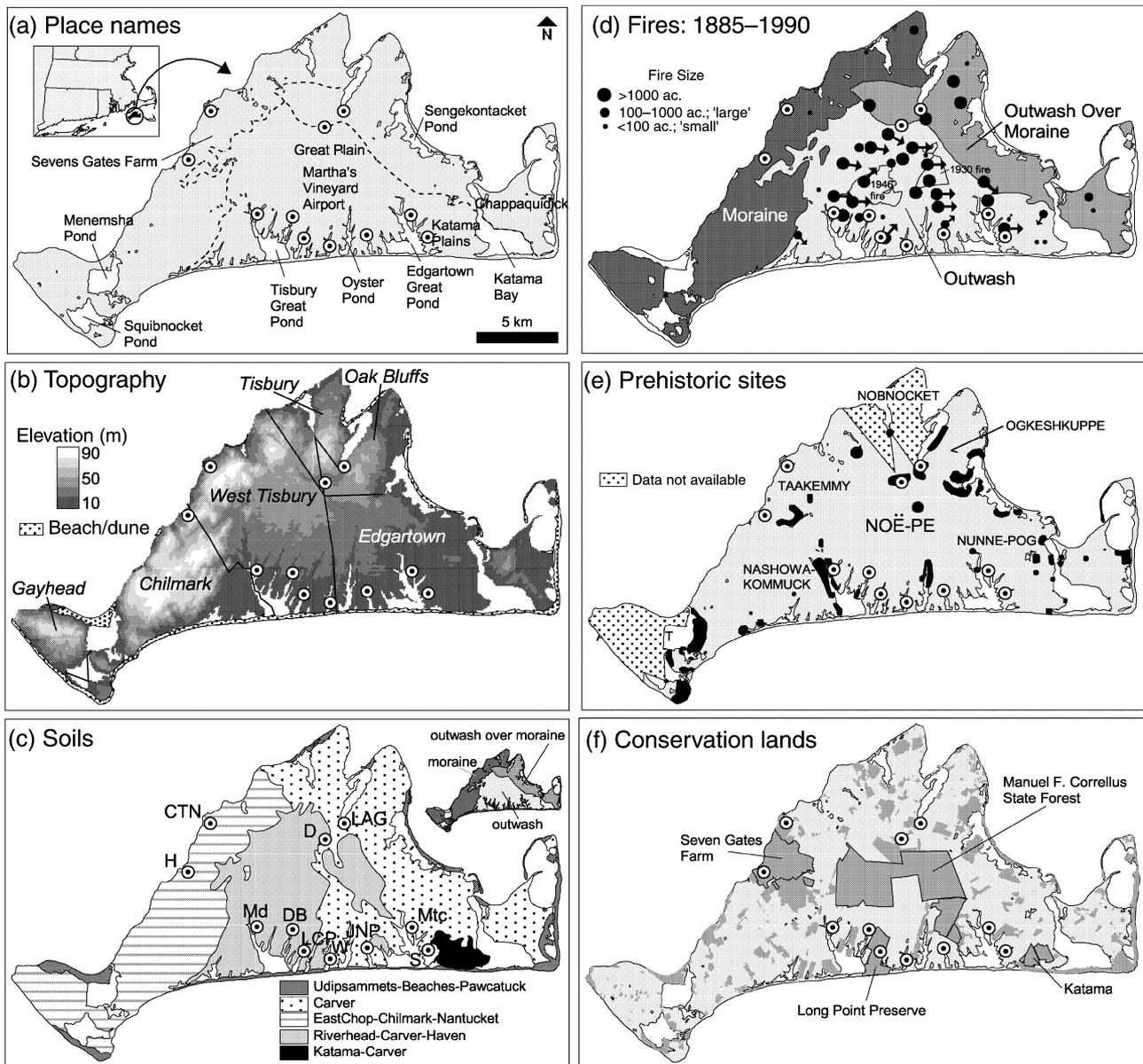


Figure 1 Geographical, political and historical characteristics and pollen sampling sites (dots) on the island of Martha's Vineyard (see inset map showing the location relative to the southern New England mainland): (a) major place names referred to in the text; (b) topography and town divisions; (c) general soils map after Fletcher & Roffinoli (1986) depicting the locations of coring sites: H, Harlock Pond; CTN, Cedar Tree Neck Bog; D, Duarte Pond; LAG, Lagoon Pond; S, Slough Cove; Mtc, Mashacket Cove; JNP, Jobs Neck Pond; W, Watcha Pond; LCP, Long Cove Pond; DB, Deep Bottom Cove; Md, Muddy Cove; (d) major surficial geological divisions (moraine, northern outwash over moraine and southern outwash) and fires during the historical period depicting three size classes, direction of fire movement (arrow) for a limited number of fires, and the outline of the 1930 and 1946 fires, which were mapped from aerial photographs (Foster & Motzkin 2000) and which ignited in the southwest and burned to the north and east to form triangular-shaped areas; (e) location of known archaeological sites (black areas) from the Middle (2000–1000 BP) and Late (1000 BP to European contact) Woodland periods (Mulholland *et al.*, 1998, 1999; Herbster & Cherau 2000). Place names for the island and subregions, which may correspond to Indian regions or sachemships, are from Banks (1911); and (f) conservation land (dark; i.e. protected from development for conservation purposes) and the location of major conservation properties discussed in the text.

Native burning, agriculture and land clearing (Cronon, 1983; Vickery & Dunwiddie, 1997; but see Motzkin & Foster 2002). Consequently there is need to separate temporal and geographical variation in environmental, cultural

and disturbance processes in order to understand and conserve important elements of the modern landscape.

In particular, we are interested in addressing a series of general and specific questions. Broadly we seek to know:

What are the patterns of soils, geomorphology, Native American activity and natural disturbance including fire and wind, and how do these relate to pre-historical and modern vegetation patterns? And, what is the influence of dramatically changing human land-use patterns on these relationships and on processes such as fire? Specific questions concern conservation priorities, notably the mesic forests, scrub-oak shrublands and sandplain grasslands that account for many of the distinctive and uncommon plant and animal assemblages on the island. How long have these vegetation assemblages existed? How have their abundance and characteristics changed through time? And, what natural and human factors are closely associated with their long-term dynamics and distribution? Based on answers to these questions it may be possible to craft approaches to the conservation or restoration of these distinctive assemblages that conform to their long-term history.

In order to address these questions we assembled archaeological, palaeoecological, historical and geographical information at an island-wide level and analysed the last two millennia of vegetation, human activity and disturbance dynamics.

STUDY AREA

Physiography

Lying 8 km south of the Cape Cod mainland, the 22,260-ha island of Martha's Vineyard comprises the largest landmass in Dukes County, Massachusetts (Fig. 1). The triangular-shaped island contains three major geomorphological regions (Fig. 1a,b). The *moraine* is formed of a series of irregular and subparallel ridges and hills 40 to over 80 m in elevation that terminate at the western end of the island in high cliffs at Gay Head and Squibnocket. This region consists of folded and faulted Pleistocene materials, coastal-plain silts, sands and clays from the Gay Head moraine, and sands and gravels from the Martha's Vineyard terminal moraine (Fletcher & Roffinoli, 1986). Sandy glacial *outwash overlying moraine* spreads down the north-eastern end of the island forming a region of low undulating hills and shallow depressions 15–30 m in elevation. An extensive *outwash plain* stretches across the central and eastern part of the island and slopes gently from 30-m elevation in the north to < 3 m towards the southern coast where it is dissected by a series of north–south trending valleys that terminate in coastal ponds. Especially to the east and south the shoreline is fringed with barrier beaches and dunes. In all areas except the southwest corner the island is underlain by more than 100 m of Quaternary and coastal plain sediments (Fletcher & Roffinoli, 1986).

Soils vary in subtle ways in accordance to this geomorphological template and exert a strong influence over vegetation and ecological processes as well as the history of land use and land cover (Fig. 1c). Deep and excessively drained loamy coarse sands of the Carver series dominate much of the eastern half of the island on outwash and outwash over moraine (Fig. 1c). These soils currently support woodland or

human development and have low water capacity, rapid drainage and poor potential for agriculture or forest productivity (Fletcher & Roffinoli, 1986). In the south-eastern corner of this region the Carver soils are intermingled with well-drained sandy loams of the Katama series, which have moderate water-holding capacity, are well suited for cultivation, pasture, or hay and currently support agriculture, open conservation land or housing. The western third of the outwash plain includes Riverhead and Haven soils, sandy loams and very fine sandy loams, respectively, developed on outwash or aeolian materials. These finer soils generally occupy level to sloping terrain, have higher moisture capacity, and are better suited to agriculture than the Carver soils that predominate in the swales and valleys. Soils on the western and north-western hills are as variable and complex as the undulating glacial deposits and are comprised of three major series. Eastchop soils are excessively well drained to well-drained loamy sands formed on reworked outwash, till or ice-thrust coastal-plain deposits and are drought-prone and poor for agriculture. In contrast, Chilmark and Nantucket soils are sandy loams underlain by clays, silts and sand with moderate water-holding capacity and are well suited for cultivation, hay and pasture.

Overall, moisture availability and suitability for agriculture varies among these types in the following fashion: Nantucket + Chilmark > Riverhead > Eastchop + Katama > Carver. Consequently, physiography and soils make three distinct units: the western moraine with undulating hills and variable, but generally moist, productive soils; the gentle terrain of droughty outwash soils over moraine to the north; and the broad and level outwash plain with primarily coarse-textured, droughty, and unproductive soils overall, but somewhat finer, more productive soils in the west and extreme south-east (Fig. 1a,b,c).

Climate and hurricane history

Martha's Vineyard has a moderate coastal climate. Winter and summer temperatures average 0 °C and 20 °C, respectively, and an annual precipitation of 120 cm generates infrequent snow cover. Prevailing winds are from the northwest, trending to southwest in the summer, approximately twenty thunderstorms occur annually, and the island experiences occasionally intense tropical and winter storms. North-easters are most important in winter, have strong northerly winds, and may cause severe coastal erosion. In contrast, hurricanes centre on the growing season (July to October) and may damage broad areas. Regionally, the south-eastern coast receives the highest frequency and intensity of tropical storms in New England with fifty-eight hurricanes impacting Martha's Vineyard since 1620 (Fig. 2). Hurricanes generally trend north and east past the island and display considerable variation in wind intensity and direction, which is generally from the east to south (Boose *et al.*, 2001). Multi-decadal periods of relatively frequent hurricanes have been separated by comparable periods with few storms. The most intense storms (> F 2.0; five total) occurred more than a century ago. The greatest hurricane hit

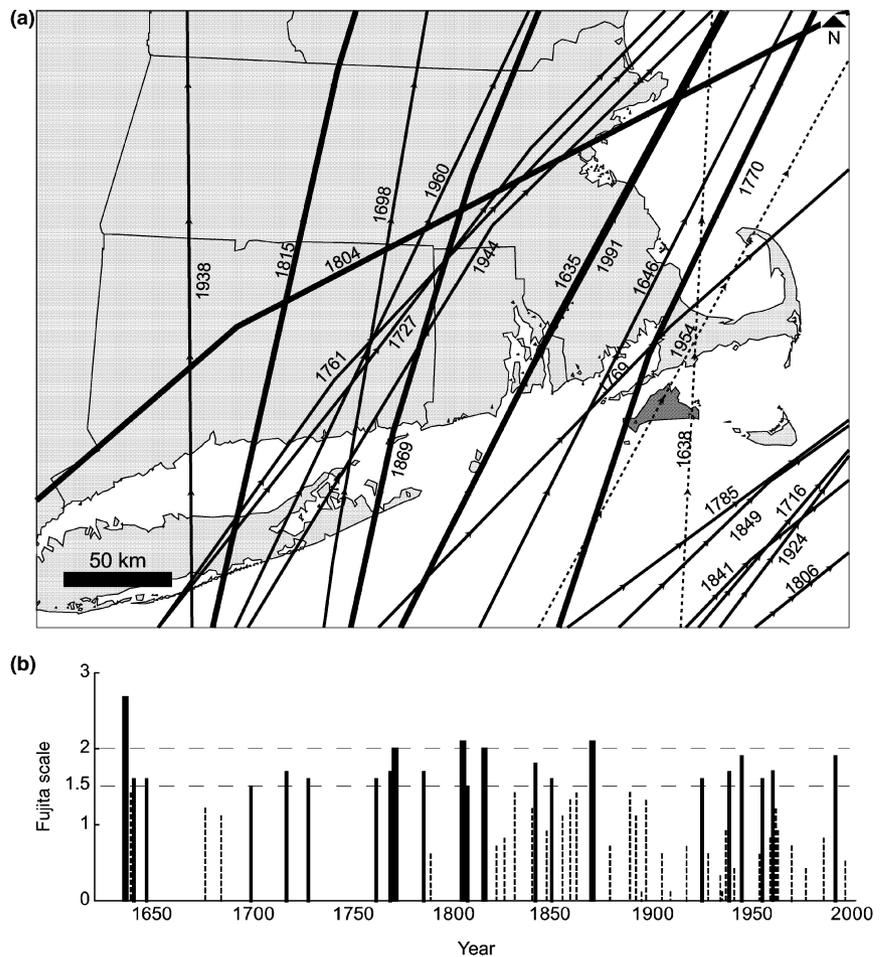


Figure 2 Tracks and timeline for hurricanes impacting Martha's Vineyard from 1635 to 2001. Storm intensity corresponds to the Fujita scale: F0, minor damage; branch break; F1, modest damage, individual or small groups of trees blown down; F2, extensive damage, large forest patches blown down; F3, severe damage; most trees on exposed sites blown down. Data and interpretation come from Boose *et al.* (2001).

shortly after European settlement in 1635 and three substantial storms (\geq F 2.0) occurred from 1770 to 1815. In contrast, lengthy periods with no storms exceeding F 1.5 occurred five times (1647–1698, 1728–1761, 1816–1841, 1870–1924, 1961–91). The major ecological effect of hurricanes and north-easters include uprooting and breakage of trees, reconfiguration of barrier beaches and shorelines, breaching of coastal ponds and salt spray damage to intolerant species.

METHODS

Palaeoecology

To assess geographical patterns in vegetation composition and dynamics across the geomorphological, edaphic, cultural and historical variability on the island the sedimentary records from eleven basins were compiled: two on the western moraine (Harlock Pond, Cedar Tree Neck Bog), two in the area of outwash over moraine (Duarte Pond, Lagoon Pond), and seven arrayed across the southern coast and outwash plain (Muddy Pond, Deep Bottom Cove, Long Cove Pond, Watcha Pond, Jobs Neck Pond,

Mashacket Cove, Slough Cove; Fig. 1c). Two of the sites are new to this study (Harlock and Duarte), whereas the others were analysed and discussed by Stevens (1996). The data for Stevens' sites were entered directly from her 1996 thesis. The basins include glacial ice-block depressions (Harlock and Duarte), one sphagnum-shrub wetland (Cedar Tree Neck Bog) and the narrow heads of coastal ponds, which are separated from the ocean by barrier beaches.

The sites were selected to collect a significant amount of local pollen from vegetation within a kilometre (Prentice, 1985; Jackson, 1990; Sugita, 1993, 1994; Jackson & Lyford, 1999). The ice-block depressions and sphagnum wetland are small (< 5 ha) basins and coring sites in the coastal ponds are either small sub-basins or the upper ends of narrow ponds that should act as small basins in terms of pollen collection (Stevens, 1996). The uppermost sediments were sampled with a polycarbonate tube (7-cm or 10-cm diameter) fitted with a piston, and deeper sediments were retrieved using a 5-cm diameter Livingstone piston corer. Cores were subsampled and the organic content determined by the percent weight loss on-ignition (LOI) at 550 °C (Bengtsson & Enell, 1986).

Sediment samples were prepared for pollen analysis following standard procedures (Faegri & Iversen, 1991), a known number of marker grains was added, and pollen was analysed at 400× magnification until 500 tree and shrub pollen grains were identified. Pollen percentages are based on a pollen sum of upland taxa, including trees, shrubs, herbs and Pteridophytes. Fossil pollen assemblages within each core were classified using the constrained incremental sum of squares method on square-root transformed pollen percentages (Grimm, 1987). This and other analyses included all upland pollen taxa that comprised more than 2% of the pollen sum for at least one sample and that are not associated with wetland habitats [e.g. black gum (*Nyssa sylvatica*), Ericaceae, sedge (*Carex*), sweet pepper bush (*Clethra*)]. This classification was used to establish objectively the onset of European land clearance and major changes in pollen throughout the record.

Past vegetation changes among sites were compared through detrended correspondence analysis (DCA) of the fossil pollen assemblages with analyses specifically focusing on: individual sites, all sites for the pre-European period or the European period, and all sites combined for both periods. Charcoal abundance was assessed using the point count method (Clark, 1982). Steven's sites were dated at Beta Analytic Laboratories (Miami) using conventional C-14 analysis of bulk samples, whereas calibrated AMS (accelerated mass spectroscopy) radiocarbon dates of homogenized sediment were determined at the NSF University of Arizona, AMS Laboratory for Harlock and Duarte Ponds. All dates were calibrated using Calib 4.3 (Stuiver *et al.*, 2002). The Pb-210 activity of sediments from Harlock and Duarte Ponds was assessed at the Harvard Forest using standard procedures to provide time control for the past 150 years (Binford, 1990). The rise in weed pollen serves to identify the initial transformation of vegetation to European agriculture approximately 325 years ago (Foster & Motzkin, 1999).

Fire

In addition to the long-term assessment of fire activity provided by the sedimentary charcoal records detailed chronologies of all known fires from 1855 to present were compiled from: Dunwiddie & Adams (1994), *Vineyard Gazette* newspaper, Massachusetts Department of Environmental Management, The Nature Conservancy (T. Chase, Pers. comm.), and Steve Vancour (Pers. comm.). These sources provide fire location, an estimate of approximate size, and, less frequently, the major direction of fire spread. From the resulting data we compiled a timeline and map of fire locations, sizes, and spread (cf. Foster & Motzkin, 1999). For purposes of cartographic display fires were categorized as: small (< 40 ha [< 100 acres]), medium (40–100 ha [100 – 1000 acres]), and large (> 400 ha [> 1000 acres]).

Land-use history

Many sources were used to characterize forest extent and agricultural land use since European settlement. The amount

of cultivated land, pasture and quantity of sheep came from tax evaluations (1775–1860), state agricultural censuses (1860–1905), and federal censuses (1925–92). Estimates of historical forest cover came from text and map sources: 1840s and 1880s – United States Coast and Geodetic Survey (1848; 1897), 1907 – State Foresters Report (Rane, 1918) and 1938 – aerial photographs delineated by Janice Stone at the University of Massachusetts at Amherst and digitized after being zoom-transferred to US Geologic Survey topographic sheets; 1951 and 1971 landcover – Massachusetts Map Down project (MacConnell *et al.*, 1991); 1985 – MassGIS (1985); 1992 – MassGIS (2001).

RESULTS

Prehistoric human activity

The abundant ethnohistoric sources and archaeological sites yield considerable insight into the distribution, subsistence patterns and potential impacts of native people on Martha's Vineyard (Ritchie, 1969; Mulholland *et al.*, 1998, 1999; Chilton, 1999, 2000; Herbster & Cherau, 2000). An empirical model of artifact distribution places the majority of prehistoric sites on well to excessively drained soils < 300 m from freshwater or 75 m from the coast (Mulholland *et al.*, 1998). Associated tools, artifacts and plant and animal remains indicate that the Middle Woodland (2000–1000 yrBp) and Late Woodland (1000 yrBp–1700 AD) period cultures were semi-sedentary, subsisting on marine and terrestrial animal and plant resources, with only modest horticulture (Bragdon, 1996; Mulholland *et al.*, 1999; Herbster & Cherau, 2000; Chilton, 2000, 2002).

The population may have associated into regional distributions with place names corresponding to known archaeological concentrations (Banks, 1911; Gookin, 1947; Cook, 1976; Mulholland *et al.*, 1998; Fig. 1e). Major centres include Lake Tashmoo, Lagoon Pond and Sengekontacket Pond in the north, Squibnocket Pond and Menemsha Pond in the south-west, Tisbury Great Pond and the head of Oyster Pond and Edgartown Great Pond on the south shore, and along Katama Bay and on Chappaquidick in the southeast (Mulholland *et al.*, 1998; Herbster & Cherau, 2000). Pollen cores derived from water bodies adjacent to archaeological sites include Lagoon Pond, Duarte Pond, Muddy Pond and Deep Bottom Pond (Fig. 1c,e). However, there are few archaeological sites near the south shore ponds, possibly because these small ponds were isolated from the sea by barrier beaches and therefore did not support the abundant shellfish, which were available in large ponds and occur in many middens (Mulholland *et al.*, 1999). During historic times residents have opened these small ponds to the sea specifically to promote saltwater incursion and shellfish production.

Maize which arrived in New England c. 1100 AD, was not widespread until 1300 AD, and is uncommon in archaeological sites (Luedtke, 1988; Bragdon, 1996; Chilton, 1999, 2000). Consequently, there is no evidence to support the popularized notion of widespread slash and burn agriculture, sizable maize fields, or large permanent villages of agricul-

turists, at least until European contact (Cronon, 1983; Denevan, 1992; Little, 1988). Indeed, the agriculture, permanent settlements and fortified villages documented in ethno-historic sources may have been induced by trading and other interactions with Europeans (Bragdon, 1996; Chilton, 1999). Thus, there is little reason to suspect that natives had the motivation or tools to clear extensive areas of forest or to maintain sizable open vegetation beyond that associated with seasonal encampments (Motzkin & Foster, 2002). Nonetheless, deer are a major faunal remain in most archaeological sites and it is plausible that fire was actively used to manipulate game habitat (cf. Day, 1953; Bragdon, 1996; E. Chilton, Pers. comm.).

European contacts occurred increasingly in the sixteenth and early seventeenth centuries and initiated major cultural changes (Ceci, 1977). Contact period population estimates for Martha's Vineyard range from 1500 (Ritchie, 1969) to 3500 people (Banks, 1911; Cook, 1976). A major disease outbreak in 1616–17 decimated populations up the New England coast and by the time of extensive historical records Indian activity was likely substantially altered from that reflected in archaeological sites (Bendremer, 1993; Bernstein, 1993; Bragdon, 1996).

Historical land-use and land-cover dynamics

Commencing in 1641 with the first permanent settlement at Edgartown much of the island except the centre of the large

outwash plain was deforested and transformed (Figs 3–5). Agriculture and maritime activities provided subsistence and economic bases and the human population concentrated on the island's margins (Fig. 3). Extensive pastures were developed on the western moraine, south shore, and Chappaquidick, separated according to ownership or land use by stone fences on the moraines and wooden or ditch fences on the outwash soils. Pastures supported diverse livestock and were grazed most heavily from 1775 to 1815 when there were up to 20,000 sheep, 3500 cattle, 400 horses and 800 pigs (Freeman, 1807; Banks, 1911; Fig. 4).

The growing population and industries, including a brickworks and whale oil factory, stressed the island wood supply. In Edgartown an ordinance in 1683 limited the taking of firewood on common land; in 1762 the island was described as holding as many inhabitants as the land could comfortably support (Banks, 1911); in 1788 residents commenced substituting peat for firewood (Banks, 1911); and by 1802 firewood was extensively imported from the mainland (Freeman, 1807). In 1848 woodland was restricted to small patches in inhabited areas and the large expanse on the central plain (Fig. 5). Sources from the eighteenth and nineteenth centuries corroborate that although the plain was never cleared of native growth that it was cut and burned repeatedly and became a broad tangle of gnarly scrub oak (*Quercus ilicifolia*, *Q. prinoides*) and sprouting tree oaks

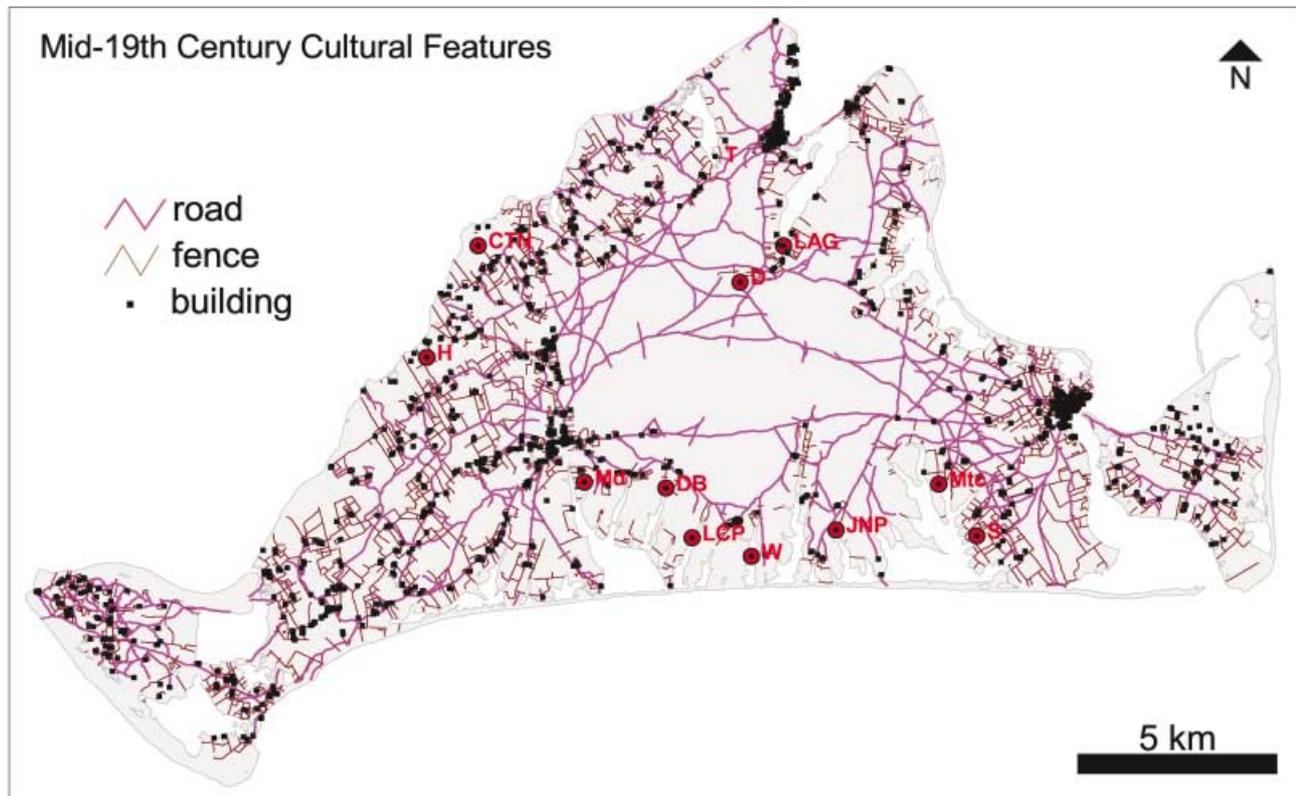


Figure 3 Map of major cultural features, including buildings, agricultural fences and roads on Martha's Vineyard in 1848, near the peak of agricultural activity. Data are from the US Coast and Geodetic Survey (1848).

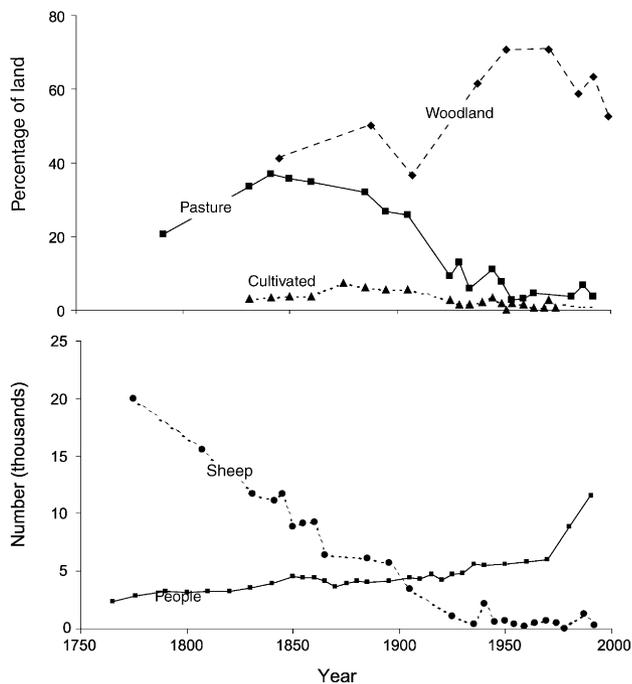


Figure 4 Historical changes in land cover and populations of sheep and humans on Martha's Vineyard showing the major decline in agricultural activity and increase in woodland cover since the mid-nineteenth century. See Methods for the sources of data.

(e.g. *Q. alba*, *Q. velutina*, *Q. stellata*; cf. Dunwiddie & Adams, 1994; Foster & Motzkin, 1999; Appendix 1).

Commencing in the late nineteenth centuries and accelerating through the early twentieth century agricultural decline and natural reforestation of pastureland paralleled a New England-wide trend (Foster *et al.*, 1998; Fig. 4). Firewood cutting also declined as industrial and home use shifted to coal. As a consequence, forests expanded in extent and stature. Between 1840 and 1880 woodland cover increased from 40% to 50% (Fig. 5). Initially, forests developed primarily on and along the western moraine as existing woodland fragments expanded onto adjacent farmland or coalesced (Fig. 5). In contrast, there was little change along the south shore or around Edgartown or Chappaquidick. The 1880 maps confirm that new forests contained large amounts of pitch pine, especially in northern and north-western areas (Fig. 5). Consequently, the vegetation in the late nineteenth century had a pronounced geographical pattern: hardwoods dominated the central, permanently wooded area on the outwash plain and in the younger forests in the southwest; mixed pine and hardwoods occurred in the north and northwest; and pine was heavily scattered in new woodlands around the exterior of the forested area. By 1950, woodlands covered 70% of the island.

Through the twentieth century there was an accelerating shift to a strongly seasonal tourism economy, a boom in house construction, reduction in forest cover (to 55%), and

growing interest in land protection and conservation of unusual species and habitats. Conservation land currently covers 18% of the island and is owned and managed principally by state agencies, regional conservation organizations and private individuals. Notable tracts of protected land occupy the outwash plain (Manuel Correllus State Forest), the western moraine (Seven Gates Farm), and the southern coast (Long Point Reserve; Fig. 1). The modern landscape is forested but interrupted by towns, housing and other development, especially on the east and northern sides. Extensive open-land habitat (i.e. grasslands and shrublands) is restricted to the southern shore, barrier beaches, the margins of coastal ponds, and agricultural land and airfields. Some of the largest scrub-oak dominated shrublands in the north-eastern US occupy long and narrow north-south depressions on the central outwash plains (Foster & Motzkin, 1999).

Geographical and historical variation in the fire regime

Based on stratigraphic charcoal and historical records Martha's Vineyard has experienced an active fire history in which striking patterns of temporal and spatial variability have been controlled by geographical, biotic, and cultural factors. From the earliest palaeoecological record, Martha's Vineyard has experienced many fires (Figs 6–8 & 1d). Over the past 115 years of good historical information more than twenty fires exceeded 400 ha in area and at least nine covered more than 2000 ha (Table 1; Fig. 1d). During this brief period fires exhibited pronounced seasonal and longer trends. More than 90% of burns occurred in spring (late March to June), although two 4000-ha fires burned in July. No substantial fires occurred before March, and only four burned after October. Temporally, there is a long-term trend of declining fire size: since the late 1940s only one exceeded 600 ha and since 1965, none has reached 40 ha.

The geomorphological, vegetational and meteorological setting controls broad-scale fire patterns. With prevailing spring and summer winds from the southwest to west and strong on-shore breezes near the coast, fires tend to move inland and to the north and eastern sides of the island (Foster & Motzkin, 1999; Fig. 1d). Physiography reinforces and adds complexity to this pattern. The western moraine is dissected by hills, hollows, ponds and streams that provide local fire breaks and pockets of finer soils that support mesic, less flammable vegetation than the sandier regions of the island. Because of these characteristics, the protection afforded by the ocean to the west, and prevailing winds, the moraine is least prone to fire, and has not experienced any large burns historically. The palaeoecological record corroborates this interpretation and indicates that fire activity has always been low at Harlock Pond and Cedar Tree Neck Bog (Fig. 10). Similarly, Muddy Cove stands out among south coastal sites in having low charcoal values similar to the morainal sites. Muddy Cove is closest to the moraine among coastal ponds, is situated in an extensive area of Riverhead soils that supported relatively mesic vegetation (see below), and is somewhat sheltered from fire by a stream, valley, and

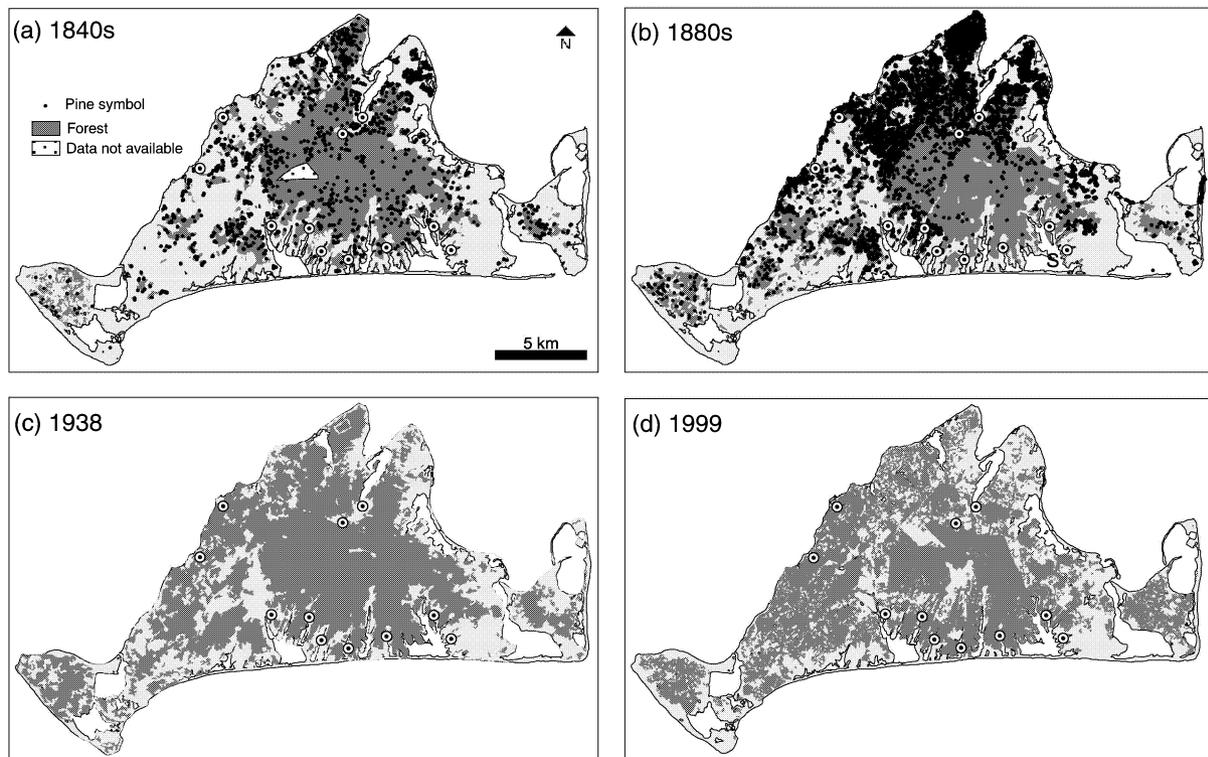


Figure 5 Historical changes in forest cover and open areas on Martha's Vineyard. Data derived from the US Coast and Geodetic Survey (1848–1885), interpretation of 1938 aerial photographs, and MRLC-1992. Black dots indicating locations of pine trees are only available for the nineteenth century maps.

pond to the west and north. These factors led to a reduced importance of fire during pre-settlement times.

Across the drier and flatter outwash plain two distinct patterns of fire occurrence are recorded in lake sediments and the historical record. The northern sites (Duarte and Lagoon Pond) have extremely high charcoal values with relatively little change from pre-European to historical times (Fig. 10). In contrast, the south coastal sites exhibit high to moderate values during pre-European times that decline to c. 50% after European settlement. These sites exhibit one of the largest and most consistent declines in charcoal with European settlement in New England (Patterson & Backman, 1988a,b; Stevens, 1996; Parshall & Foster 2002).

Differences in fire history between these two areas can be explained by geography, human activity and vegetation history. With fires sweeping to the east and north, the dissected landscape, geographical location, on-shore winds and narrow stretches of continuous land along the south shore shelter the south coastal ponds from many fires. Conversely, Duarte and Lagoon Ponds are fully exposed to fires sweeping northeast with prevailing winds across the plain expanse. The north coastal ponds supported greater pre-European human habitation than the south coast, which may have further increased the incidence of fire. Over the last 300 years differences in land use and land cover caused these two areas to diverge further in fire activity. Whereas the necks of land between south coastal ponds were cleared of

woodland, intensively grazed, and lightly plowed for pasture improvement and crops, much of the area around Duarte and Lagoon Ponds and stretching for miles to the south remained in highly flammable scrub oak and woodland vegetation (Fig. 5; Foster & Motzkin, 1999; Raleigh, 2000). Consequently, whereas fuel loadings around coastal ponds were cropped low, in the north they remained high. This land-cover shift was associated with greatly decreasing values for charcoal in the south and only modest change in the north (Fig. 10). Historical data confirm a lower incidence of fire along the south coast and its narrow necks of land and underscore the tendency for fires to move north and east across the plain (Table 1; Figs 1c & 1d).

Long-term vegetation dynamics

Island-wide, the pre-European vegetation was wooded and comprised fairly distinct compositional groups corresponding to the three physiographic regions: moraine, northern outwash over moraine, and outwash plain. Long pollen records confirm that although geographical differences in vegetation persisted, the composition in each region changed substantially on centennial time-scales. Following European settlement compositional variation in vegetation decreased.

Broad-scale and long-term vegetation changes are well summarized by the DCA of all sites (Figs 7 & 8). During pre-European times the morainal sites are distinguished by

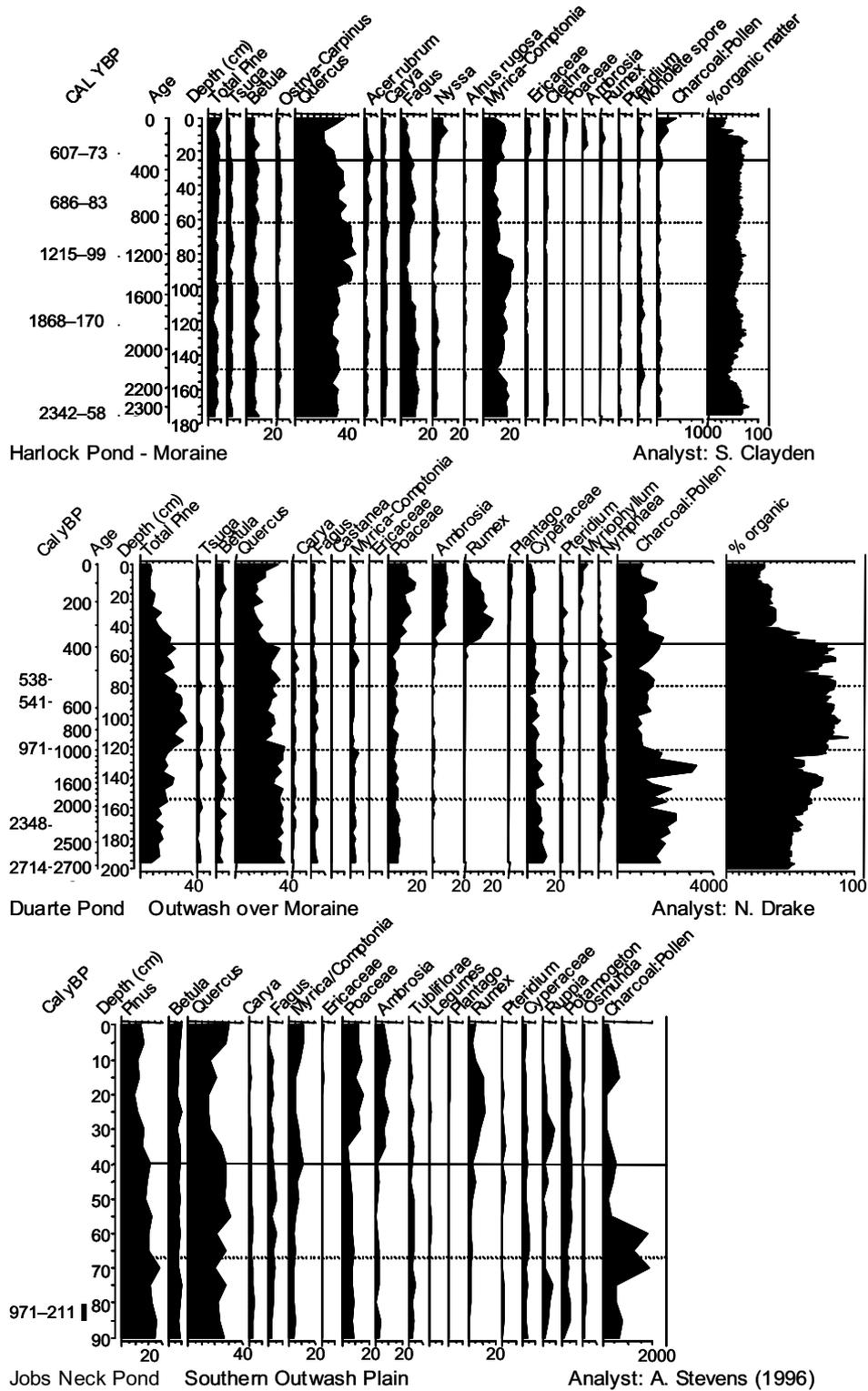


Figure 6 Representative pollen diagrams from the moraine (Harlock Pond), the northern outwash (Duarte Pond) and the southern coastal area (Jobs Neck Pond). Data from Jobs Neck Pond are from Stevens (1996).

high percentages of beech, oak, birch and hickory, the northern outwash/moraine sites by higher pine, and the south shore outwash by intermediate levels of oak, hickory, birch, pine and lesser amounts of beech and grass (cf. Fig. 9). In the European period the variation is reduced as all sites exhibit a pronounced decline in tree pollen and increase in grass, ragweed and sorrel. Northern and southern sites become more tightly grouped and are joined by Cedar Tree Bog. Harlock Pond exhibits the least amount of change and becomes an outlier. Conversely Muddy Cove becomes an outlier as it exhibits substantial increases in open-land taxa.

Western moraine (Harlock Pond and Cedar Tree Neck Bog)

Morainal sites, in undulating terrain with a low fire frequency and pockets of fine-grained soils, supported distinct, mesic broad-leafed forests. Before European settlement oak (c. 30%) and beech (10%) were dominant with lesser amounts of red maple, black gum, hickory and hop hornbeam. Pine and open-land taxa (e.g. grass, bracken fern, weed taxa) were at the lowest of any sites. At Harlock Pond the period from 2400 to 1540 yrBp exhibits little change, but c. 1500 yrBp apparently drier conditions prevail as beech, red maple, and black gum decline and oak increases abruptly to 40–45%. By 1000 yrBp, diverse and mesic forest had developed. With European settlement the vegetation changed less dramatically than elsewhere. Weeds and grass pollen increased to 5 or 10% and then declined to the present. Tree pollen declined and then rebounded as oak became increasingly dominant. Overall, the forests became

less diverse since the seventeenth century. Local impacts of land use, including clearing, sheep grazing and water table modification are seen in the substantial increases in inorganic sediments and bordering vegetation of sweet pepperbush, Ericaceae, and black gum at Harlock Pond.

South shore outwash

In comparison with the moraine the pre-European vegetation is less mesic, has more pine and has a more open structure. Oak is consistently less abundant (20%), pine ranges from 15% to 25%, hickory and beech are less than 5% and aquatic, wetland, or upland herbs (ditch-grass, sedge, Tubuliflorae, grass) range above 2–5%. Among these, grass consistently exceeds 5% and reaches 10% at some sites. Although the cores are short and not well-dated, the pre-European vegetation change appears to be minimal (Stevens, 1996). Western sites (Muddy Cove and Deep Bottom Cove) are intermediate in vegetation between that of other south shore sites and morainal sites as oak, beech and black gum are relatively higher, pine is low, and herb and grass values are low. After European settlement the southern vegetation underwent modest to major changes as weeds and grass pollen increased and oak declined.

Northern outwash over moraine

The immediate pre-European vegetation at the northern sites was characterized by abundant pine (20–35%) and oak (25–35%) and low amounts of other arboreal taxa except hickory (3–5%). However, in the long record from Duarte

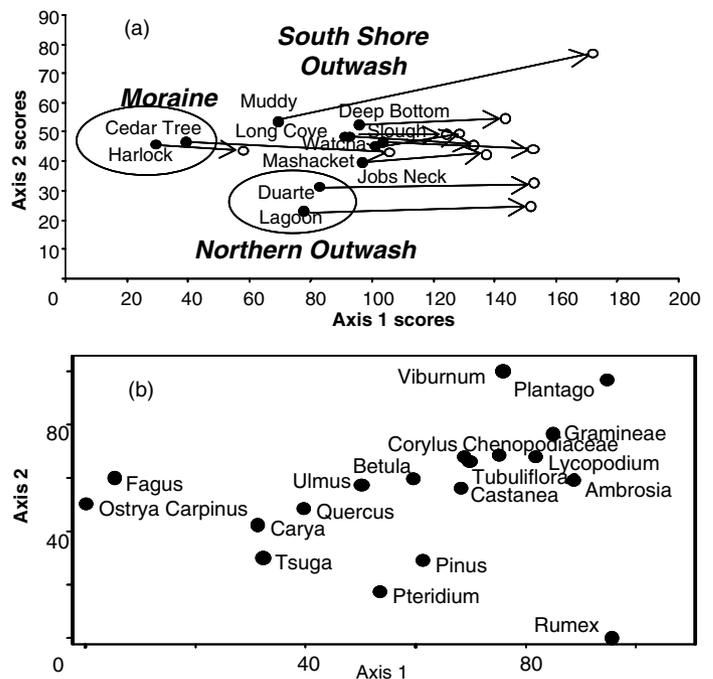


Figure 7 Detrended Correspondence Analysis (DCA) of the pre- and post-European settlement period pollen data from all eleven palaeoecological sites on Martha's Vineyard displayed on the first two DCA axes. (a) The centroids of samples for each site for the pre-European period (filled circles) and European period (open circles). Sites come from the moraine, northern outwash and southern outwash regions (see Fig. 1). (b) The distribution of major taxa used in the analysis.

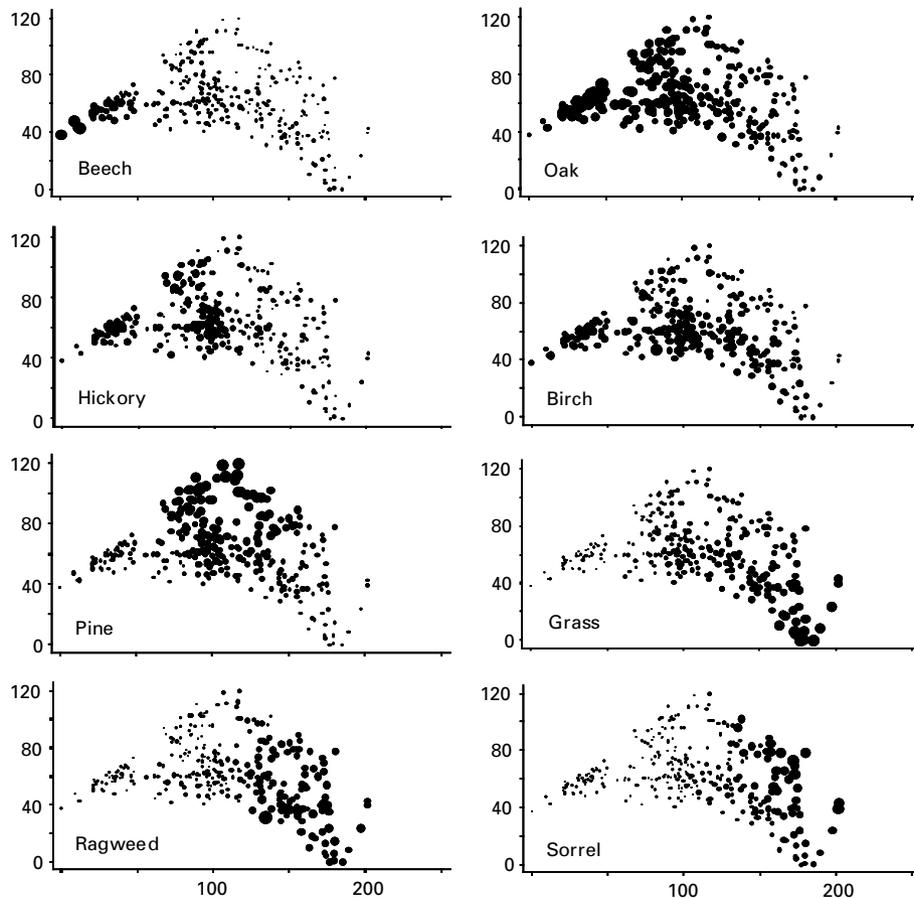


Figure 8 The abundance of major taxa in all pre-European and historical samples from all palaeoecological sites, corresponding to the analysis depicted in Fig. 7.

Pond major shifts occurred in the relative abundance of tree, wetland and herb taxa. High oak (35–38%), low pine (15–20%), and relatively high sweet gale and Tubuliflorae (not shown) characterized the period from *c.* 2700–1000 yrBp. Since then and through initial European settlement pine increased and oak, sweet gale and Tubuliflorae declined. After European settlement the vegetation changed dramatically as logging and clearing led to major declines in oak and pine and increases in sorrel, ragweed and grass to 10–20%. In the recent past oak returned to approximately pre-settlement values, herbs declined, and pine increased at Lagoon Pond.

DISCUSSION

Landscape-scale controls on ecological processes and the emergence of the modern setting for conservation on Martha's Vineyard

Despite its limited area Martha's Vineyard embraces remarkable geographical, biological and cultural variation, which, in turn, create highly varied imperatives for conserva-

tion. In physical setting, the land ranges from rolling hills and expanses of sandy outwash to coastal dunes, ponds and salt marshes. Culturally, the landscape is equally varied as pre-historical activity and sites were unevenly distributed and modern villages and development activity contrast sharply in appearance and history. The interaction among physical, biological and cultural factors gives rise to a highly varied conservation setting in which contrasting objectives range from the protection of threatened populations on fragmented habitats to the restoration of landscape-level variation in species-poor vegetation types and from the maintenance of cultural landscapes to the desire to promote natural patterns and processes.

The long-term perspective on landscape development affords insights into the background and emergence of ecological areas of contrasting conservation focus and ownership. The western moraine, with its rolling terrain includes one large private conservation area (Seven Gates Farm) that harbours extensive and maturing mesic forests supporting a relatively rich assemblage of plants that are uncommon elsewhere on the island. The central plain, including the publicly owned Manuel F. Correllus State Forest, supports one of the largest expanses of scrub oak barrens and oak-pine forest in

Table 1 Major fires on Martha's Vineyard from 1855 to 1990. Data compiled from the Vineyard Gazette (VG) newspaper, DEM (1994a,b), and unpublished data of Tom Chase (TC) and Steve VanCour (SV) as modified from Dunwiddie & Adams (1994). Fires < 100 acres are generally excluded prior to 1950. After 1950, all fires > 20 acres are listed

Year	Date	Size (ac.)	Location – landform
1855	4/6	large	Willis Plain (Great Plains) (SV) – outwash
1867	4/26	4000	Near Lagoon (SV)
1875	7/9	7–10,000	Quompacha Bottom (SV) – outwash
1883	8/11		Vineyard Haven town fire – moraine
1885	4/3	small	Gay Head-Chilmark boundary – moraine
1886	5/2	1000 s	Near Vineyard Haven, West Tisbury
1889	3/24	4000	Quampeche Bottom – outwash
1892	4/8	5–8000	Near Middletown (VG), Lagoon Heights (SV)
1894	June	large	Location unknown (Gross, 1928; DEM, 1994b)
1900	4/26	5000	Scrubby Neck toward Edgartown – outwash (DEM, 1994b)
1906	5/17		Innisfail Hotel (Oklahoma) burns in forest fire
1909	7/22	10000	On Plains (DEM, 1994b)
1914	12/24	1200	Western Great Plains to Katama – outwash
1916	5/18	12000	W. Tisbury to Farm Neck, Ocean Heights, and Edgartown – outwash
1920	8/5		Large Vineyard Haven fire
1926	5/13	6400	West Tisbury toward Ocean Heights – outwash
1927	4/29	6400	From Dr Fisher Road to Edgartown – outwash
1927	5/23	6400	From Dr Fisher Road toward Edgartown – outwash
1928	4/27	small	Indian Hill Road – moraine
1929	4/5	2500	Watcha to Tiah's Cove, Waldron's Bottom, to Oyster Pond – outwash
1929	5/3	2560	Waldron's Bottom – outwash
1929	7/2	small	Tashmoo/Herring Cr. – moraine
1930	5/9	200	West Chop – moraine
1930	5/16	5000	Between Edgartown and Oak Bluffs – outwash
1930	6/6	1000	N-NE through State Forest – outwash
1932			Two fires in State Forest (DEM, 1994a)
1935	3/29	4000	Edgartown Great Pond to Katama – outwash
1936			Eight Fires, none in State Forest (DEM, 1994a)
1937			Chappaquidick (DEM, 1994a)
1939	3/31	4000	Quampacha Bottom on Dr Fisher Road to VH Road (TC) – outwash
1940	5/17	>1000	State Forest near Edg. – VH Road. – outwash
1942	5/26	350	Job's Neck Pond to Jayne's Cove, G. Flynn – outwash
1942		1200	Near Edgartown Great Pond (DEM, 1994b)
1944		240	In MFCSF (DEM, 1994b)
1946	4/19	5120	Head of Tisbury Great Pond towards Edg./OB – outwash
1948	9/3	300	South & West towards Clevelandtown/ Edg. Airport – outwash
1951			10 fires on the Island (DEM, 1994b)
1954	4/9	1000	Between Barnes Road, Wing Road and Edgartown VH Road. – outwash
1954	5/29	2500	Tiah's Cove, WT to Edgartown – outwash
1954	7/16	100	Chappaquidick near four corners – eastern moraine
1957	4/19	35	Near State Hwy at Deep Bottom – outwash
1957	5/3	100	North of Chilmark cemetery, toward Chilmark Pond – western moraine
1958	6/13		East and north from State Forest – outwash
1959	4/24	25	Between Old Courthouse Road and State Highway – outwash
1959	5/8	500	West Tisbury Road near Deep Bottom – outwash
1960	4/22	25	Katama – outwash
1963	10/25	300	Quampacha Bottom to WT Road – outwash
1965	12/18	1200	Great Plains to Katama (TC) – outwash
1971	5/14	20	Oklahoma, Tisbury
1975	4/25	50	NE from Edgartown dump
1976	12/31	85	Edgartown: Herring Cr. Road. Katama Airfld – outwash
1987	7/31	20	Oak Bluffs behind Crosslands Nursery (TC) – outwash
1987	July	~8	State Forest

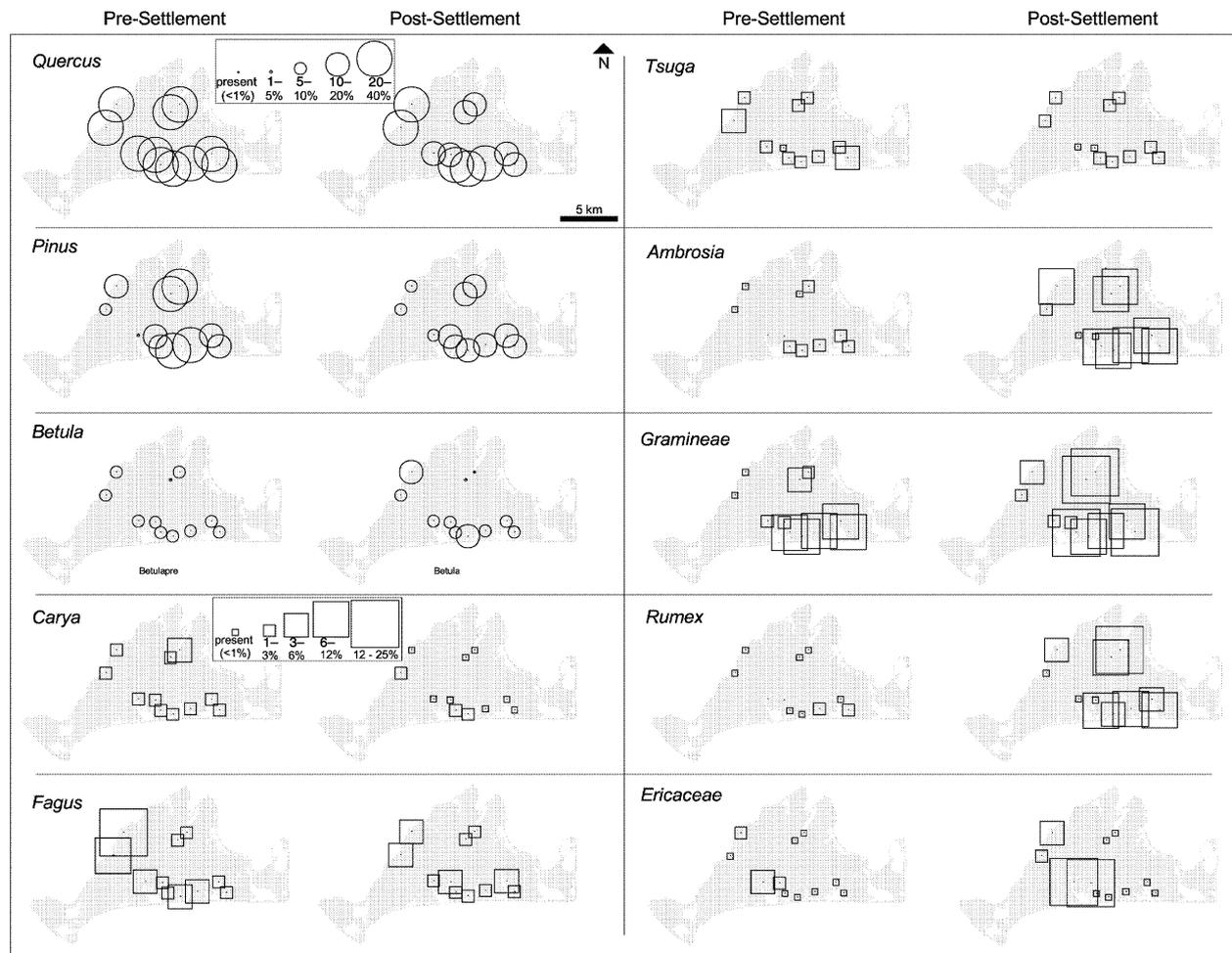


Figure 9 Maps of the average values for pollen taxa at each palaeoecological site during the pre-European period and after European settlement. Taxa that do not occur on the island (e.g. *Tsuga* (hemlock)) show no geographical pattern and little change through time. In contrast, weedy and other taxa indicative of open lands (e.g. Gramineae (grass), *Ambrosia* (ragweed), *Rumex* (sorrel)) increase after European settlement especially at outwash sites, whereas *Pinus* (pine) increases and *Fagus* (beech) and *Carya* (hickory) decline.

New England and many uncommon lepidopteran and wildlife species. Finally, the grass and shrubland necks along the south coast harbour an unusual array of open-land plants and animals on properties largely managed by non-profit environmental organizations (e.g. The Trustees of Reservations) and private owners, many of who have no conservation protection on their land. The current status, future trajectories and management options for these distinct land areas can only be understood within the broad perspective of a geographical-historical study of the entire island.

A number of key observations regarding the long-term patterns of vegetation dynamics emerge from the consideration of historical and ecological sources. First, landscape-scale variation in vegetation is long-standing and driven by variation in soils and geomorphology that is also associated with substantial variation in fire and human activity. Although the specific structure of the vegetation on the moraine, northern outwash and southern coast have chan-

ged, in some cases in major ways, with climate and European land use, the distinctiveness of each area has persisted through time. Secondly, in contrast to expectations raised by ethnographic sources and historical, ecological and conservation literature, there is no evidence for the direct impact of Native Americans on the vegetation, at least at the scale resolved by pollen analysis. At the time of European settlement Martha's Vineyard, like Nantucket and Cape Cod, was wooded with no substantial areas of grassland, shrubland or heathland. Indians may have been an important ignition source for fire, especially on areas of outwash. However, island-wide patterns of fire and vegetation were more obviously controlled by physiography than apparent patterns of human activity. Finally, European land use exerted major impacts on vegetation, soils, fire, and the environment and initiated the formation of extensive open lands. These impacts have important ramifications for ecological interpretation and conservation activity as the modern landscape

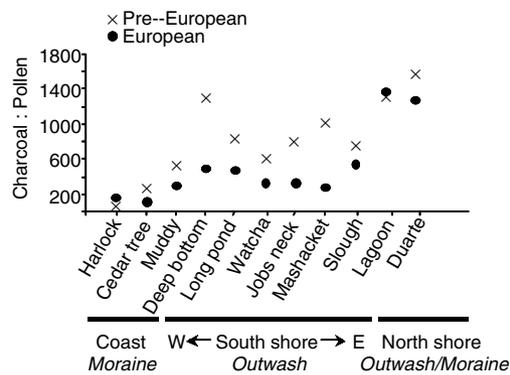


Figure 10 Average values of charcoal to pollen ratios for pre-European samples and samples since European settlement. Three patterns correspond to major landforms and geography: morainal sites and the southern site closest to the moraine have low values that decline with settlement; southern outwash sites have high values that fall markedly with settlement; and northern outwash sites have extremely high values that remain high after settlement.

bears strong evidence of the cumulative impacts of historical processes.

Vegetation, human activity and important ecological processes, especially fire, sort out strongly according to the three major physiographic divisions of the island, as described below.

Development of mature mesic forests on the moraine

Throughout the period preceding European settlement mesic hardwood forests of oak, beech, red maple, hickory and black gum dominated the rolling and hilly terrain of the western moraine. This region supported the lowest incidence of fire on the island because of its windward location, low Native American population (and presumably infrequent ignitions), mesic vegetation and dissected terrain that inhibited the spread of fire. Indeed, the extremes in fire activity across the island were remarkable; whereas the central plain exhibited some of the highest charcoal values in New England, charcoal values on the moraine around Harlock Pond were more comparable with those on moist uplands in western Massachusetts (Patterson & Backman, 1988a; Fuller *et al.*, 1998; Parshall & Foster 2002; Parshall *et al.*, 2003).

Although much of the moraine was deforested and subjected to intense sheep grazing in the eighteenth and nineteenth centuries, the area rapidly reforested as agriculture declined (Ogden 1958; Foster & Motzkin, 1999). Today much of the area is heavily forested, with scattered areas in pasture. Moist soils, an abundant seed source from fencerow and woodlot trees, and protection from fire, wind and salt spray were conducive to rapid succession and the recovery of a mesic hardwood forest (Shaler, 1888; Dunwiddie & Adams, 1994). Although there were modest declines in hickory and beech and increases in oak and pine around Harlock Pond as a consequence of land use (Dunwiddie & Adams, 1994), forest composition changed only modestly through the

historical period. Today conservation areas such as Whiting Hill on Seven Gates Farm, are notable for their extensive older forests with a mesic and relatively rich understory. These forests play an important role in island-wide biodiversity because of their contrasting structure and composition relative to most regions and their inferred similarity to pre-historical morainal forests. The value of these stands is largely one of natural characteristics and therefore a policy of protection would serve to maintain and enhance their stature and value.

Restoration of an oak barrens and woodland landscape on the central plains

The environment, vegetation, and history of the central plain and adjoining area of outwash soils over moraine provide a striking contrast to the moraine. Occupying coarse, droughty soil, the pre-European vegetation across the plain was dominated by pitch pine, oak trees and scrub oak, presumably with an open ericaceous understory (cf. Foster & Motzkin, 1999; Eberhardt *et al.*, 2003). Based on the high charcoal values for Duarte and Lagoon Pond, the entire plain was apparently subjected to intense fires on an ongoing basis. Through the historical period much of the area was heavily cut and burned but the large central plain remained wooded because of the absence of surface water for grazing animals and poor soil suitability for crops (Foster & Motzkin, 1999; Dunwiddie & Adams, 1994). The continuity of woody, scrub vegetation provided highly flammable fuel loadings and consequently charcoal values and fires remained at high levels until the recent past. As a consequence of this history, and despite changes in the relative abundance of pine and oak and impacts including creation of fire breaks and plantations on portions of the state property, the vegetation patterns and species composition across much of the central plain appear to have remained relatively similar over time.

The conservation priorities on the plain focus on the unusual extent of scrub oak barrens that forms a topographically defined landscape element within the oak and pine forest. To maintain and restore this natural pattern as well as the array of plant and animal assemblages management recommendations have included eliminating non-native plantations, re-introducing prescribed fire, and, in the many situations where fire is socially unacceptable, mowing to perpetuate the low stature scrub communities (Foster & Motzkin, 1998, 1999). The Correllus State Forest represents one of the largest conservation properties on the island and protects some of the best sand plain scrub oak and oak-pine woodland in the north-eastern US. Consequently, through judicious management there is the potential to restore a unique sandplain landscape mosaic (Adams, 1992).

Maintenance of cultural grasslands and shrublands along the south coast

The south coast of Martha's Vineyard includes coastal sandplain grass and shrublands, uncommon open-land plant

assemblages that are the focus of intense conservation activity because they support a number of unusual plant and animal species (Vickery & Dunwiddie, 1997; MNHESP, 2001). Central to efforts at preservation or restoration of these communities is interpretation of the disturbance regime that may have been responsible for initiating and maintaining this successional vegetation in an otherwise forested landscape (Dunwiddie, 1989, 1990, 1994; Motzkin & Foster, 2002). Indeed, the prevailing notion that these communities have a lengthy pre-European history because of Indian land-use practices including agriculture, village clearing and burning, has led to active fire management programs by conservation organization and public agencies (Motzkin & Foster, 2002).

Results from this study provide insights into the dynamics of these open-land communities and the factors controlling their distribution. Specific conclusions include: evidence for substantial areas of pre-European grassland is weak or ambiguous and lends little support to the interpretation that fire or Indian activity were important factors in creating pre-historical grasslands; open-land vegetation became abundant during the post-European period and therefore its distribution and characteristics are strongly tied to the pattern of historical land use especially deforestation and grazing; and, maintenance of this successional vegetation may require active management through cultural activity including agriculture. Maintenance of open-land habitats is critical for important species and is feasible because of the slow rate of reforestation on windy and droughty sites.

Pre-European weed and grass pollen do reach 4–10% for south coastal sites and Duarte Pond. Although this pollen signature may indicate open-structured forest, patchy woodland or an open-land mosaic, interpretation remains ambiguous because of our inability to separate wetland and upland grass and sedge pollen (Stevens, 1996). Numerous lines of evidence do suggest a significant pollen signal from wetlands. The ponds have gentle shores, fringing wetlands and emergent vegetation; and historical documents describe them as supporting 'meadows' (a vernacular term for open wetland; Foster, 1999), black grass and mowing areas (Freeman, 1807; Banks, 1911; Stevens, 1996; Raleigh, 2000). The pollen data often includes numerous wetland and aquatic taxa such as *Myrica/Comptonia* (sweet gale), *Nyssa sylvatica*, *Carex* (sedge), *Acer rubrum* (red maple) and *Ruppia* but few pollen indicators of open landscape such as Ericaceae or *Pteridium* (bracken fern; Fig. 6).

European settlement, clearing of the forests and widespread grazing by thousands of sheep and cows led to broad-scale establishment of pasture and related grasslands and marked increases in grass, herbs, shrubs and weed species across the island including the southern coast (Figs 3–5). Through the ensuing centuries upland areas currently supporting open vegetation experienced intense agriculture including grazing, plowing, mowing, burning and manure applications. Consequently, European land use not only created most areas of open vegetation, but it strongly shaped the composition of all open areas. With farm abandonment and reforestation open vegetation declined, paralleled by a

decline in weed, grass and non-arboreal pollen (NAP; Figs 6–8 & 9; see Motzkin & Foster, 2002).

The relationship between open vegetation, fire and Indian activity is ambiguous. The presumed link between human activity and grassland is predicated on the belief that Indians were agriculturalists occupying semi-permanent and concentrated villages (Cronon, 1983). With little archaeological support for this contention, the major human impact on the pre-European landscape might have been fire. However, on Martha's Vineyard, areas with consistent grass pollen supported neither the highest concentration of Indian sites or charcoal. In contrast, northern sites supported many Indian sites and high fire activity, but high grass pollen only at Duarte Pond. Meanwhile southern ponds, with few archaeological sites and lower fire activity, have the highest levels of grass pollen. Fire ecology studies do not provide strong support for the fire : grassland linkage, at least in New England (Parshall & Foster 2002; Patterson *et al.*, 1983). Although intense and repeated burning may maintain grasslands by killing intolerant woody species, fire is relatively ineffective in creating new grassy areas in woodlands.

However, there are numerous caveats to this interpretation. The absence of archaeological sites may be due to destruction by an eroding southern coast or inadequate study. If the vegetation did include a large herb component it might not produce much charcoal when burned. Meanwhile, slow succession on the exposed coast means that open vegetation could be maintained with less frequent fire than required further inland (P. Dunwiddie, Pers. comm.). Whereas moist soils and protection from the wind may aid reforestation on the moraine, towards the coast reforestation may be slow because of dry soils, exposure to strong winds and salt spray, and limited upwind dispersal. Consequently, retention of these valuable open habitats should require relatively low levels of active maintenance, especially if they involve the application of historically relevant processes. Although fire is one approach, it is likely that the re-application of traditional agriculture or its substitutes may be more likely to succeed ecologically and socially. Such practices include grazing by sheep or cows, and mowing. Not only are these the disturbances that initiated the open vegetation, but they are easily controlled and applied at whatever season is deemed most effective or desirable. In contrast, fire is difficult to use in the modern landscape because of safety and air quality concerns as well as laws that preclude its use during the most effective time of the year: the growing season (Dunwiddie, 1999).

CONCLUSION

On close examination the coastal landscape of Martha's Vineyard presents a great diversity of habitats, vegetation and ecological processes that change in complex fashion through time in response to changing land use and fire regimes linked to geography, topography and environment. The broad patterns of vegetation are strongly related to soils and physiography, which also influence disturbance patterns like fire. Pre-European human impact on the vegetation is undetectable, although extreme differences in fire regimes

occur across the relatively small landmass. Although ignitions may be related to human activity and fire may be an important element in shaping vegetation composition, its overall influence on vegetation structure appears to be slight. Consequently, significant human controls over vegetation and landscape process only emerge following European settlement when woodlands were opened for agriculture. The legacies of this historical land-use activity persist in the landscape and strongly shape the current character of the vegetation and the management imperatives for conservation activity. Using history to interpret modern ecological patterns yields a range of contrasting approaches to conservation on different portions of this highly varied landscape.

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Appendix I Historical quotes pertaining to the vegetation and appearance of the Great Plain on Martha's Vineyard that contains Manuel F. Correllus State Forest

1669	'...land (at) Meeshackett containing I judge 63 acres more or Less Bound with the Shrubbed plain or Comon Land on the North...' (A deed reference to T. Buchard's holdings; Banks (1911). Note: Meeshackett is on the south-eastern portion of the Great Plain, on the eastern side of Edgartown Great Pond. This represents one of the earliest references to shrub plains in the north-eastern US)
1698	'a barren ragged plain of no town.' Athearn (1698), referring to the central portion of the Great Plain
1784	'Tisbury Wood Land.' Crevecoeur (1784)
1794	'...vast plains of bitter oaks between Edgartown and Tisbury.'
1807	'Waste Land, Tisbury.' Smith (Massachusetts Archives, 1794)
1807	'More than one half of these two townships (Edgartown and Tisbury) is covered with shrub oak and bitter oak, is of little or no value, and is not enclosed (i.e. fenced).' Freeman (1807)
1830	'All the houses are within a mile or two of the sea coast: the internal parts of the island will probably always remain without inhabitants.' Freeman (1807)
1830	'rather thick and interspersed with short stunted oak shrubbery with the exception of a small part thereof which may be termed woodland...'
1859	Crapo (Massachusetts Archives, 1830)
1859	'Having passed from the township of Holmes Hole into Tisbury, the road lay through what would have been an oak forest, except none of the trees (exceeded) some four feet in height – (our guide) affirming this to be their mature growth, and that no larger ones had grown since the forest was cleared by the original settlers.' Anonymous (1859)
1860	(From West Tisbury) 'Toward the south and east it is a plain, chiefly covered with a growth of stunted shrubbery...' Strother (1860).
1860	This generally untillable area (the terrace drift or plain) of Martha's Vineyard has an extent of about 33,000 acres. At present about 25,000 acres of this area is covered by low, scrubby woods, principally composed of varieties of small oaks; the remainder consists of abandoned fields which are slowly returning to the condition of forest. Frequent fires sweep over the district, destroying the parts of trees which are above ground, but not injuring the roots, from which a tangle of stems quickly springs up. Originally this region was heavily wooded...' Shaler (1888)
1890	'...wide, level, sandy plains, covered with a growth of bear, chincapin and post oak scrub from knee to waist high, so stiff and matted as to be almost impenetrable.' (Brewster, in Gross, 1928)
