RARE PLANT SPECIES IN MASSACHUSETTS

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242 vascular plant species were listed as rare in Massachusetts (Coddington & Field, 1978). There are several problems inherent in a state list of rare plants. Because the boundaries of states are political rather than natural, the plant species in a state represent diverse communities and ecosystems, some of which may be better represented elsewhere. The historical occurrences of species in states are usually established from herbarium records, some of which may be inaccurate and need evaluation by experts. The publication of a state rare plants list usually causes new information to come to light, rapidly making the list obsolete.

In Massachusetts, all of these problems obtain. Nevertheless, certain patterns of rarity can be distinguished among Massachusetts rare plant species, and these patterns are broad enough to indicate general patterns in the distribution of rare plant species in the state.

The 242 species on the Massachusetts rare plants list can be divided into groups: 1) species rare throughout their ranges; 2) range limits: species at the northern or southern limits of their ranges; 3) species with highly disjunct distributions; and 4) species with a restricted total range: endemic to Massachusetts, endemic to New England, or endemic to a small geographic area. With the exception of a few species made rare by human activity alone (e.g. *Rhododendron maximum* (Ericaceae), collected by gardeners; *Ribes americana* (Saxifragaceae), the object of a government control program because it is the alternate host of a plant disease), most of the species on the Massachusetts rare plants list fit into these categories.

SPECIES RARE THROUGHOUT THEIR RANGES

This category is typified by the orchid *Isotria medeoloides*, which occurs from Ontario (Stewart, 1978) to North Carolina and Missouri (Fernald, 1950) but is nowhere common. The only known occurrence of this species in Massachusetts is documented by a herbarium sheet dated 1899.

Setaria geniculata (Gramineae), another Massachusetts species rare throughout its range, is one of the rare prairie species studied by Rabinowitz (1978). The species appears to be adapted for long-distance dispersal.

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RANGE LIMITS

Range limit species are at the extreme edges of their distributions due to a combination of factors, such as reduced availability of suitable physical habitat and increased competition (Grant & Antonovics, 1978).

Many species on the Massachusetts rare plants list are at the northern limits of their distributions. A few of these are found in western Massachusetts. One occurs in woods (*Cimicifuga racemosa,* Ranunculaceae). The others are found in open habitats such as roadsides (e.g. *Aster prenanthoides,* Compositae) and meadows (e.g. *Carex Bushii,* Cyperaceae). A larger number of species at the northern limits of their ranges are found in eastern Massachusetts. A few of these occur in shaded habitats such as woods (e.g. *Tipularia discolor,* Orchidaceae). Most occupy open or relatively open habitats, commonly sandy or peaty pond shores (e.g. *Rhynchospora inundata,* Cyperaceae), sandy dry barrens (e.g. *Onosmodium virginianum,* Boraginaceae), and other open habitats such as tidal mud flats, lake shores, fields, and roadsides. Some species at the northern limits of their distribution are found in both eastern and western Massachusetts. For these, the most common habitat is fresh-water pond shores (e.g. *Fuirena pumila,* Cyperaceae). Note that this habitat is found both in coastal areas and in western Massachusetts on sandy plains on the site of glacial Lake Hitchcock.

A few species reach the southern limit of their ranges in Massachusetts. Five of these species occur in shaded habitats such as woods (e.g. *Polystichum Braunii,* Polypodiaceae). The others occur in habitats which are mostly open, such as bogs (e.g. *Platanthera obtusata,* Orchidaceae) and open mountain tops (e.g. *Luzula parviflora,* Juncaceae).

In eastern Massachusetts the species at the southern limits of their ranges are found in mostly open habitats such as pond shores (e.g. *Isoetes faveolata,* Isoetaceae), sea beaches (*Elymus arenarius,* Gramineae), ledges and rocky beaches (e.g. *Sagina nodosa,* Caryophyllaceae), and salt flats (e.g. *Suaeda americana,* Chenopodiaceae).

DISJUNCTS

In Massachusetts there are many disjunct localities of species that occur mainly to the south of the state. Only a few of these are found in shaded habitats such as woods (e.g. *Carex Willdenowii,* Cyperaceae) and swamps (*Magnolia virginiana,* Magnoliaceae). Most of

the others occur in open habitats such as fresh water pond shores (e.g. *Psilocarya nitens*, Cyperaceae, and *Echinodorus tenellus*, Zosteraceae), and barrens.

A few disjunct localities of species occurring mostly to the north of the state are found in Massachusetts, occurring in such habitats as woods (e.g. *Halenia deflexa*, (Gentianaceae), sea beaches (e.g. *Rumex pallidus*, Polygonaceae), and "boreal" habitats such as mountain tops (e.g. *Lycoodium Selago*, Lycopodiaceae).

Some disjunct species in Massachusetts cannot be characterized as northern or southern species. Some are widespread species infrequently distributed throughout their ranges. Others are restricted in total distribution. Several Massachusetts disjunct species occur in Nova Scotia, Cape Cod and Massachusetts offshore islands, Block Island, Rhode Island, Long Island, New York, and New Jersey, sometimes extending farther south along the coastal plain. Examples of this include *Sabatia Kennedyana* (Gentianaceae), which occurs in Nova Scotia, eastern Massachusetts and Rhode Island, southeastern North Carolina and northeastern South Carolina (Perry, 1971); and *Corema Conradii* (Empetraceae), found in northeastern Canada including Nova Scotia, sporadically south on the coast to outer Cape Cod, and in the New Jersey Pine Barrens (Fernald, 1950).

ENDEMICS AND RESTRICTED-RANGE SPECIES

There are taxonomic questions about many of the taxa listed as Massachusetts or New England endemics and restricted species. Sometimes named as species and sometimes as varieties, these taxa may represent hybrids, geographically isolated populations, ecotypes, newly-evolved or relict species. With the exception of *Paronychia argyrocoma* var. *albi-montana* (Caryophyllaceae), all of them are associated with the coastal plain, and most occupy open habitats.

Only two plant taxa have ever been considered to be endemic to Massachusetts. One, *Juncus pervetus*, was only known from one locality on Cape Cod, where it apparently persisted for a few years. The habitat at this site has been severely altered, but even before habitat changes occurred, the plant could no longer be found. Unless it can be relocated, its status as a species will remain in question.

The other Massachusetts endemic is *Amelanchier nantucketensis* (Rosaceae), a Nantucket shrub. This was originally distinguished from other *Amelanchier* species because of its smaller size, spreading habit, and short petals (Bicknell, 1911). Later studies of the genus (Weigand, 1912; Jones, 1946) considered *A. nantucketensis* to be part of such other species as *A. oblongifolia* var. *micropetala* and *A. canadensis*. According to both Weigand (1912) and Fernald (1946, 1950), the genus *Amelanchier* frequently forms hybrids. Field observations by Coddington (1978, unpublished) suggest that whatever the origin and species status of *A. nantucketensis*, it is a recognizable entity in the field. It occurs on shores of fresh water ponds and in sandy barrens.

Three taxa on the Massachusetts rare plants list are endemic to New England: *Isoetes foveolata* (Isoetaceae), *Paronychia argyrocoma* var. *albimontana* (Caryophyllaceae), and *Eupatorium leucolepis* var. *novae-angliae* (Compositae). The genus *Isoetes* is poorly understood and poorly collected (R. J. Hickey, pers. comm.); until more work is done on it, the status of *I. foveolata*, a shallow-water aquatic found in southern New Hampshire and Massachusetts, remains questionable. *Paronychia argyrocoma* var. *albi-montana* is a highly disjunct variety of a species which otherwise occurs in Virginia, West Virginia, North Carolina, Georgia, and Tennessee (Core, 1941). Variety *albi-montana* is found at a few localities on rocky mountains in southern Maine and New Hampshire, and on a rocky island at sea level in northeastern Massachusetts. *Eupatorium leucolepis* var. *novae-angliae*, another disjunct variety, is limited to southeastern Massachusetts and Rhode Island, where it occurs in sandy soil near fresh water ponds.

Twelve species on the Massachusetts rare plants list have a restricted distribution. Two are western disjuncts (*Ludwigia polycarpa*, Onagraceae, and *Psilocarya nitens*, Cyperaceae), occurring in extremely limited areas on the eastern coastal plain and also in the midwest. Other species (e.g. two *Isoetes* species, two *Bidens* species) are poorly defined and understood taxonomically. *Sabatia Kennedyana* (Gentianaceae), a notable disjunct mentioned above, occurs in Nova Scotia, coastal Massachusetts and Rhode Island, and the Carolinas. Two species of dry sandy areas, *Helianthemum dumosum* (Cistaceae), and *Agalinis acuta* (Scrophulariaceae), occur only in eastern Massachusetts, Rhode Island, Connecticut, and Long Island. Populations of *H. dumosum* were relocated on Cape Cod

and Nantucket in 1978 (J. Coddington, unpublished). Recent searches for *A. acuta* throughout its range (J. Canne, *in litt.*) and in Massachusetts (J. Coddington, K. Field, unpublished) failed to locate the species. This species is believed to be a root parasite (Musselman and Mann, 1977).

HISTORICAL CAUSE FOR MASSACHUSETTS PLANT DISTRIBUTIONS

Some of the patterns of distributions of Massachusetts rare plant species can be explained by examining the recent glacial, geological, and vegetational history of the state. Features of late Wisconsin glaciation which are important to an understanding of plant distribution are the following:

1) During the late Wisconsin, ice covered most or all of present-day Massachusetts. The ice sheet extended to central Long Island (Sirkin, 1971), Block Island, Rhode Island (Sirkin, 1976), Martha's Vineyard (Kaye, 1964a & 1964b), off Nantucket, across southwestern and northern Georges Bank to the edge of the Nova Scotian Shelf (Pratt & Schlee, 1969; Schlee & Pratt, 1970).

2) The area around the northwestern Atlantic, especially between latitudes 42° and 60° north, experienced severe cooling during the late Wisconsin, estimated at —18°C maximum cooling at about 18,000 BP (before present) (MacIntyre et al., 1976; CLIMAP, 1976). The severity of the cooling was caused by a southward shift in the Gulf Stream during maximum glaciation (CLIMAP, 1976).

3) Sea level reached a low approximately 130m below its present level at about 16,000 BP (Milliman & Emery, 1968).

4) Lack of shoals off Nova Scotia and the dispersal of gravel at the edge of the Nova Scotian Shelf indicate that the glacier flowed directly into the sea in this area (Schlee & Pratt, 1970). However, on and to the west of Georges Bank, the ice was separated from the shoreline by a broad band of exposed continental shelf (Pratt & Schlee, 1969).

5. Fossil peat which was deposited in fresh water and salt marsh environments is now found as far out from the present-day coastline as Georges Bank and the Nantucket Shoals (Livingston, 1964; Emery et al., 1967; Field et al., 1979). This shows that a much larger coastal land area was exposed in southern New England following glaciation. Evidence from salt marsh peat on Cape Cod (Redfield &

Rubin, 1962) and in southern New Hampshire (Keene, 1971) shows that the sea has been slowly covering this exposed land for 6000 to 7000 years.

Changes in climate during and following the Wisconsin glaciation are often inferred from paleobotanical evidence. It is known that during glaciation, temperate species were displaced far to the south of their present ranges. Tundra vegetation occurred in New Jersey (Sirkin et al., 1970) and far south in the Alleghenies (Maxwell & Davis, 1972); boreal forest species occurred in Georgia and Florida (Whitehead, 1973) and in the Delmarva Pensinsula (Sirkin, et al., 1977).

Using radiocarbon-dated assemblages of fossil pollen, the sequence of vegetation immediately following glacial retreat has been reconstructed in many areas of glaciated northeastern North America (e.g. Long Island, Sirkin, 1971; Connecticut, M. Davis, 1969; Block Island, Sirkin, 1976; central Massachusetts, M. Davis, 1958; Martha's Vineyard, Ogden, 1963, Kaye, 1962, 1964a, 1964b; Maine, R. Davis et al., 1975; southeastern Canada, Livingston, 1968). The sequence differs slightly in different areas, yet the general pattern is similar throughout the Northeast.

Vegetation immediately south of the glacial edge consisted of mostly non-arboreal species such as sedges and grasses, along with birch and willow. This open vegetation was gradually replaced by boreal forest, often passing through a stage of "forest-tundra" or "park-tundra" (e.g. see Sirkin, 1976; M. Davis, 1969). As temperate species invaded from the south, the vegetation usually passed through a pine stage and a pine-oak stage.

The rate of invasion of temperate forest species following glaciation was controlled by the dispersal and colonizing ability of each species, more than by climate (Livingston, 1968; M. Davis, 1976). Rapidly colonizing species were able to move north quickly, and may have occurred farther to the north than their present-day distributions during a period of maximum warming at about 5,000 BP (M. Davis, 1976). On the other hand, the ranges of some slow-colonizing species may still be expanding to the north (M. Davis, 1976).

Pollen spectra cannot give an absolutely accurate picture of post-glacial climate and habitats, for several reasons. Attempts to correlate modern pollen with vegetation have shown that some pollen is transported great distances before deposition (R. Davis & Webb,

1975). In addition, pollen can often be identified only to family or genus. Therefore, a particular pollen assemblage will contain an average sampling of a diverse group of plant communities, but can give little information about particular habitats and communities. Habitats and communities must be inferred from other data.

What was post-glacial Massachusetts like? First of all, a broad expanse of coastal plain was exposed for a long period of time. Numerous glacial lakes existed in Massachusetts during and after ice retreat (e.g. see Brooks & Deevey, 1966). Beavers were active in New England as early as 12,000 BP (Kaye, 1962), creating their characteristic open habitats. Some of the same Massachusetts deposits that contain beaver-chewed wood also contain charred wood. Kaye (1962) reasoned that this indicates a drier climate which allowed forest fires to occur naturally. However, presence of humans on the exposed continental shelf, along with other large mammals such as moose, muskox, and mastodon, also occurred quite early (see Edwards & Emery, 1977), so it is possible that not all fires occurred naturally. It has been frequently been observed that present-day coastal areas in southern New England are much more open than inland areas; on certain isolated coastal areas such as Block Island, very few trees are found at all.

To summarize, in post-glacial Massachusetts, it is likely that because of the presence of glacial lakes, beavers, large grazing mammals and humans, large areas of open habitat occurred for thousands of years. In addition, many of the dominant temperate tree species invaded slowly, and at the extreme edge of the coast, probably did not occur at all.

Fernald (1925, 1929, 1939) explained the presence of endemics and plant species with Cordilleran affinities by hypothesizing that certain high mountains remained uncovered by ice during the Wisconsin glaciation. A pre-Pleistocene flora survived in these areas, and was later restricted to them. The suggested areas are parts of Nova Scotia, Labrador, the Gaspé Peninsula, and islands in the Gulf of St. Lawrence, as well as isolated mountain tops to the south. In addition, Fernald hypothesized that plants survived glaciation on the exposed continental shelf (Fernald, 1918, 1942, 1943).

The idea that plants persisted in nunataks during glaciation is frequently found in the literature. Most recent authors favor continental shelf refugia, however. For example, Terasmae (1973, p. 210) states that "both arctic and boreal species grew in these unglaciated

coastal areas that extended from the Grand Banks (east of Newfoundland) southward to the Georges Bank region east of New York".

Geological evidence has shown that this area did exist, although it did not occur along Nova Scotia. However, with an average annual temperature anomaly of —18° C during glaciation (CLIMAP, 1976), it is unlikely that temperate species could have survived on the continental shelf. Instead, the exposed shelf probably served as a dispersal corridor after glaciation, as well as an area of open habitats where some of the coastal endemics of open habitats probably evolved. Rising sea level later restricted coastal plant species into disjunct populations.

Fernald himself and many authors since Fernald have suggested that east-west dispersal occurred along the foot of the retreating glacier across North America (Drury, 1969). The habitat immediately south of the glacier supported an arctic-alpine type flora, which later became restricted to arctic and montane habitats. This theory seems better able to explain relationships between eastern and Cordilleran floras than does the presumed survival of a pre-Pleistocene flora in nunataks.

DISCUSSION

Four groups of Massachusetts rare plant species have been discussed and geological-historical explanations for three of these groups have been presented.

Group 1). Geological explanations do not explain species that are rare throughout their ranges.

Groups 2 and 3). Species at the southern and northern limits of their ranges, and disjuncts: Since boreal species migrated northward through New England from southern areas following glaciation, it is to be expected that some of them would still persist in patches of "boreal" habitat in New England. In Massachusetts, a large proportion of species at the southern limit of their ranges are found in Berkshire County, where cold, high areas in the mountains create boreal habitat conditions.

Southern species at the northern limit of their ranges are more common in eastern Massachusetts, where temperate coastal-plain habitat occurs. Again, species have been migrating north since glaciation. It is likely that populations of southern species became established during the period of warming that occurred 5000 years ago.

Climatic cooling and rise of sea level left disjunct populations of these species. An example of this is *Magnolia virginiana* (Magnoliaceae) in Massachusetts.

Plants from the east and west mixed in open arctic-alpine habitats along the southern border of the retreating ice-sheet. The retreat of the glacier left disjunct populations; this explains the presence of western disjuncts in the flora of Massachusetts.

Group 4). Endemics and restricted species: Following glaciation, there was a large exposed land area with a variety of open habitats such as meltwater estuaries, shores of glacial lakes and sand deposits left after these lakes dried, beaver meadows, and coastal barrens. This allowed coastal endemics to evolve or become established. In the last 6000 years, coastal areas have been shrinking because of rising sea level and coastal subsidence, and many of the factors creating open habitats are no longer present. This explains the large number of coastal endemics and species of open habitats which are now rare.

The history of Massachusetts since the last glaciation, including changing habitats and vegetation, explains the present distribution of many rare plant species. In addition, a large proportion of rare plant species exist in "rare habitats". Some, such as open habitats on the coastal plain, were more common in the past; others, such as serpentine and limestone outcrops, were always rare. In order to preserve rare plants in Massachusetts, therefore, it is necessary to preserve the specialized habitats of these species.

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