Dwarf Pitch Pine Communities in the Southern Taconics

Race Mountain, Bear Mountain, and "Hill 1914"

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Front cover: The summit of Race Mountain with 1 – 2 m tall pitch pine and exposed bedrock.

Back cover: View of Mount Everett (left) and Race Mountain (center) from Bear Mountain, CT.

All photos by David Orwig unless noted otherwise.

Summary

We used a combination of dendroecological, historical, and field studies to examine the long-term history, development, and vegetation dynamics of 3 dwarf *Pinus rigida* (pitch pine) locations in this region: "Hill 1914" on the eastern boundary of Mount Everett State Reservation and Race Mountain in southwest Massachusetts and nearby Bear Mountain in northwestern Connecticut. All three sites supported communities dominated (80 to 98% relative importance) by stunted *P. rigida*, which apparently persisted in the absence of frequent fire because of the harsh site conditions, especially shallow soils and frequent damage from winter storms. Cone serotiny, which is characteristic of dwarf *P. rigida* communities elsewhere in the eastern U.S., was not observed on any of the summits, consistent with the lack of frequent fire.

Of the three areas studied, Race Mountain had the highest density of dwarf *P. rigida* (1482 stems ha^{-1}), approximately three times the density on Bear Mountain. Hill 1914 had the highest *P. rigida* basal area (18 m^2 ha^{-1}), ~ four times the basal area on Bear Mountain. Interestingly, Bear Mountain had substantially lower densities of dead *P. rigida* than the other summits, and supported higher *P. rigida* seedling and sapling densities and contained more upright stems with well-defined leaders. Understory vegetation among the three sites was quite similar, with several herb and shrub species (*Deschampsia flexuosa*, *Aronia* sp., *Gaylussacia baccata, Quercus ilicifolia,* and *Vaccinium angustifolium*) common at all plots. Average age of *P. rigida* was greater on Hill 1914 (111 years) than on Race Mountain (93 years). Although none of the sites was characterized by old-growth *P. rigida*, Hill 1914 supported the oldest known *P. rigida* in Massachusetts (228 years old). Based on our experience with pine barren ecosystems throughout the northeastern U.S., we consider the complex of dwarf communities on the summits of the southern Taconics to be exemplary and worthy of the most stringent of conservation measures.

DWARF PITCH PINE COMMUNITIES IN THE SOUTHERN TACONICS:

RACE MOUNTAIN, BEAR MOUNTAIN, AND "HILL 1914"

INTRODUCTION AND BACKGROUND

Several summits in the southern Taconic Mountains of Massachusetts, Connecticut and New York are known to support dwarf (i.e., 1 – 2m tall) pitch pine communities that are rare throughout the eastern U.S. In a previous study, we documented the vegetation composition, structure, and dynamics of the largest known dwarf pitch pine community in the Taconic region, on the summit of Mt. Everett, in the town of Mount Washington, Massachusetts (Motzkin *et al.* 2002a, b). Results from that study determined that dwarf pitch pine communities have occurred on the summit of Mt. Everett through the historical period, with no evidence that the site was ever forested with taller stature trees at any point during the past few hundred years. Significantly, we determined that dwarf pitch pine has persisted on Mt. Everett in the absence of frequent fire, unlike other dwarf pitch pine communities in the eastern U.S. where fire has played an important role in structuring the vegetation. In addition, whereas cone serotiny (cones sealed with resin that open only with heat from a fire) is common in other dwarf pitch pine communities, pitch pines on Mt. Everett are non-serotinous, consistent with the evidence of infrequent fire on the summit in recent centuries.

Age structure analyses indicated that pitch pines on the summit of Mount Everett are uneven-aged; ages ranged from 12 – 170 and the average age was 78. However, few pitch pines exceed 130 years of age, and trees on the summit are thus substantially younger than those that have been documented from other rocky areas in the Northeast (Abrams and Orwig 1995; Orwig *et al.* 2001; Parker 2004). Hardwoods on the summit are substantially younger than pine, with most red oaks and red maples establishing from 1940 – 1980. In some areas, hardwoods have overtopped pitch pine, apparently resulting in mortality. Overall, we found that the dwarf pitch pine community on Mt. Everett is not only rare but also characterized by ecological processes and stand dynamics that is extremely uncommon and poorly documented elsewhere in the eastern U.S.

In the current study, we extend our previous investigation to three additional sites to determine whether vegetation structure, stand age, and dynamics in nearby portions of the Taconics are similar to those reported for the summit of Mt. Everett. We sampled vegetation composition and structure on a rocky bench on the eastern slope below Mt. Everett (so-called "Hill 1914"), on the summit of Race Mountain in Mount Washington, Massachusetts, and on the summit of Bear Mountain in Salisbury, Connecticut. To add further insights to our work, we conducted age structure analyses for Hill 1914 and Race Mountain but not Bear Mountain. Methods for the current study are identical to our previous investigations on Mt. Everett (Motzkin *et al.* 2002a, b), enabling direct comparison of the results among sites.

STUDY SITES

Race Mountain and Hill 1914 are located in the town of Mount Washington, in southwestern Berkshire County, Massachusetts (42°06'N 73°26'W); Bear Mountain is located in the town of Salisbury, in northwestern Litchfield County, Connecticut; all three study sites are within the Taconic Mountains ecoregion (Griffith *et al.* 1994; Figure 1). Hill 1914, informally named after a stone monument on the site that is inscribed with "1914," is located on a rocky bench ~ 1 km east of the summit of Mount Everett. The site is located at the eastern boundary of the 445-ha Mount Everett State Reservation, managed by the Massachusetts Department of Conservation and Recreation, at an elevation of 626 m a.s.l. Race Mountain is located ~ 2 km south of Mt. Everett within the Mt. Washington State Forest, at a maximum elevation of 721 m. Bear Mountain is located ~ 6.5 km southwest of Mt. Everett, at a maximum elevation of 707 m; Bear Mountain is the highest summit in Connecticut. The bedrock of all three sites and nearby portions of the Taconic Range is comprised of thrust sheets of phyllitic bedrock (Zen, 1983). Soils on the summits and

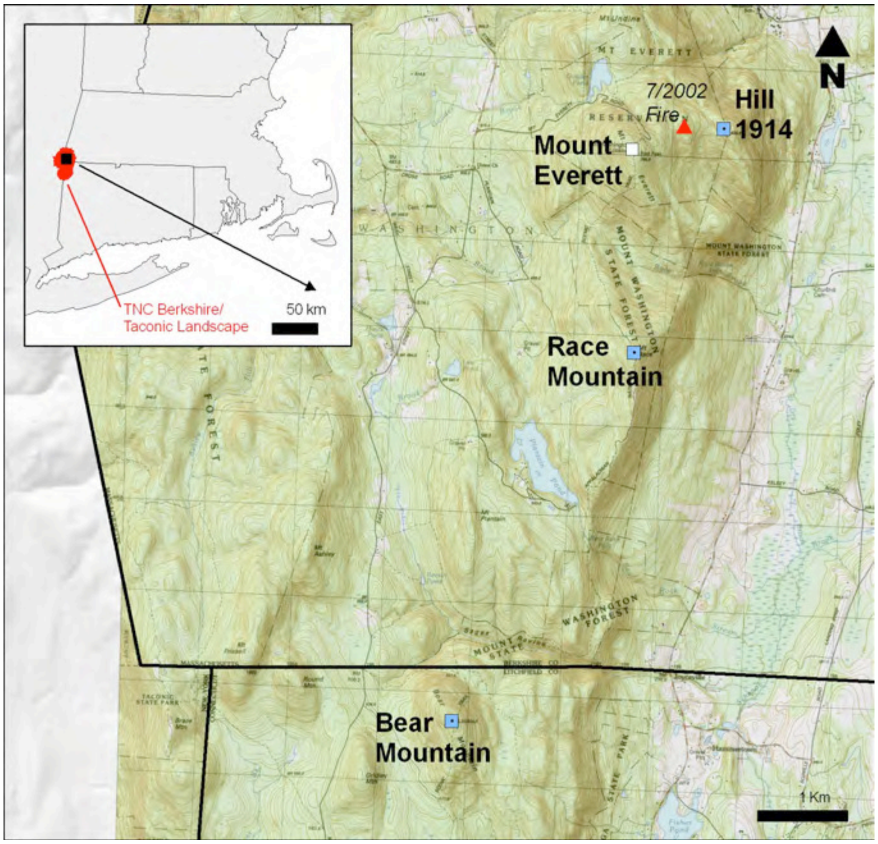


Figure 1. Location of Hill 1914, Race Mountain, and Bear Mountain in the southern Taconic Mountains. Also indicated are Mount Everett and the July 2002 fire (see Discussion).The Berkshire Taconic Landscape conservation focus areas of The Nature Conservancy is indicated in red on the inset map (from TNC).

upper slopes are very stony glacial tills of the Taconic-Macomber association, derived mainly from phyllite, slate, and shale (Scanu 1988). Soils are shallow, somewhat excessively drained gravelly loams, and bedrock outcrops are common. The regional vegetation is transition hardwoods, hemlock, and white pine (Westveld *et al.* 1956).

Berkshire and Litchfield Counties have a continental climate; mean winter temperature in Berkshire County is -4.4º C, mean summer temperature is 18.9º C, and mean annual precipitation is 109 cm, with approximately 180 cm of snow (Scanu 1988). Due to the high elevations of these summits relative to surrounding lowlands, mean temperatures are likely to be several degrees cooler on the summits, and snowfall amounts are likely to be higher. Although no weather data are available from these summits, anecdotal accounts from nearby Mt. Everett indicate that the summits are subject to more frequent ice storms than the surrounding lowlands (Leverett 2000).

METHODS

Vegetation and Age Structure

Vegetation on each summit was sampled in three, 15 m x 15 m plots located in areas of representative dwarf pitch pine vegetation. At each plot, the basal diameter of all live and dead pitch pines > 5 cm, and the diameter-at-breast-height (dbh; 1.37 m) of all other trees (> 5 cm dbh) were measured using calipers, with the average of two measurements recorded for asymmetrical stems. The number of saplings (pitch pines 2.0 - 4.9 cm basal diameter and other trees < 5 cm dbh) was tallied within the entire 15 x 15 m plot and seedlings of each species (pitch pines < 2 cm basal diameter and other trees < 1.37 m height) were counted within a 5 m x 5 m subplot in the southwestern portion of each plot.

In each plot, the percent cover of each herb, shrub, and woody species was estimated in the following cover/abundance classes: 1= < 1%; 2 = 1 – 3%; 3 = 3 – 5%; 4 = 6 – 15%; 5 = 16 – 25%; 6 = 26 – 50%; 7 = 51 – 75%; 8 = > 75%. A metal probe was used to determine the depth to bedrock in five random locations in the plot, and slope, aspect, and percent cover of exposed bedrock were estimated. As part of extensive reconnaissance, observations of tree growth-form and evidence of disturbance were recorded in each plot as well as across each site. Average tree height and the heights of several of the tallest trees in each plot were estimated.

In order to determine tree age-structure on Hill 1914 and Race Mountain, increment cores were extracted from a minimum of eight stems per plot, representing the range of species and stem sizes characteristic of each plot. Increment cores also were extracted in some instances from nearby trees outside of plots. Cores were dried, mounted, and sanded using very fine sandpaper (600 grit) prior to ring counts with dissecting microscopes. The total age of stems was estimated for cores that did not reach the pith. Despite great care in preparing the cores, the extremely slow growth of many of the trees, coupled with the potential for false or missing rings, indicate that our estimates of tree ages are subject to several sources of potential error (Hager 1995). However, in most cases we believe that they are accurate to within several years.

Disturbance History

In order to evaluate the occurrence of recent fires on the summits, we searched each plot for fire scars and stem charring. Historical maps and aerial photos were also used to evaluate the disturbance and vegetation history of the study sites. Additional historical information was derived from Tillinghast's (1999) compilation of historical references and personal communication from E. Tillinghast.

RESULTS

Vegetation and Site Characteristics

Hill 1914

Pitch pine dominates this site with 95% of the stems (1185 ha^{-1}) and 95% of the basal area (18.01 m^2 ha^{-1}) (Figure 2; Table 1). The only other tree species represented in the study plots was white pine (*Pinus strobus*). Average pitch pine basal diameter across the plots was 13 cm (Table 2). The majority of pitch pine stems had basal diameters of 5 to 20 cm, although several trees exceeded 25 cm basal diameter (Figure 3). Dead pitch pine stems < 10 cm basal diameter were common throughout the site (Figure 3). Pitch pine height varied substantially, from frequent low-lying mats of vegetation < 1 m in height to several upright stems 3.8 to 4.4 m tall and (Figure 4). We estimate that at least 27% of pitch pine stems originated as basal sprouts from older stems. Despite evidence of some soil charcoal, we did not observe any charred stems or cone serotiny at this location.

Figure 2. Hill 1914 with marker and dense, low statured pitch pine. The general height of the canopy in the photograph is approximately 2m tall.

Sapling density was low at Hill 1914 (311 stems ha^{-1}) and consisted primarily of *Acer rubrum* and a few *Amelanchier* species and *P. rigida* stems (Table 3). *Acer rubrum* (1467 ha^{-1}) and *P. rigida* were also the most abundant seedlings on this site (Table 4). The abundance of *A. rubrum* regeneration is noteworthy in light of its absence in the overstory of these plots. Understory vegetation at Hill 1914 is dominated by low shrubs, especially *Vaccinium angustifolium* and *Gaylussacia baccata*, with moderate amounts of *Quercus ilicifolia* (Table 5). The herb layer is very sparse, with *Deschampsia flexuosa* and *Gaultheria procumbens* occurring most frequently (Table 6). The amount of exposed bedrock was variable (5-50 %), with an average of 15-25%. Soils were extremely shallow, averaging only ~ 6 cm.

Table 1. Overstory vegetation composition of live and dead stems within three plots on Hill 1914.

Species	Density (ha^{-1})	Rel. Density (%)	Basal area (m^2 ha^{-1})	Rel. Basal area (%)	Rel. I.V.* (%)
Live stems					
Pinus rigida	1185	95.3	18.01	94.3	94.8
Pinus strobus	59	4.7	1.09	5.7	5.2
Totals	1244		19.10		
Dead stems					
Pinus rigida	281	--	1.46	--	--

* Relative Importance Value calculated as the average of relative density and basal area.

Table 2. Average tree and edaphic factors in plots established on Hill 1914, Race Mountain, and Bear Mountain.

Plot	Diameter cm* (pitch pine)	Age ± S.D. (pitch pine)	Max Age (pitch pine)	Diameter cm (other species)**	Age ± S.D. (other species)	Average Soil depth (cm)	Exposed Rock***(%)
Hill 1914-1	12.9 ± 4.6	121 ± 48	189			7.6	20
Hill 1914-2	12.2 ± 5.4	100 ± 61	228			5.2	38
Hill 1914-3	13.7 ± 5.1	112 ± 29	161	14.6 ± 5.1	43 ± 11	5.6	8
Race-1	10.5 ± 4.6	95 ± 30	132	12.0	36	11.6	8
Race-2	9.7 ± 3.0	64 ± 35	110			5.4	20
Race-3	10.0 ± 2.9	103 ± 37	159	7.0 ± 1.3	27 ± 0	14.0	20
Bear-1	11.7 ± 4.0			6.3 ± 1.9			20
Bear-2	10.7 ± 4.7			8.5 ± 3.9			20
Bear-3	9.2 ± 3.5						8

*Diameter height = ~ .2 m for pitch pine and 1.37 m for all other species.
**Other species = white pine, red maple, red oak, serviceberry, and paper birch.
***Values represent cover class mid-points.

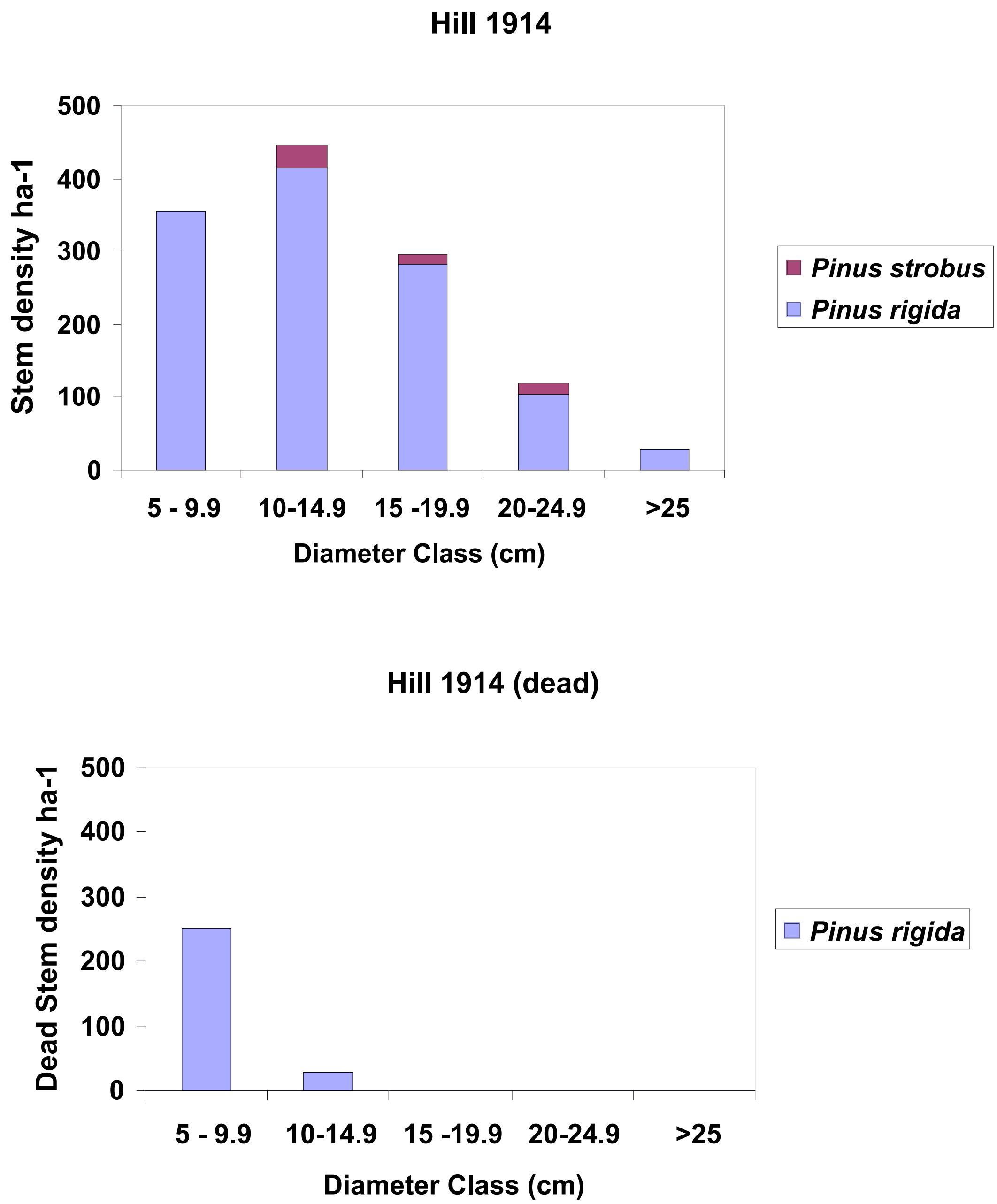


Figure 3. Diameter distribution of live (top panel) and dead (bottom panel) stems on Hill 1914. Diameter is basal diameter for pitch pine and diameter at breast height for white pine.

Figure 4. Pitch pines 2 – 3m tall within sample plot on Hill 1914.

Table 3. Sapling density (stems ha^{-1}) on three study sites in the southern Taconic Mountains.

Species	**Hill 1914**	**Race Mountain**	**Bear Mountain**
Acer rubrum	163	163	119
Amelanchier sp.	59	74	859
Betula papyrifera	--	--	104
Betula populifolia	--	430	1141
Pinus rigida	44	415	444
Pinus strobus	30	--	--
Prunus pensylvanica	--	--	44
Quercus rubra	15	119	59
Total	311	1201	2770

Table 4. Seedling density (stems ha^{-1}) on three study sites in the southern Taconic Mountains.

Woody Understory	**Hill 1914**	**Race Mountain**	**Bear Mountain**
Acer pensylvanicum	133	--	--
Acer rubrum	1467	133	--
Amelanchier sp.	--	--	1467
Betula populifolia	--	267	400
Pinus rigida	533	267	2400
Quercus rubra	133	--	133
Total	2266	667	4400

Table 5. Percent cover of woody understory species in plots at three study locations in the southern Taconic Mountains. Values are mid-points of cover classes.

Woody Understory	1914-1	1914-2	1914-3	Race-1	Race-2	Race-3	Bear-1	Bear-2	Bear-3	% frequency
Acer pensylvanicum	0.5		0.5							22
Acer rubrum	0.5		2	2	0.5	0.5		2	2	78
Amelanchier sp.	0.5		0.5	0.5	0.5	0.5	10	0.5	10	89
Aronia sp.	0.5	0.5	0.5	2	2	10	10	2	10	100
Betula papyrifera						2				11
Betula populifolia				0.5	0.5	0.5	10	10	10	67
Gaylussacia baccata	62	20	37	62	37	62	37	20	37	100
Hamamelis virginiana			0.5				0.5			22
Kalmia latifolia		10	0.5		10	0.5				44
Pinus rigida	0.5	10	0.5	2	10	10	10		2	89
Pinus strobus		0.5	0.5	0.5						33
Prunus pensylvanica							0.5		0.5	22
Quercus ilicifolia	20	10	37	37	20	10	10	37	62	100
Quercus rubra	0.5	0.5	0.5		2	10	0.5	0.5	0.5	89
Rhododendron prinophyllum			0.5			2			0.5	33
Rubus sp.									0.5	11
Tsuga canadensis	0.5	0.5								22
Vaccinium angustifolium	62	37	62	37	62	62	62	62	62	100
Viburnum cassinoides							0.5			11
Species richness	10	9	13	9	10	11	11	9	12	

Table 6. Percent cover of herbaceous species in plots at three study locations in the southern Taconic Mountains. Values are mid-points of cover classes.

Herb layer	1914-1	1914-2	1914-3	Race-1	Race-2	Race-3	Bear-1	Bear-2	Bear-3	% frequency
Antennaria plantaginifolia	0.5									11
Aralia nudicaulis			0.5				2	0.5	2	44
Carex pensylvanica				0.5	0.5			0.5	0.5	44
Cypripedium acaule			0.5				0.5			22
Deschampsia flexuosa	0.5	2	0.5	0.5	0.5	0.5	0.5	2	0.5	100
Gaultheria procumbens	0.5	0.5	0.5	2	0.5	0.5				67
Maianthemum canadense	0.5	0.5		0.5	0.5	0.5	4	0.5	2	89
Melampyrum lineare		0.5								11
Polypodium sp.			0.5							11
Potentilla tridentata					0.5		0.5			22
Pteridium aquilinum	0.5			2						22
Solidago spp.				0.5			0.5			22
Trientalis borealis	0.5						0.5	0.5	0.5	44
Uvularia sessilifolia			0.5							11

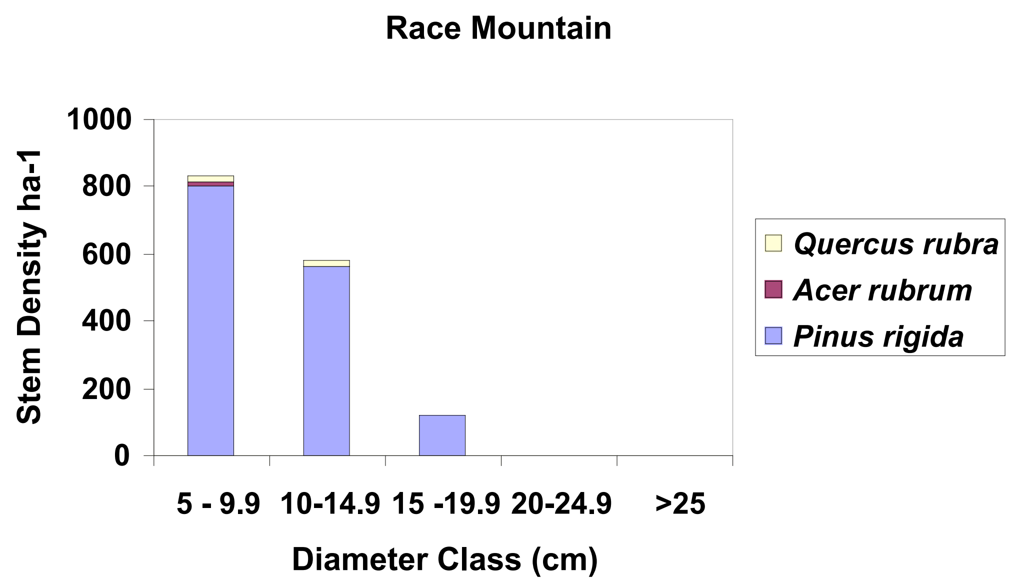
Race Mountain

Over 97% of the stem density (1482 stems ha^{-1}) and basal area (13.19 m^2 ha^{-1}) of the summit vegetation was comprised of pitch pine (Table 7). Average basal diameter of pitch pine was 10 cm across plots (Table 2) and stems < 10 cm were common (Figure 5). Dead pine stems < 10 cm basal diameter were also common across the summit. We estimate that at least 41% of pitch pine stems originated as basal sprouts. The average height of the tallest pitch pine in our plots was 2.7 m, while the average pitch pine height was ~ 1.6 m (Figure 6). Red oaks occurred at very low density in our plots on Race Mountain; the average height of the tallest red oak sapling was 3.6 m.

Table 7. Overstory vegetation composition of live and dead stems on the summit of Race Mountain, southwestern Massachusetts.

Species	Density (ha^{-1})	Rel. Density (%)	Basal area (m^2 ha^{-1})	Rel. Basal area (%)	Rel. I.V.* (%)
Live stems					
Acer rubrum	15	1.0	0.04	0.3	0.7
Pinus rigida	1482	97.1	13.19	98.2	97.7
Quercus rubra	30	2.0	0.24	1.8	1.9
Totals	1527		13.43		
Dead stems					
Pinus rigida	489	--	2.16	--	--

* Importance value calculated as the average of relative density and basal area.



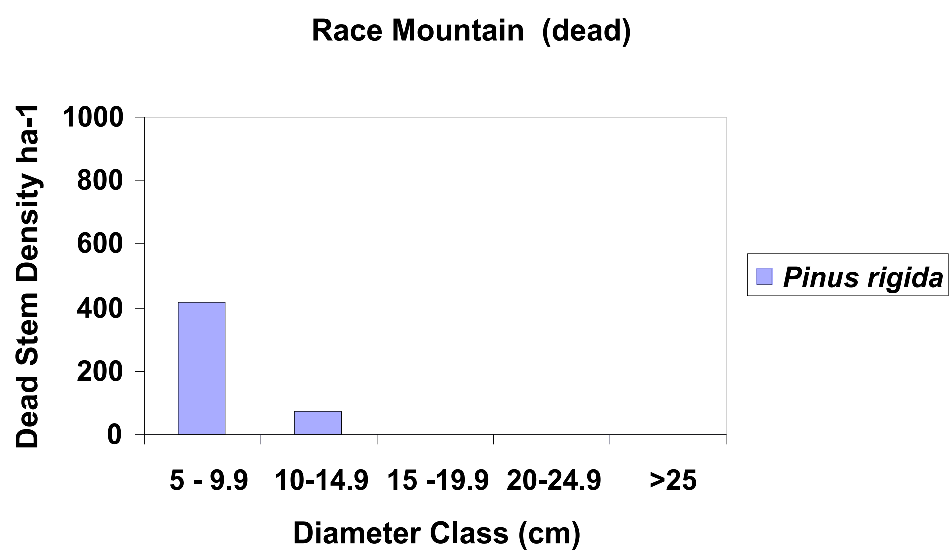


Figure 5. Diameter distribution of live (top panel) and dead (bottom panel) stems on Race Mountain, southwestern Massachusetts. Diameter is basal diameter for pitch pine and diameter at breast height for red oak and red maple.

Figure 6. View of the summit of Race Mountain with 1 – 2 m tall pitch pine and exposed bedrock.

Betula populifolia and *P. rigida* were the most abundant saplings and seedlings on Race Mountain (Tables 3 and 4). Understory vegetation at Race Mountain was dominated by low shrubs, especially *Vaccinium angustifolium* and *Gaylussacia baccata*, with moderate amounts of *Quercus ilicifolia* (Table 5). The herb layer was very sparse, with *Maianthemum canadense*, *Deschampsia flexuosa,* and *Gaultheria procumbens* occurring most frequently (Table 6). The amount of exposed bedrock was generally 5-25%, and average soil depths were only ~ 10 cm.

Bear Mountain

The overstory vegetation on the summit of Bear Mountain was noticeably sparse, with only 652 stems ha^{-1} and 5.56 $m^2\ ha^{-1}$ total basal area (Table 8; Figure 7). Pitch pine comprised 75% of stems while red maple and red oak each made up 9%. Pitch pine stems averaged between 9 and 12 cm basal diameter across plots (Table 2), while hardwood species were mostly ~ 5 – 10 cm (Figure 8). Very low densities of dead pine stems (30 ha^{-1}) were observed within the sample plots on the summit. We estimate that at least 34% of pitch pine stems originated as basal sprouts, and we found charring on the exposed root system of a dead pine stem on the summit as well as abundant soil charcoal on the north slope (Figs. 9 and 10).

Table 8. Overstory vegetation composition of live and dead stems on the summit of Bear Mountain, northwestern Connecticut.

Species	Density (ha^{-1})	Rel. Density (%)	Basal area (m^2 ha^{-1})	Rel. Basal area (%)	Rel. I.V.* (%)
Live stems					
Acer rubrum	59	9.0	0.38	6.8	7.9
Amelanchier arborea	15	2.3	0.04	0.7	1.5
Betula papyrifera	30	4.6	0.06	1.1	2.9
Pinus rigida	489	75.0	4.67	84.0	79.5
Quercus rubra	59	9.0	0.40	7.2	8.1
Totals	652		5.56		
Dead stems					
Pinus rigida	30	--	0.12	--	--

* Importance value calculated as the average of relative density and basal area.

Figure 7. View of Bear Mountain summit, northwestern Connecticut, with a sparse overstory of pitch pine and dense shrubs and hardwood saplings.

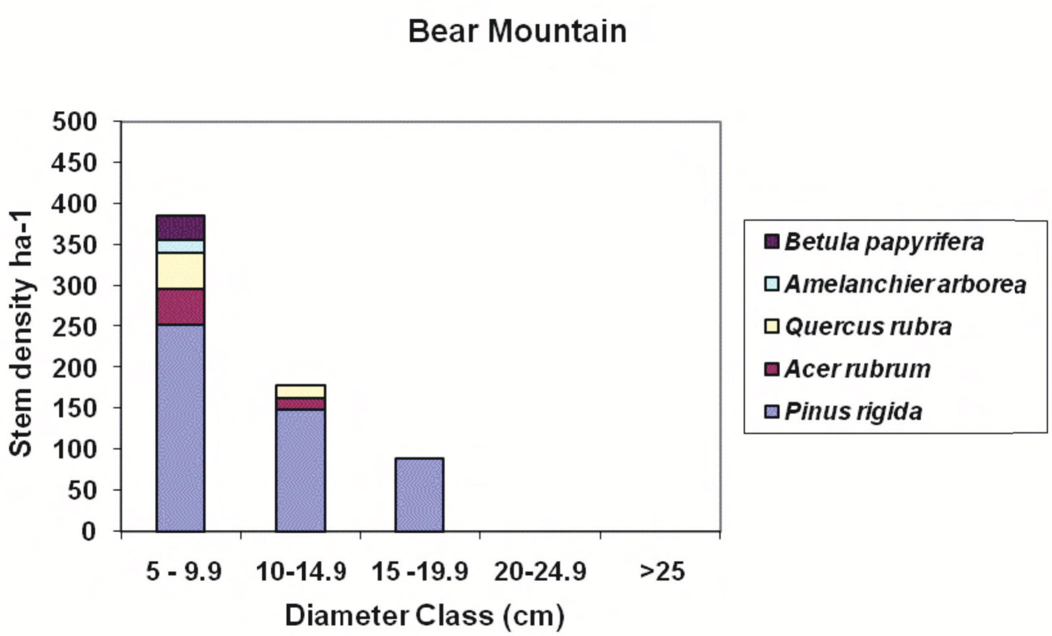


Figure 8. Diameter distribution of live stems on Bear Mountain, northwestern Connecticut. Diameter is basal diameter for pitch pine and diameter at breast height for other species.

Figure 9. Pitch pine with charred roots on the rocky summit of Bear Mountain.

Figure 10. Abundant charcoal amidst lichens and leaves on the soil surface of the upper north slope of Bear Mountain.

In contrast to the overstory, understory vegetation was particularly abundant with sapling densities of 2770 stems ha^{-1} and seedling densities of 4400 stems ha^{-1} (Tables 3 and 4). *Betula populifolia* dominated the sapling layer, although both *Amelanchier* and *P. rigida* were common in the sapling and seedling layers (Tables 3 and 4). Other understory vegetation at Bear Mountain was dominated by low shrubs, especially *Vaccinium angustifolium*, *Gaylussacia baccata,* and *Quercus ilicifolia* (Table 5). The herb layer was very sparse, with *Maianthemum canadense*, *Deschampsia flexuosa, Trientalis borealis,* and *Aralia nudicaulis* occurring most frequently (Table 6).

Age Structure

Hill 1914

Age structure of pitch pine was consistent across the site, with average ages exceeding 100 years in all 3 plots despite the diminutive size of the trees (Table 2). Pine recruitment began in the 1770s and was fairly continuous until the 1950s (Figure 11). The oldest individual (228 years in 2002) is believed to be the oldest known pitch pine in the state. The few white pine that were aged were < 50 years old.

Race Mountain

Pitch pine ages on the summit of Race Mountain ranged from 14 to 159 years old, with continuous recruitment of individuals since 1843 (Figure 12). Twenty-five percent of aged pitch pine became established between 1938 and 1951. Average pine age within plots ranged from 64 to 103 (Table 2). Several younger red oak and red maple became established within the last 50 years at this location.

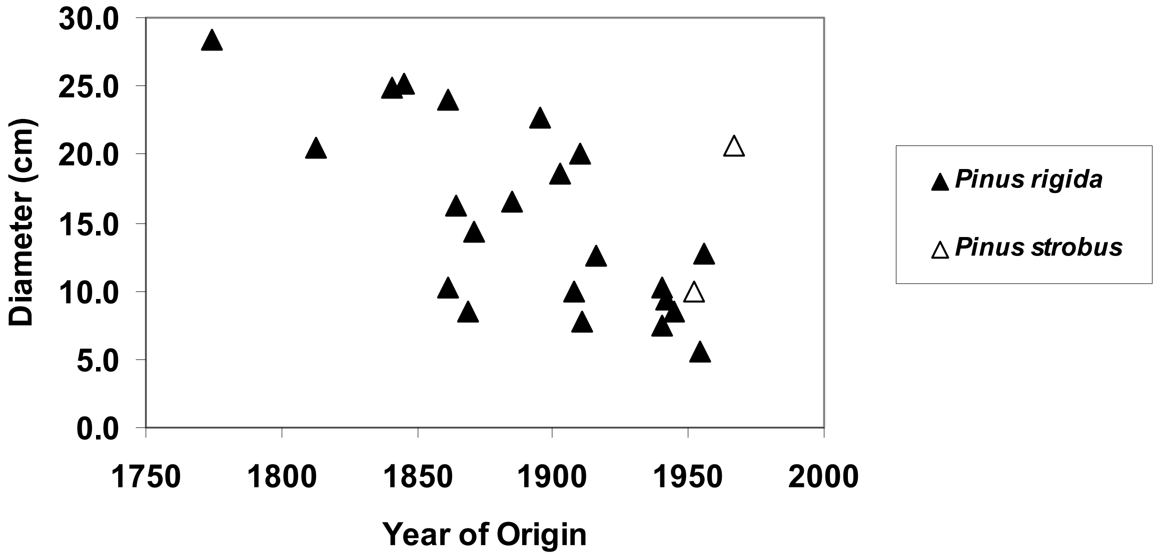


Figure 11. Age versus diameter of cored trees (n = 24) on Hill 1914. Diameter is basal diameter for pitch pine and diameter at breast height for white pine.

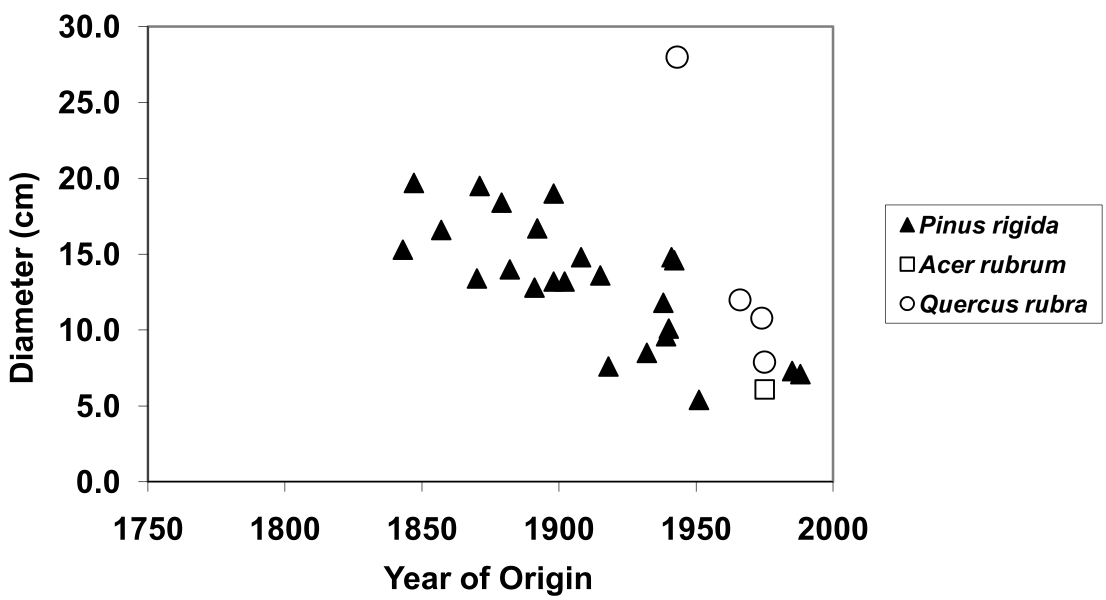


Figure 12. Age versus diameter of cored trees (n = 30) on the summit of Race Mountain. Diameter is basal diameter for pitch pine and diameter at breast height for all other species.

Insect Pests, Frost, and Ice Damage

On Race Mountain, and to a lesser extent on the other summits, we observed pitch pines in the summers of 2001 and 2002 that had shoots with globular swellings that were partly covered in sap; in some cases, these shoots had yellow needles or needles and twigs that were apparently dying near the swollen masses. Moth larvae were found inside these swellings. We collected two twigs with such swollen masses; a moth that developed from these twigs was identified by M. Mello (Research Director, Lloyd Center for the Environment, Dartmouth, MA) as *Retinia comstockiana*, one of several common pine tip moths (Figure 13). Numerous additional pitch pines had broken twigs that did not appear to result from storm damage and may have resulted from similar damage associated with this insect species.

Figure 13. The pine tip moth, *Retinia comstockiana*, a common twig borer on pitch pines on the summit of Race Mountain. Photo by A. Ellison.

We observed frost damage to newly emerging scrub oak leaves on Bear Mountain in Spring 2003, and we have observed similar damage to scrub oak on Mt. Everett in the past. It is likely that similar damage has occurred frequently on these summits. Scrub oak is frost sensitive and the first flush of leaves is frequently killed by late spring frosts in pine barrens throughout the Northeast (Motzkin *et al.* 2002c). In addition, we noted occasional broken pitch pine branches within all study sites, presumably resulting from ice or other storms within the past few years (Figure 14).

Figure 14. Pitch pine branch recently broken, apparently due to ice, on Bear Mountain, northwestern Connecticut.

Fire History

We found no fire scars, and little evidence of stem charring on the sites we examined in this study, with the exception of Bear Mountain where soil charcoal and a heavily charred exposed root mass were observed (Figs. 9 & 10). Old campfire rings were observed on the summits of Race and Bear Mountains, with a stone fire back and nearby pile of cut dead pitch pines on Race Mountain.

Although detailed historical records comparable to those for the summit of Mt. Everett are not available for these summits, Tillinghast (1999) cites a 1929 Berkshire County Commissioner report that notes: “There was a fire in June on Race Mountain but it did not reach our bounds” (i.e., the bounds of the Mt. Everett State Reservation: MESRC 1930). The location of the 1929 fire on Race Mountain is unknown.

DISCUSSION

The southern Taconic Mountains of Massachusetts, Connecticut and New York support several examples of dwarf pitch pine communities that are rare elsewhere in the eastern U.S. Although the dwarf pitch pine communities on the summit of Mt. Everett are more extensive than those found on Race Mountain, Bear Mountain, or Hill 1914, results of this investigation confirm that vegetation composition, structure, and dynamics on these locations are similar to those documented from Mt. Everett, with some important differences (see below). All four sites support uneven-aged, stunted pitch pines, which apparently persist and regenerate in the absence of frequent fire because of the harsh site conditions. Factors such as shallow soils and frequent damage from winter storms prevent most other species from getting established on these sites, allowing the better adapted pines to continue to establish and grow slowly. Cone serotiny, which is characteristic of dwarf pitch pine communities elsewhere in the eastern U.S., was not observed on any of the summits, consistent with the lack of frequent fire.

Stand composition and structure

Our results document moderate variation in vegetation structure and composition among sites. Of the three sites investigated for the current study, Race Mountain has the highest density of dwarf pitch pines (1482 stems ha^{-1}), approximately three times the density of dwarf pines on Bear

Mountain. Hill 1914 has the highest pitch pine basal area (18 m^2 ha^{-1}), ~ four times the pitch pine basal area on Bear Mountain. Thus, Bear Mountain has substantially lower density and basal area of pitch pine than either Race Mountain or Hill 1914. Interestingly, Bear Mountain also has substantially lower densities of dead pitch pines than the other summits, and Bear Mountain supports a higher frequency of upright stems with well-defined leaders (Figure 15). Although we did observe several prostrate, contorted pitch pines on Bear Mountain, some with sprout growth forms, most pitch pines were more upright and had less contorted growth forms than on the other summits. Pitch pine seedling and sapling densities are high on Bear Mountain, and the relative basal areas and importance values of pitch pine on Bear Mountain (rel. BA=84%, rel. IV=80%), Hill 1914 (94%, 95%), and Race Mountain (98%, 98%) are all substantially higher than those recorded on Mt. Everett (53%, 54%).

Figure 15. Young, upright pitch pines with intact terminal leaders common on Bear Mountain, northwestern Connecticut.

In contrast, red oak, which represents an important component of the summit vegetation on Mt. Everett (relative density=28%, relative basal area= 35%, relative importance value=32%), was absent or much less abundant in the plots we sampled on the other three sites. Similarly, red maple was more abundant on the summit of Mt. Everett. Thus, the most striking difference between the summit of Mt. Everett and the sites investigated in this study is that dwarf pitch pine communities on Mt. Everett have a substantial component of hardwoods emerging above the stunted pines, with a few red oaks and red maples exceeding 7.5 m, which is approximately 6 m taller than the average pitch pine height and ~ 5 m taller than the average height of the tallest pitch pines on Mt. Everett (Motzkin *et al.* 2002b). In contrast, the dwarf pitch pine communities that we investigated on nearby locations have fewer tall hardwoods and appear more similar to photos of the summit of Mt. Everett from the late 19th and first half of the 20th centuries (Figure 16). In addition, *P. rigida* regeneration is more abundant on these sites without dense overstory hardwoods. Bear Mountain in particular had 2200 more pine seedlings ha^{-1} than Mt. Everett.

Understory vegetation among the three sites examined in this study was quite similar, with several shrubs (*Aronia* sp., *G. baccata, Q. ilicifolia,* and *V. angustifolium*) common at all plots. These same species were also abundant on the summit of Mt. Everett (Motzkin *et al.* 2002b) and on the pine outcrop at Wachusett Mountain (Parker 2004).

Age structure reconstructions (Bear Mountain not included)

Age structure reconstructions indicate that, similar to Mt. Everett, Race Mountain and Hill 1914 are characterized by dwarf pitch pines that are uneven-aged. This contrasts with pitch pine barrens on sand plains throughout the Northeast, where relatively even-aged cohorts typically result from episodic establishment after fire or other disturbance (Lutz 1934; G. Motzkin unpubl. data). However, ~25% of aged pitch pine stems on Race Mountain established between 1938 and 1951,

Figure 16. Comparison of present-day structure of Race Mountain (top panel) with 1930s view to the SW from Mt. Everett (bottom panel, photo from Eleanor Tillinghast). Note abundant short pitch pines in the foreground of the view from Mount Everett, with no tall hardwoods, similar to Race Mountain. Bear Mountain is the hill in distance on the left.

suggesting the possibility that these stems may have established in response to fire, possibly the 1929 fire reported by Tillinghast (1999), or other undocumented disturbance on the summit. Similarly, 27% of pine stems established on Hill 1914 during this time period, suggesting that this also may represent a response to an unknown disturbance. The few hardwoods and white pines that we sampled in our plots on Race Mountain and Hill 1914 have established since 1950. This corresponds broadly with the increase in hardwood establishment from 1940 to 1980 that we documented on Mt. Everett, raising the possibility that regional climatic changes, or increased time since undocumented historical disturbances on these sites, may have enabled increased hardwood establishment during the past half century.

Average age of pitch pines is greater on Hill 1914 (111 years) than on Race Mountain (93 years) or Mt. Everett (78 years). In addition, two pitch pines sampled on Hill 1914 exceed the maximum ages recorded on Race Mountain (159 years in 2002) or Mt. Everett (170 years in 2000); one of these stems was 228 years old in 2002, and is believed to be the oldest known pitch pine in the state. Pitch pines exceeding 200 years are rare in Massachusetts, but have also been documented from Montague Plain (Hager 1995), Pine Cobble in Williamstown (T. Rawinski, pers. comm.), and Mount Wachusett in central Massachusetts (Parker 2004). It is unclear why none of the trees sampled in the southern Taconics or elsewhere in Massachusetts approach the maximum ages of pitch pines documented from harsh rocky summits in the Shawangunks of New York, where trees exceeding 300 years have been documented (Abrams and Orwig 1995). Similarly, we know of no pitch pines in Massachusetts that approach the maximum age (>260 years) that we have recorded for native red pines (*Pinus resinosa*) on exposed rocky sites in the Connecticut Valley (unpublished data).

Fire History, Serotiny, and the Persistence of Dwarf Pitch Pine Communities

Our results documenting uneven-aged pitch pine establishment on Race Mountain, Hill 1914, and Mt. Everett are similar to results of age structure reconstructions for pitch pine on Wachusett Mountain (Parker 2004) and for jack pine (*Pinus banksiana*) growing on exposed rocky sites in Acadia National Park in Maine (Conkey *et al.* 1995). Although elsewhere in North America jack pine has high levels of cone serotiny (cones sealed with resin that open only with heat from a fire) and typically regenerates in response to fire, in coastal Maine it has low levels of serotiny and apparently persists in the absence of frequent fire (Conkey *et al.* 1995). Similarly, although fire and cone serotiny are frequent on most other sites that support dwarf pitch pines in the eastern U.S., dwarf pitch pines in the southern Taconics are non-serotinous and persist in areas with little historical or dendroecological evidence of frequent fire. Our observations do not support statements by Wessels (1999) that: "Mount Everett's pitch pine show little or no serotiny in their cones while nearby populations on Race and Bear Mountains have high levels of serotiny, suggesting that Mount Everett's pitch pines are genetically isolated from those to the south on this ridge system." In fact, on all three sites visited as part of this study as well as on Mt. Everett, we observed that most pitch pine cones were open, despite the lack of recent fire on any of the sites. Although we did occasionally see closed cones, there is no evidence that these were cones were truly serotinous.

Pitch pine cones may remain closed for many reasons and the presence of closed cones alone does not confirm serotiny. For instance, immature cones are generally closed, aborted cones may remain closed, and mature cones may open and close in response to changes in humidity (Conkey *et al.* 1995). We were able to open closed cones in the southern Taconics easily, indicating that they were not sealed with the resins characteristic of serotinous cones. In addition, some of the closed cones we opened had no seeds, suggesting that either: (1) they had already released seeds and then re-closed, presumably in response to changes in humidity, or (2) that the cones and seeds may not have developed to maturity for unknown reasons. In summary, we did not observe any pitch pine cone serotiny on Mt. Everett, Hill 1914, Race Mountain, or Bear Mountain, and we suspect that if serotiny occurs at these sites, it is extremely rare. The lack of cone serotiny in these forests is consistent with the lack of evidence of frequent fire on these sites during at least the past century.

Although fires have apparently been uncommon on the study sites during the last century, the earlier history of fire remains unclear. In particular, it is possible that fires may have occasionally escaped and spread upslope during the 19th century when intensive charcoal production occurred throughout the region (Gordon 2001). We observed numerous charcoal hearths on the lower slopes of Bear Mt. and elsewhere in the Taconics, suggesting the possibility that escaped fires may have impacted the study sites prior to the decline of the charcoal industry in the late 19th or early 20th centuries. It is also possible that fire was used on the summits historically to improve berry production, a practice that was common in many rocky barrens in the east (Batcher *et al.* 1997; Copenheaver *et al.* 2000). Thus, although we found no early historical references to fire on these sites and age structure analyses confirm that pitch pines have successfully regenerated in the absence of fire, fires may have occasionally occurred on these sites. In particular, the shorter stature of the vegetation across the summits of Race and Bear Mountains compared to Mt. Everett is consistent with more recent disturbance on these two hills, as is the abundance of charcoal on Bear Mountain and the reference to a fire in 1929 on Race Mountain.

Interestingly, a wildfire that ignited in early July 2002 east of the summit of Mt. Everett, between Mt. Everett and Hill 1914 (Figs. 17-18), provides insight into the potential role of even infrequent fire in the region. Although the cause of the fire remains unclear, the presence of a campfire ring within the burn suggests that it may have been inadvertently set by campers (Cohen

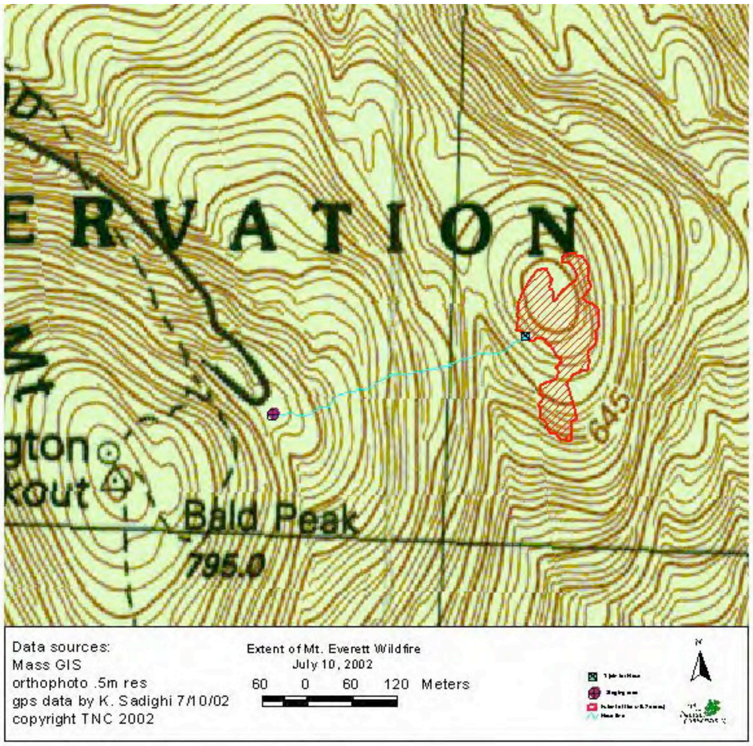


Figure 17. Outline of fire area that smoldered for seven weeks on the eastern slope of Mount Everett in 2002. Hill 1914 is located east of the fire, not visible from this map.

Figure 18. View of fire area from Hill 1914 towards the summit of Mt. Everett. Note brown foliage of top-killed pines and smoke rising from ground fire. Photo was taken in late August- 2002, approximately 6 weeks after the fire ignited.

2002). However, we also noted lightning damage to one or more trees on the sight when we visited the area in late August 2002, suggesting the possibility that the fire may have been naturally ignited. The inaccessibility of the site greatly impeded efforts to extinguish the fire, and a decision was ultimately made by fire control personnel to call off active attempts to extinguish the fire. The fire smoldered for approximately seven weeks before ultimately being extinguished by soaking rains, representing the longest burning wildfire that we are aware of in recent history in Massachusetts. We visited the area six weeks after the fire was ignited and although the fire had apparently spread very slowly, smoke continued to rise and low flames occasionally erupted from the smoldering duff (Figure 19).

Figure 19. Smoldering organic matter on the soil surface and charred base of tree with exposed roots within the fire area from the fire in summer 2002 in Mount Everett State Reservation. Photo was taken in late August, approximately 6 weeks after the fire ignited.

The effects of the fire were extremely heterogeneous at the scale of meters; in some areas the entire organic layer had been consumed and the root systems of huckleberry (*Gaylussacia baccata*) and other shrubs had been killed, whereas in other areas the organic layer was largely intact. A subsequent re-visit to the site confirmed that although the above ground-stems of many trees had been killed, some oaks and pitch pines had re-sprouted (Figure 20). We have not re-visited the site in recent years to record the long-term fate of these sprouts, or to determine the extent to which pitch pines or other species established as seedlings in response to the fire. Although fires are infrequent on the summits of the Taconics, when fires do occur, they may have long-term effects on vegetation composition and structure, particularly if they occur during summer droughts when rates of spread are typically low but when severe fires may smolder for long periods of time and thus consume the organic layer. Because of the steep slopes and or shallow soils, much of the charcoal from such fires may be washed from the site by subsequent rains, leaving little evidence of fire on the site.

Figure 20. Pitch pine sprouts following the fire on the eastern slope of Mount Everett.

Several studies have investigated the possibility that dwarf versus normal-stature pitch pines may result from genetic differences among populations (Andresen 1959, Good and Good 1975, Guries and Ledig 1982, Fang *et al.* 2006). Guries and Ledig (1982) found that dwarf pitch pines are genetically similar to nearby tall-stature trees in the New Jersey pine barrens. Similarly, based on the results of reciprocal transplant experiments, Fang *et al.* (2006) determined that height, growth rate, survival, and growth form of pitch pines on Long Island, NY are more strongly related to transplant location than to seedling origin (i.e., dwarf versus normal-stature parents). They conclude that dwarf versus normal-stature growth forms may result from plastic response to environmental conditions, noting edaphic differences among sites with dwarf versus normal-stature trees (Landis *et al.* 2005, Fang *et al.* 2006). However, the specific mechanisms by which differences in edaphic conditions result in such substantial variation in growth form remain unresolved (Fang *et al.* 2006).

Although no comparable studies have been conducted for the pitch pine populations in the Taconics, we hypothesize that dwarf pitch pines in the region may similarly reflect harsh environmental conditions rather than strong genetic differentiation among nearby populations. In particular, all of these sites are characterized by extremely rocky, exposed conditions and frequent ice and wind storms (Figure 21). In several locations we observed normal-stature pitch pines immediately down slope of the dwarf communities, in areas where gene flow is likely; thus, we suspect that genetic factors may be less important in controlling these differences in height and growth forms than differences in exposure and depth of soils.

Figure 21. Pitch pine trees on the summit of Mount Everett in 1945, indicating tremendous ice accumulation on branches. Photos provided by E. Tillinghast.

Conclusions

The southern Taconic Mountain region is a critical conservation priority, supporting extensive areas of unfragmented forest and several rare species and priority natural communities, including the dwarf pitch pine communities that were the focus of this investigation. The region has been identified by The Nature Conservancy and the Massachusetts Natural Heritage and Endangered Species Program (BioMap 2001) as one of the highest priorities for conservation in the Northeast (see inset, Figure 1). In addition, in 2006 the Massachusetts Executive Office of Environmental Affairs designated more than 7,000 acres of lands managed by the Department of Conservation and Recreation in Mount Washington State Forest and Mount Everett Reservation as a Large (Matrix) Forest Reserve, including several summits that support dwarf pitch pine communities. Results from the current study as well as our previous studies of Mt. Everett (Motzkin *et al.* 2002a, b) confirm the ecological significance of these communities. These summits support dwarf pitch pine communities that are extremely rare throughout the eastern U.S. Importantly, these communities are also characterized by ecological dynamics that are highly unusual even among dwarf pitch pine communities: the communities have apparently persisted for centuries in the absence of frequent fire. Although none of the sites is characterized by old-growth pitch pines comparable to those documented in the Shawangunks (Abrams and Orwig 1995), Hill 1914 supports the oldest known pitch pine in Massachusetts. Based on our experience with pine barrens throughout the northeastern U.S., we consider the complex of dwarf communities on the summits of the southern Taconics to be exemplary and worthy of the most stringent of conservation measures. Additional studies are warranted to investigate other similar sites in the region. In addition, we recommend that a series of permanent plots be established that will enable future investigators to document disturbance history and long-term changes in forest composition and structure on these sites. Particular attention should be paid to evaluating the extent to which hardwoods may increase on these sites over time, potentially threatening the dwarf pitch pine communities.

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