ECOLOGICAL MANAGEMENT OF SANDPLAIN GRASSLANDS AND COASTAL HEATHLANDS IN SOUTHEASTERN MASSACHUSETTS

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ABSTRACT

Ecological management in endangered grasslands and heathlands is focussed on limiting or reversing the encroachment of *Gaylussacia baccata, Myrica pensylvanica, Quercus ilicifolia,* and other shrubs, and on increasing herbaceous taxa, especially rare grassland species. Several studies were initiated between 1982–1989 to investigate the effects of prescribed burning and mowing on coastal heathland vegetation composition and structure. Results are summarized from 14 sites in which treatments differed by type, season, and frequency. Single treatments did not achieve significant long-term reductions in shrub cover or frequency. Spring burns repeated every 2–4 years slowed the expansion of many shrub species. Biennial burning or mowing during the summer reduced shrub cover and-or frequency. Forbs and grasses increased in frequency following all treatments; burning was more successful than mowing. However, cover of *Schizachyrium scoparium, Carex pensylvanica,* and other graminoids decreased after most treatments. More aggressive management methods, including multiple treatments during the growing season, harrowing, and herbicide application, may be necessary for long-term control of shrub expansion, where restoration, rather than maintenance, is desired.

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INTRODUCTION

Several vegetation types dominated by low shrubs, grasses, and other herbaceous species are found intermingled in coastal areas along the eastern seaboard of North America. These communities form a vegetation continuum, from open sandplain grasslands, with a diversity of graminoids and forbs, to coastal heathlands, dominated by low ericaceous shrubs (Dunwiddie et al. 1996). The sandplain grasslands are a globally endangered community that occurs from Cape Cod, Massachusetts to Long Island, New York (Massachusetts Natural Heritage and Endangered Species Program 1993). They are similar in many respects to the prairies of the Midwest, including their dominance by little bluestem grass (*Schizachyrium scoparium*), but include a distinctive association of primarily coastal taxa as well. Many regionally and even globally rare plants occur in this community, including the bushy rockrose (*Helianthemum dumosum*), yellow sandplain flax (*Linum intercursum*), sandplain blue-eyed grass (*Sisyrinchium fuscatum*), sandplain gerardia (*Agalinis acuta*), and eastern silvery aster (*Aster concolor*). Short-eared owls (*Asio flammeus*), northern harriers (*Circus cyaneus*), upland sandpipers (*Bartramia longicauda*), grasshopper sparrows (*Ammodramus savannarum*), and regal fritillary butterflies (*Speyeria idalia*) are some of the rare fauna that also occur in these areas.

Coastal heathlands have a broader geographic range than sandplain grasslands, extending from the Canadian Maritimes to northern New Jersey. However, they are also a rare community in the northeastern United States, and include some of the same endangered species that occur in grasslands. The vegetation is dominated by members of the Ericaceae, as well as species in other families with similar growth forms and physiognomies, including the Empetraceae, Myricaceae, and Cistaceae. In Massachusetts, heathlands and grasslands are often intermixed, and usually occur on dry, sandy, nutrient-poor glacial deposits. Oftentimes, the communities are not readily distinguished, and may share many species with other coastal communities as well, such as sand dunes and scrub oak-pitch pine barrens (Dunwiddie et al. 1996).

This vegetation continuum also reflects a successional trend in many areas, with woody plants encroaching into sandplain grasslands, and taller shrubs and trees overtopping the ericads in heathlands. This succession is accompanied by a loss of many plant and animal species considered rare by state Natural Heritage Programs (Rawinski 1984, Godfrey and Alpert 1985, Massachusetts Natural Heritage Program 1989). Therefore, studies were begun by the Massachusetts Audubon Society in 1981 to understand the composition, origins, extent, and dynamics of coastal grasslands and heathlands in order to develop methods for maintaining these seral stages. These studies suggested that prior to European settlement, most grasslands and heathlands occurred in areas where saltspray inhibited

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the growth of trees (Dunwiddie 1989, 1990a). Human-ignited fires, especially in the spring and during summer droughts, played an important role in maintaining grass, shrub, and xeric forest communities in coastal New England in presettlement times (Patterson and Sassaman 1988). Forest clearing and livestock grazing in the 17th and 18th centuries resulted in the expansion of heathlands further from the shoreline. In the 20th century, the removal of grazing animals and fire suppression has resulted in the succession of woody plants which has eliminated many heathland sites. More recently, real estate development has claimed other sites, and the most extensive heathlands today remain in exposed locations on Nantucket Island, Martha's Vineyard, the Elizabeth Islands, and Cape Cod, Massachusetts in areas that were cleared for pastures but have not yet completely overgrown with taller woody plants.

Shrubs and trees are slowly reclaiming these areas, although this process is hindered by harsh winds and saltspray on the open landscape. If grasslands and heathlands are to be preserved in locations other than in small, restricted areas within a few hundred meters of the shoreline, management efforts must focus on techniques for slowing, interrupting, or reversing the succession of taller woody plants. The purpose of the studies described in this paper is to identify the most effective methods for controlling woody plants and encouraging growth of native herbaceous species in these habitats on Nantucket, Martha's Vineyard, and Cape Cod.

It is difficult to design a well-controlled study to determine the impacts of these management techniques on ecosystems. Not only are there many portions of the biota that may be significantly and differently affected, but the innumerable permutations of season and frequency of treatment, combinations of methods, identification of short-term versus long-term effects, and the need for controls and replicates vastly exceeds the resources, time, and space available to most organizations. One alternative, used in this paper, is to identify similar patterns or trends in species' responses to treatments that occur repeatedly in different studies in similar habitats. The objective of this paper is to highlight common trends among grassland and heathland plants that have occurred as a result of treatments applied in several studies of prescribed burning and mowing in these communities.

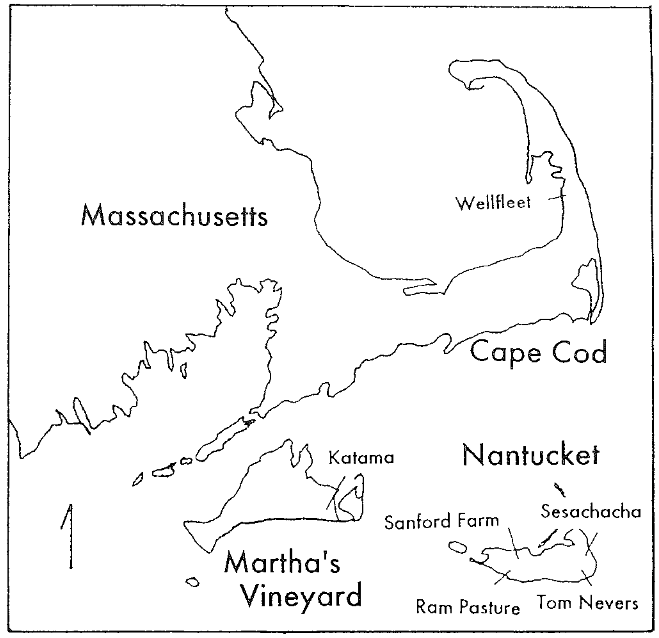

Figure 1. Locations of research sites in southeastern Massachusetts.

METHODS

Studies were established between 1982 and 1989 at six different locations on Nantucket, Martha's Vineyard, and Cape Cod (Figure 1), and include both coastal heathlands (Tom Nevers, Wellfleet heathland, Sesachacha heathland) and sandplain grasslands (Ram Pasture, Wellfleet grassland, Sanford Farm, Katama). The seven sites included fourteen treatment plots between 0.02 hectare and 15 hectares (Table 1). Each of the seven sites also contained an untreated reference plot. The first study was set up in Ram Pasture in 1982 to examine the effects of three different treatments applied biennially: spring burning, summer burning, and summer mowing. The plots have received seven treatments in 14 years. Plots established in subsequent years at the other locations have employed various burning, mowing, and combination treatments (Table 1).

A standardized methodology was used at all sites to measure plant responses to treatments (Dunwiddie 1986). Percent cover (estimated in one of six cover classes) and frequency were measured for all plant species found in 20×100 square centimeter quadrats located along transects across each research site; data were collected from a minimum of 30 quadrats in each of the plots. Average maximum height values were obtained by measuring the tallest individual in each quadrat of those species with cover values that exceeded 5%. All plots were monitored prior to the initial treatment, and every 1–4 years thereafter.

Prescribed burns were generally ignited as strip headfires using a driptorch. Grassland fuel loads averaged between 850–1000 grams per square meter (dry weight), about half of which was woody. Flame lengths in most burns in herbaceous-dominated fuels were less than 2 meters. In contrast, flames occasionally exceeded 10 meters in *Gaylussacia* and other shrub fuels. Spring burns were the most intense, summer burns the least, and fall burns were intermediate. Mowing and brush cutting were carried out using a rotary cutter drawn by a tractor.

These studies were part of ecological management programs in which site selection was guided primarily by ecological objectives. This generally precluded opportunities for replication and randomized assignment of treatments. Therefore, statistical tests were not applied to the data. Instead, trends in common among species and between sites with similar treatments were

Table 1. Study areas, set-up and treatment dates (Month/Day) on Nantucket (Nan.), Martha's Vineyard, and Cape Cod. S = Set-up, B = Burn, C = Cut.

Location	Tom Nevers, Nan.			Ram Pasture, Nan.			Sanford Farm, Nan.		Katama, Martha's Vineyard			Wellfleet, Cape Cod		Sesachacha Heathland,
Treatment	Oct. Burn	April Burn	Dormant Cut	Aug. Burn	Aug. Cut	April Burn	Unit D B/C	Unit B B/C	Oct. Burn	April Burn	Dormant Mow	Grass Burn	Heath Burn	Nan. Burn
Area	0.04ha	0.04ha	0.02ha	0.25ha	0.25ha	0.25ha	3.5ha	3ha	7ha	7ha	7.5ha	0.5ha	2.5ha	15ha
1982						S-9/19								
1983				S-7/21 B-8/5	S-7/26 C-8/3	B-4/13								
1984														
1985	S-7/25 B-10/5	S-8/13	S-7/31 C-9/15	B-8/5	C-8/3	B-4/13								
1986							S-8/29	S-6/30	S-7/23	S-7/22	S-7/23			
1987		B-4/27		B-8/2	C-8/1	B-4/12	B-5/9	B-3/25	B-10/31	B-4/26	C-10/15			
1988	B-10/31		C-10/7									S-7/26		
1989		B-4/21		B-8/2	C-8/1	B-3/20	C-3/1	B-3/23 C-6/25				B-4/20	S-7/27	S-7/12
1990			C-2/1				B-2/1 C-3/25						B-4/19	
1991				B-8/3	C-8/1	B-4/13		B-4/3		B-4/14	C-3/15			B-3/29
1992	B-10/7	B-3/6	C-3/4					C-9/2	B-11/19			B-3/17		
1993				B-8/3	C-8/1	B-5/2		B4/8						
1994														B-11/14
1995				B-8/10	C-8/6	B-5/9	B-4/17 C-9/5	B-3/29 C-9/5						

compared to provide general indications of management effects.

RESULTS AND DISCUSSION

Changes in the composition of the study plots over time, both in the absence of disturbance (reference plots), and as a result of various treatments, are summarized in Tables 2–6. Data are grouped within the tables by community (heathlands in Tables 2–3, grasslands in Tables 4–6), site, and treatment. Average percent cover and frequency were calculated based on the total number of quadrats per plot (usually 30). Species were included in the tables where cover or frequency values exceeded 5% in at least one of the plots. Only pretreatment and the most recent year's values from each site are depicted to simplify the tables. A third descriptor, maximum height, had too few measurements for most species to yield meaningful results. Height data for three species at one site (Ram Pasture) are depicted in Figure 2 and illustrate patterns often observed at other sites.

Composition of Grasslands and Heathlands

When considered collectively, Tables 2–6 provide a useful characterization of heathland and grassland composition. In general, the cover of ericoid species in heathland sites (Tables 2–3) was greater than 50%, whereas it approached that level in only a few sandplain grasslands (Tables 4–6). Graminoids and other herbaceous species were less prominent in heathlands, where cover values of these taxa rarely exceeded 15%, in contrast to the 30–90% cover in sandplain grasslands. Species richness was similar in heathlands and grasslands (6.6±2.1 species per quadrat versus 6.5±0.5). However, the proportion of shrubs was higher (55%) in the former than in the latter (30%).

Both grasslands and heathlands are rapidly being overtaken by taller woody vegetation (Dunwiddie 1992), but little data are available to quantify the rate at which this succession is occurring. Analyses based on aerial photographs of clonal shrubs in sandplain grasslands on Nantucket (Dunwiddie, unpublished data, Harper 1995) depict shrub cover increasing from about 20% in 1938 to 30–40% in 1988, an increase of 0.2–0.4 percent per year. This compares with a rate of 0.75–0.9 percent per year in black huckleberry (*Gaylussacia baccata*) cover measured in the reference plots at Katama and Ram Pasture (Tables 4 and 6). The general increase in shrubs in grasslands mirrors a rapid loss of the herbaceous taxa (Harper 1995). This is well-illustrated in the reference plot at Ram Pasture, where large increases in shrub cover, frequency, and height over the last 12 years have been matched by a three- to four-fold decline in herbaceous cover (Table 4).

Treatment Effects on Shrubs

All treatments generally resulted in the top-killing of shrubs, with a consequent short-term decline in

Table 2. Cover (C) and frequency (F) of major species at heathland treatment plots in Tom Nevers, Nantucket. Values <1 percent are indicated by "+".

	Reference				Oct Burn				Dormant cut				Apr burn			
	1985		1989		1985		1992		1985		1994		1985		1994	
Species	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F
Agrostis sp.																
Amelanchier nantucketensis	3	30	2	33	2	23	+	22	2	40	1	43	+	17	+	13
Arctostaphylos uva-ursi	+	10	+	7	24	53	15	42	37	93	14	80	5	22	2	12
Aronia arbutifolia	3	40	1	40	1	15	+	18	3	37	+	37	1	5	+	8
Aster dumosus	+	10	+	7					+	3	+	10				
Aster linariifolius					+	8	0	0	+	17	+	7				
Aster paternus					+	12	+	13	3	47	+	37	+	7	+	2
Aster spectabilis	+	17	+	7	1	27	+	25	3	53	2	87	2	20	+	22
Carex pensylvanica	1	40	+	27	7	73	2	85	6	93	2	100	3	47	+	53
Cladonia spp.													+	3		
Deschampsia flexuosa	+	7	+	3	+	22	+	38	3	47	1	80	+	10	+	13
Epigaea repens	2	10	1	13	2	28	+	12	4	30	+	27	+	5	0	0
Gaultheria procumbens	15	77	9	80	6	52	3	52	12	97	2	100	6	53	2	53
Gaylussacia baccata	6	13	7	13	16	65	13	65	9	33	7	30	48	85	35	88
Helianthemum dumosum					+	2	+	2	+	7	+	7			+	3
Lysimachia quadrifolia	+	20	+	20	+	13	+	13	+	40	+	27	+	8	+	7
Myrica pensylvanica	6	67	9	73	2	23	2	30	4	40	4	40	5	47	2	37
Quercus ilicifolia	26	60	31	67	58	93	40	83	12	50	9	50	59	98	41	82
Quercus prinoides	38	87	39	87	15	70	25	73	23	57	26	67	20	72	34	73
Rosa virginiana	2	23	+	27					+	13	+	20	+	7	+	8
Rubus hispidus	2	23	3	33	3	17	+	23	2	17	1	20	+	10	1	15
Schizachyrium scoparium					+	7	+	5	2	40	1	40	+	5	+	5
Vaccinium angustifolium	18	73	16	77	9	67	7	72	21	100	17	100	4	27	5	37
Vaccinium pallidum	32	97	41	100	13	70	17	73	15	97	13	100	19	80	13	70
Sum	160	730	166	740	162	752	128	760	165	111	107	1167	173	637	138	608
Ericoids	80	353	86	370	72	358	57	345	101	490	59	477	87	318	58	297
Other Shrubs	77	283	79	307	80	225	68	230	43	217	39	237	82	213	77	025
Graminoids	2	47	+	30	7	102	3	128	12	197	5	240	4	62	1	72
Forbs	1	47	+	33	3	67	+	57	8	193	4	200	2	40	+	35
Lichens and Mosses									+	13	+	13	+	3	0	0

Table 3. Cover (C) and frequency (F) of major species at heathland treatment plots in Wellfleet, Cape Cod and Sesachacha Heathlands, Nantucket. Values <1 percent are indicated by "+".

	Wellfleet Heath								Sesachacha Heathlands							
	Reference				Apr Burn				Reference				Apr Burn			
	1989		1990		1989		1991		1989		1990		1989		1995	
Species	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F
Agrostis sp.									+	37	+	32	+	2	+	2
Arctostaphylos uva-ursi	69	100	64	92	39	68	23	60	13	25	13	25	20	49	8	39
Aster dumosus									+	6	+	4	+	4	+	5
Aster linariifolius													+	13	+	16
Aster paternus									+	15	+	17	2	40	1	39
Carex pensylvanica	4	85	4	85	4	91	7	85	14	96	14	92	7	96	7	93
Cladonia spp.	17	54	21	77	24	77	8	70	7	25	5	26	+	9	0	0
Danthonia spicata									+	19	+	19	+	20	+	25
Deschampsia flexuosa	1	54	+	54	3	82	2	75								
Dichanthelium spp.													0	0	+	7
Epigaea repens													3	20	1	16
Festuca ovina/rubra													+	4	+	18
Gaylussacia baccata	12	15	12	15	13	27	3	15	25	49	21	49	17	31	7	36
Helianthemum dumosum													+	9	+	11
Hudsonia eric./toment.	2	31	2	31	3	41	+	35	2	13	3	15	+	9	+	7
Lechea maritima					+	5	+	15								
Myrica pensylvanica									3	9	3	9	1	9	+	7
Potentilla canadensis													+	2	+	5
Rosa virginiana									3	21	3	23	2	33	1	41
Rubus hispidus													+	4	+	5
Schizachyrium scoparium	+	8	+	8	1	32	2	35	4	75	5	77	7	76	6	77
Solidago tenuifolia													4	44	2	48
Vaccinium angustifolium									5	11	4	11	19	64	16	68
Sum	109	400	110	431	102	523	57	490	86	513	82	502	95	647	57	666
Ericoids	83	146	78	138	54	136	27	110	50	132	46	130	62	198	35	191
Other Shrubs	1	15	4	15	12	27	9	40	8	45	9	47	10	62	4	64
Graminoids	6	154	5	154	8	223	11	205	9	255	20	245	15	233	14	259
Forbs	2	23	2	23	+	14	+	30	2	57	2	53	6	140	4	145
Lichens and Mosses	18	62	22	100	27	123	9	105	7	25	5	26	+	13	+	7

Table 4. Cover (C) and frequency (F) of major species in sandplain grassland treatment plots at Ram Pasture, Nantucket. Values <1 percent are indicated by "+".

	Reference				Aug burn				Aug mow				Apr burn			
	1983		1995		1983		1995		1983		1995		1982		1995	
Species	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F
Agrostis sp.	1	30	+	10	2	20	+	30	1	34	+	41	2	37	0	0
Arctostaphylos uva-ursi					5	27	2	27	0	0	+	3				
Aronia arbutifolia					2	7	+	7	3	24	2	24	4	17	2	23
Aster dumosus	7	57	2	53	2	50	1	67	4	59	4	79	3	40	2	67
Aster linariifolius	+	3	+	3	+	20	+	23					+	7	+	7
Aster paternus	+	7	+	3	12	43	15	77	+	10	2	34	2	17	4	37
Carex pensylvanica	15	57	6	77	2	30	2	83	2	24	3	76	2	23	2	80
Danthonia spicata	+	17	+	13	+	23	+	23	0	0	+	48	+	7	0	0
Dichanthelium spp.	+	3	0	0	+	10	1	40	0	0	+	17	1	17	+	23
Epigaea repens	+	3	0	0	4	30	3	27					+	20	+	23
Festuca ovina/rubra	13	63	3	90	6	50	2	73	6	55	2	97	14	77	+	73
Gaylussacia baccata	15	30	26	43	16	37	15	37	17	62	6	62	18	43	12	50
Helianthemum dumosum	+	10	+	10	1	27	1	37	1	21	+	14	1	10	+	7
Myrica pensylvanica	2	27	11	40	9	50	3	13	5	28	+	10	4	33	2	30
Polygala polygama					+	3	+	20	+	3	0	0	+	3	+	7
Potentilla canadensis	0	0	+	7	0	0	+	27	+	10	+	28	0	0	+	3
Rosa virginiana	4	43	4	60	3	37	1	33	5	59	1	31	2	40	+	27
Rubus hispidus	12	57	13	77	22	60	3	30	12	66	3	55	8	47	2	33
Rumex acetosella	+	3	0	0	1	17	+	17	+	14	+	24	+	3	+	3
Schizachyrium scoparium	40	97	9	83	37	87	25	97	43	100	25	100	49	90	21	100
Sisyrinchium fuscatum					0	0	+	13	0	0	+	3	+	3	0	0
Solidago tenui./gramin.	0	0	+	7	+	7	+	3	2	21	+	24	0	0	0	0
Vaccinium angustifolium	5	17	14	33	4	17	7	20	12	31	13	48	15	47	22	60
Sum	124	577	94	697	138	760	87	1003	124	676	75	924	133	630	76	710
Ericoids	23	77	52	120	39	170	32	133	38	134	26	141	39	150	38	167
Other Shrubs	17	107	20	157	28	113	4	77	25	179	7	134	18	113	7	97
Graminoids	70	273	18	280	48	233	30	337	52	214	32	400	68	260	24	290
Forbs	15	117	6	140	18	223	20	437	10	148	10	248	8	103	8	153
Lichens and Mosses	+	3	0	0	4	20	+	20					+	3	+	3

shrub cover (summarized as "ericoids" and "other shrubs" in Tables 2–6) and height in most plots. However, nearly all shrubs in heathlands and grasslands readily resprouted after burning or cutting. False heather (*Hudsonia ericoides*) and broom crowberry (*Corema conradii*) are notable exceptions; the response of the latter species to burning is described elsewhere (Dunwiddie 1990b). The resprouting abilities of widespread and often dominant species such as *Gaylussacia baccata,* dwarf chinquapin oak (*Quercus prinoides*), scrub oak (*Quercus ilicifolia*), and chokeberry (*Aronia arbutifolia*) are illustrated by their relatively constant frequency values following multiple dormant season treatments (Tables 2–5).

Gaylussacia baccata is a particularly aggressive clonal shrub in sandplain grasslands. It typically forms dense stands from 0.5–1.7 meters tall, and is responsible for crowding out many herbaceous taxa (Harper 1995). At most sites, both cover and frequency values of this species showed little change following repeated treatments, but continued to increase in the reference plots. These results contrast with those of Niering and Dreyer (1989), who studied the impacts of annual and biennial spring burning on *Schizachyrium scoparium*-dominated grasslands in Connecticut over an 18-year period. In their studies, *Gaylussacia* increased in cover and frequency at rates equal to or exceeding those found in the reference plots. One possible explanation for this difference with our results may be the greater proximity of the Massachusetts sites to the ocean, where saltspray impacts may slow the rate of shrub regrowth.

Lowbush blueberry (*Vaccinium angustifolium*) is another vigorous clonal resprouter, and often increased after burning or mowing. This species is unlike the other common clonal ericaceous shrub, *Gaylussacia,* in being shorter (0.1–0.4 meters tall), more deeply rooted, and often coexisting with many herbaceous sandplain species. Thus, its apparent encouragement as a result of the treatments did not exclude other graminoids and forbs, as would a similar increase in *Gaylussacia.*

Bayberry (*Myrica pensylvanica*) has a stature similar to *Gaylussacia,* and also forms dense, clonal stands that preclude much herbaceous growth. However, its response in grasslands to burning is unlike many other shrubs, in that treatments significantly reduced both cover and frequency of this species (Tables 4, 6).

Quercus ilicifolia and *Q. prinoides* are frequently dominant in heathlands, and are well-represented in the Tom Nevers plots (Table 2). Top-killing of the taller (2–4 meters) *Q. ilicifolia* resulted in declines in the cover and frequency of this species following treatments, but this appeared to release the shorter (0.5–1.5 meters) *Q. prinoides,* a clonal species that exhibited a corresponding increase in the same parameters. Both are well-adapted to fire and resprout readily, although *Q. ilicifolia* does not reproduce by clonal expansion.

Two members of the Rosaceae, Virginia rose

Table 5. Cover (C) and frequency (F) of major species in sandplain grassland treatment plots at Katama, Martha's Vineyard. Values <1 percent are indicated by "+".

	Reference				Oct burn				Dormant mow				April burn			
	1986		1994		1986		1994		1986		1993		1986		1993	
Species	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F
Agrostis sp.	+	11	+	42	+	9	+	26	+	9	+	46	+	9	+	13
Aster dumosus	1	25	+	28	+	9	+	29	+	9	+	14	+	6	+	16
Aster linariifolius	+	22	+	31	+	14	1	29	+	17	+	23	3	47	6	66
Aster paternus	+	8	+	6	1	20	1	40	0	0	+	9	2	28	2	44
Aster solidagineus	2	36	+	22	2	17	+	29	0	0	+	9	+	31	+	50
Baptisia tinctoria	4	19	6	25	+	3	+	11	+	3	+	6	3	31	7	53
Carex pensylvanica	17	89	9	89	16	97	6	100	19	91	14	97	32	97	12	100
Cladonia spp.	+	3	+	6	2	17	0	0	+	6	+	11				
Danthonia spicata	+	14	+	17	+	9	+	31	+	6	+	29	+	9	+	19
Dichanthelium spp.	0	0	+	3	0	0	+	37	+	6	+	9	+	16	+	34
Festuca ovina/rubra	0	0	+	11	+	6	+	20	+	6	+	11	+	16	+	22
Gaylussacia baccata	22	39	28	50	3	11	6	14	24	46	20	69	9	13	9	13
Myrica pensylvanica					4	17	7	20								
Polygala polygama					0	0	+	3								
Potentilla canadensis					0	3	2	45					+	9	+	18
Rosa virginiana	+	3	+	17	2	31	2	51	2	14	+	11				
Rubus hispidus	37	75	19	81	30	97	12	91	22	86	18	86	7	31	13	59
Schizachyrium scoparium	18	86	3	79	18	86	12	86	13	77	4	77	14	88	10	88
Solidago graminifolia	2	17	1	31	3	57	+	34	4	51	1	51	+	6	+	6
Solidago tenuifolia	2	28	+	36					1	11	+	11	+	19	1	22
Tephrosia virginica	14	61	8	50	2	26	2	23	2	29	+	17	9	47	4	53
Vaccinium angustifolium	5	44	8	58	18	83	38	91	9	46	6	66	1	19	7	28
Sum	138	639	96	753	113	669	100	920	110	566	80	720	94	619	84	894
Ericoids	28	86	36	111	25	111	51	126	34	94	25	137	10	31	16	41
Other Shrubs	47	111	29	133	42	163	18	183	28	123	29	126	17	81	21	116
Graminoids	35	200	13	242	34	206	19	303	36	200	20	274	47	234	23	275
Forbs	28	239	18	261	10	171	12	309	11	143	6	171	20	266	25	456
Lichens and Mosses	+	3	+	6	2	17	0	0	+	6	+	11	+	6	+	6

Table 6. Cover (C) and frequency (F) of major species at sandplain grassland treatment plots at Sanford Farm, Nantucket, and Wellfleet, Cape Cod. Values <1 percent are indicated by "+".

	Sanford Farm												Wellfleet Grassland							
	Reference				Unit B burn/cut				Unit D burn/cut				Reference				Apr bum			
	1986		1990		1986		1994		1986		1990		1988		1990		1988		1992	
Species	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F
Agrostis spp.	+	7	+	7	3	31	3	31	3	26	+	32								
Anthoxanthum odoratum					+	29	+	6												
Arctostaphylos uva-ursi									1	11	+	5	10	40	10	35	7	22	6	25
Aster dumosus	3	33	+	33	1	11	+	11	2	32	2	37								
Aster linariifolius													2	47	2	48	+	41	1	47
Aster paternus	3	20	+	27	+	9	+	14	5	37	3	42								
Carex pensylvanica	15	60	7	67	3	46	4	89	13	42	11	68	11	100	6	96	13	100	6	100
Chrysopsis falcata					2	46	4	51	1	11	1	16								
Cladonia spp.	+	13	+	13	22	66	+	9	7	37	0	0	66	93	64	91	39	97	+	47
Danthonia spicata					+	31	+	31	+	16	+	26								
Deschampsia flexuosa													4	93	3	100	3	94	1	88
Dichanthelium spp.					0	0	+	31					+	10	+	9	+	6	+	31
Festuca ovina	+	13	+	40	9	54	2	74	2	32	+	32								
Helianthemum canadense																	+	16	+	16
Juncus greenei					+	20	+	31	+	11	+	32								
Lechea maritima					+	3	+	9					0	0	+	8	+	6	+	41
Myrica pensylvanica	13	47	23	53	12	46	5	23	16	42	11	42								
Polygala polygama					0	0	+	3												
Potentilla simplex					+	6	+	17	+	21	+	26								
Rosa virginiana	9	60	4	67	4	34	5	34	8	42	6	47								
Rubus hispidus	22	67	20	80	10	20	9	23	8	26	5	16								
Rumex acetosella	0	0	+	33	3	40	2	66	2	37	1	53	+	13	+	17	+	13	+	16
Schizachyrium scoparium	16	73	8	73	14	80	10	97	18	79	10	89	10	87	12	87	9	75	13	88
Sisyrinchium fuscatum					0	0	+	17												
Solidago tenuifolia	3	33	+	40	+	9	+	23	3	21	5	21								
Vaccinium angustifolium	5	33	9	33					12	32	12	32								
Sum	135	653	120	800	100	691	55	851	123	689	85	768	116	613	111	635	82	638	32	594
Ericoids	46	120	53	127	12	54	6	29	34	89	28	84	12	43	13	39	8	31	6	47
Other Shrubs	47	220	39	253	29	80	20	80	21	95	13	89	3	10	4	9	2	13	2	9
Graminoids	31	153	16	200	27	263	20	374	36	211	22	295	26	300	21	300	26	316	21	334
Forbs	14	147	12	207	9	214	10	343	25	258	20	300	3	77	2	91	2	88	2	128
Lichens and Mosses	+	13	+	13	22	80	+	26	7	37	0	0	72	183	71	196	44	191	+	75

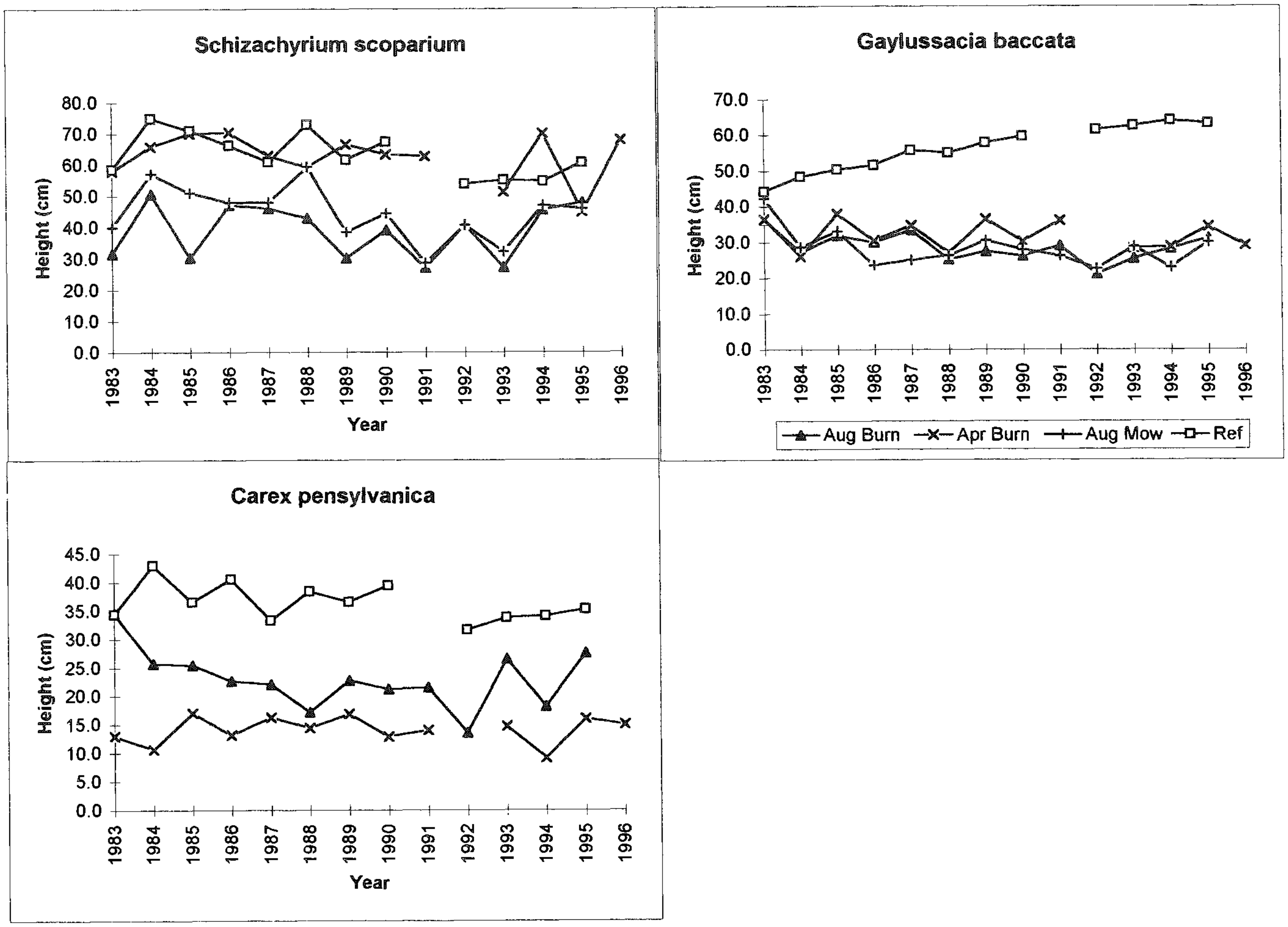

Figure 2. Annual average maximum heights of *Schizachyrium scoparium, Carex pensylvanica,* and *Gaylussacia baccata* in four treatment plots at Ram Pasture (Nantucket).

(*Rosa virginiana*) and dewberry (*Rubus hispidus*), exhibited mixed responses to treatments, increasing at some sites, and decreasing at others.

Overall, the treatments applied in this study have had mixed success in controlling shrub expansion in sandplain grasslands. Single burns reduced cover of most shrubs for only a few years. Repeated burning or cutting were more effective than single burns in arresting the spread of shrubs. However, for aggressive species such as *Gaylussacia baccata* and the *Quercus* shrubs, burning or cutting alone only appear to slow or halt their spread, but not reverse this process.

The seasonal timing of treatments may be an important factor in affecting vegetation responses, and deserves further investigation. At the one site where growing season treatments were applied (Ram Pasture, Table 4), burning or mowing in August appeared to be more successful in slowing encroachment of shrubs than the dormant season treatment at this or at any of the other sites. Many shrubs may be particularly vulnerable, at least during parts of the growing season. These results were especially noteworthy in the August burn plot, since summer burns were extremely patchy, rarely covering more than about 30% of the plot. Yet when compared with the untreated reference plot, where shrub expansion has continued at a rapid rate, shrub encroachment was markedly slowed in the biennial spring burn plot at Ram Pasture.

Treatment Effects on Forbs

All treatments, with the exception of the heathland burn plots at Tom Nevers, resulted in an increase in the species richness of forbs, as indicated by the average percent frequency values. These increases included both biennials and perennials (annuals are extremely rare in these sites), which became more conspicuous in longer duration studies with repeated treatments (Ram Pasture, Katama, Sanford Farm Unit B), were greater in plots that were burned rather than mowed, and were most pronounced in the summer burn site in Ram Pasture, where forb frequency has nearly doubled.

These data reflect the proliferation of new plants of many forb species across the study sites. Several species of *Aster* particularly reflect these trends, but they are also apparent with diverse other taxa, including *Baptisia tinctoria, Polygala polygama, Potentilla canadensis,* and *Sisyrinchium fuscatum.* Various explanations may account for the spread of different species.

The removal of litter, thatch, and dense lichen cover by burning was observed in several sites to accompany increased seedling germination and growth of many forbs. Removal of a dense shrub canopy, even though the shrubs often persisted with a lower stature, also appeared to provide abundant openings in which herbaceous taxa thrived. Many forbs also were observed to bloom prolifically following burning. This response may increase seeds and facilitate the colonization of newly exposed habitats, although data on seedling establishment were not collected.

Nonnative forbs are uncommon in these study sites. Sheep sorrel (*Rumex acetosella*) is the only nonnative species that occurs regularly at several sites, but nowhere is it a prominent component of the flora. It appeared to be relatively unaffected by either of the burn treatments at Ram Pasture, but increased in frequency in the burned and mowed sites at Sanford Farm.

The effects of treatments on several state-listed rare taxa are worth mentioning. The frequency of *Sisyrinchium fuscatum* increased consistently following repeated treatments at two sites; Ram Pasture August Burn (Table 4), which has been burned in August seven times in thirteen years, and Sanford Farm Unit B (Table 6), which has received a combination of five spring burns and three mowings. The frequency of a second rare species, *Helianthemum dumosum,* also increased in the summer burn plot at Ram Pasture (Table 4), but remained largely unchanged in response to spring burning. A third state-endangered species, the papillose nut-rush (*Scleria pauciflora*), also appeared in the Ram Pasture August Burn plot after several summer burns, but is absent from the monitoring quadrats, and therefore is not recorded in Table 4. The scarcity of these and other rare taxa at most sites makes it difficult to characterize their responses to treatments unambiguously.

Large declines in cover and frequency were observed in lichens following burning. A single burn often was sufficient to remove most ground lichens (primarily species of *Cladonia* and *Cladina*). With the elimination of lichen cover, which can be as high as 70% in some locations prior to burning (Wellfleet and Sanford Farm, Table 6), an extensive matrix of bare sand may be exposed between the clumped bunchgrasses and other vascular plants. The lichens reestablished slowly; in their absence, numerous vascular plant seedlings, including species of *Dichanthelium, Lechea, Helianthemum,* and *Rumex,* were observed germinating in the openings.

Treatment Effects on Graminoids

The species richness of graminoids, like the forbs, has also increased markedly in response to treatments in both grasslands and heathlands. Species of *Dichanthelium, Carex, Agrostis, Deschampsia, Danthonia, Schizachyrium,* and *Festuca,* have all generally increased in frequency following burning or mowing. The increase of both forbs and graminoids as a result of the burning and mowing treatments indicates considerable success in achieving the goals of maintaining and enhancing populations of many herbaceous species, including rare taxa, in grassland and heathland sites.

As noted previously with the shrubs and forbs, the responses of plants to treatments applied in this study are frequently complex, and vary among species, life form, and location, as well as by the parameter being measured. Simple characterizations of species as increasers or decreasers (Swan 1970, Niering and Dreyer 1989) did not appear to be generally useful because of the complexity of these responses. For example, in plots burned in the spring, Pennsylvania sedge (*Carex pensylvanica*) and *Schizachyrium scoparium* both tended to decrease in cover, but increased in frequency. Furthermore, while *Carex* usually decreased in height following these burns, *Schizachyrium* often grew taller the first year after a burn.

Productivity of *Schizachyrium scoparium* has been reported by several authors to increase in response to burning in the eastern United States (Jordan 1965, Swan 1970, Niering and Dreyer 1989). Although no measurements were made to directly monitor changes in productivity in this study, other parameters expected to correlate with above-ground biomass, such as height and cover, did not show sustained increases in this species following burning. *Schizachyrium* exhibited an increase in apparent vigor at most sites only in the first year after a burn (Figure 2, for example). This was especially pronounced at Wellfleet (not illustrated), where height of *Schizachyrium* averaged 85% greater than in the reference plot. However, by the second year, no significant differences could be detected. Furthermore, there was no long-term increase in cover or height of this species with repeated burning (Ram Pasture, Figure 2). Thus, while many graminoids at the Massachusetts sites appeared to become more frequent following repeated spring or summer burning, the vigor of individual plants may not increase.

Declines in cover, in contrast to frequency, were observed almost universally among graminoids in the treatment plots. In most cases, these declines did not appear to be clearly related to increases in other, potentially competitive taxa, such as taller shrubs. One explanation for this pattern may be that the extremely sandy soils of these sites fail to retain important nutrients released from the vegetation by burning. As a result, long-term losses of fertility may occur following repeated treatments, and plants may regrow to a smaller size. Alternatively, the declines may be partly an artifact resulting from the removal of grass leaf litter that had been included in pretreatment estimates of cover. However, this would not account for the continued decline in values over more than 10 years, as has occurred at Ram Pasture.

Priorities for Future Research

Burning and mowing in grasslands and heathlands were associated with increases in forb and graminoid diversity, and with the slowing of shrub encroachment. These results document considerable success in maintaining many of the vegetational characteristics of these endangered plant communities, and in enhancing populations of many herbaceous species, including rare taxa. The data suggest that the current practice of dormant season burning (March–April and October–November), which is widespread among conservation organizations in New England for maintaining grasslands and heathlands, will help preserve many of the floristic attributes of these habitats.

However, the results from the single summer burn plot at Ram Pasture (Table 4), suggest that burning during the growing season might be more effective in achieving ecological objectives. Historical fires are documented to have occurred primarily in the spring (March–May), but also during summer droughts. These latter fires may have been particularly severe, sometimes smouldering for long periods in organic soils, consuming the duff layer, and resulting in long-term changes in site soil characteristics (personal observations). Summer fires may be difficult to prescribe for several reasons. Smoke production is dramatically greater during summer burns when fuel moistures are higher. Lingering duff fires prolong the likelihood of smoke-related problems, and may be impossible to suppress if they are widespread over large burn units. The abundance of tourists during the summer also compounds logistical problems and increases the potential for conflicts. These factors probably preclude the implementation of a summer burn program that would be ecologically meaningful at a scale of hundreds of acres per year.

The results from plots where burning was combined with cutting, such as at Sanford Farm, suggest that more aggressive, combination treatments may be a more effective alternative than burning alone. This may be especially valuable where shrubs have overtaken communities to such an extent that removal of woody plants and restoration of the herbaceous flora, rather than merely maintenance of existing grasslands or heathlands, are the primary ecological objectives. Repeated cycles of spring burning followed by a summer cutting may provide significant control of shrubs, and should be explored more extensively in future studies.

Other management alternatives may be appropriate in some areas. Studies of areas on Nantucket that were grazed by sheep until about 1950 reveal substantial, long-lasting impacts on shrub cover, as well as increases in many herbaceous taxa (Dunwiddie 1997). Besides grazing, applying herbicides and plowing are two other options that may offer potential for longer-term shrub control. The use of a plow or disk harrow to break up clonal shrub patches may help reverse encroachment of this vegetation into sandplain grasslands. Several sites on Nantucket and Martha's Vineyard that were cleared in this manner to produce firebreaks in the past have remained virtually free of shrubs for several decades. The scarcity of nonnative species suggests that control of exotics is unlikely to be a problem, even when areas are heavily disturbed using this approach.

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