JFSP Product #446

Enhancing oak regeneration habitat: effects of fire upon seedlings and competing vegetation in Maine

Alison C. Dibble, Ph.D.

Catherine A. Rees

USDA Forest Service, Northeastern Research Station

686 Government Rd., Bradley, ME 04411

adibble@fs.fed.us, crees@fs.fed.us

Draft 29 June 2004

Abstract: When fire is used as a restoration tool to enhance regeneration habitat for northern red oak (*Quercus rubra*) in early successional forests, there could be inadvertent effects on invasive woody plants that also occupy the stand. In an early successional, mixed conifer-hardwood stand with advanced regeneration of red oak and abundant seedlings of the non-native, invasive shrub, alder buckthorn (*Frangula alnus*), we conducted a low intensity spring burn to see if oak regeneration could be favored over buckthorn. We identified paired subject seedlings of northern red oak and alder buckthorn in September 2002, burned in May 2003 and remeasured seedlings and associated plots in September 2003. In the burn, 88.6% of the oaks and 78.1% of the buckthorns survived. Resprouting was common among the survivors of each species. We did not detect a threshold size above which subjects of either species survived. All oaks and buckthorns survived from 2002-2003 in the control area. The number of woody seedlings of *Cornus alternifolia, Lonicera* sp., *Prunus* spp., *Rubus* spp., and *Viburnum* spp. decreased significantly in the burn. Although the number of seedlings of alder buckthorn appeared to decrease in the burn and increase in the control, neither change was significant. Percent cover of forest herbs; *Fragaria* sp., *Onoclea sensibilis*, and *Potentilla* sp., increased significantly in the burn. A single, low intensity, spring burn is not effective method of promoting red oak regeneration over that of alder buckthorn.

Key words: oak, buckthorn, controlled burn, invasive plants, restoration

Introduction

The lack of natural oak (*Quercus*) regeneration in successional habitats is a concern in eastern North America. Oak is being replaced by other hardwood species, more mesophytic species, and more shade tolerant species within its historic range (Lorimer 1985, Crow 1998). This decline of oak may be attributed to lack of fire (Lorimer 1985). Although the use of fire for site preparation does not consistently result in increased oak reproduction (Reich et al. 1990, Johnson 1974, Nyland et al 1982, Wendell and Smith 1986), fire has been proposed as a treatment that promotes oak germination and establishment (Kuddes-Fischer and Arthur 2002). Huddle and Pallardy (1999) found that a low intensity spring fire led to greater survivorship of *Quercus rubra* and *Q. alba* seedlings than did an autumn fire. However, fire may also promote establishment of undesirable species (e.g., *Acer rubrum*, Huddle and Pallardy 1999).

Fire has been considered a valuable tool in controlling some invasive plants but dormant season burning can lead to vigorous regrowth of undesirable woody species (Richburg et al 2001). Non-native, invasive plants such as alder buckthorn (*Frangula alnus*) could increase in size and vigor immediately following a fire, or present a large crop of seedlings. In such a case, survival and growth of young oaks amidst the competing vegetation could be impacted.

In the northeastern U.S., poor oak sites such as low-lying, spent agricultural lands present marginal habitat for quality hardwoods. Such stands are often infested with non-native plants in this region, especially near roads, settled areas, or farmsteads. Compared to upland sites with rich, well-drained, deep soils, restoration for timber may not be cost effective. Because low sites are valuable to wildlife, and provide habitat for diverse understory plants, their ecological value is high and unless some action is taken, a shift in forest species composition can be expected over time.

We tested prescribed fire as a restoration technique on a degraded site to see if a spring fire could improve the potential of existing oak regeneration and diminish the potential of copious, undesirable buckthorn regeneration by differentially affect growth and survivorship in seedlings of both species. We sought to identify a threshold size for oak and buckthorn seedlings below which fire was a primary cause of mortality. We also investigated the affect of prescribed fire on the abundance of all woody seedlings and on herb composition and cover.

Our hypothesis is that a spring fire will reduce the density and stature of the undesirable non-native shrub, alder buckthorn more than that of red oak, herbaceous cover will remain unchanged and the number of shrub seedlings in the treatment area will diminish.

Methods

The study area is in the Penobscot Experimental Forest (PEF), Bradley, Penobscot County, Maine. We established the study in a ca. 5 ha section of the PEF that has no other research currently under way. This former farmland contains remnants of an apple orchard and is currently occupied by early successional mixed conifer-hardwood forest dominated by, gray birch *(Betula populifolia),* trembling aspen (*Populus tremuloides)*, northern red oak *(Quercus rubra),* and apple (*Malus* sp., introduced and spreading by seed), with sparse white pine (*Pinus strobus*), red spruce (*Picea rubens),* balsam fir *(Abies balsamea),* northern white cedar (*Thuja occidentalis)*, and eastern hemlock (*Tsuga canadensis)*. The area is adjacent to an eastern provenance planting. The aspect is west, with slope < 5 degrees. The soils in the vicinity have been described as primarily a deep, poorly drained fine sandy loam (USDA 1959). Tree roots of softwoods are typically exposed aboveground in this part of the PEF.

The study area was heavily invaded by alder buckthorn, with up to 452 seedlings/ m^2. Other non-native invasive plants included Asian shrub honeysuckles (*Lonicera* spp., especially *L. morrowii*), and a few scattered individuals of multiflora rose (*Rosa multiflora*), winged burning bush (*Euonymus alatus*), common buckthorn (*Rhamnus cathartica*), and Japanese barberry (*Berberis thunbergii*).

Measurement of fuels

In the treatment area we located two transects on which to collect fuels data. Transects were oriented on an azimuth of 40 degrees magnetic and were spaced 30 m apart. To cover the proposed treatment area one transect was 70 m long and the other was 40 m long. We chose eight random locations along the transects at least 10 m apart to locate plots and from which to begin planar intercept lines or Brown lines (Brown 1974). We collected data on tree basal area, vegetation cover, canopy cover and nonwoody litter biomass at each fuel plot location. Two Brown Lines each originated one meter away from the fuel plot center (one at 9 m and one at 11 m for Transect 1 Plot 10 m.)

At plot center we recorded trees using a 10 basal area factor prism. We identified individual trees to species and recorded whether they were dead or alive. We counted every other borderline tree. We readings using a convex spherical densiometer while standing over plot center. We averaged readings from the the four cardinal directions. In the control area, which lies just northeast of the treatment area, we did not collect fuels data.

We modified the collection of fuel data using Brown lines (Brown 1974) in order to reduce variance in the hour fuels data. We collected 1 hour fuel data (0-0.64 cm diameter dead detached twigs) from sampling planes 3.7 m (12 ft) in length. 10 hour fuel data (0.64-2.54 cm diameter) were collected from sampling planes 7.3 m long. 100 hour fuel data (2.54-7.62 cm diameter) were collected from sampling planes 14.6 m long. This enabled us to sample more hour fuels on each line in order to reduce variance in the data. We recorded fuel depth, litter depth and shrub height at three points along the sampling plane and duff depth at two points. We measured fuels to a maximum height of 1.2 m and shrubs to a maximum height of 3 m. We collected leaf litter, 1 and 10 hr fuels from a 1600 cm^2 area, 1 m southeast of each plot center. The samples were dried to constant weight, sorted into leaf litter and hour size classes, and weighed. Fuel loads prior to the burn are shown in Table 1.

We did not collect fuels data in the control area which is located northeast of the treatment area.

Paired tree seedlings and plots

In the treatment and control areas, we flagged all oaks seedlings we encountered. From these individuals we arbitrarily chose seedlings in a range of statures (i.e., distance from ground to apical bud without straightening the stem), 12 – 297 cm and a range of diameters, 1 – 23 mm at 10 cm above the soil surface. Each seedling was tagged with an aluminum tag bearing a unique number. The tags were wired loosely about the base of each seedling. After the oaks were tagged, we sought out buckthorn seedlings of similar stature in the same vicinity to be paired with each oak. Buckthorn seedlings ranged in height from 14 – 282 cm (0.46 – 9.25 ft) and diameter from 1 – 15 mm (0.04 – 0.6in). Buckthorn seedlings were generally smaller in diameter than the paired oak of similar stature.

We marked and measured 35 seedlings of northern red oak in the treatment area and for each, a seedling of smooth buckthorn that was similar in height. We also marked and measured the same number and similar stature of each in the control area (total 140 seedlings). Variables quantified on each seedling were species, stature, and diameter at the root crown (2 measurements taken with a caliper, at right angles to each other and averaged)

We drove a permanent steel rod into the ground 0.56 m north of the subject tree to aid in relocation of the plot. Surrounding each of the tagged oak and buckthorn seedlings, we established a 1 m^2 circular plot (these plots did not overlap). Within these plots we measured percent cover of herbs by species to the nearest 1 percent up to 5 percent and to the nearest 5 percent for cover greater than 5 percent. We counted all woody seedlings in the plot and tallied stems by species noting whether they were alive or dead. In addition, we noted the number seedlings that were taller in stature than the subject. Seedlings up to 12.7 mm diameter at breast height were tallied as alive or dead. Pre-treatment plot and subject tree data were taken in September and October 2002 and post-treatment data in September and October 2003. We did not measure fuel parameters post-treatment.

Treatment: On May 6, 2003, a controlled burn was conducted in the treatment area by the U.S. Fish and Wildlife Service Northeast Zone Management Officer. Air temperatures ranged from 45 – 50 F, relative humidity from 45-58%. Wind was from the east southeast at 3 to 5 mph under the canopy although winds aloft were from 4 – 6 mph gusting to 13 mph. One hour fuel moisture ranged from 6.6 – 9.2 percent and 10 hour fuel moisture from 8.5 – 9.2 percent (based on weather data). The perimeter of the area was burned out, and then strips through the unit were burned. The fire affected 70 percent of the treatment area. The few subject trees and associated plots that had been skipped were fired individually using a drip torch. The result was a low intensity fire, described by the crew as "creeping" and patchy. Flame lengths were mostly around 25 cm, with occasional flames to 2 m, and in one case flames ascended a paper birch (*Betula papyrifera*) to ca. 3 m. We estimated that the treatment reduced at least 50 percent of fine fuels.

Post-treatment measurements

After treatment and the summer growing season we measured height, diameter at 10 cm from the ground, diameter of the root collar, and number of post-fire stump sprouts produced onall of the subject seedlings of oak and buckthorn that survived the treatment, and in the control. We censused woody plant seedlings, and estimated percent cover for herbs in the $1m^2$ quadrats that were centered around subject seedlings.

Data analyses

We used a paired t-test to compare number of woody seedlings and herb cover in September-October before the May burn to the number of seedlings five months after the burn (alpha=0.05). We used this same test to compare aspects of the subject seedlings, including oak vs. buckthorn stature.

We divided the seedling species into three groups: (1) native, (2) non-native and invasive, and (3) questionable. The third category was necessary because we could not reliably identify immature, nonreproductive seedlings that have close relatives among our native flora (Haines and Vining 1998). Examples are highbush cranberry (*Viburnum opulus* spp. *opulus* from Europe could be present as well as the native *V. opulus* var. *americanus*; included in our data are the clearly native *Viburnum recognitum, V. nudum spp. cassinoides, V. acerifolium*, and possibly *V. lentago*). We found red raspberry (*Rubus idaeus*, which is from Europe according to Fernald 1950), and mountain ash (*Sorbus aucuparia*, compare to the native *S. americana*). We used a two group paired t-test to uncover structure in the seedling count data, with Bonferonni adjustments (SYSTAT 10.2).

Results

Paired oak and buckthorn subjects

There were no clear trends regarding subject oak and buckthorn seedling mortality. All oaks and buckthorns survived from 2002-2003 in the control. In the burn, 88.6% of the subject oaks and 78.1% of the subject buckthorns survived.

We had hoped to find a threshold size for oak survivorship in the burn treatment, but no clear pattern emerged. The four dead oak subjects in the treatment area ranged in stature from 18 - 91 cm and diameters (at 10 cm above the soil surface) were 1 - 10 cm pretreatment. For the seven dead buckthorn subjects, the range in stature was 18 - 232 cm and the range in diameter was 1 - 15 mm. Between 2002-2003, in the burn, the average stature of surviving seedlings decreased for both species (paired t-test, $p = .004$). Oaks decreased significantly by an average of 24 cm. Buckthorn subjects decreased by an average of 9 cm but this was not significant. In the control area, average heights of both species increased ($p=0.008$); the average increase of oak by 12 cm was significant while the average increase of 3 cm for buckthorn was not significant.

Post-fire stump sprouts developed on 60 percent of the oak subjects that survived the fire, compared to 40 percent of buckthorn subjects which had sprouts. All sprouts recorded except one oak subject were shorter in stature or the same height as the subject had been in 2002. Sprout-producing oak subjects ranged in stature from 46 – 297 cm, and in diameter from 1.5 – 23 cm at 10 cm above the soil surface, and 3.5 – 26.5 cm at the root collar. For buckthorn subjects, post-fire sprouts developed on plants that ranged in stature from 24 – 111 cm, and in diameter from 1 – 7 cm at 10 cm above the soil surface, and 2 – 9.5 cm at the root collar.

Average diameter of all buckthorn subjects at 10 cm above the soil surface showed no significant change in the treatment or control areas. Average oak subject diameters decreased significantly in the treatment area (average decrease 1.1 mm) and increased significantly in the control by an average of 1.8 mm. Decreasing diameters in the treatment area for both species were largely the result of the subject being top killed and resprouting from the root.

Woody seedlings other than the oak and buckthorn subjects

In the treatment area the total number of woody seedlings per m^2 decreased significantly and we expect that this was due to the burn. Seedlings of *Lonicera* sp., *Viburnum* spp. (*V. nudum* var. *cassinoides*, *dentatum*, *lentago*, *opulus* var. *opulus*, *acerifolium*), *Rubus* spp. (*R. hispudus*, *pubescens*), *Prunus* spp. (*P. serotina*, *virginiana*) and *Cornus alternifolia* all decreased significantly in the treatment area (Table 2). In the control area, Viburnum spp. increased as did *Quercus rubra* (Table 2.). Red maple was the only woody species to decrease significantly in the control. Buckthorn seedlings were extremely abundant in both the treated area and the control. Although buckthorn seedlings decreased in the burn and increased in the control, neither was significant.

Seedlings in the burn decreased significantly for these native species: *Cornus alternifolia, Prunus* spp., *Rubus hispidus/R. pubescens*; for non-native, *Lonicera* sp., and for questionably native *Viburnum* spp. In the control, *Viburnum* spp. decreased, as did red maple, while northern red oak increased.

When woody seedlings were considered in terms of species groups, stem count decreased significantly in the burn for native species (P=0.039) and species for which nativeness was a question (P=0.000), but not for non-native species (mostly buckthorn). In the control, there was no significant change in stem count for both native and non-native invasive species groups, but stems of species for which nativeness was a question were significantly fewer in 2003 (P=0.048).

Herbs

Total herb cover on the treated plots increased mainly due to significant increase in percent cover of sensitive fern, cinquefoil (*Potentilla simplex*), and strawberry (*Fragaria virginiana*) on the treated plots. No herbs in the burn decreased significantly.

Total herb cover on control plots remained unchanged. In the control area, there were significant increases for *Gaultheria procumbens* and *Mitchella repens,* and sweet vernal grass *(Anthoxanthum odoratum)*. Herb richness (number of species per plot) was also unchanged on both treated and control plots.

When we considered the herb cover changes in terms of species groups, we found a slight but insignificant decrease from 2002 to 2003 for invasive woody plants in the burn (P=0.443).

Discussion

The high number of alder buckthorn seedlings quantified in this study demonstrates the ineffectiveness of a single low intensity burn to significantly affect survivorship. This means that restoration must proceed with either more fire, or another type of treatment. At this low, moist site, there is a slow accumulation of fuels, high fuel moisture close to the ground, and difficulty in coordinating controlled burn resources with conducive weather. Unless fuels are added, fire will probably not be a viable option for controlling invasive woody plants and promoting oak regeneration at this site.

Other approaches to enhancing oak regeneration at this site, such as hand-pulling or applying herbicide to invasives, would be labor intensive, prohibitively expensive, or could risk chemical pollution in a site that is heavily used by desirable wildlife. The implications of this result for poorly-drained, invaded forests across the northeast are that the control of the invasive species is a considerable challenge and will require persistence and ingenuity.

Herbs that increased in cover on the burned site are all clonal species. Perhaps the growth of these species was stimulated by root injury caused by the fire. Shallow rooted species may be better equipped to compete for nutrients post-fire than more deeply rooted ones (Chapin and Van Cleve 1981). McGee et. al (1995) found that perennial forbs with shallow rhizomes increased more in cover than species with deeper rhizomes post-fire. We did not find recruitment of any new herb species, either native or non-native, to the burn or the control areas. The fact that most of the herbaceous species on our plots are perennials and that we did not find changes in species composition suggests that the herbaceous stratum in this forest type is relatively stable.

Five year survival of seedlings germinating from acorns on a site dominated by sensitive fern (*Onoclea sensibilis*) was poor (Scholz 1955). Competition with ferns resulted in 77 percent mortality after five years with 60 percent of the mortality occurring between July and September of the first growing season. Average root mass of surviving seedlings was smaller than that of seedlings on other sites, but mass of above ground parts to below ground parts was larger. On our study site where sensitive fern benefited from the burn treatment, survival and growth of oak seedlings germinating in the future may be diminished due to increased competition.

Sixty percent of the oak subject seedlings in our study resprouted after fire. Huddle and Pallardy (1999) found that seedlings of northern red oak survived fire better than those of red maple. They attribute this ability in part to the higher percentage of starch reserves maintained by oak in the spring, but suggest that superior survival after fall burns may be due to greater bark accumulation and thus better insulation or increased heat tolerance of shoots. The ability of oak seedlings to resprout appears to be greatest when seedlings are between 3 and 10 cm diameter (Johnson 1974, Harlow et al. 1996).

References

Adams, A. S., and L. K. Rieske. 2003. Prescribed fire affects white oak seedling phytochemistry: implications for insect herbivory. Forest Ecology and Management 176: 37-47.

Brown, J.K. 1974. Handbook for inventorying down woody material. USDA Forest Service Gen. Tech. Rep. INT16, 24 pp., illus.

Brown J.K., R.D Oberheu, C.M. Johnson. 1982. Handbook for inventorying surface fuels and biomass in the Interior West. USDA Forest Service General Technical Report INT-129. Intermountain Forest and Range Experiment Station, Ogden, Utah. 48p.

Brissette et al – description of PEF

Dibble, A. C., C. A. Rees, M. J. Ducey, and W. A. Patterson III. 2003a. Fuel bed characteristics of invaded forest stands. Pp. 26-29. Using fire to control invasive plants: What's New, What Works in the Northeast. 2003 Workshop Proceedings. University of New Hampshire Cooperative Extension, Durham, NH. http://www.ceinfo.unh.edu/forestry/documents/WPUFCI03.pdf

Dibble, A. C., W. A. Patterson III, and R. H. White. 2003b. Relative flammability of native and invasive exotic plants of the Northeastern U.S. Pp. 34-37. Using fire to control invasive plants: What's New, What Works in the Northeast. 2003 Workshop Proceedings. University of New Hampshire Cooperative Extension, Durham, NH. http://www.ceinfo.unh.edu/forestry/documents/WPUFCI03.pdf

Chapin, F.A. III; van Cleve, K. 1981. Plant nutrient absorption and retention under differing fire regimes. In: H.A. Mooney; T.M. Bonnicksen, N.L. Christensen, J.E. Loton and W.A. Reiners (eds) Fire regimes and ecosystem properties. Gen. Tech. Rep. WO-26, US Forest Service, Washington, DC. 301-321.

Crow 1998

Harlow, W. M.; Harrar, E.S.; Hardin, J.W.; White, F.M. 1996. Textbook of Dendrology, 8th edition. McGraw-Hill, NY. 534pp.

Huddle, J.A., and S. G. Pallardy. 1999. Effect of fire on survival and growth of *Acer rubrum* and *Quercus* seedlings. Forest Ecology and Management 118: 49-56.

Johnson, P.S. 1974. Survival and growth of northern red oak seedlings following a prescribed burn. Research Note NC-177, US Forest Service, St. Paul, MN. 3 pp.

Kelly, D.L. 2002. The regeneration of Quercus petraea (sessile oak) in southwest Ireland: a 25-year experimental study. Forest Ecology and Management 166: 207-236.

Kuddes-Fischer, L.M. and M. A. Arthur. 2002. Response of understory vegetation and tree regeneration to a single prescribed fire in oak-pine forests. Natural Areas Journal 22(1): 43-52.

Lorimer, C. G. 1992. Causes of the oak regeneration problem. Pp. 14-39 in D. Lolftis and C. E. McGee, eds. Proceedings, Oak Regeneration: Serious Problems, Practical Recommendations. General Technical Report SE-84, U.S. Forest Service, Southeastern Forest Experiment Station, Asheville, N.C.

Lorimer, C. G., J. W. Chapman, and W. D. Lambert. 1994. Tall understory vegetation as a factor in the poor development of oak seedlings beneath mature stands. Journal of Ecology 82: 227-237.

Lorimer 1985

McGee, G.G.; Leopold, D.J.; Nyland, R.D. 1995. Understory response to springtime prescribed fire in two New York transition oak forests. Forest Ecology and Management 76:149-168.

Nyland et al 1982

Reich et al. 1990

Richburg, J. A., A. C. Dibble, and W. A. Patterson III. 2001. Woody invasive species and their role in altering fire regimes of the Northeast and Mid-Atlantic states. Pp. 104-111 in K.E.M. Galley and T. P. Wilson (eds.). Proceedings of the Invasive Species Workshop: the Role of Fire in the Control and Spread of Invasive Species. Fire Conference 2000: the First National Congress on Fire Ecology, Prevention and Management. Misc. Publ. No. 11, Tall Timbers Research Station, Tallahassee, FL.

Scholz, Harold F. 1995. Growth of northern red oak seedlings under variable conditions of ground cover competition. Technical Note No. 430. Lake States Forest Experiment Station, US Forest Service, St. Paul, MN. 2pp.

United States Department of Agriculture. 1959. Penobscot County Soil Survey. Natrual Resources Conservation Service.

Wendell and Smith 1986

Acknowledgments

We thank the University of Maine for permitting the controlled burn and use of the study area. We appreciate help from Rick Vollick, U.S. Fish and Wildlife Service at Sunkhaze Meadows National Wildlife Refuge, and his burn crew of 2003, for conducting the treatment. Data collection assistance was provided by Anna-Maria Easley, Matt….??

Table 1. Average number of seedlings per 1 m2 quadrat for northern red oak and European buckthorn, other than the subject seedlings in each quadrat, in 2002 and 2003.

		burn	control
buckthorn	2002	44.6	154.87
	2003	37.84	157.86
oak	2002	1.324	3.622
	2003	1.216	2.918

Figure 1. Average number of seedlings per 1 m2 quadrat for northern red oak and European buckthorn, in the burned area and an untreated control. Values are shown in Table 1.

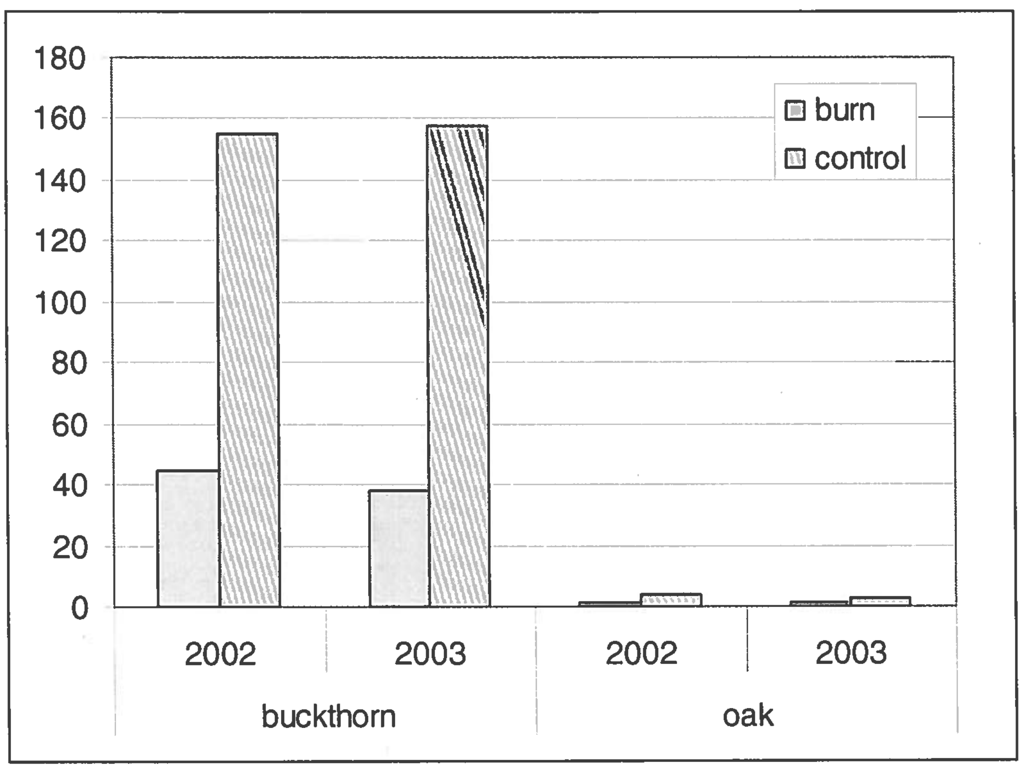

Fig. 2. Changes in percent cover over one year for four species that were common in both the burned area and the control area.

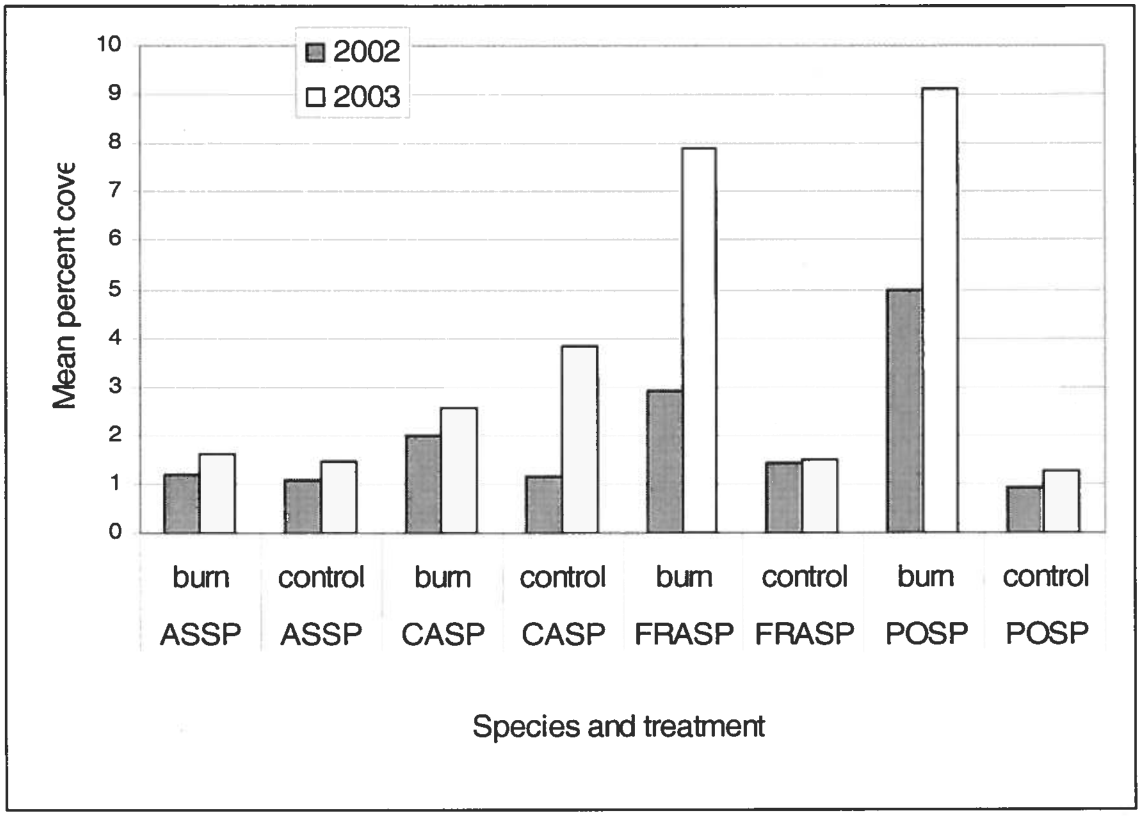

Table 1. Pre-burn fuel load in the treatment area of Penobscot Experimental Forest, Bradley, ME.

Variable	Amount
1 hour fuels (sticks 0-0.64 cm dia.)	2.3 kg/ha
10 hr fuels (0.64-2.54 cm dia.)	4.0 kg/ha
100 hr fuels (2.54-7.62 cm dia.)	6.0 kg/ha
Average duff depth	3.6 cm
Average fuel depth	10.7 cm
Basal area	30.6 m^2/ha
Crown closure	89%

Table 2. Average woody plant seedlings per 1 m2 quadrat associated with subject northern red oak and buckthorn seedlings; two-group t-test results include pooled variance t probability and 95 percent confidence interval.

Species	Treatment	N	Mean ± SD 2002	Mean ± SD 2003	Probability	95% C.I.
Cornus alternifolia	burn	35, 35	2.343 ± 2.235	1.689 ± 1.689	0.016	0.226 to 2.116
Fraxinus americana	burn	6, 6	1.500 ± 0.837	0.500 ± 0.548	0.034	0.090 to 1.910
Prunus spp.	burn	68, 68	10.794 ± 6.324	8.235 ± 5.359	0.012	0.571 to 4.547
Sorbus spp.	burn	10, 10	1.300 ± 1.059	0.500 ± 0.527	0.046	0.014 to 1.586
Viburnum spp.	burn	71, 71	6.254 ± 6.208	1.817 ± 2.147	0.000	2.895 to 5.978
Quercus rubra	control	61, 61	2.197 ± 1.833	2.918 ± 1.696	0.026	-1.354 to -0.088
Viburnum spp.	control	69, 69	7.623 ± 9.988	4.710 ± 5.760	0.038	0.168 to 5.658