Frangula alnus

INTRODUCTORY

AUTHORSHIP AND CITATION:
Gucker, Corey L. 2008. Frangula alnus. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [2010, January 29].

FEIS ABBREVIATION:
FRAALN

NRCS PLANT CODE [89]:
FRAL4

COMMON NAMES:
glossy buckthorn
alder buckthorn
European alder buckthorn
smooth buckthorn

TAXONOMY:
The scientific name of glossy buckthorn is *Frangula alnus* Miller (Rhamnaceae) [32,46].

SYNONYMS:
Rhamnus frangula L. [18,65,83,92]
Rhamnus frangula L. var. *angustifolia* Louden [65]

LIFE FORM:
Shrub-tree

FEDERAL LEGAL STATUS:
None

OTHER STATUS:
Information on state-level noxious weed status of plants in the United States is available at Plants Database.

DISTRIBUTION AND OCCURRENCE

SPECIES: Frangula alnus

GENERAL DISTRIBUTION:
Glossy buckthorn is a nonnative species common throughout southeastern Canada and the northeastern United States. Populations are less common in western and central states and provinces including Idaho, Wyoming, Colorado, Nebraska, Saskatchewan, and Manitoba. In the United States, glossy buckthorn's southern limits are West Virginia, Tennessee, Illinois, and Iowa [28,89]. Plants Database provides a map of glossy buckthorn's North American distribution.

Introduction(s): Glossy buckthorn is native to Europe, northern Africa, and central Asia [64]. The first known North American collection occurred in 1898 in London, Ontario [27]. Spread of glossy buckthorn in North America was likely facilitated through ornamental and rehabilitation plantings. In New England and the Midwest, glossy buckthorn was planted as an ornamental and used for wildlife habitat improvement [95]. In an article published in 1963, glossy buckthorn was suggested for ornamental use in the southern Great Plains [44]. In a Nevada roadside vegetation guide published in 1963, glossy buckthorn was noted as a species that would "prove useful in time" [84]. Glossy buckthorn was also recommended for use in field break plantings in a 1993 publication from Minnesota [78]. However, the sale of nonnative buckthorns (glossy buckthorn and *Rhamnus* spp.) is now banned in Minnesota and Illinois [15].

Local North American distributions: In North America, glossy buckthorn has been described as "widely naturalized", "rather local", and "locally well established" from Nova Scotia to southern Manitoba and from Minnesota to New Jersey [3,65,75,83]. In the 1950 Gray's Manual of Botany, glossy buckthorn was described as "recently and rapidly spreading" and "likely to become obnoxious" [22]. In the 1982 New England Flora, glossy buckthorn was considered uncommon but described as "rapidly spreading" [80]. In Tennessee, glossy buckthorn was first reported in 1974 from Marion County [51]. Along the Middle Loup River in Sherman County, Nebraska, glossy buckthorn was "thoroughly established" as of 1999 [76]. In 1996 Colorado flora, glossy buckthorn populations were noted on slopes above the Boulder Creek floodplain [94].

Local distribution changes: The spread of glossy buckthorn has been documented in parts of southeastern Canada and the midwestern and northeastern United States. Often initial establishment occurred in urban and/or disturbed areas. Spread rates and abundance generally increased over time.

Noncultivated glossy buckthorn plants were first collected from the southern Ontario cities of London, Ottawa, and

Guelph in 1898, 1899, and 1906, respectively. By 1930, glossy buckthorn occurred up to 25 miles (40 km) from these urban areas, but by 1950, occurred up to 93 miles (150 km) from the first collection sites. In the early 1990s, glossy buckthorn primarily occurred in native communities near urban areas, but its rate of spread into other native and agricultural areas has increased. In some areas, glossy buckthorn comprises more than 90% of the vegetative biomass over several acres. Glossy buckthorn dominates the Leitrim fen near Ottawa and the Sifton bog near London [5].

In a period of 20 years, glossy buckthorn has "overrun" about 30% of the 2,500-acre (1,000 ha) Cedarburg bog in Wisconsin (Reinartz University of Wisconsin-Milwaukee Field Station 2001 as cited in [15]). Through a review of the available literature, Taft and Solecki [86] found reports of a well-established glossy buckthorn population in Cook County, Illinois, in 1912. By 1955, glossy buckthorn occurred in 5 northeastern Illinois counties and by 1978, occurred in 18 counties [86]. Glossy buckthorn was first collected from Michigan in 1934, where it has been more recently described as "locally aggressive" and as a "serious pest" in bogs, fens, and disturbed damp areas [92]. The first glossy buckthorn collection from Ohio was made in Lake County in 1927 by a botanist who noted it was "becoming well established". Researchers speculated that European starlings, introduced into northeastern Ohio in 1921, may have been instrumental in the dispersal and spread of glossy buckthorn. As of 1977, glossy buckthorn in Ohio was still distributed primarily in the northeastern portion of the state [42]. Based on the study of 11 early successional sites in southeastern New Hampshire, glossy buckthorn occurrence was positively correlated with the abundance of agricultural fields and other disturbed lands (R^2=0.176, P=0.057) [45]. In eastern white pine (*Pinus strobus*)-dominated stands in southeastern New Hampshire, researchers estimated that glossy buckthorn had established about 36 years earlier and spread as an "advancing front" at a rate of about 20 to 22 feet (6.2-6.7 m)/year. Spread rate was significantly slower in the time soon after establishment (1.1 feet (0.35 m/year)) than in the later stages (P=0.004). In southeastern New Hampshire, canopy openness was positively related to the basal area of glossy buckthorn (P<0.001) [26,27].

HABITAT TYPES AND PLANT COMMUNITIES:
Glossy buckthorn forms thickets and occupies similar habitats in its native and nonnative ranges. Reviews report that glossy buckthorn in its native range occurs in calcareous wetlands, alder (*Alnus* spp.) thickets, heath-oak (*Erica-Quercus* ssp.) woodlands, and pine and spruce (*Pinus* and *Picea* spp.) forests [12,13]. In native European habitats, "gregariousness" is common for glossy buckthorn [31].

In North America, glossy buckthorn is commonly described in wet to moist habitats including bogs, fens, marshes, riverbanks, pond margins, and disturbed areas of larch (*Larix* spp.) and Atlantic white-cedar (*Chamaecyparis thyoides*) swamps but is also found in drier sites such as sand forests, roadsides, and prairies [42,60,92]. In these habitats, glossy buckthorn may rapidly form dense even-aged thickets [12,13]. Glossy buckthorn has been described as "aggressive" and as a "serious pest" in damp to wet habitats [60,92].

In southern Ontario, glossy buckthorn occupies habitats ranging from early-seral old fields to mature woodlands and forests. Fens, sedge (*Carex* spp.) marshes, and swamps with red maples (*Acer rubrum*), Atlantic white-cedars and/or alders are prime habitats. In very dense, light-limited forests, glossy buckthorn may be restricted to forest edges [5]. In Gavin bog in Lake County, Illinois, glossy buckthorn occurs in the understory of the tamarack (*L. laricina*) forested zone and as a nearly "impenetrable" thicket in the tall-shrub zone [86]. In Pennsylvania's Allegheny National Forest, glossy buckthorn occurs in grass-shrublands, riparian savannas, wet to mesic roadsides, riverine big bluestem (*Andropogon gerardii*) grasslands, and less commonly in mesic hardwood forests [68]. Glossy buckthorn dominates the shrub layer of alluvial swamp communities such as red maple-silver maple-swamp white oak (*A. saccharinum-Q. bicolor*) on eastern Massachusetts floodplains [47]. On old fields in Durham, New Hampshire, the wrinkleleaf goldenrod-northern dewberry (*Solidago rugosa-Rubus flagellaris*)-glossy buckthorn understory occurs in partially open eastern white pine forests [41].

Glossy buckthorn is often associated with disturbances. In central and western Massachusetts, researchers found that previously plowed sites were more than twice as likely to have glossy buckthorn than pastures or woodlots. Areas with a greater proportion of forest cover were less likely to have glossy buckthorn (P=0.085). There was also a trend of finding glossy buckthorn on sites where soils had low carbon:nitrogen ratios; however, researchers noted that soil properties were likely related to land use and vegetation type [61]. Glossy buckthorn and disturbed sites are discussed more in Successional Status.

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

SPECIES: Frangula alnus

GENERAL BOTANICAL CHARACTERISTICS:
This description provides characteristics that may be relevant to fire ecology and is not meant for identification. Keys for identification are available (e.g., [18,28,83]).

Glossy buckthorn grows as a multistemmed shrub or single-stemmed small tree up to 23 feet (7 m) tall [21,28,60,83]. Trees produce stout, erect branches [9]. Leaves are deciduous, simple, and generally arranged alternately. Blades are dark-green and shiny above, measure 2 to 3 inches (5-8 cm) long, and are about half as wide. Margins are entire to slightly wavy [9,28,83]. Studies in European habitats suggest that plant age and site conditions can affect glossy buckthorn's appearance. While common as a multistemmed shrub when young, glossy buckthorn develops into a small tree with age. In the shade, shrub forms are sparse and leaves are larger, thinner, and less rigid than those in the sun [31]. Glossy buckthorn flowers are small (diameter <6 mm), inconspicuous, and occur singly or in clusters of 2 to 8. The 2- to 3-seeded, berrylike drupe fruits occur in small clusters [9,28,83]. As of 2008, descriptions of the glossy buckthorn root systems were generally lacking, although its shallow root system has been described as "extensive" (Fagan, personal observation cited in [20]).

Native plants that resemble glossy buckthorn include alderleaf buckthorn (*Rhamnus alnifolia*) and lanceleaf buckthorn (*R. lanceolata*) [15].

SEASONAL DEVELOPMENT:
Glossy buckthorn flowers are common from June to September in the Adirondacks [9], May to June in the northeastern United States and adjacent Canada [28], and May to July in Illinois [65]. However, flowers and fruits

develop and mature sporadically throughout the growing season. It is common to find flowers, unripe green fruits, maturing red fruits, and fully ripe black fruits on a single plant any time from July to September [3,9,21,28,93]. Glossy buckthorn leaves turn nearly yellow in the fall but remain on the stems longer than those of most other associated deciduous species [64]. In the fall, glossy buckthorn is easily identified by its delayed deciduousness [39].

RAUNKIAER [72] LIFE FORM:
Phanerophyte
Geophyte

REGENERATION PROCESSES:
Glossy buckthorn reproduces by seed production and seedling establishment [86,90] and regenerates from root crown sprouts following top-kill [31,60,92].

Pollination and breeding system: Glossy buckthorn produces perfect flowers [75]. Based on studies conducted in glossy buckthorn's native European habitats, flowers are insect-pollinated and self-incompatible [36,63]. Flowers were visited by bees, wasps, flies, and beetles [31].

In southern Spain, the details of glossy buckthorn's reproductive biology were evaluated. Glossy buckthorn flowers had nectaries, but nectar volume was low (0.2 µl/flower, *n*=8). Sugar concentration averaged 9.8% in shady sites and 26.6% in sunny sites. About 21 of the 47 insect species that visited glossy buckthorn flowers were likely pollinators. When more than 4,300 flowers were bagged, just a single fruit was produced, indicating that self-fertilization did not occur. Flowers contained in mesh bags also failed to produce fruits, indicating the wind was not a suitable pollination agent [63].

Seed production: Most sources indicate that glossy buckthorn produces "abundant" seed each year ([34,92], Hubbard 1974 as cited in [13]). However, weather conditions and seed predators may affect seed production and survival. In southern Britain, Godwin [31] reported that glossy buckthorn seed is "set very freely indeed every year", but that in dry conditions, flowers drop before mature, and seed crops are reduced.

Glossy buckthorn reaches reproductive age early [30]. McClain [60] reported that plants less than 3 feet (0.9 m) tall produced fruit. Sprouts of mature top-killed plants have produced fruit in their first growing season [73].

Studies conducted in southern Spain provided estimates of glossy buckthorn's reproductive potential, which was reduced in dry conditions. Glossy buckthorn produced an estimated 10,200 to 36,600 flowers/plant. On average, fruits contained 1.5 seeds. Calculations based on the proportion of available ovules that developed into viable seeds suggested that medium- to full-sized glossy buckthorn individuals could potentially produce between 430 and 1,560 offspring/year, but seedlings and juveniles were rare in the study area [63]. The end of the flowering period was triggered by summer drought, and successful fruit production was confined to times of peak pollinator abundance. The flowering period was shorter and seed production was 50% lower in 2001?when conditions were drier, warmer, and windier?than in 2000 [36].

Seed predation: Studies in Germany and England indicate that small mammals feed on glossy buckthorn seed [30,49]. In southwestern Germany, level of seed predation varied by vegetation type and stature. When a known quantity of seeds was left out for a single night, predation of glossy buckthorn seed was 0% in a mixed 30- to 50-year-old shrubland dominated by 13- to 20-foot-tall (4-6 m) vegetation. In stands dominated by glossy buckthorn shrubs less than 15 years old and 5 to 10 feet (1.5-3 m) tall, 27% of seeds were removed; and in an abandoned meadow 47% of seeds were removed. Feces and seed processing evidence found near the seed trays suggested that rodents were the primary seed predators [49].

Seed dispersal: Many researchers indicate that birds are important dispersers of glossy buckthorn seed [31,64,92], but other potential dispersal agents include small mammals, gravity, and water [31,35]. In European habitats, glossy buckthorn seedlings often occurred beneath the parent tree, and clumps of seedlings germinating from abandoned mouse caches were also encountered [31]. In the Wicken fen in Cambridgeshire, England, the majority of glossy buckthorn fruits fell when ripe. Experiments and field observations suggested that mice harvested and cached seed. As

many as 30 to 50 glossy buckthorn seedlings germinated from abandoned caches [30].

Glossy buckthorn produces fruits throughout the growing season, and seeds have a laxative effect on birds, making seed dispersal continual and effective [34,39,64]. In southern Ontario, researchers observed American robins, Bohemian waxwings, cedar waxwings, rose-breasted grosbeaks, and European starlings feeding on glossy buckthorn fruits (Darbyshire and others, personal communications as cited in [5]), making them likely dispersers. Since introductions of glossy buckthorn and European starlings were nearly synchronous in northeastern Ohio, researchers speculated that European starlings may have been instrumental in glossy buckthorn dispersal [42].

The importance of water in the dispersal of glossy buckthorn in North America is unclear. Some researchers report that glossy buckthorn fruits may float for weeks in water (Ridley 1930 as cited in [86]), and that naked seeds may float for up to a week in water (Praeger 1913 as cited in [31]). However, ripe fruits collected in Ontario sank immediately in water [5]. Along small mountain streams in southern Spain, birds were important dispersers of glossy buckthorn seed and took an average of 53% of seeds [37], but water was an important secondary dispersal method [35].

Seed banking: Sources suggest that glossy buckthorn seed remains viable in the seed bank for at least 2 years and perhaps longer ([15], Kinzel 1926 as cited in [31]). Following removal of a glossy buckthorn canopy, glossy buckthorn seedlings are common and are likely the result of germination from the seed bank [24,26,79,87]. However, seed bank studies are generally lacking. In deciduous forests of Van Cortlandt and Pelham Bay parks in the Bronx, New York, glossy buckthorn occurred in aboveground vegetation plots but did not emerge from soils samples taken from these plots [50].

Germination: Fresh glossy buckthorn seeds germinate more readily than dried seeds, and warm temperatures may be necessary to encourage germination. Most available studies, however, are either experimental or based on observations made in glossy buckthorn's native habitats, and their relevance to North American specimens and field conditions is unknown. In European habitats, spring germination of glossy buckthorn from seed sources in wet surface litter has been described as "abundant" [31]. From collections made in England's Wicken fen, 90% to 100% of glossy buckthorn seeds from fleshy fruits germinated under controlled conditions, but when fruits or seeds were dry, germination was "very greatly" reduced [30]. Glossy buckthorn seeds collected from open-grown trees near Copenhagen, Denmark, reached 46% to 79% maximum germination/plant. Seeds were stratified for about 20 weeks, and germination trials occurred in the laboratory [67].

Germination was best (81% after 170 days and 91% after 272 days) for glossy buckthorn seed sown in the greenhouse immediately after collection. Collections were made in early September, but the collection area was not given. Glossy buckthorn seed germination was 26% after 255 days when fresh seed was sown outdoors immediately after collection. When seeds were dried and stored over the winter, germination 90 days after spring sowing ranged from 34% to 37% regardless of storage conditions [1].

Seedling establishment/growth: Most studies and observations suggest that glossy buckthorn produces abundant seedlings, and growth and survival are best in open conditions. Glossy buckthorn seedlings were common on *Sphagnum* hummocks throughout Gavin bog in Lake County, Illinois, where glossy buckthorn was dominant in the tall shrub zones and in the understory of tamarack zones [86]. Densities of glossy buckthorn seedlings and saplings were 1,166/ha and 200/ha, respectively, in river birch (*Betula nigra*)-dominated stands in the Matanzas Prairie Nature Preserve in central Illinois [90].

During a 2-year field experiment in eastern white and red pine (*Pinus resinosa*) stands in southern New Hampshire, the density of glossy buckthorn seedlings was 5 times greater where more than 90% of glossy buckthorn cover was removed than in uncut plots. Seedlings were likely the result of seed bank germination. Glossy buckthorn seedling density decreased sharply from the 1st to the 2nd year after canopy removal [24,26].

In a review, glossy buckthorn seedling establishment was considered best on exposed soil in areas where light levels were high [13]. High light levels and herbivory protection were most conducive to seedling growth and survival in the Mt Toby Demonstration Forest, Massachusetts. Growth and survival were greater for glossy buckthorn seedlings transplanted to plots where the canopy was removed than for seedlings transplanted to plots with a closed canopy of

14-year-old birch (*Betula* spp.) and pin cherry (*Prunus pensylvanica*). Protection from herbivory increased seedling height and diameter growth but did not increase survival. Unprotected seedlings failed to flower, but 81% of protected seedlings flowered [48].

Growth and survival of glossy buckthorn with and without canopy cover and herbivory protection [48]		
Canopy removed (*n*=7-8)	Protected	Unprotected
Absolute height growth (cm/yr)	65.17	6.66
Absolute diameter growth (mm/yr)	6.55	1.88
Percent survival (2000-2002)	52	57
Canopy intact (*n*=4-8)		
Absolute height growth (cm/yr)	-0.11	0.87
Absolute diameter growth (mm/yr)	0.13	0.07
Percent survival (2000-2002)	29	41

Growth: A review reports that glossy buckthorn grows rapidly and has a long growing season [13]. Site conditions that affect water table depth and water table fluctuations may affect glossy buckthorn growth. See Site Characteristics for details.

Vegetative regeneration: Glossy buckthorn sprouts "prolifically" from its roots and and/or root crown after being wounded or top-killed [89,58,29]. In England, glossy buckthorn is "strikingly characteristic" of burned and grazed areas [29].

A review reports that glossy buckthorn sprouts can be "prolific" and almost immediately fecund. Mature glossy buckthorn plants cut to the stem base early in the growing season may produce sprouts up to 6.6 feet (2 m) tall in the same year [12]. Sprouts may produce fruit in their first growing season (Brue 1980 as cited in [12]). A glossy buckthorn shrub with stems ranging from 2.8 to 4.3 inches (7-11 cm) in diameter produced 50 sprouts after cutting [12]. In mixed-conifer-hardwood swamps in Wisconsin's Cedarburg bog, 100% of girdled or cut stems sprouted from their stumps. As stem diameter increased, so did the length of the sprout. The number of sprouts/plant ranged from 13 to 47, and length of the longest sprout/plant ranged from 3 to 7 feet (0.9-2.1 m). Some sprouts produced fruit in their first year [71].

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SITE CHARACTERISTICS:
Glossy buckthorn occurs on moist to wet sites in mixed woodlands, thickets, sphagnum bogs, and on roadsides, lake shores, ditches, and streambanks across its range [18,28,80,83,92].

Continental climates predominate in glossy buckthorn's southeastern Canadian and northeastern US habitats. Farrar [21] indicates that glossy buckthorn is tolerant to USDA hardiness zone 2, which may reach temperatures of -50 °F (-58 °C) or lower. While glossy buckthorn may be "most aggressive" on wet sites, it occurs on "drier" sites as well [15]. It occurs in permanently moist wetlands, in shallow soils over rocks where moisture collects temporarily, and on sandy

sites with high water tables [81]. In glossy buckthorn's native European habitats, moderately dry soils are tolerated, but glossy buckthorn is more characteristic of moister soils [31]. In its native habitats, glossy buckthorn occupies nearly any soil texture and is recommended for revegetation of waterlogged clay soils that are low in nutrients and humus [13]. However, plants likely will not survive permanently waterlogged conditions [31]. In eastern Massachusetts, glossy buckthorn dominated the shrub layer of red maple-silver maple-swamp white oak floodplain woodlands with silty loam soils where the pH ranged from 4.5 to 5.5 [47]. In Ottawa, glossy buckthorn occurs on moist to mesic acid, neutral, or alkaline soils as well as low-nutrient wetlands and fens [5].

Glossy buckthorn grew tallest and most rapidly where depth to the water table was intermediate and water table fluctuations were lowest on a mined peat bog in Delafield, Wisconsin. Site 1, mined in the 1960s, had more vegetation cover than sites 2 and 3, which were mined in the 1980s. Glossy buckthorn growth rates were lowest at site 2, where depth to the water table was intermediate. Growth rates were highest at site 1, which had the lowest water table fluctuations [96].

Glossy buckthorn growth as related to water table characteristics in a mined Wisconsin peat bog [96]

Year	Average height increase (cm) for the growing season	Average growth rate (g/g/yr)	Average depth to water table (cm)	Average water table fluctuation (cm)
Site 1				
1986	34.1	1.5	23.1	26
1987	24.1	0.80	37.2	32
Site 2				
1986	22.3	1.0	17.8	44
1987	7.1	0.36	22.5	67
Site 3				
1986	30.4	1.3	23.9	37
1987	21.6	0.98	24.5	68

SUCCESSIONAL STATUS:
In its native European habitats, glossy buckthorn is described as "on the whole intolerant of shade". Glossy buckthorn is typical in the understory of open woodlands, is often abundant following logging and/or grazing, but is rare in late-seral, closed-canopy forests [31]. Based on studies and observations made in the Wicken fen of Cambridgeshire, England, glossy buckthorn was an early species in fen succession. It was one of the first to dominate the shrub stage but was later replaced by common buckthorn [30].

In the United States and Canada, glossy buckthorn is described in many early-seral nonnative habitats. Colonization of newly disturbed or abandoned sites by sprouting is nearly guaranteed if glossy buckthorn was present before the disturbance. Colonization by seed dispersed onto disturbed sites is also common. Contrary to reports from its native European habitats, reports from the United States and Canada indicate that glossy buckthorn tolerates both full sun and heavy shade [15,93], suggesting it may be less restricted to open-canopy woodlands and disturbed sites in North American habitats. In southern Ontario, glossy buckthorn occurs in old fields, shaded ravines, and dense woodlands, but may occupy only edge habitats in very dense forests [5,83].

Although possible in shady sites in North America, glossy buckthorn growth and reproduction may be reduced in low

light conditions. In New England, glossy buckthorn fails to produce seed in densely shaded sites but may persist vegetatively for up to 50 years [12]. In the Mt Toby Experimental Forest, glossy buckthorn seedling survival and growth were compared in clearings and in the understory of a 14-year-old mixed-hardwood stand. Seedling survival, height, biomass, leaf area, and relative height growth were greater in clearings than in the understory [77]:

Differences in the characteristics of glossy buckthorn seedlings growing in the open and in a woodland understory [77]

Characteristic measured	Survival (%)	Height (cm)	Biomass (g)	Leaf area (cm^2)	Relative height growth rates (cm/m/d)
Open	62a	43.9a	4.97a	421a	1.62a
Understory	48a	12.5b	0.14b	13.7b	0.10b

Values within a column followed by different letters are significantly different (P=0.05).

Glossy buckthorn is common in early-seral and recently disturbed habitats. Colonization or regeneration can be nearly immediate on disturbed sites. At the W. K. Kellogg Biological Station in southwestern Michigan, the emergence and density of glossy buckthorn stems increased with time since abandonment of an agricultural field with 3 small, adjacent forest fragments. Glossy buckthorn first appeared in the 3rd year after abandonment, and new seedlings emerged nearly every year after, through 7 years of abandonment. Density of glossy buckthorn was 0.17 plants/200 m^2 in the 3rd year after abandonment and 2.5 plants/200 m^2 in the 5th [23]. In a New England horse paddock abandoned for 10 years, a dense stand of glossy buckthorn 10 to 15 feet (3-4.6 m) tall dominated to the near exclusion of any other species [12]. In the Cedar Creek Natural History Area, glossy buckthorn was not present before a severe windstorm but had a density of 6.6 individuals/ha 11 years after the storm and 9.9 individuals/ha 14 years after the storm. Straight-line winds caused substantial mortality in the even-aged eastern white pine stand [2]. In southeastern Wisconsin, glossy buckthorn occurred with low frequency within 1 month of draining and surface mining that removed the existing vegetation and most of the seed bank [58]. After early spring or summer logging in Massachusetts, "germination of glossy buckthorn seeds (was) extraordinary, with hundreds of plants per square meter" (MacDougall, Land Manager for Essex County Greenbelt in Massachusetts, as cited in [12]). In western Massachusetts, researchers found that glossy buckthorn was positively associated with low carbon:nitrogen ratios and high-intensity harvests (>10 m^2 of basal area of stumps/ha) in mixed-hardwood, eastern white pine, eastern hemlock (*Tsuga canadensis*), and/or oak forests harvested in the last 20 years (P=0.003) [62].

FIRE EFFECTS AND MANAGEMENT

SPECIES: Frangula alnus

FIRE EFFECTS:

Immediate fire effect on plant:

While fire likely kills glossy buckthorn seedlings, older plants are generally only top-killed [60].

Postfire regeneration strategy [85]:

Tall shrub, adventitious buds and/or a sprouting root crown
Ground residual colonizer (on site, initial community)
Secondary colonizer (on- or off-site seed sources)

Fire adaptations and plant response to fire: Mature glossy buckthorn sprouts after fire from the root crown

following top-kill by fire [6,82]. In a review, Solecki [82] reports that sprouting is generally stimulated by 1 or 2 fires, but that annual or biennial "hot fire" for 5 to 6 years may be effective in reducing glossy buckthorn abundance. Sprouting was "vigorous" after a 31 May 1951 fire in a "middle-aged" glossy buckthorn-dominated fen in Cambridgeshire, England [33].

Colonization of burned sites through seed germination is also possible. In the Wicken sedge fen of England, glossy buckthorn seedlings on areas burned in mid-August were "unusually abundant", especially in burned mire vegetation. The fire removed most aboveground plant parts and left a black ash layer [29].

Generally glossy buckthorn sprouts appear soon after fire. While abundance is typically lower on burned than unburned sites soon after fire, abundance typically increases with time since fire. Glossy buckthorn sprouts were 3 to 5 feet (1-1.5 m) tall 100 days after a "major fire" in woodlands dominated by northern white-cedar (*Thuja occidentalis*) and quaking aspen (*Populus tremuloides*) near Ottawa, Ontario. The fire occurred on 23 June 1999, spread 49 feet (15 m)/minute, produced flames heights over 100 feet (30 m), and deposited ash 25 miles (40 km) away [6]. The frequency of glossy buckthorn was 0.4% on burned sites 100 days after the fire and 2% 465 days after the fire. Frequencies were 23% on an adjacent undisturbed site and 11% in bulldozer tracks in unburned woodland [7]. Four years after a low-severity May fire in a red pine-eastern white pine stand in Michigan, the density of glossy buckthorn stems that were less than 3 feet (1 m) tall and 0.8 inch (1.9 cm) DBH was 444 stems/ha on burned and 778 stems/ha on unburned sites. On sites burned twice in 3 years by low-severity May fires, there were no similarly sized glossy buckthorn stems on unburned and once-burned sites, but on twice-burned sites, cover was 0.28%. For more details and information from this study, consult the Research Project Summary of Neumann and Dickmann's [66] work. Densities of glossy buckthorn stems increased after 1 and 2 fires on a dry sand prairie in the Clark and Pine Nature Preserve of northwestern Indiana. One year after an October fire in 1986, the total number of glossy buckthorn stems increased by 48% from prefire stem densities. Increases in stem density were largest for stems less than 2 inches (5 cm) tall. After plots were burned a second time in April 1988, the total number of glossy buckthorn stems in September increased 59% from the number counted in 1986. Increases were again largest for stems less than 2 inches (5 cm) tall [69,70,71].

FUELS AND FIRE REGIMES:
In its native habitat of southern Switzerland, glossy buckthorn was most frequent on sites with an average fire-return interval of up to 50 years and least frequent on sites unburned for more than 100 years [16]. While fire regimes were not explicitly described in invaded North American habitats, glossy buckthorn's ability to sprout following top-kill suggests a tolerance of short fire-return intervals. Persistence in shaded sites [12] and widely animal-dispersed seed [31,34,39,64] suggest that long fire-return intervals could be tolerated as well. In laboratory tests, glossy buckthorn produced low heat of combustion (11.45 MJ/kg) and total heat release (11.32 MJ/kg) when burned. These values were much lower than those of other associated native vegetation, suggesting that glossy buckthorn populations could possible alter properties of the native fuel bed [17]. The Fire Regime Table summarizes characteristics of fire regimes for vegetation communities in which glossy buckthorn may occur. Follow the links in the table to documents for more detailed information on these fire regimes.

FIRE MANAGEMENT CONSIDERATIONS:
A sparse surface fuel layer [15] and "prolific" postfire sprouting [33,82] may limit the usefulness of fire to control glossy buckthorn. However, while the complete removal of glossy buckthorn through burning is unlikely, seedlings are easily killed [60], and a short-term reduction in stem abundance is possible [7,66]. Associated native species may benefit from the short-lived reduction in shade after fire in dense glossy buckthorn stands [81].

Reviews report that fire spread can be difficult without dry and/or windy conditions in glossy buckthorn thickets, which are typically too shady to support much groundlayer vegetation [13,15]. However, if fires are possible, some suggest that combinations of cutting and burning may be useful in controlling glossy buckthorn. Once adult plants are top-killed, growing-season fires may kill seedlings and saplings. Another fire in the next growing season may be necessary to remove seedlings germinating from the soil seed bank [87]. Solecki [82] and Heidorn [39] suggest that repeated "hot" fires set nearly every year for 5 to 6 years may provide glossy buckthorn control. However, Lampa (1984, personal communication cited in [13]) indicates that given a glossy buckthorn seed source, exposed soils on the burned area are more hospitable to establishment than unburned areas with intact vegetation. Additional information on the use of fire in conjunction with other control methods is discussed in Integrated management.

MANAGEMENT CONSIDERATIONS

SPECIES: Frangula alnus

IMPORTANCE TO WILDLIFE AND LIVESTOCK:
Birds, Henry's elfin butterflies, and small mammals feed on glossy buckthorn. A number of bird species feed on glossy buckthorn fruits and are important in seed dispersal [31,64,92]. In southern Ontario, American robins, Bohemeian waxwings, cedar waxwings, rose-breasted grosbeaks, and European starlings were observed eating glossy buckthorn fruits (Darbyshire others, personal communications in [5]). The laxative effect of fruits may, however, limit their nutritional value [34].

Studies in the Wicken Fen in Cambridgeshire, England, showed that mice harvested, consumed, and cached glossy buckthorn fruits or seeds [30].

In Ottawa-Carleton, Ontario, which is near the northern limit of Henry's elfin's range, glossy buckthorn provides important rearing habitat and food. As glossy buckthorn abundance has increased in this area, so have Henry's elfin populations. Populations of Henry's elfin in the area have increased 7 fold from 1980 to 1996 [4].

OTHER USES:
Glossy buckthorn has been used medicinally as a laxative, purgative, and cancer treatment (others cited in [81]).

IMPACTS AND CONTROL:
Impacts: Many North American studies have shown that glossy buckthorn dominance can negatively affect native species richness, simplify vegetation structure, disrupt food webs, and delay succession [12]. However, in native Scots pine (*Pinus sylvestris*) forests of northeastern Germany, there was a significant ($P<0.001$) positive relationship between the occurrence of glossy buckthorn and species richness. Forests with glossy buckthorn had significantly more threatened vascular species ($P<0.05$), threatened bryophyte species ($P<0.001$), and total woody species ($P<0.001$), as well as nonnative species ($P<0.01$) [52].

In its nonnative US and Canadian range, glossy buckthorn is often referred to as a "problem" species. In 2004, the eastern region of the Forest Service ranked glossy buckthorn as "highly invasive" due to its potential or known invasion of natural habitats and "replacement" of native species [88]. In Vermont, a 1998 report characterized glossy buckthorn as "highly invasive" and noted it was displacing native plants on local and widespread scales [91]. In a survey of The Nature Conservancy staff, glossy buckthorn was identified as a "serious threat" to multiple sites or large geographical areas [11]. In the Leitrum Albion Road wetlands in Canada's Ottawa-Carleton area, glossy buckthorn has been referred to as a "menace" [19]. Glossy buckthorn made the top 10 list of priority nonnative invasive plants in southern Canada considered to have a "major impact" on native vegetation [8].

While most studies have focused on glossy buckthorn's impact on native vegetation, there are other potential impacts on agricultural crops, birds, insects, succession, and fire ecology. Glossy buckthorn is an alternate host for the fungus that causes oat rust disease [14] and for alfalfa mosaic virus (Marani and Giunchedi 1976 as cited in [81]). A study conducted by Milwaukee's Zoological Society found that common buckthorn and glossy buckthorn supported fewer arthropods than did 11 species of native trees and shrubs [15]. In an abandoned horse paddock in New England where glossy buckthorn dominated to the near exclusion of any understory species, the loss of the herbaceous understory led to changes in moisture, temperature, humidity, and light on the site, altering grasshopper, mouse, vole, and snake habitats. Dense glossy buckthorn stands also decreased the recruitment of native shrubs and the diversity of bird foods [12]. One researcher suggested that "timely high-quality native food (was) replaced by easily accessible junk food"; glossy buckthorn was referred to as junk food because of its laxative effect, which may be a net energy loss

(MacDougall, Land Manager for Essex County Greenbelt in Massachusetts, as cited in [12]).

Allelopathic potential probably does not play a part in glossy buckthorn's negative impacts. In laboratory experiments, glossy buckthorn root and leaf extracts did not inhibit germination and stimulated seedling growth of the test species. Researchers cautioned, however, that field conditions could produce results different from the laboratory setting [53].

Long growth periods and densely packed glossy buckthorn stems are often suggested as partly responsible for glossy buckthorn's replacement or exclusion of native species. Glossy buckthorn may have a competitive advantage, since it leafs out earlier and retains leaves longer than most associated native species [74]. Glossy buckthorn is described as "having a serious impact on the ecology of our Midwestern forests". Dense glossy buckthorn thickets shade native tree species, decreasing tree seedling establishment, and early leaf production by glossy buckthorn restricts the light available to native spring ephemerals (McDougall, USDA/FS forester for the Northeastern Area State and Private Forestry, personal communication cited in [10]). However, not all research has shown a negative relationship between glossy buckthorn and native vegetation. When the composition of 58 wetlands in southeastern Ontario was studied, researchers found no evidence that nonnative wetlands species, including glossy buckthorn, excluded native species. Native species richness and nonnative species richness were positively correlated, and nonnative species were no more likely than native species to be dominant. This study, however, involved only a single year of study and did not evaluate change over time [40].

In some wetland habitats, glossy buckthorn threatens the persistence of rare or threatened species. In Ottawa, glossy buckthorn occurs in low-nutrient wetlands such as fens and shores where many rare and endangered species are concentrated [5]. Since the arrival and spread of glossy buckthorn in the Gavin bog of Illinois, abundance of endangered highbush blueberries (*Vaccinium corymbosum*) and sensitive-listed bog birches (*Betula pumila*) has decreased [86].

Several studies have shown that glossy buckthorn can negatively affect native herbaceous cover, total species richness, and overstory recruitment. In eastern white pine stands on southeastern New Hampshire old fields, high glossy buckthorn basal area was associated with low woody seedling density ($P<0.001$), low herbaceous cover ($P=0.048$), and low groundlevel species richness ($P=0.01$). Generally, the variability in these factors was low with high glossy buckthorn basal area, and high with low glossy buckthorn basal area. Species on sites where glossy buckthorn dominated the midstory started growth early in the spring and/or had clonal growth habits [25,26,27]. Total herbaceous layer cover, total species richness, and woody plant seedling richness were significantly lower on plots invaded by glossy buckthorn than on uninvaded plots in a riparian savanna near Salmon Creek in the Allegheny National Forest ($P\leq0.002$). Nonwoody species richness was not significantly different between invaded and uninvaded plots, but the dominant on invaded plots was bearded shorthusk (*Brachyelytrum erectum*) and on uninvaded plots was wrinkleleaf goldenrod (*Solidago rugosa*) [68]. In eastern white pine forests in Lebanon, New Hampshire, sugar maple, red maple, and white ash (*Fraxinus americana*) saplings had lower growth under a glossy buckthorn subcanopy than in areas where the subcanopy was cleared. Over a 9-year period, stem growth of the native tree saplings was significantly lower and, over a 5-year period, radial growth was significantly lower under the subcanopy than in cleared areas ($P<0.05$). Average sapling mortality under glossy buckthorn was 10.4% and in the open was 5.0%. Fewer than 10% of native saplings were expected to penetrate the subcanopy [20]. During a 2-year field experiment in eastern white and red pine stands in southern New Hampshire, first-year native tree seedling density was significantly lower on plots with glossy buckthorn than on plots where the glossy buckthorn canopy was removed ($P=0.048$) or on uncut plots ($P=0.042$). Presence of glossy buckthorn did not significantly affect herbaceous cover or groundlayer species richness, but researchers noted that short experiment duration, low sample size, and/or the very low cover of herbaceous vegetation in the study area may have affected results. Native tree seedling suppression may have resulted from competition for light, space, nutrients, and/or moisture [24,26].

Control: Studies have shown variable success in the control of glossy buckthorn. "Vigorous" sprouting following top-kill makes control difficult and prolongs management. Integration of multiple methods may be most effective. Efforts to eradicate glossy buckthorn from Wisconsin in the 1950s were unsuccessful [14]. In the Gavin bog of Illinois, glossy buckthorn dominates in the tamarack forest zone and tall shrub zone. Researchers predicted that eliminating glossy buckthorn and replacing it with native species was unlikely under any management involving fire, cutting, and herbicide treatments [86].

It is likely that successful management of glossy buckthorn will involve prioritization, site-specific strategy development, and a long-term commitment [12]. Control efforts targeting glossy buckthorn seedlings are likely to succeed [10]. Studies in a mined peat bog in Delafield, Wisconsin, showed that glossy buckthorn growth rates were highest in late spring or early summer. Control efforts may be more effective during this time [96]. Many potential control methods are discussed in a review by Converse [13].

While control of glossy buckthorn is seen as a priority in southern Canada [8], successful control may eliminate an important food source and developmental habitat for Henry's elfin near the northern limit of its range in Ottawa-Carleton, Ontario [4].

Water level manipulation: In some wetland systems, glossy buckthorn dominance has coincided with low water levels. Restoration of flooding or high water tables may provide some control. In the Leitrim Albion Road wetlands in Ottawa-Carleton, aerial photos and other management records showed that increased glossy buckthorn growth coincided with draining and ditching operations [19]. Several researchers suggest that flooding or high water tables may eliminate glossy buckthorn in areas where water tables were artificially lowered [15,39,82].

Prevention: Probably the most effective and economical management of glossy buckthorn would involve preventing its establishment. Prevention methods would likely include minimizing disturbances, restricting the sale and use of glossy buckthorn, and public education. In 11 early-seral sites in southeastern New Hampshire, glossy buckthorn was positively correlated with the abundance of agricultural fields and other disturbed lands (R^2=0.176, P=0.057) [45]. In the late 1980s in eastern Massachusetts, glossy buckthorn transplants were used to vegetate artificially created wetlands [43]. Restrictions on the use and sale of glossy buckthorn as well as increased education about its impacts would likely promote prevention.

Physical and/or mechanical: Even when done repeatedly, pulling, mowing, and/or cutting glossy buckthorn rarely provides substantial control, but some researchers note that associated native plants may benefit. In Lincoln, Massachusetts, pulling young glossy buckthorn plants from a very small area appeared to benefit sundews (*Drosera* spp.) and pitcher plants (*Sarracenia* spp.) [12]. However, 1 year after glossy buckthorn shrubs were pulled from a site in northern Massachusetts, differences before and after were not discernible (MacDougall, Land Manager for Essex County Greenbelt in Massachusetts, as cited in [12]). Glossy buckthorn was generally unaffected by 3 consecutive years of June or July mowing in a sedge meadow with high shrub density in the Kettle Moraine region of southeastern Wisconsin. Glossy buckthorn density before mowing was 6.1 to 12.3 stems/m² and after was 5 to 6 stems/m². Before mowing, the frequency of glossy buckthorn was 66% to 86% and after was 73% to 77% [59]. Researchers suggested that mowing increased the density of glossy buckthorn roots and may have increased glossy buckthorn's resistance to other control methods [12].

Glossy buckthorn stems that were cut twice in a single growing season for 2 to 3 successive years were less dense and shorter than stems on an untreated control site in a Wisconsin calcareous fen. Herbaceous ground cover was greater on sites cut twice than on sites cut once (Lovely 1983, personal communication as cited in [13]). While cutting did not remove glossy buckthorn from a dense thicket in Ottawa, it did increased overall native species cover. In the first growing season after cutting, overall native species cover was significantly greater on cut than on uncut plots (P=0.008). Following cutting, glossy buckthorn sprouting was "vigorous". The average number of sprouts ranged from 20 to 38/m², and their average height ranged from 6 to 13 inches (16-34 cm). Native species cover increases were likely due to the short-term removal of heavy shade [81].

Fire: See Fire Management Considerations.

Biological: No biological controls for glossy buckthorn have been released to date (2008), but testing is occurring, and releases may be made by 2010 [15].

Chemical: The effectiveness of herbicides to control glossy buckthorn may increase if used in conjunction with other control methods. In Massachusetts, herbicide treatment of cut stumps provided control for 2 to 3 years. Treated stumps produced sprouts after that time [12]. Herbicides considered useful in glossy buckthorn control are discussed by

Solecki [82].

Integrated management: Most studies reporting some level of success in the control of glossy buckthorn involved more than one control method and repeated treatments. Heidorn [39] indicated that repeated cutting or girdling of glossy buckthorn followed by herbicide treatments was often effective. Since glossy buckthorn's leaf retention made it easy to identify and associated vegetation was dormant, fall treatments minimized nontarget effects [39]. In mixed-conifer and hardwood swamps in the Cedarburg bog in Wisconsin, just 3 of 150 glossy buckthorn plants survived after cutting and stump herbicide treatments. Sprouts from the 3 survivors were small and deformed at the end of the first posttreatment growing season [73]. When sites were plowed and seeded with little bluestem (*Schizachyrium scoparium*) in Lincoln, Massachusetts, glossy buckthorn abundance decreased [12].

Some studies suggest that the use of fire with cutting or revegetation may control glossy buckthorn. Prescribed fire and mowing were used to control glossy buckthorn in the Wolf Road Prairie in Illinois. No treatment comparisons were provided, and the effort was ongoing [54]. Northeastern Illinois oak woodlands at Cap Sauers Holding were managed starting in 1989 with spring and/or fall prescribed fire and cutting and removal of nonnative woody vegetation. Unmanaged woodlands on the McClaughry Springs Forest Preserve also in Illinois were used as a comparison to evaluate the effectiveness of burning and cutting treatments. Fires occurred 1 to 4 times in 7 years; frequency of cutting was not provided. Glossy buckthorn density in managed woodlands decreased significantly between 1988 and 1995 (P=0.0001), but cover of glossy buckthorn increased, although not significantly, from 2.6% in 1988 to 3.3% in 1995. Researchers suggested that fall fires may have been less successful than spring fires. In unmanaged woodlands, the density of glossy buckthorn increased from 1,090 stems/ha in 1992 to 5,590 stems/ha in 1995 [55]. On sites where stems are cleared and stumps are herbicide treated, fire and postfire seeding may limit glossy buckthorn reestablishment. In oak woodlands in University of Wisconsin's arboretum, 4 follow-up treatments were compared on sites cleared of glossy buckthorn [79]:

Number of glossy buckthorn seedlings 1 year after follow-up treatments on cleared plots [79]

Treatment	Low-severity, November prescribed fire and postfire seeding*	November prescribed fire only	Seeding only	No additional treatments
Glossy buckthorn density (seedlings/144-m² plot)	6	99	143	191

*7 grass and 18 forb woodland species.

APPENDIX: FIRE REGIME TABLE

SPECIES: Frangula alnus

The following table provides fire regime information vegetation types where glossy buckthorn may occur. Only potential vegetation types from north-central and northeastern US habitats where glossy buckthorn is most widely distributed are listed in the table below. For habitats on the fringe of glossy buckthorn's distribution, consult the expanded FEIS Fire Regime Table.

Fire regime information on vegetation communities in which glossy buckthorn may occur. For each community, fire regime characteristics are taken from the LANDFIRE Rapid Assessment Vegetation Models [57]. These vegetation models were developed by local experts using available literature, local data, and/or expert opinion as documented in the PDF file linked from

the name of each Potential Natural Vegetation Group listed below. Cells are blank where information is not available in the Rapid Assessment Vegetation Model.

Great Lakes Northeast Southern Appalachians

Great Lakes

- Great Lakes Grassland
- Great Lakes Shrubland
- Great Lakes Woodland
- Great Lakes Forested

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
Great Lakes Grassland					
Mosaic of bluestem prairie and oak-hickory	Replacement	79%	5	1	8
	Mixed	2%	260		
	Surface or low	20%	2		33
Great Lakes Woodland					
Northern oak savanna	Replacement	4%	110	50	500
	Mixed	9%	50	15	150
	Surface or low	87%	5	1	20
Great Lakes Forested					
Northern hardwood maple-beech-eastern hemlock	Replacement	60%	>1,000		
	Mixed	40%	>1,000		
Conifer lowland (embedded in fire-prone system)	Replacement	45%	120	90	220
	Mixed	55%	100		
Conifer lowland (embedded in fire-resistant ecosystem)	Replacement	36%	540	220	≥1,000
	Mixed	64%	300		
Great Lakes floodplain forest	Mixed	7%	833		
	Surface or low	93%	61		
Great Lakes spruce-fir	Replacement	100%	85	50	200
Minnesota spruce-fir (adjacent to Lake Superior and Drift and	Replacement	21%	300		
	Surface or low	79%	80		

Lake Plain)					
Great Lakes pine forest, jack pine	Replacement	67%	50		
	Mixed	23%	143		
	Surface or low	10%	333		
Maple-basswood	Replacement	33%	≥1,000		
	Surface or low	67%	500		
Maple-basswood mesic hardwood forest (Great Lakes)	Replacement	100%	>1,000	≥1,000	>1,000
Maple-basswood-oak-aspen	Replacement	4%	769		
	Mixed	7%	476		
	Surface or low	89%	35		
Northern hardwood-eastern hemlock forest (Great Lakes)	Replacement	99%	>1,000		
Oak-hickory	Replacement	13%	66	1	
	Mixed	11%	77	5	
	Surface or low	76%	11	2	25
Pine-oak	Replacement	19%	357		
	Surface or low	81%	85		
Red pine-eastern white pine (frequent fire)	Replacement	38%	56		
	Mixed	36%	60		
	Surface or low	26%	84		
Red pine-eastern white pine (less frequent fire)	Replacement	30%	166		
	Mixed	47%	105		
	Surface or low	23%	220		
Great Lakes pine forest, eastern white pine-eastern hemlock (frequent fire)	Replacement	52%	260		
	Mixed	12%	>1,000		
	Surface or low	35%	385		
Eastern white pine-eastern hemlock	Replacement	54%	370		
	Mixed	12%	>1,000		
	Surface or low	34%	588		
Northeast					

- Northeast Woodland
- Northeast Forested

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
Northeast Woodland					
Eastern woodland mosaic	Replacement	2%	200	100	300
	Mixed	9%	40	20	60
	Surface or low	89%	4	1	7
Northeast Forested					
Northern hardwoods (Northeast)	Replacement	39%	≥1,000		
	Mixed	61%	650		
Eastern white pine-northern hardwoods	Replacement	72%	475		
	Surface or low	28%	>1,000		
Northern hardwoods-eastern hemlock	Replacement	50%	≥1,000		
	Surface or low	50%	≥1,000		
Northern hardwoods-spruce	Replacement	100%	≥1,000	400	>1,000
Appalachian oak forest (dry-mesic)	Replacement	2%	625	500	≥1,000
	Mixed	6%	250	200	500
	Surface or low	92%	15	7	26
Beech-maple	Replacement	100%	>1,000		
Northeast spruce-fir forest	Replacement	100%	265	150	300

Southern Appalachians

- Southern Appalachians Grassland
- Southern Appalachians Woodland
- Southern Appalachians Forested

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval	Maximum interval

				(years)	(years)
Southern Appalachians Grassland					
Bluestem-oak barrens	Replacement	46%	15		
	Mixed	10%	69		
	Surface or low	44%	16		
Eastern prairie-woodland mosaic	Replacement	50%	10		
	Mixed	1%	900		
	Surface or low	50%	10		
Southern Appalachians Woodland					
Oak-ash woodland	Replacement	23%	119		
	Mixed	28%	95		
	Surface or low	49%	55		
Southern Appalachians Forested					
Bottomland hardwood forest	Replacement	25%	435	200	≥1,000
	Mixed	24%	455	150	500
	Surface or low	51%	210	50	250
Mixed mesophytic hardwood	Replacement	11%	665		
	Mixed	10%	715		
	Surface or low	79%	90		
Appalachian oak-hickory-pine	Replacement	3%	180	30	500
	Mixed	8%	65	15	150
	Surface or low	89%	6	3	10
Eastern hemlock-eastern white pine-hardwood	Replacement	17%	≥1,000	500	>1,000
	Surface or low	83%	210	100	>1,000
Appalachian oak forest (dry-mesic)	Replacement	6%	220		
	Mixed	15%	90		
	Surface or low	79%	17		

*Fire Severities—

Replacement: Any fire that causes greater than 75% top removal of a vegetation-fuel type, resulting in general replacement of existing vegetation; may or may not cause a lethal effect on the plants.

Mixed: Any fire burning more than 5% of an area that does not qualify as a replacement, surface, or low-severity fire; includes mosaic and other fires that are intermediate in effects.

Surface or low: Any fire that causes less than 25% upper layer replacement and/or removal in a vegetation-fuel class but burns 5% or more of the area [38,56].

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