Rhamnus cathartica, R. davurica

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Common buckthorn
Photo by Elizabeth J. Czarapata.

AUTHORSHIP AND CITATION:
Zouhar, Kris. 2011. Rhamnus cathartica, R. davurica. 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/ [2011, March 16].

FEIS ABBREVIATION:
RHASPP
RHACAT
RHADAV
RHADAVD
RHADAVN

NRCS PLANT CODE [219]:
RHCA3
RHDA

RHDAD2
RHDAN2

COMMON NAMES:
for *Rhamnus cathartica*:
common buckthorn
European buckthorn

for *Rhamnus davurica*:
Dahurian buckthorn

TAXONOMY:
The scientific name of common buckthorn is *Rhamnus cathartica* L. (Rhamnaceae) [68,77,111,124,138,184,200,229,230,242,244].

The scientific name of Dahurian buckthorn is *Rhamnus davurica* Pall. (Rhamnaceae) [56,77,111,138,156,200,228,244]. Two subspecies of Dahurian buckthorn are recognized in North America: *R. davurica* subsp. *davurica* [111,244] and *R. davurica* subsp. *nipponica* (Makino) Kartesz & Gandhi [111,138].

In this review, the term "buckthorns" is used when describing information pertaining to the genus (*Rhamnus*), the species are referred to by their common names, and infrataxa are identified by scientific name.

Hybrids: A review by Kurylo and others [120] notes that the native distributions of nearly 42 *Rhamnus* species overlap or cooccur in their native range, and that many of these species can hybridize with *R. cathartica*. In Michigan, there is evidence of hybridization between common buckthorn and Chinese buckthorn (*R. utilis*) [64].

SYNONYMS:
for*Rhamnus cathartica*:
Rhamnus catharticus L. [187]

for *Rhamnus davurica*:
Rhamnus citrifolia (Weston) W. Hess & Stearn. [68,173]
Rhamnus dahurica Pall. [202]

for *Rhamnus davurica* subsp. *davurica*:
Rhamnus davurica Pall. var. *davurica* [77]

for *Rhamnus davurica* subsp. *nipponica*:
Rhamnus davurica var. *nipponica* Makino [77]

LIFE FORM:
Tree-shrub (common buckthorn)
Shrub-tree (Dahurian buckthorn)

DISTRIBUTION AND OCCURRENCE

SPECIES: Rhamnus cathartica, R. davurica

- GENERAL DISTRIBUTION
- HABITAT TYPES AND PLANT COMMUNITIES

Three extensive literature reviews on common buckthorn [116,120,175] provided substantial information on its distribution, biology, ecology, and management and were used throughout this review. Summary information from literature reviews in other documents (e.g., [6,74]) was also used to discuss common buckthorn's distribution and occurrence.

GENERAL DISTRIBUTION:

Common buckthorn is not native to North America but was deliberately introduced before and during the early 1800s by colonists from Europe, primarily as an ornamental hedge plant. It subsequently escaped cultivation [116,175] and has established throughout the north-central and northeastern United States and the maritime provinces of Canada [116].

At the time of this writing (2010), common buckthorn occurred outside cultivation from Nova Scotia west to Alberta, Canada, in the north, and in the United States from Maine south along the Atlantic Coast to Delaware and west to Montana and Utah [120]. In Canada, it is most abundant in southern Quebec and Ontario [120,175], with scattered populations in the western provinces, though it is said to be spreading to new locations in Alberta [175]. Common buckthorn occurs east and southwest of the Canadian Shield, a geological formation of bare Precambrian Era rock, but it is uncommon on or north of the Canadian Shield [200]. In the United States, common buckthorn is most common in New England, southern Michigan and Wisconsin, southeastern Minnesota, and northern Illinois and Iowa [120]. At the edges of its distribution (e.g., Colorado, Montana, Utah) common buckthorn may be infrequent [38,120,123,229,230]. Common buckthorn's frequency is relatively low in Maine; it occurred on only 18 of 2,759 forested plots surveyed in Maine in 2003 [149]. Plants Database provides a distribution map of common buckthorn in the United States and Canada, although its accuracy is questionable [120,228].

Common buckthorn is native to Europe and the northern and western parts of Asia, from southern Scandinavia (below 61° 40') and western Siberia (56° 40') in the north, to northern Afghanistan, Iran, Turkey, and northeastern Spain in the south. It occurs sparingly at high altitudes in northern Algeria and Morocco [120]. Kurylo and others [120] provide a detailed description of the distribution of common buckthorn in both its native range in Eurasia and northern Africa and its nonnative North American range.

Introduction and spread: A review by Mack [135] indicates that common buckthorn was first brought to North America for ornamental purposes, and it had already established outside cultivation by around 1800. Common buckthorn seed was available for purchase in the United States as early as 1807 from a nursery in Philadelphia that advertised it as "indigenous to the United States of America". Seed was widely available in Massachusetts, New York, and Pennsylvania beginning in the early 1800s and was sold in Maryland, Ohio, Indiana, and California beginning in the late 1800s [134]. Common buckthorn is mentioned in US floras as early as 1824 [74], and it appeared in taxonomic collections in the northeastern United States by the 1880s (Wolf 1938 as cited by [6]). Common buckthorn was first collected in Michigan at Ann Arbor in 1914, and within 2 years was recorded as "plentiful and naturalized" around Birmingham and Bloomfield Hills [225]. It was recommended as a hedge plant as early as 1849 [74] and was planted as potential shelterbelt species in the northern Great Plains in the early 1900s [62]. It was also used in "conservation plantings" advocated by federal agencies (Knopf and others 1988 as cited by [47]). However, in the 1920s it was recognized as an alternate host for oat crown rust (*Puccinia coronata*) and was no longer recommended in states where oats (*Avena* spp.) were grown [74]. In the latter half of the 20th century, common buckthorn was commonly planted [77,229] and occasionally escaped to various habitats in North Dakota, eastern South Dakota, southeastern Wyoming, Nebraska [77], and Colorado [229]. Common buckthorn was not reported in oak (*Quercus*) openings in northwestern Ohio in 1928 and was reported as rare (observed in fewer than 5 places) in 1979 [53]. The Vermont Agency for Natural Resources reported in 2003 that common and glossy buckthorn (*Frangula alnus*) were widespread in the Champlain Valley, the Taconic Foothills, and the Connecticut River Valley, and they were spreading into the Vermont Piedmont region and up the Winooski, Lamoille, and Connecticut river valleys [223].

In Canada, common buckthorn was widely planted from Nova Scotia to Saskatchewan for hedges, shelterbelts and/or ornamental purposes [175,184] because of its compact structure with many spiny branches, ease of propagation [175], hardiness, and ability to tolerate a variety of soils and site conditions. It was introduced to Saskatchewan in the 1930s as a potential shelterbelt species. It was deselected after recognition that it was an alternate host to oat crown rust, but not before it had escaped from cultivation [6]. Common buckthorn spread rapidly in southern Ontario in the first half of the 20th century and has since established across Canada from Nova Scotia to Alberta [175].

Dahurian buckthorn is not native to North America but was introduced from Asia, where it is native to China, North Korea, Mongolia, eastern Siberia [56,242] and Japan [56]. Dahurian buckthorn is not as widespread in North America as common buckthorn, occurring mostly in the north-central United States, from North Dakota south to Nebraska, and in scattered states eastward and along the Atlantic Coast [138,219]. Dahurian buckthorn was commonly cultivated and planted in windbreaks of the northern Great Plains [202] and has escaped cultivation in North Dakota, South Dakota, and Nebraska [77]. It is reported as "rarely adventive" in DuPage County, Illinois [156]; is "rare" in suburban woodlands in North Carolina and Virginia; and occurs in suburban areas near Louisville, Kentucky, and Knoxville, Tennessee [228]. In Canada, it is reported only on Prince Edward Island [219].

Introduction and spread: It is unclear when Dahurian buckthorn was first introduced to North America. It was extensively planted after the mid 1930s in the northern Great Plains [63]. In 1941, Dahurian buckthorn was being recommended as a useful shelterbelt plant in the oat-growing states (Engstrom and Stoeckler 1941 as cited by [74]). However, in 1953 George [62] recommended against planting Dahurian buckthorn in commercial oat-growing areas because like "all other buckthorns, this species acts to some extent as the alternate host of crown rust of oats" [62]. Dahurian buckthorn was not recorded in the flora of Illinois until sometime between 1956 and 1978 [98].

Plants Database provides a distribution map of Dahurian buckthorn and its infrataxa in the United States and Canada. The North American range of *R. davurica* subsp. *davurica* is the same as that of the species [219], whereas that of *R. davurica* subsp. *nipponica* is restricted to Connecticut, Rhode Island [138,219], and possibly Massachusetts [194].

HABITAT TYPES AND PLANT COMMUNITIES:

- **Common buckthorn**
  - Native habitats
  - North American habitats
    - Canada
    - Great Lakes
      - Forest and woodland
      - Riparian woodland
      - Savanna
      - Prairie
      - Wetlands
    - Northeast and New England
      - Forest and woodland
      - Successional forests on old fields
      - Disturbed forests
      - Urban forests
      - Alvar communities
    - Great Plains
    - Western North America
- **Dahurian buckthorn**

Common buckthorn: Common buckthorn is a component of a large number of habitat types and plant communities from very wet alkaline fen peat to comparatively dry and open woods in both its native [120] and introduced ranges [74].

Native habitats: In its native range, common buckthorn occurs open forests, woodlands, and wetland carrs (see mire) [120]. In Europe it is widespread but local in sunny, stony, and dry places, in scrub, woodland, hedges, mixed woods of conifers and deciduous trees, and pine (*Pinus*) forest understories [71]. In open woods and shrublands it may form dense thickets with blackthorn (*Prunus spinosa*), bloodtwig dogwood (*Cornus sanguinea*), and oneseed hawthorn (*Crataegus monogyna*). It is also common in the sunny shrublands of the predominantly limestone rock steppes in Hungary, Austria, and Czechoslovakia (Hegi 1975 as cited by [74]). In the coastal area of western Estonia, common buckthorn occurs as a scattered, low shrub along with common juniper (*Juniperus communis*) and European cranberrybush (*Viburnum opulus*) in a calcareous alvar grassland [110].

In Great Britain, common buckthorn occurs primarily in 4 plant communities: alkaline fen peat; seral scrub; ashwoods (*Fraxinus* spp.) or oakwoods; and hedgerows on limestone soils. In uncut shrub carr communities on alkaline peat, common buckthorn is characteristic of seral communities and codominates with glossy buckthorn, large gray willow (*Salix atrocinerea*), European cranberrybush, and oneseed hawthorn. Common buckthorn is a characteristic component of chalk scrub along with several other shrubs and trees. It occurs in open ash and oak woodlands on limestone and base-rich soils. It is very widespread in hedgerows [71]. See Godwin [70,71] for more information on associated species in Great Britain.

North American habitats: In North America common buckthorn has established, persisted, and spread in many areas of anthropogenic influence including roadsides, fencerows, disturbed areas, and pastures (see Site Characteristics). It commonly occurs in old fields undergoing succession (see Old-field succession). Common buckthorn also occurs in less disturbed wildlands including ravine slopes [200], riparian areas (e.g., [160]), shrub-carr (e.g., [41]), other wetlands (e.g., [74,133]), and wetland edges [120]; and upland sites such as oak woodlands (e.g., [74,96,131]), savannas (e.g., [5,131]), open forests (e.g., [74,160]), alvars [31,188], and aspen (*Populus* spp.) groves [6].

Common buckthorn seems to be most invasive in selectively cut or grazed woodlands, along woodland edges, in canopy openings, or in thickets growing within prairies. Open oak or lowland woodlands are more frequently invaded than sugar maple (*Acer saccharum*) forest (personal communications cited by [36]). Common North American plant associates include trees such as pine, oak, basswood (*Tilia americana*), and ash; and shrubs such as juniper (*Juniperus* spp.), viburnum (*Viburnum* spp.), rose, and dogwood (*Cornus* spp.) [74].

Canada: Throughout its range in Canada, common buckthorn is abundant in urban areas and nearby woodlands, and sometimes occurs in rural thickets but does not generally occur in well maintained pastures. It is most prevalent in southern Ontario, Quebec, and the Maritimes where it occurs along fences and roadsides, on abandoned farmland, in open woods, and on moist, well-drained soils adjacent to lakes and streams [175]. It occurs in riparian woodland, aspen groves, and prairie shrubland in Saskatchewan. It is reported to thrive in the shade of other trees and shrubs (but see Shade tolerance) and has become the dominant understory species at some sites [6,45]. Herbaria records in Canada indicate a broad range of shrub and tree species associated with common buckthorn [175]. Qaderi and others [175] provide detailed lists of plant species associated with common buckthorn in the Canadian provinces.

In Ontario, common buckthorn occurs in both dry and moist habitats including open pastures, fencerows, roadsides, clearings, low woods, rocky woods, and on the slopes of ravines [200]. Common buckthorn establishes and persists even in closed-canopy forests throughout Ontario (Tanentzap and Bazely cited in [212]). A 1952 survey found that common buckthorn covered large areas in eastern Ontario and was especially common along fencerows, in open woods, and along the sloping banks of lakes, rivers, and streams, but it was not found in pastures. In parts of Ontario County, common buckthorn shrubs were up to 20 feet (6 m) tall and extended as solid hedges along every fencerow for miles [160]. In and around Ottawa, common buckthorn occurred on sites dominated by red maple (*Acer rubrum*), sugar maple, white ash (*Fraxinus americana*), basswood, and quaking aspen (*Populus tremuloides*) [50]. In openings among well-spaced oaks along the Trent River in eastern Ontario, the shrub and herb layer was dominated by weeds, including common buckthorn, Tatarian honeysuckle (*Lonicera tatarica*), smooth brome (*Bromus inermis*) and timothy (*Phleum pratense*) [30]. In forest patches adjacent to the Thames River Valley and its tributaries around London, Ontario, presence of common buckthorn was positively correlated with seedlings of ash, black cherry (*Prunus serotina*), American elm (*Ulmus americana*), and glossy buckthorn; and negatively correlated with seedlings of American black currant (*Ribes americanum*), hickory (*Carya* spp.), lilac (*Syringa* spp.), and maple (*Acer* spp.) ($P<0.05$). There was a positive correlation between the frequencies of mature common buckthorn and glossy buckthorn ($P<0.001$) [226]. A detailed study of the vegetation of the Medway River Valley in southwestern Ontario found that common buckthorn was particularly abundant in slope and upland communities in abandoned agricultural land. It dominated the understory of partially open riverbank communities where common trees included green ash (*Fraxinus pennsylvanica*), eastern cottonwood (*Populus deltoides*), sycamore (*Platanus occidentalis*), crack willow (*Salix fragilis*), basswood, and black walnut (*Juglans nigra*); and was abundant along woodland edges and in a sewer corridor. It was also an abundant to common understory tree in upland areas including mesic sugar maple-American beech (*Acer saccharum-Fagus grandifolia*) forest and several second-growth successional communities. More recent studies in London, Ontario, found that common buckthorn does not prosper under a black walnut canopy. Surveys in 1993 and 1994 revealed that common buckthorn was the most abundant woody species in the drier half of the Sifont Botanical Bog Natural Area. It formed almost pure stands in some areas, particularly where the canopy had been opened following the death of trees such as American elm [175].

Among 9 riparian and forest plant communities characterized along a toposequence bordering Lac des Deux-Montagnes in Quebec, common buckthorn was an important species in the shrub layer of the silver maple/ostrich fern (*Acer saccharinum*/*Matteuccia struthiopteris*) forest between 74 and 79 feet (22.5-24.0 m) above sea level; this was 5 to 10 feet (1.5-3.0 m) above the mean lowest water level of the lake. This type of silver maple forest had the shortest period of flooding during the spring. Common buckthorn was not noted in other plant communities described in the area [224].

Great Lakes: In addition to urban and rural areas where it has been cultivated and travel corridors and fencerows where it has been dispersed, common buckthorn occurs in many native plant communities in the Great Lakes region including forests, woodlands, savannas, prairies, riparian areas, and wetlands. In the North-central Great Plains, common buckthorn is classified as a facultative upland species: one that does not usually occur in wetlands but is occasionally found in them [178] (see Soil moisture and texture for more information on this topic).

Among the diverse habitats where common buckthorn occurs, it seems to be most common in deciduous forests and woodlands, including those in riparian areas (e.g., [74,156,201]) and in open wetlands [74], where it is sometimes a component of shrub-carrs [41]. It is not often reported in coniferous forests, but it occurred in red pine-eastern white pine (*Pinus resinosa-P. strobus*) plantations in Michigan [162]. Several studies of common buckthorn have been conducted at the University of Wisconsin Arboretum in Madison. Common buckthorn occurs to some degree in all of the plant communities within the Arboretum but is most prevalent in the open wetlands, lowland woods, and oak woods. It is present,though at low densities, in planted spruce-fir (*Picea-Abies* spp.) forest, pine woods, and maple woods, where it is confined mainly to trail edges or gaps in the canopy. In prairies and savannas, common buckthorn is very rare, with individual shrubs occurring occasionally along trails [74]. During 1997 to 2001, sites were surveyed in Illinois to determine presence and dominance of nonnative species. The survey covered 141 palustrine emergent wetlands, 133 forests, and 128 grasslands; common buckthorn was most common in forests. It occurred in the ground layer of forests in the northern part of the state (21 locations) and dominated the ground layer at 2 forest locations. It was present on 2 forested sites in central Illinois and absent from forested sites in southern Illinois. Common buckthorn was present in the shrub/sapling layer of 17% of all upland and riparian forests surveyed and dominant in 4%. It was not among the most common or dominant species in grasslands or wetlands in either the ground layer or the shrub/sapling layer [201].

Forest and woodland: Common buckthorn establishes persistent populations in many temperate forest understories in North America (e.g., [20,74,88,89,131]). It can also become a dominant woody plant in these communities [140,201], though it may attain its highest dominance where it establishes in unforested sites (see details of Mascaro and Schnitzer's study in Successional Status) [140]. In moist, disturbed woodlands in the Midwestern states, associates include boxelder (*Acer negundo*), black walnut, black cherry, glossy buckthorn, American elm, Virginia creeper (*Parthenocissus quinquefolia*), poison-ivy (*Toxicodendron radicans*), black raspberry (*Rubus occidentalis*), American black elderberry (*Sambucus nigra subsp. canadensis*), and riverbank grape (*Vitis riparia*) (Swink and Wilhelm 1969 as cited by [74]). At the University of Wisconsin Arboretum, common buckthorn continually invades remnants of oak forest and areas planted to sugar maple [133]. In 8 forested sites studied in southern Wisconsin, it dominated all size classes up to 10 inches (25 cm) DBH, demonstrating that common buckthorn dominance can extend beyond understory size classes. Where common buckthorn was dominant, its mean relative density and basal area were 81% and 45%, respectively. Common buckthorn relative basal area varied significantly ($P<0.05$) with landform type, with relative and absolute basal area averaging 7% and 4 m^2/ha in floodplains, 58% and 14 m^2/ha in mesic forests, and 83% and 34 m^2/ha in swamps. Compared to 8 native-dominated sites on similar soils, common buckthorn dominance fundamentally altered forest structure (see stand structure for details). Comparable native sites were most often dominated by silver maple, eastern cottonwood, green ash, shagbark hickory (*Carya ovata*), and American elm in riparian sites; northern red oak (*Quercus rubra*), basswood, American beech, black cherry, and white ash on mesic sites; and red maple (*Acer rubrum*), green ash, and American elm in swamps [140].

At the University of Wisconsin Arboretum, common buckthorn is often associated with nonnative Bell's honeysuckle in the understory of deciduous forest sites. A positive correlation (P=0.01) was found among densities of Bell's honeysuckle and common buckthorn in Wingra Woods, which is dominated by northern red oak, and Wingra Swamp (see Wetlands) [10]. Common buckthorn occurred in the understory of a 60-year-old second-growth forest dominated by white oak (*Quercus alba*), bur oak (*Quercus macrocarpa*), black oak, and shagbark hickory, with an understory composed primarily of Bell's honeysuckle in the shrub layer and bittersweet nightshade (*Solanum dulcamara*) in the ground layer [74]. On a forested study site with a mature, closed canopy dominated by northern red oak, shagbark hickory, and sugar maple, the relative densities of the 4 primary understory shrub species were as follows: common buckthorn (24.8%), Bell's honeysuckle (2.5%), gray dogwood (*Cornus racemosa*) (53.5%), and black cherry (5.7%). These species also comprised the majority of a nearby hedgerow [88,89].

Leitner's [131] study in 28 upland, oak-dominated woodlots in southeastern Wisconsin showed that common buckthorn abundance was greatest in the more xeric communities dominated by bur oak and white oak, decreased in mesic communities, and was absent from the most mesic community dominated by sugar maple. Common buckthorn was the most common nonnative species in these stands; Bell's honeysuckle was the next most common but occurred at low densities. Even in woodlots with the densest common buckthorn populations, other species such as dogwood, viburnum, and chokecherry (*Prunus virginiana*) were present in the shrub layer, and common buckthorn monocultures were not observed. Importance and density values for common buckthorn in these communities are presented in the following table [131]:

Common buckthorn importance** and density in 5 upland forest types in southeastern Wisconsin. Values are means of the component stands of each community [131].

Measure of common buckthorn abundance	Communities classified by tree stratum*					Communities classified by shrub stratum	
	BO	WO	WOC	DM	M	Non-maple	Maple
Tree importance (%)	2.62	0.37	---	---	---	0.77	---
Shrub importance (%)	21.40	11.51	4.98	1.78	---	10.38	0.11
Seedling importance (%)	22.55	17.73	2.34	1.94	---	11.90	0.54
Tree/shrub density (#/ha)	3,355	1,476	601	147	---	1,449	9
Seedling density (#/ha)	65,036	35,276	1,844	1,029	---	27,534	91

*Listed in order from xeric to mesic: BO=bur oak group; WO=white oak group; WOC=white oak-cherry group; DM=dry-mesic group; M=mesic group.
**Importance values are either the mean of the sum of relative density, relative frequency, and relative basal area (for trees) or relative cover (for shrubs and seedlings).

Common buckthorn occurs in similar forested sites in Minnesota. Two regional parks were heavily infested with common buckthorn ranging from seedlings to large shrubs to trees with trunks 12 inches (30.5 cm) DBH. Dominant tree species at both sites were northern red oak and bur oak [18]. Common buckthorn was the most abundant tree species at 7 study sites in west-central Minnesota. At one site it comprised 50% of all stems in the herbaceous layer. Common buckthorn relative abundance varied substantially among 3 parks, but when composition data were combined, it accounted for 37% of small trees (<7 feet (2 m) tall, <4 inches (10 cm) DBH). Other common species in this size class on these sites included green ash (6%), sugar maple (15%), and eastern hophornbeam (*Ostrya virginiana*) (26%) [243]. At Pipestone National Monument in southwestern Minnesota, common buckthorn grows from 10 to 20 feet (3-6 m) tall and invades the understory of both riparian woods and oak savanna, in many cases virtually excluding native midstory and understory species [20].

Riparian woodland: Common buckthorn occurs in riparian forests in the north-central United States where American elm and green ash are common dominants. In 1965 and 1966, it occurred in riparian forests along the Red River in North Dakota, South Dakota, and Minnesota with an average frequency of 42.6% and average density of 31.87 individuals/acre in the 54 stands surveyed [227]. A study of floodplain forest vegetation on the Lower Wisconsin River comparing historical data from Curtis's 1950 survey to data collected in summer of 2001 found that these forests were increasingly dominated by sugar maple, hackberry, and bitternut hickory in the overstory, and native common prickly-ash (*Zanthoxylum americanum*) and nonnative common buckthorn in the understory [82]. In southeastern Wisconsin, common buckthorn occurred in both the shrub and tree strata in lowland forest stands dominated by silver maple, with black ash (*Fraxinus nigra*) and green ash as subdominants. American elm was among the next most common tree species. The shrub layer was dominated by currant (*Ribes* sp.), blackberry (*Rubus* sp.), and gray dogwood. Stands were variably affected by Dutch elm disease and consequently had variable amounts of American elm mortality [51].

Savanna: Common buckthorn is often a component of oak savanna remnants and oak forests thought to have succeeded from savanna with fire exclusion. Five Midwest oak savanna types were classified based on field observations in 1986 in northwestern Indiana, northeastern Illinois, and southern Wisconsin: tallgrass, mesic, eastern sand, dry sand, and northern sand savannas. Of these, common buckthorn was most common in tallgrass savanna but also occurred in mesic savanna. Tallgrass savanna was historically characterized by a canopy of bur oak and over 300 species of herbaceous plants [164]. Without fire, these sites are invaded by quaking aspen, smooth sumac (*Rhus glabra*), American hazelnut (*Corylus americana*), and the nonnative glossy and common buckthorns, which displace most other plant species on mesic sites. Agricultural development, succession, and invasion of buckthorns have nearly eliminated tallgrass savanna. The best example of tallgrass savanna found by the authors was in a Chicago suburb along a railroad where frequent fire apparently maintained the savanna. In mesic savanna, white oak and northern red oak are more common than bur oak [83]. In the Chicago region in the 1970s, several nonnative shrubs including common buckthorn and Tatarian honeysuckle became widespread in oak savanna remnants and contributed to dense shading, which has contributed to a loss of savanna ground cover species [4].

Prairie: Common buckthorn is occasionally mentioned as an invader in prairie communities (e.g., [36]), though Gourley [74] suggests that common buckthorn is associated with shrublands, hedgerows, lowland river vegetation, and open woods within the grassland biome of North America. A 1989 study of remnant glacial drift hill prairie sites at Waterworks Ravine Hill Prairie in Illinois found that the prairie was being rapidly eliminated by encroaching woody vegetation. Common buckthorn occurred in one of the largest remnant sites but did not occur in a "degraded" remnant. Winged burning bush (*Euonymus alatus*) was the dominant woody plant in both areas [16]. At Pipestone National Monument in Minnesota, common buckthorn occurred in small patches of the prairie but was most abundant in a woody draw in mixed stands with Tatarian honeysuckle, green ash, and other woody species [14].

Wetlands: Common buckthorn occurs in sedge meadows [133,247], swamps [10,225], and shrub carr communities [41] (a wet-ground shrub community that represents an intermediate stage of succession from wet prairie, fen, or sedge meadow to lowland forest or conifer swamp). At the University of Wisconsin Arboretum common buckthorn established in sedge meadows downstream from Lake Wingra following water table draw-down and stabilization to protect nearby housing from flooding [133]. At the Arboretum a "high occurrence" of common buckthorn was noted in disturbed wetlands dominated by tussock sedge (*Carex stricta*). Common buckthorn was either confined to isolated clusters of only 1 tree and/or a few saplings, or it occurred in very large thickets surrounded by wetland vegetation that had very little common buckthorn. This may be because there were fewer perch trees to aid common buckthorn seed dispersal in the wetland [74]. A survey at Wingra Swamp in September 1970 found common buckthorn occurring among "a dense growth" of red-osier dogwood (*Cornus sericea*), pussy willow (*Salix discolor*), and American cranberrybush (*Viburnum trilobum*) in association with thickets of Bell's honeysuckle [10].

Common buckthorn was among the most frequent introduced woody species in disturbed hardwood forests in Wisconsin in the 1950s [42], but it was most abundant in native shrub-carr communities [41]. Tall red-osier dogwood and various willows dominated shrub-carr communities, reaching 5 to 10 feet (1.5-3.0 m) in height with 50% to 90% canopy cover, with an understory intermediate between meadow and forest in composition [40]. A survey of shrub-carr vegetation in southeastern Wisconsin from 1959 to 1961 found that common buckthorn occurred in 3.9% of the 76 stands examined and dominated the cover in 1 of 8 stands that had been undisturbed for more than 20 years [235].

The Cedarburg Bog is one of the largest intact wetlands in southeastern Wisconsin. The majority of the wetland is forest dominated by tamarack (*Larix laricina*) and northern whitecedar (*Thuja occidentalis*), but the area also includes shrub thickets, wet meadow, shallow marsh, and emergent aquatic plants. While not considered invasive, common buckthorn is 1 of 21 nonnative species that occurs in Cedarburg Bog. It had a frequency and cover of 2.4% and 8.8%, respectively, in 1991; and 1.8% and 8% in 2006 [150].

Northeast and New England: Information on habitat types and plant communities supporting invasive populations of common buckthorn in the northeastern United States is more limited than that from the Great Lakes region. Common buckthorn is common in disturbed areas and often occurs along fencerows [175,198], roadsides [194,198], hedgerows [194], pastures [175,194], and "wasteground" [198]. Common buckthorn also commonly occurs in urban, rural, and wildland forests and woodlands, and old fields undergoing succession (see Forest and woodland, below). It occurs in globally rare alvar communities (e.g., [31,188]). In the northeastern United States, common buckthorn is classified as an obligate upland species [178], suggesting that it rarely occurs in wetlands in that region. However, some sources note frequent occurrence of common buckthorn along wetland edges in the Northeast. In New Jersey, for example, common buckthorn has been observed or collected in upland woods and thickets, floodplain forests, and margins of sinkhole ponds, but it appears to be most frequent along the edges of calcareous fens and in open woods adjacent to fens [198].

On the eastern shore of Lake Ontario, common buckthorn occurred on barrier dunes in a poison-ivy-riverbank grape-eastern cottonwood community [19]. In Clark Reservation State Park in New York, common buckthorn occurs in an area with soils described as thin (over limestone) and drought-prone, along with the nonnstives St Johnswort, pale swallow-wort (*Cynanchum rossicum*), and motherwort (*Leonurus cardiaca*). Common buckthorn occurs with Tatarian honeysuckle throughout the park [196].

Forest and woodland: No evidence was found suggesting that common buckthorn occurs in undisturbed forest or woodland in the northeastern United States. Common buckthorn is often rare or occurs only along roads or trails within forested sites. Forested or woodland sites where common buckthorn is invasive are often second-growth forests on abandoned agricultural lands, sites of recent timber harvest or other canopy disturbance (e.g., windthrow or disease), or areas supporting other nonnative species.

Common buckthorn is uncommon and occurs only along damp roadsides in Black Rock Forest in southern New York, a forest characterized by mixed oaks and dominated by northern red oak [11]. In southwestern Vermont and northwestern Massachusetts, common buckthorn was associated with Tatarian honeysuckle on at least 1 of 4 relatively undisturbed forested study sites; its basal area did not exceed 0.50 m^2/ha in any stand [241]. On a 12-acre (5-ha) hillslope dominated by sugar maple and nonnative Norway maple in suburban Ithaca, New York, common buckthorn occurred at a density of 67 stems/ha, a relative density of 8%, a mean DBH of 4 inches (10.2 cm), a basal area of 0.58 m^2/ha, a relative dominance of 2%, and an importance value of 5%. Common buckthorn saplings were more common under sugar maple than under Norway maple. No common buckthorn seedlings were observed in any plots [139]. In New River Gorge National River in West Virginia, common buckthorn occurred in a yellow-poplar (*Liriodendron tulipifera*)-white oak-northern red oak-sugar maple forest on slopes, bottomlands, and floodplains. Shrub and subcanopy species included northern spicebush (*Lindera benzoin*), witch-hazel (*Hamamelis virginiana*), great laurel (*Rhododendron maximum*), and pawpaw (*Asimina triloba*). Mulitflora rose was also common. Herbaceous species composition varied with site characteristics; several are listed [210]. Common buckthorn was noted but rare in clumps of eastern cottonwood along the Hudson River, New York, in 1954 [148].

Successional forests on old fields: Common buckthorn occurs in the northeastern modified successional forest association, which is part of the black cherry-red maple-Canada serviceberry-oak (*Prunus serotina*-*Acer rubrum*-*Amelanchier canadensis*-*Quercus* spp.) forest alliance. The alliance occurs in New Jersey, New York, and Pennsylvania and has been described in several National Park Service sites including Fort Necessity National Battlefield [171], Gettysburg National Military Park and Eisenhower National Historic Site [167], Johnstown Flood National Memorial [170], Delaware Water Gap National Recreation Area [166], Allegheny Portage Railroad National Historic Site [168], Friendship Hill National Historic Site [169], and Valley Forge National Historical Park [172]. The association is composed of early-successional woody vegetation and typically occurs on sites that have been cleared for agriculture. At Delaware Water Gap National Recreation Area in Pennsylvania and New Jersey, common buckthorn is a component of the tall shrub layer in bottomland, mixed-hardwood palustrine forest, which is also part of the black cherry-red maple-Canada serviceberry-oak forest alliance, but specific to the Park. The forest type has variable species composition and is typically weedy and composed of early-successional woody vegetation. Past and adjacent land uses, typically as pasture or farm land, influence species composition. Perles [166] provides site characteristics and a complete list of possible associates.

In the Bristol Hills of New York, common buckthorn dominated 3 mesic, abandoned pastures, where it was associated with hawthorn (*Crataegus* spp.), quaking aspen, and black cherry trees, and speckled alder (*Alnus incana* subsp. *rugosa*), sugar maple, and gray dogwood saplings. Common buckthorn also occurred in shrub-dominated areas on mesic and dry-mesic old fields containing eastern white pine, red maple, sugar maple and shagbark hickory [193]. It occurred at low densities in the tall shrub stratum in 5 woody community types at various stages of succession (14-200+ years old), with the highest relative importance values (<5%) in the early- to mid-successional gray dogwood, common juniper-Allegheny blackberry-sweetfern (*Juniperus communis-Rubus allegheniensis-Comptonia peregrina*), and oak-viburnum community types. Common buckthorn occurred in the herb stratum in the gray dogwood, common juniper-Allegheny blackberry-sweetfern, eastern white pine (*Pinus strobus*) and oak-viburnum community types, with the highest importance value in the common juniper-Allegheny blackberry-sweetfern community type [103]. See Old-field succession for more details on these studies. In southern New Hampshire, common buckthorn occurs on old fields and regenerating forest sites where dominant forest overstory species include maples, oaks, eastern white pine, and eastern hemlock (*Tsuga canadensis*) [109].

Disturbed forests: Common buckthorn may be an abundant shrub in disturbed settings within the eastern white pine-oak forest alliance of the northeastern United States. This alliance occurs in New England south and west to Pennsylvania and West Virginia and possibly New Jersey. Associated species are described by Perles [166]. Common buckthorn occurred in 8.1% of 148 randomly selected forest sites that had been harvested between 1984 and 2003 in central and western Massachusetts, and 23% of the sites in this group had other invasives [146]. Also in central and western Massachusetts, common buckthorn was among several species associated with "high-intensity" tree harvest on 126 sites [147].

Urban forests: Species composition and structure differed in remnant (had canopy cover in both 1939 and 1978 aerial photos) and regenerated (had no canopy cover in 1939, but had canopy cover in 1978) urban forest patches in Syracuse, New York. Common buckthorn occurred in 78% of regenerated sites and 100% of remnant sites. In regenerated forest patches it was sometimes dominant in communities characterized by either sugar maple, Norway maple, or boxelder. In remnant forest patches, common buckthorn had higher importance values in communities characterized by black oak than those characterized by sugar maple; it had significantly greater average stem density and basal area in black oak communities (330 stems/ha and 0.58 m²/ha, respectively) than in sugar maple communities (70.7 stems/ha and 0.11 m²/ha) ($P<0.05$) [246].

Alvar communities: Common buckthorn has invaded alvar communities, which are globally imperiled habitats [31,188]. At Chaumont Barrens Preserve in north-central New York, common buckthorn was most abundant in a disturbed roadside edge community and had progressively lower abundance in limestone woodlands, calcareous pavement barrens, and alvar grassland. Common buckthorn was one of the most abundant shrubs along the roadside edge and in limestone woodlands, which are composed of deciduous trees, coniferous trees, or a mixture. Frequency and total density of common buckthorn were significantly higher in the coniferous and mixed woods than in the deciduous woods ($P<0.05$). Common buckthorn cover was relatively low in calcareous pavement barrens (savanna communities consisting of a mosaic of shrub-savanna and rock outcrop vegetation) but similar to that of eastern redcedar and chokecherry. In the alvar grasslands, the abundance of all shrubs including common buckthorn was low. There was no significant difference in native herb and graminoid richness among different cover classes of common buckthorn. However, there were more nonnative species associated with common buckthorn than with gray dogwood or common juniper. Nonnative species richness was significantly greater in plots with low to medium cover of common buckthorn than in plots with no shrubs ($P<0.05$) [188].

Great Plains: Very little information was available regarding common buckthorn occurrence or ecology in the Great Plains. Along the Lower Platte River in eastern Nebraska, common buckthorn had an average importance value (relative density + relative frequency + relative dominance) of 5.9, and basal area of <0.1 m²/ha in a transitional forest type on well-drained sites bordering the floodplain. This type was dominated by basswood, bur oak, and hackberry, with many roughleaf dogwoods (*Cornus drummondii*) in the understory. Common buckthorn was especially dense (21 trees/ha) on 1 of the 4 transitional forest sites identified. It either did not occur or had low basal area and importance values in riverbottom forest and upland terrace forests in the area [185]. Common buckthorn was not recorded in this area in a survey conducted from 1855 to 1857 [186].

Western North America: Very little information was available regarding common buckthorn occurrence or ecology in western North America as of 2010. In west-central Montana, common buckthorn occurs in bottomland *Populus* forest in the Missoula Valley and the entire drainage of Rattlesnake Creek north of Missoula [123]. It occurs along streambanks and in disturbed areas in Wyoming [49].

Common buckthorn and Dahurian buckthorn were planted at 6 surface coal mine reclamation sites in Wyoming and Colorado. Both species survived and grew at 4 of the 6 sites during the first year after planting. Native vegetation at the sites where they survived was either a big sagebrush (*Artemisia tridentata*)/grassland or a mixed-shrub community dominated by Saskatoon serviceberry (*Amelanchier alnifolia*), Gambel oak (*Quercus gambelii*), quaking aspen, big sagebrush, common snowberry (*Symphoricarpos albus*), and chokecherry. At the 2 sites where neither species survived, native vegetation was either a rabbitbrush (*Chrysothamnus* sp.)/grassland or a grassland with scattered mixed shrubs such as common snowberry and Saskatoon serviceberry [102]. See Soil disturbance for a more detailed site description.

Dahurian buckthorn: Considerably less information was available regarding native plant communities in which Dahurian buchkthorn establishes and persists. According reviews, it is considered an invader of woodlands, savannas [43,90], forests, and/or barrens in the eastern and western Midwest [43], but is not as widespread as the other nonnative buckthorns [90].

At the Spicebush Swamp Preserve in West Hartford, Connecticut, numerous Dahurian buckthorns were noted during a survey in 1976. Specimens were later identified as *Rhamnus davurica* subsp. *davurica*. Most of the Preserve is red maple swamp. The remainder is characterized as rolling old-field slopes that had been used as pasture until 1962. The old-field portion was dominated by eastern redcedar, multiflora rose, gray dogwood, silky dogwood, Morrow's honeysuckle (*Lonicera morrowii*), blackcherry, apple (*Malus* spp.), white ash, common buckthorn, and *R. davurica* subsp. *davurica*. *Rhamnus davurica* subsp. *davurica* occurred in every stage of maturity, and the largest individual was 3.75 inches (9.5 cm) DBH. Another individual was about 16.5 feet (5.0 m) tall. *Rhamnus davurica* subsp. *davurica* was especially dense in a small burned area, from which other woody and herbaceous plants were virtually excluded [173].

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

SPECIES: Rhamnus cathartica, R. davurica

- GENERAL BOTANICAL CHARACTERISTICS
- SEASONAL DEVELOPMENT
- REGENERATION PROCESSES
- SITE CHARACTERISTICS
- SUCCESSIONAL STATUS

Three extensive literature reviews on common buckthorn [116,120,175] provided substantial information on its distribution, biology, ecology, and management and were used throughout this review.

GENERAL BOTANICAL CHARACTERISTICS:

- **Botanical description**
  - Common buckthorn aboveground description

  - Common buckthorn belowground description
  - Dahurian buckthorn description
  - Life span and age distribution
  - Plant architecture and stand structure
- **Raunkiaer life form**

Botanical description: These descriptions cover characteristics that may be relevant to fire ecology and are not meant for identification. Keys are available for identification of common buckthorn (e.g., [38,77,124,156,184,225,230]) and Dahurian buckthorn (e.g., [77,156]). Dahurian buckthorn could easily be confused with the native lanceleaf buckthorn (*R. lanceolata*), but the larger, opposite leaves and clustered stems of Dahurian buckthorn can distinguish it [202].

Common buckthorn aboveground description: Common buckthorn is a large shrub [6,35,38,68,77,77,200,202] or small tree [38,54,68,77,200,242]. It is a polymorphic species within its native range, likely due to hybridization with other buckthorns [120]. In North America, common buckthorn is described as a large, coarse shrub [26,200], often as wide as high [202], with many stems [71] and many branches [77,202], or with a single main stem and ascending branches [35] (see Plant architecture and stand structure). The shrub form typically ranges from about 3 to 13 feet (1-4 m) tall [6,35,77,202], sometimes up to 16 to 20 feet (5-6 m) [38,68,77,200]. The tree form typically reaches about 16 to 26 feet (5-8 m) tall [38,54,68,77,200,242] and 4 inches (10 cm) in diameter [54]. Common buckthorn individuals are typically less than 13 feet (4 m) tall in Canada [175]. A common buckthorn tree reached 61 feet (~19 m) tall in Ann Arbor, Michigan [48]. Mature common buckthorn plants have long, somewhat angled shoots [175] with branches forming almost right angles with the main stem [71]. Branchlets are stout [200] and semirigid [202], 1.5 to 2 mm in diameter, and slightly flattened [202]. Many branches end in a single, small thorn [35,38,54,68,200,230] ranging from 0.2 to 0.9 inch (0.5-2.2 cm) long [175]. Young common buckthorn bark is smooth [202]; older bark is somewhat scaly [71,202] or fissured [71].

Common buckthorn leaves are simple and occur near branch tips [35]. Leaves range from 0.6 to 2.8 inches (1.5-7 cm) long [35,38,68,77,202,225,230,242] or longer [175,200] and 0.4 to 2.8 inches (0.9-7 cm) wide [38,77,175,200,202,230,242]. Leaves are mostly deciduous [71] but often remain green and do not fall until late autumn (see Seasonal Development).

Common buckthorn is typically dioecious (see Pollination and breeding system), and flowers are functionally unisexual and 4-merous [38,175,242]). Flowers are small and inconspicuous [35] and occur in dense clusters [71,200] on branches of the current season [77,202]. Staminate flowers occur in axillary clusters of 2 to 8 flowers [77,202] (up to 40 [175]). Pistillate flowers occur in clusters of about 2 to 15 [77,202] (up to 30 [175]). Common buckthorn fruits occur singly or in clusters. If clustered they occur at nodes on the end of short spur branches [202] or at the base of leafstalks [35]. The fruit is a globose drupe [55,71,77,156,225,242], ranging from 5 to 10 mm in diameter [35,38,71,77,202,230,242] and usually bearing 4 seeds [35,38,68,77,202,230], but ranging from 1 to 5 seeds per fruit [175]. Seeds are 4 to 5 mm long [77,175,202].

Common buckthorn belowground description: Common buckthorn roots have been described as "extensive" [209], though a review by Gourley [74] suggests that common buckthorn roots do not extend very far and that common buckthorn appears to draw its nourishment from upper and middle horizons of soil. Root morphology likely varies with site characteristics. Depth and length of the roots of a 38-year-old common buckthorn individual that was 15 feet (4.6 m) tall and growing in a deep, clayey soil with the water table >15 feet deep were measured at the North Dakota Agricultural Experiment Station at Fargo. The longest common buckthorn roots were 18.5 feet (5.6 m) long; the ratio of root length to plant height was 1.2; about 75% of the roots were in the top 2 feet (0.6 m) of soil, 24% were in the 3rd foot (0.9 m) of soil, and 1% were in the 4th foot (1.2 m) of soil. The greatest depth of roots and the depth of the largest roots were just over 4 feet [245]. In "extremely wet and mucky" soils at the University of Wisconsin Arboretum, very large common buckthorn individuals had very shallow, large lateral roots [74]. Similarly, the whole common buckthorn root system was in the top few centimeters of soil above the water table in alkaline peat in England [71].

Dahurian buckthorn description: Dahurian buckthorn is morphologically very similar to common buckthorn, although the branches of Dahurian buckthorn are more stout [48,202], the shrubs less densely branched [202], and the leaves longer and more uniformly shaped [48]. Most Dahurian buckthorn individuals in North America are smaller in stature than common buckthorn, typically reaching 8 feet (2.5 m) in height [202]. Dahurian buckthorn may be taller in its native range. The Flora of Japan [56] describes it as a shrub or small tree 13 to 16 feet (4-5 m) tall, and the Flora of China [242] says that it may reach 33 feet (10 m) tall. A North American landscaping manual describes Dahurian buckthorn as a spreading shrub or small tree reaching 25 to 30 feet (7.6-9 m) tall [48], presumably under cultivation. Only one other detailed description of Dahurian buckthorn [202] was found in the available literature from North America as of 2010. Dahurian buckthorn was described as an open shrub, with single or clustered trunks, medium-hard wood, and trunk bark that often peels back from around old limb scars. Twigs are 2 to 2.5 mm in diameter, flattened, rigid, smooth [202], and occasionally ending in a short spine [48,56,202]. The Flora of China describes Dahurian buckthorn as unarmed and much branched [242].

Dahurian buckthorn's leaves are deciduous [56], simple, glabrous, opposite [202] or partially opposite [56], fascicled [242], and typically more than 2 times as long as wide [138]. In North America, Dahurian buckthorn leaves are described as 2.8 to 4 inches (7-10 cm) long and 0.8 to 1.2 inches (2-3 cm) wide [202]. Descriptions from its native range indicate slightly larger leaves: 1.6 to 5 inches (4-13 cm) long and 0.8 to 2.4 inches (2-6 cm) wide [56,242]. Broad-leaved Dahurian buckthorn individuals may be *R. davurica* subsp. *davurica*, while the narrow-leaved plants may be *R. davurica* subsp. *nipponica* [77].

Flowers of Dahurian buckthorn are unisexual and occur on short pedicels, 6 to 10 mm long, in axillary clusters on new growth [56,202], or on short shoots [56,242]. Staminate flowers are numerous [56] and less than about 0.4 inch (1 cm) in diameter [202,242]; pistillate flowers are few and are slightly smaller than staminate flowers, 4 to 5 mm in diameter [56]. Dahurian buckthorn fruits are drupes, 5 to 8 mm diameter, with 2 seeds ranging from 5 to 6 mm long and 3.6 to 3.7 mm wide [56,202,242].

A description of Dahurian buckthorn's belowground morphology was not found in the available literature as of 2010.

Life span and age distribution: The typical life span of common buckthorn is not clear. The oldest common buckthorn individual in Mary Mix McDonald Woods near Chicago was 72 years [95]. The age of the oldest common buckthorn specimen around Saskatoon was 56 years [6]. At Pipestone National Monument in southwestern Minnesota, the oldest specimen was 33 years old, while most individuals in the understory of riparian woods and oak savanna were 10 to 20 years old [20]. At the University of Wisconsin Arboretum, common buckthorn occurred in even-aged stands in both open wetlands and an oak woodland understory. In the woodland, common buckthorn age ranged from 14 to 44 years and averaged 24.2 years compared to a range of 12 to 23 years and an average of 15.35 years in the wetlands ($P<0.0001$). Common buckthorn trees produced fruit at a younger age in wetlands than in the woods (see Seed production) [74]. Once common buckthorn is established, reproduction from seed results in a vigorous, young population [6].

No information was available regarding the life span or age distribution of Dahurian buckthorn (as of 2010).

Plant architecture and stand structure: Common buckthorn growth form differs among age classes and successional stages, and among open and shaded sites. At Wicken Fen in England, common buckthorn was described as a diffuse, many-stemmed bush up to 10 or 15 feet (3-5 m) tall in the early stages of succession, but in later stages it formed a single-stemmed tree, 31 feet (9.4 m) tall, with a dense crown 22 feet (6.7 m) in diameter [71]. Similarly, observations in Ontario indicate that mature common buckthorn shrubs exhibit 2 basic shapes: tall and narrow in open areas, and squat in areas with competing woody vegetation [175]. In Wisconsin, however, common buckthorn in shaded woodlands generally had a 1- or 2-stemmed trunk with few side branches, whereas open-grown trees in wetlands usually had multiple trunks with numerous side branches [74]. Common buckthorn growth habit has been described as dense, with interlocking branches [36,86].

Although no quantitative evidence was available to describe common buckthorn abundance in European habitats, scientists who have observed common buckthorn in mainland Europe report that large, dense thickets do not usually occur [116]. In England, however, it can form nearly monospecific stands in some fens [69,116]. This is evident in a series of maps of Wicken Fen shown by Godwin [69] in his 1936 publication and by Godwin and others [72] (dated 1972). The 1972 map shows dense and widespread stands of common buckthorn about 50 years after cessation of haying. The authors describe "enlargement and fusion of the crowns" of common buckthorn [72]. Dense, continuous, sometimes monospecific thickets of common buckthorn are often reported in areas where it is invasive in North America (e.g., [4,20,36,45,75,95,141,160]).

Common buckthorn is sometimes the dominant understory species where it invades North American forests (e.g., [6,140,246]) and may form dense, understory thickets in both the shrub [45,95] and herb layers [45], fundamentally altering the structure of invaded forest stands [140]. In some areas it forms large, nearly monotypic stands, with few other species in the shrub or herb layers [75]. Sapling densities as high as 34,600 stems/ha have been reported (Moriarty personal communication cited in [116]). A dense understory of common buckthorn seedlings is a common characteristic of mature common buckthorn stands in North America [6,45,74,243], though this is not reported from Europe [116,119]. The average number of seedlings beneath a dense common buckthorn stand in Saskatchewan was >100 seedlings /m² [6]. At 4 study sites in west-central Minnesota, selected specifically because of abundant common buckthorn populations and representing an "extreme" of regional common buckthorn invasion, common buckthorn was the most abundant tree species, accounting for more than 75% of the small tree (>7 feet (2 m) tall, <4 inches (10cm) DBH) composition. At one site it also comprised over 50% of all stems in the herbaceous layer. Common buckthorn seedlings were common throughout the sites, and seedling abundance increased exponentially with overstory common buckthorn abundance [243]. Where it occurred in open woods in eastern Ontario, many thousands of small common buckthorn saplings and seedlings covered the ground in shaded locations, and plants up to 12 feet (~4 m) tall occurred in openings [160]. In riparian woodland and shrub communities around Saskatoon, Saskatchewan, common buckthorn thickets occurred in a 2-layered understory beneath an open canopy of green ash and Manitoba maple (*Acer negundo* var. *interius*). The dense, taller common buckthorn layer was 7 to 16 feet (2-5 m) high and composed of well-spaced, mature, male and female shrubs. The shorter layer consisted of a ground cover dominated by common buckthorn seedlings and stunted saplings reaching 20 inches (50 cm) in height. A total of 71 nonfruiting and 72 fruiting stems with basal diameter >0.4 inch (1 cm) occurred in these plots, an equivalent of 9,467 stems/ha and 9,600 stems/ha, respectively [45].

Photo by S. Kelly Kearns

Photo by Wisconsin DNR

Photo by Wisconsin DNR

Common buckthorn may dominate a forest understory with thickets of sprouting stems (ramets) [140] and seedlings (genets) [6,45,74,140,243]. A study of mesic, floodplain, and swamp sites in southern Wisconsin found that ramets were more dense on common buckthorn-dominated than native-dominated sites ($P<0.05$), and that common buckthorn genets were more abundant than those of native trees up to and including size classes of 8 to 10 inches (20-25 cm) DBH. This evidence indicates that common buckthorn dominance can extend beyond understory size classes. Common buckthorn may dominate a site by reproducing sexually, generating numerous shoots, reaching large size, or some combination thereof. Among the 8 forest sites where common buckthorn was dominant, its mean relative density and basal area were 81% and 45%, respectively, exceeding that reported for 4 other woody invaders found in the northeastern United States. Compared to 8 native-dominated sites on similar soils, common buckthorn dominance fundamentally altered forest structure, especially by increasing density [140].

Mean density, basal area, and woody-species richness in native- versus common buckthorn-dominated sites in southern Wisconsin [140]

Characteristic	Native dominated (*n*=8)	Common buckthorn dominated (*n*=8)
Density (stems/ha, all species)		
All stems	2,310	7,065*
Living stems	1,879	4,244*
Dead stems	431	2,820*
All genets	1,901	3,459*
Living genets	1,592	2,465*
Dead genets	309	995
All ramets	409	3,796*
Living ramets	287	1,790*
Dead ramets	122	2,006*
Basal area (m^2/ha)		
All stems	38	41
Living stems	35	38
Dead stems	3	3
Total number of woody species >1cm DBH (species/site)	10	8
*Means within the row are significantly different ($P\leq0.05$).		

Common buckthorn typically has a patchy distribution in invaded woodlands. Individual common buckthorn plants on study sites in central New York were more strongly clumped in forests than in plantations, and those in old fields were intermediate in their degree of clumping [144]. Common buckthorn forms dense patches in the shrub layer of relict white oak-northern red oak woodlands in the Chicago area. Intervening, noninvaded areas have considerably less growth in the shrub layer [95]. Among 3 site types in central New York (old fields, plantations, and maple-beech forests), common buckthorn plants were generally aggregated, but moreso in smaller size classes: Seedlings were markedly aggregated at all old-field and plantation plots. Saplings were aggregated at 2 of 3 old-field and all 4 plantation plots. Adult plants were aggregated at 2 of 4 old-field and 3 of 4 plantation plots. These analyses were not conducted for maple-beech plots because of the low number of non-seedlings in those plots [144]. See the section on Shade tolerance for details on these study site attributes.

Common buckthorn density and stand structure likely vary among site types and plant communities. In southern Wisconsin, basal area of living common buckthorn stems on common buckthorn-dominated sites ranged from 3 to 48 m²/ha, with a mean of 15 m²/ha. Common buckthorn relative basal area varied significantly with landform type (P<0.05): Relative and absolute basal area averaged 7% and 4 m²/ha in floodplains, 58% and 14 m²/ha in mesic forest sites, and 83% and 34 m²/ha in swamps. At one swamp site, common buckthorn comprised 100% of all woody stems, reaching 48 m²/ha in living basal area. Common buckthorn ranked 1st or 2nd in basal area and density on the 3 mesic sites. Conversely, it occurred in the understory but was among the 3 most dominant species on only 1 of 3 floodplain sites [140]. Additional details of this study by Mascaro and Schnitzer are given in Successional Status. At the University of Wisconsin Arboretum, common buckthorn occurred in even-aged stands in both open wetlands and oak woodland understories, but common buckthorn trees were younger (see Life span) and larger (P<0.001) in the wetlands [74]. Among 3 site types in central New York (old fields, plantations, and maple-beech forests), common buckthorn density was lowest in maple-beech forests, and stems were almost entirely <0.4 inch (1 cm) in basal diameter. Similarly, populations of common buckthorn in old fields were dominated by seedlings (<0.2 inch (0.5 cm) basal diameter). Density of common buckthorn was highest in plantations, and populations were less skewed toward smaller age classes than in the other habitats (P<0.001) [144]. A typical common buckthorn thicket in Mary Mix McDonald Woods averaged 18 to 21 common buckthorn individuals more than 2.5 inches (5 cm) DBH per 100 m², with an average age of 33 to 34 years. A typical thicket at the East Woods averaged 12 individuals more than 2.5 inches (5 cm) DBH per 100 m², with an average age of 22 years (unpublished data cited by [93,95]).

No information was available regarding plant architecture or stand structure of Dahurian buckthorn (as of 2010).

Raunkiaer [177] life form:

Phanerophyte

SEASONAL DEVELOPMENT:

Common buckthorn: Common buckthorn seedling establishment begins in early spring. In 1995, the first common buckthorn seedling of the season appeared in early April in London, Ontario. In 1993, 1994, and 1995, further flushes of seedlings appeared from May to September. Most seedlings emerged in May and June, but smaller cohorts arose at regular intervals until the end of August [175]. Common buckthorn germination was observed in mid- to late summer in Minnesota [116].

Budbreak of common buckthorn in North America has been recorded as early as 10 April in southern Wisconsin [88] and as late as early May in London, Ontario [175]. In southern Wisconsin in 1986, common buckthorn leaf emergence occurred around 10 April in the understory of a restored hardwood forest with a mature, closed canopy, and around 24 April in an open habitat [88]. Budbreak of planted, 1-year-old common buckthorn seedlings was not influenced by mulch (which caused higher mean minimum soil temperatures), and occurred 8.2 to 12.4 days after 9 April 2002 [205]. In London, Ontario, common buckthorn leaves were expanded by early May (2007, 2008) [175].

Common buckthorn flowers may appear with leaves [38,68]. In parts of the United States and Canada, common buckthorn begins flowering as early as May (see the table below). Common buckthorn fruits turn from green to red to black on ripening, and no flowers remain when fruits become black [71,175]. Fruits may ripen as early as August [200] but typically ripen in September in North America. In 1995 in London, Ontario, the first common buckthorn fruits appeared on 3 June and began to turn red by 7 August. By 5 September, about 20% of the fruits were red and 80% black. The fruits were fully ripe by mid-September. Timing of flowering and fruiting is generally delayed in the western and Maritime provinces compared with Ontario [175].

Flowering and fruiting dates reported for common buckthorn by geographic area. Blank cells indicate that information was not available.

Area	Flowering dates	Fruiting dates
United States		
Illinois	May to June [156]	
Adirondacks	June	September [35]
Great Plains	May to June [77] May to July [209]	

Intermountain West	May to July [38]	
New England	May 18 to June 17 [194]	
Northeast	May to June [138]	
Northern Great Plains	Late May	September [202]
Canada		
Ontario	bud: 9 to 25 May full bloom: 3 to 13 June	green: 22 June to 6 July red: 18 to 26 August black: 5 to 18 September
Quebec	bud: 26 May full bloom: 9 June	green: 28 June red: 25 August black: 13 September
Maritimes*	bud: 30 May to 3 June full bloom: 17 to 20 June	green: 9 to 12 July red: 12 to 13 August black: 14 to 16 September
Western provinces*	bud: 25 May to 2 June full bloom: 8 to 14 June	green: 3 to 10 July red: 15 to 28 August black: 15 to 20 September [175]
Other countries		
China	May to June	July to September [242]
England	May to June	September and October [71]
*For detailed information from specific provinces, see Qaderi and others [175].		

Common buckthorn fruits have a strong tendency to persist on the branches [35,71,202] and may remain until December [202] or later [71]. Seed dispersal can occur anytime between September and April [65]. In 1995 in London, Ontario, drupes were fully ripe by mid-September, and by 5 November, almost 90% of them had fallen. However, some trees shed most fruits in late winter or early spring [175]. Common buckthorn seed dispersal was completed by 15 April in northwestern Oklahoma [86]. Timing of common buckthorn seed dispersal depends in part on the rate of removal by birds and therefore is related to their preference for it relative to cooccurring plants [65] (see Seed dispersal). In southern Wisconsin, American robins and cedar waxwings ate ripe common buckthorn fruit in October, November, March and April. Bird droppings containing common buckthorn seeds were found on top of the snow in February [74].

Common buckthorn retains its leaves until early November in southern Wisconsin [74,88]. In the early spring (April), most thorns from the previous year senesce before new ones develop; so, for a brief period, very few are apparent [175].

Wisconsin herbaria specimens of common buckthorn from a range of years and habitats were used to compile the following list of phenological extremes [74]:

Phenological events recorded on specimens of common buckthorn from Wisconsin herbaria [74].

Date	Event
20 March	Earliest leaf buds
28 March	Earliest flower buds
9 May	Oldest branch with last year's fruit intact
13 May	Earliest flowers

1 June	Earliest green fruit
7 July	Latest flowers
31 July	Latest green fruit
3 November	Latest with leaves

Phenological niche separation: In Europe, common buckthorn does not differ phenologically from associated shrub species [116], and it has been suggested that persistence and invasiveness of common buckthorn in North American forest understories may be caused in part by its relatively high carbon gain due to early budbreak and foliation relative to neighboring deciduous species [116,205]. Several studies demonstrate this pattern, although common buckthorn budbreak and foliation do not always precede those of associated native species [175]. Barnes [10] found that the leaves of common buckthorn flushed earlier in the spring and remained later in the fall compared to 5 cooccurring native shrubs at Noe Woods in the University of Wisconsin Arboretum in 1971. Mean duration of foliation of common buckthorn exceeded that of native shrubs by up to 54 days [10]. Another study at the University of Wisconsin Arboretum in 1986 [88] showed similar results, although differences in leaf longevities between nonnative shrubs (common buckthorn and Bell's honeysuckle) and native shrubs (gray dogwood and black cherry) in forest understories were less than those observed by Barnes [10]. During the 1986 study year, nonnatives had leaves present 21 to 28 days longer than the native species in both understory and open habitats [88]. Mean budbreak of common buckthorn was 5.7 days earlier than mean budbreak of native Carolina buckthorn (*R. caroliniana*) in irrigated plots in Iowa [205].

Extended leaf longevity in common buckthorn may increase its seasonal carbon gain compared to associated native species. Harrington and others [88] compared seasonal trends in photosynthesis of common buckthorn, Bell's honeysuckle, gray dogwood, and black cherry in understory and open habitats. In understory habitats, common buckthorn made approximately 38% of its total annual carbon gain while gray dogwood shrubs were leafless. In the open habitat, extended leaf longevity of nonnative shrubs contributed relatively less to annual carbon gain: No net carbon gain in common buckthorn was attributed to early photosynthesis, while late autumn photosynthesis accounted for only 3% and 4% of annual carbon gain in common buckthorn following senescence of gray dogwood and black cherry, respectively. Midday photosynthetic rates from mid-May to early October were roughly 10 times lower in understory shrubs than open-grown shrubs [88].

Forested areas invaded by common buckthorn may be shadier throughout the growing season than uninvaded areas. Light measurements, taken over a 3-month period in areas where common buckthorn occurred in relatively high densities, showed that percent light penetration was consistently less under common buckthorn at all height levels examined (6.5 feet (2 m), 3 feet (1 m), and ground). The difference in light penetration under common buckthorn was greatest early in the growing season (May), particularly at 6.5 feet (2 m) above the ground. As the season progressed and the canopy leafed out, light intensity beneath the forest in general, and common buckthorn in particular, declined. By June, light penetration under common buckthorn was only about 50% of that reaching the general forest floor; this was similar in July. In June and July, the percentage of light reaching the general forest floor was only slightly greater than that under common buckthorn in May [131].

Underground phenology: Woody species utilize stored, belowground carbohydrate reserves to survive dormancy and disturbance. These reserves naturally fluctuate over the course of a year, declining in the spring during leaf flush and shoot elongation and increasing during the growing season when excess photosynthate is produced (review by [183]). Total nonstructural carbohydrates (TNC) were lowest in common buckthorn root crowns during leaf expansion (June), and highest at bud break (April) and leaf senescence (October) of both 2002 and 2003 at Eagle Lake Regional Park, Minnesota [18]. See Use of prescribed fire as a control agent: Fire timing, for additional details of this study. At Montezuma National Wildlife Refuge in the Finger Lakes region of New York, periods of low TNC for common buckthorn included early spring just after full leaf expansion and stem elongation (May and June), early fall before leaf senescence, and during dry months. Thus, common buckthorn TNC decreased at the start of the growing season as expected but unexpectedly decreased at the end of the growing season. In 2001, common buckthorn TNC increased by almost 18% by August, but TNC declined by 8% between August and October (a period of low precipitation). In 2002, common buckthorn TNC increased over the growing season by 12%, then declined almost 12% between October and November. While the late-season drop was unexpected for both years, comparison of precipitation and TNC data suggested a trend of reduced TNC with below-average precipitation. The authors recommend that control treatments be timed to correspond with periods of low TNC to increase effectiveness [182].

Dahurian buckthorn: Considerably less information on the phenology of Dahurian buckthorn was available in published literature as of 2010. The following table shows the flowering and fruiting dates reported by area. Blank cells indicate that information was not available.

Area	Flowering dates	Fruiting dates
Illinois	May to June [156]	
Northern Great Plains	June	September [202]
China	May-June	July to October [242]
Japan	May to June [56]	

REGENERATION PROCESSES:
Reproduction in common buckthorn is entirely by seed [71], although stems can regenerate from stump and root sprouts following top-kill or damage. Very little information was available (as of 2010) on Dahurian buckthorn regeneration processes.

- **Pollination and breeding system**
- **Seed production**
- **Seed dispersal**
- **Seed banking**
- **Germination**
- **Seedling establishment**
- **Plant growth**
- **Vegetative regeneration**

Pollination and breeding system: Common buckthorn is either dioecious [26,38,68,71,202,242] with unisexual flowers borne on separate plants, or polygamodioecious [55,77], with some hermaphrodite flowers [175]. Common buckthorn flowers are honey-scented and insect-pollinated. Insect visitors are abundant [71]. Pollinators are typically bees (Hymenoptera) and flies (Diptera) [175].

Counts of fruiting common buckthorn shrubs at Wicken Fen and Gog-Magog Hills in England showed a ratio of 6:1 or 7:1 of female to male shrubs. Statistical analysis indicated no change in the ratio with age or habitat condition [71]. Norman and others (unpublished data cited by [175]) also found a majority of female trees in 6 out of 7 sites in London, Ontario; usually the ratio of females to males was greater than 3:1. Numbers of fruiting and nonfruiting stems were near equal in riparian woodland and shrub communities studied near Saskatoon, Saskatchewan [45].

Dahurian buckthorn is dioecious [56,202,242].

Seed production: The age at which common buckthorn begins to produce fruit and seed is unclear and may depend on growing conditions. Delanoy and Archibold [45] indicate that common buckthorn typically requires 5 to 6 years before it fruits, while a review by Knight and others [116] says that reproduction has been reported in common buckthorn shrubs 9 to 20 years old in North America. Godwin [71] states that it "flowers and fruits very early, certainly at 11 years" in Great Britain. In a garden in southern England, common buckthorn produced fruit at age 4, and all individuals reproduced annually after their first reproduction [79]. Common buckthorn seedlings in open wetlands, one measuring 57 inches (144 cm) in height and 1 inch (2.5 cm) in circumference, produced fruit. Common buckthorn of this size occurring in a nearby oak woodland usually did not bear fruit [74].

Quantitative information on common buckthorn seed production is limited. Fruit production in common buckthorn has been described as "very prolific" [69] in southern England, and observations in northwestern Oklahoma noted a "heavy crop" of fruit [86]. A total of 249 common buckthorn fruits and 174 seeds was collected in seed traps under 3 large female common buckthorn shrubs in a population south of Saskatoon; the trays were set out in October and retrieved the following spring [6]. A many-stemmed common buckthorn, 7 feet (2 m) tall, bore 1,455 fruits on 27 September 1932 in southern England [69]. In a nature reserve in southwestern Germany, seed rain was measured using seed traps placed along transects through mature scrub (generally 30-50 years old and 13-20 feet (4-6 m) tall), of which common buckthorn was a component. A total of 1,402 common buckthorn seeds was collected from primary seed rain (intact fruits) and 546 from secondary seed rain (seeds that were regurgitated or defecated by birds; i.e., exposed seeds) [119].

Site conditions are likely to affect fruit production in common buckthorn. Godwin [71] suggests that few fruits are produced in "exposed places", and many of these fruits have nonviable seeds. In southern Wisconsin, common buckthorns in open wetlands seemed to produce more fruit than those in oak woodland or lowland forest sites, although similar numbers of seedlings occurred in each site type [74].

A study in central New York found that total common buckthorn seed rain was affected by both presence of artificial perches and by habitat type. Seed rain of common buckthorn was among the highest of 6 nonnative and 10 native taxa collected in seed traps in 3 habitats. One-half of the seed traps at each plot were provisioned with an artificial perch. Common buckthorn seed rain reflected the local density of adult plants in each habitat and was consistently higher in traps under perches, reflecting the importance of dispersal by birds [145].

Total common buckthorn seeds collected in ten 1-m² seed traps in 4 plots in each of 3 habitats in central New York between June 2003 and June 2004 [145]		
Habitat	Perch	No perch
Maple-beech	3	0
Old field	39	12
Plantation	14	4

Common buckthorn fruits contain 2 to 5 seeds [69,74,130,232], but they generally have 4, and usually only 1 or 2 mature [202]. A study in London, Ontario, reported over 85% of common buckthorn fruits contained 4 seeds, but 42% of fruits had only 1 viable seed. Trees with small fruit crops had fewer seeds per fruit but often had heavier seeds. Individual seed weights ranged from <1 mg to 41 mg, but no seeds weighing less than 10 mg were viable (Major 1986 as cited by [175]). Details on resource allocation and morphology of common buckthorn fruits are presented by Lee and others [130].

As of this writing (2010), no information was available regarding seed production in Dahurian buckthorn, other than the following observation: At the Spicebush Swamp Preserve in West Hartford, Connecticut, "heavy fruiting" of *Rhamnus davurica* subsp. *davurica* was observed during each of 3 consecutive years [173].

Seed predation: Predation of common buckthorn seeds affects total seed rain and is likely to vary among sites. A study in Germany found that common buckthorn seeds had 0% survival (100% predation) in mature scrub, 36% survival in pioneer scrub, and 53% survival in an abandoned meadow. Rodents were the main seed predators [119]. Studies of seed predation in old fields in Tompkins County, New York, found greater predation under herb cover than in openings. The study was conducted in October and November (during or after the main period of seed dispersal) of 1985 and 1986. In 1985, all of the seeds in openings were accounted for, while 100% of the seeds under herbs were missing, indicating 100% predation. In 1986 there was no difference in seed counts under herbs or in openings. Apparently, most seeds were consumed by small nocturnal rodents, particularly deer mice [65]. A study in Madison County, New York, found that common buckthorn seed predation by rodents and invertebrates varied among habitats. Rates of postdispersal seed predation were highest in maple forests and lowest in old fields. Predation was attributed primarily to granivorous rodents [143]. In a similar study in the same location, seed predators selected native species over nonnatives when offered seeds of 5 species: natives silky dogwood (*Cornus amomum*), and red raspberry; and nonnatives common buckthorn, Morrow's honeysuckle, and multiflora rose. Significantly fewer seeds of common buckthorn (5 out of 27), Morrow's honeysuckle, and multiflora rose were lost after 1 night of visitation by granivorous rodents (*P*>0.05) [195].

Seed dispersal: Common buckthorn seeds are dispersed primarily by gravity and birds and may also be dispersed by other animals or by water. Humans disperse common buckthorn by planting it for hedges, shelterbelts, and other uses ([160], review by [74]). Once shrubs mature, long-distance spread is facilitated by vertebrate dispersers, especially birds that consume the fleshy, juicy fruits [35,202]. The seeds have a laxative effect [54] that facilitates distribution [90]. The rate and degree of long-distance spread depend on availability and habits of dispersers (review by [104]). Varied accounts in the literature and observations cited by Qaderi and others [175] imply differences in dispersal patterns among years and among individual common buckthorn trees. In some years, many fruits remain on common buckthorn trees for 12 months or more, shriveling during the summer months. In other years fruits start to drop in late autumn and continue to be shed intermittently over winter [175]. Catling and Porebski [32] stated that common buckthorn fruits are retained on shrubs until the following spring unless eaten.

Common buckthorn seed and seedling densities tend to be greater in areas where density of adult common buckthorn shrubs is high, and seedling density is especially high under common buckthorn canopies (see stand structure). Soil samples taken from 4 alvar communities in Chaumont Barren Preserves, New York, revealed a relationship between the number of seeds and the number of adults present in each community, suggesting that most of the seeds found in each community came from local adults [188]. Archibold and others [6] found that about 90% of common buckthorn fruits and seeds in their Saskatchewan study fell directly beneath the canopies of mature female shrubs. This resulted in a dense understory of common buckthorn seedlings. Common buckthorn seedlings and young trees often occur at the bases of large common buckthorn trees or under some other fruiting tree, shrub, or other perch site (e.g., fencerows, hedges) [6,74,158].

Despite the fruit's bitter taste and relative unpalatability, many species of birds in both North America [6,74,116,190,231] and Europe [71,116] have been observed eating common buckthorn fruit, and the seeds are dispersed by regurgitation or defecation [74,119,234]. Exposed seeds may also be eaten by birds [69]. In a 2-year study in New York, 64% to 100% of the fruit on common buckthorn shrubs at 2 sites was consumed by birds (Sherburne 1972 as cited by [116]). In old fields in central New York, common buckthorn seed rain was concentrated within 10 to 16 feet (3-5 m) of parent plants, nonfruiting common buckthorn plants, and artificial perches [144]. In mature scrub in Germany, about 28% of total common buckthorn seed rain was composed of seeds that were regurgitated or defecated by birds [119]. Of 1,455 fruits on one common buckthorn shrub observed at Wicken Fen, 431 fruits and about 69 seeds were collected in a trap below the canopy on 24 December 1932. An additional 1,004 fruits were presumed to have been eaten by birds and the seed dispersed elsewhere in their feces [69].

Mammals such as rodents [65,69,143], white-tailed deer [161], and elk (Ridley 1930 as cited by [36]) may eat common buckthorn fruits and disperse the seeds (see Seed predation). Although mouse predation of seeds may impede seedling recruitment, stores of cached seeds that are not retrieved by mice may germinate [69]. Two common buckthorn seeds germinated from white-tailed deer feces collected from a mixed-deciduous forest site near Ithaca, New York [161]. See Importance to Wildlife for more information on animals that consume common buckthorn seeds and fruits.

Common buckthorn fruits can float and remain viable in water, and thus be dispersed by rivers and streams. Fresh common buckthorn seeds and fruits can float for several hours in still water and up to 30 minutes in agitated water (unpublished experiments cited by [175]). Praeger (1913 cited by [71]) reported that dry common buckthorn fruits can float for 6 days and seeds for 3.5 days. Seventy-seven percent of common buckthorn seeds germinated after being placed in water for 2 weeks in the spring in Saskatchewan [6].

According to management guidelines [199], birds eat the fruit of all nonnative buckthorns, including Dahurian buckthorn, and the severe laxative effect of the fruit helps distribute the seed. As of 2010, no additional information was available on seed dispersal in Dahurian buckthorn.

Seed banking: Few published studies on seed banking of common buckthorn were available as of 2010. Common buckthorn seed densities under mature common buckthorn individuals or stands may range from 15 seeds/m² [45] to 5,000/m² [175]. Common buckthorn seeds may remain viable in the soil for several years. Seeds in intact fruit may be viable but dormant, so fruit remaining on branches may comprise an aerial seed bank, while fallen fruits may contribute to the soil seed bank.

Flooding and seed predation may affect common buckthorn seed bank density. Four studies report a wide range of common buckthorn seed densities in the soil seed bank under mature common buckthorn. Seed banks beneath large, 26-foot-tall (8 m), fruiting trees of common buckthorn in the Sifton Bog Conservation Area in London, Ontario, all had more than 1,000 seeds/m², and some had up to 5,000 seeds/m² (Cavers and others unpublished data cited by [175]). The buried seed bank beneath mature common buckthorn shrubs in a population near Saskatoon, Saskatchewan, averaged 620 seeds/m² in the top 4 inches (10 cm) of soil and was composed entirely of common buckthorn. Common buckthorn seedlings emerged from all soil samples collected from beneath this stand [6]. In a riparian woodland near Saskatoon, Saskatchewan, on-ground fruit counts were 124 fruits/m², and density of common buckthorn seeds in the top 4 inches of soil averaged 15 seeds/m² [45]. Common buckthorn seeds placed in water in the spring retained some viability (77% germinated after 2 weeks), but seeds became nonviable after 2 months of immersion [6]. This suggests that high water levels during spring runoff could reduce common buckthorn density in the soil seed bank. In second-growth riparian forest along Little Otter Creek in Vermont, mature common buckthorn shrubs occurred in understory plots 16 to 82 feet (5-25 m) from the stream edge. Little Otter Creek is an unregulated stream that floods into the riparian forest to distances of about 328 feet (100 m) from the stream edge each spring; the riparian forest is free of standing water by mid-June. Common buckthorn seeds were not detected in the seed rain 5 m from the stream; they occurred at a density of 16,000 seeds/ha at 15 m and at a density of 8,000 seeds/ha at 25 m. Common buckthorn seeds were not detected in the soil seed bank either 5 or 25 m from the stream edge (the seed bank was not sampled at 49 feet (15 m) from the stream edge) [105].

Common buckthorn seeds may remain viable in the soil for at least 2 years [71] and possibly as long as 6 years (Ahrens 1999 as cited by [191], management guidelines by [78]). Seeds survive the winter either in the soil seed bank or in shriveled fruits on parent plants [175]. Archibold and others [6] recorded a germination rate of 88% for fresh common buckthorn seed, which was followed by a rapid loss of viability that resulted in few seeds germinating beyond 1 year of dispersal. Miller (2005 as cited by [45]) also reported that only a small fraction of the annual common buckthorn seed crop remains viable beyond the first year. In a riparian woodland near Saskatoon, Saskatchewan, total fruit production, on-ground fruit counts, and density of seeds in the top 4 inches (10 cm) of soil were reduced after 74% of fruiting stems had been killed using 2 treatments over 6 years. In untreated versus treated plots examined 1 year after the second treatment, on-ground fruit counts were 124 fruits/m² versus 1 fruit/m², and soil seed bank densities were 15 seeds/m² versus 7 seeds/m², respectively [45]. The depletion of the seed bank implies that most common buckthorn seeds do not persist beyond the first year of dispersal. However, observations in Michigan indicated dense seedling establishment following the removal of mature common buckthorn shrubs and, after hand-pulling over 125,000 seedlings from approximately 540 feet² (50 m²), the area was soon revegetated again with common buckthorn from the disturbed seed bank and missed seedlings [214].

Under field conditions, common buckthorn seeds inside intact fruits may remain viable longer than seed separated from fruits. Common buckthorn fruits were collected from trees in London, Ontario, in early April 1993. Whole undamaged fruits and washed separated seeds were placed in artificial soil in a greenhouse. The separated seeds germinated quickly with up to 80% producing seedlings in 3 weeks, but seeds in whole fruits germinated slowly and intermittently over a 5-month period (Cavers and Thomas unpublished data cited by [175]). In some years, dried fruits remained on common buckthorn trees for a year or more, and the seeds inside them remained viable. This aerial seed bank included seeds that eventually germinated more than 1.5 years after they were produced [175]. Archibold and others [6] suggested that under field conditions the rotting of common buckthorn fruit may delay germination until spring. Seeds extracted and dried to a moisture content of about 10% showed high germination and emergence rates after storage at 27 °F (-3 °C) for 3.5 years [215].

Germination: Some fresh common buckthorn seed is germinable and does not require scarification or stratification for germination [2,69,175,215]; however, seeds must be extracted from fruits for germination to occur [6,74], and scarification may increase germination rate [74,175]. Germination rates are higher for seeds that have overwintered in the field than for fresh seeds [6,175,204]. Common buckthorn seedling emergence is inhibited by a litter or herbaceous layer [18,65,118] and is increased by soil disturbance [18,65,74].

Common buckthorn seedlings do not emerge from intact fruits. Seeds dispersed in fruits may not germinate until the following spring, probably after the fruit has decayed or been consumed by animals [6]; this allows the entire growing season for seedling establishment. Seeds that overwintered in the field did not germinate with the pulp left on. With pulp removal, germination percentages ranged from 76% to 92%. Mean time to germination was about 42 days, and germination peaked at 34 to 40 days [6,74]. Dupont and others (1997 cited by [175]) suggested that the role of frugivores was more to remove the pulp of the fruit than to break dormancy or scarify seed during passage through the digestive system.

Effects of passage of common buckthorn seeds through an animal's digestive system are unclear, though it may hasten germination. Acid scarification of common buckthorn seeds has shown variable effects on germination (e.g., [65,74,116]). Leaching seeds in running water for 2 hours, exposure to concentrated sulfuric acid for 1 minute, or rubbing seeds between 2 layers of fine sandpaper increased both the rapidity and percentage of common buckthorn germination (Govinthasamy and Cavers unpublished data cited by [175]).

Some fully mature common buckthorn seeds lack dormancy [215], and several authors [2,69,175,215] report some germination of fresh seeds. Cold stratification may not be required for germination; however, total percent germination and germination rate were higher for seeds that were either exposed to cold temperatures in the laboratory [175,215] or that overwintered under field conditions [6,175,204] than for fresh or unstratified seeds. This may be why some authors recommend prechilling or state that common buckthorn requires cold stratification [13,175]. Fresh, undried seeds of common buckthorn germinated without stratification when exposed to alternating temperature regimes [215].

Percent germination and germination rate of fresh common buckthorn seed exposed to different alternating temperature regimes [215]

Temperature regime (°C)	3/25	20/30	3/15	3/20
Maximum germination	22-45%	86-95%	0	0
Time to reach 50% of maximum	6 to 11 weeks	2.5 to 3.5 weeks	--	--

Germination of common buckthorn and native Carolina buckthorn were compared in a greenhouse study. Germination percentage for common buckthorn was 48% after 0 days of cold stratification, was greatest (85%) after 42 days of cold stratification, and declined slightly after 112 days of stratification. Mean daily germination of common buckthorn consistently exceeded that of Carolina buckthorn [204].

Common buckthorn has higher seedling emergence rates in bare soil than in the presence of herbaceous plants [65,74] or leaf litter [18,74]. Removal of surface litter with prescribed spring fires increased common buckthorn seedling density [18]. Soil disturbance and/or leaf litter removal may produce a flush of common buckthorn germination by stirring up dormant, buried seed and exposing it to light. Ela (1981 unpublished report cited by [74]) found that large numbers of common buckthorn seedlings established in areas where the soil was disturbed in the process of clearing Bell's honeysuckle from a site. In field tests, more common buckthorn seed germinated on bare soil than on soil with a dense litter layer (allowing no light to reach the soil surface) or herbaceous layer (allowing approximately 10% of the ambient light to reach the soil surface), although variation was high and differences were not significant. More common buckthorn seedlings established than the total number of seeds that were planted, probably because common buckthorn seeds already in the soil germinated after removal of the leaf litter [74]. Average cumulative emergence from early May to late June for common buckthorn was 28%, 7%, and 23% in plots with bare soil, 1-year-old herbs, or 15-year-old herbs, respectively. This suggests that early-successional herbs may have inhibited common buckthorn emergence [65]. Bisikwa [18] reported that increased depths of surface litter decreased seedling emergence and establishment of common buckthorn in both field and greenhouse experiments in Minnesota (see Seedling establishment for more details).

Exposure to light may enhance germination of common buckthorn seed in disturbed soil; however, a review by Qaderi and others [175] suggests there is no light requirement for common buckthorn seed germination. Greenhouse experiments comparing 4 light intensities found the lowest germination percentages occurred in the highest light intensity (100%), greatest germination at the 50% level ($P<0.001$), and germination at 25% and 12.5% full daylight was intermediate [74]. In another study, common buckthorn seeds took 23 to 59 days to germinate in light or dark, with 44% germination in light and 24% germination in dark [153].

Prolonged flooding may be detrimental to common buckthorn germination. A slight decline in germination was noted in seeds following immersion for 2 weeks. The mean germination rate for these seeds was 77%, with a mean time to emergence of 44 days. No germination occurred in seeds that were immersed for 2 months [6]. The highest germination rates occurred in moist but not saturated soil [74].

Seedling establishment: Common buckthorn seedlings can occur at high densities near adult conspecifics, and seedling mortality rates may be relatively low in some areas. Seedlings may establish best in areas with shallow litter or bare soil.

Common buckthorn seedlings, sometimes in high densities, are often observed near parent shrubs in invaded areas [6,74,144,175,243] (see stand structure), and densities of common buckthorn seedlings beneath parent shrubs may be higher than in surrounding areas [144,175,243]. Common buckthorn seedling density beneath a dense common buckthorn stand near Saskatoon averaged 110.8 seedlings/m² at the end of the first growing season; by early spring the following year it had increased to 123.7 seedlings/m². Seedling density was lower (~74 seedlings/m²) in a sample quadrats adjacent to a game trail where the soil was very compacted, but even there common buckthorn dominated the ground layer [6]. In Sifton Bog and the Medway Valley in London, Ontario, researchers recorded over 900 common buckthorn seedlings/m² in some quadrats beneath large female trees but usually <5 seedlings/m² beneath male trees (Norman and others unpublished data cited by [175]). Common buckthorn seedlings were common throughout 4 study sites in west-central Minnesota, and seedling abundance increased exponentially with abundance of overstory common buckthorn [243]. In central New York, common buckthorn seedlings were positively associated with fruiting adult plants on 4 old-field plots and on 2 of 4 plantation plots ($P<0.05$) [144].

Mature common buckthorn shrubs may have positive or neutral effects on common buckthorn seedling growth and survival. At the Warner Nature Center in east-central Minnesota, common buckthorn seedlings growing near mature conspecifics exhibited greater growth and survival than seedlings far from mature shrubs in similar light environments [118], possibly due to increased fertility from common buckthorn leaf litter [115]. In a garden in Europe, common buckthorn seedling mortality rates were not significantly different ($P>0.05$) under common buckthorn shrubs and other shrub species [119].

While a common buckthorn canopy does not appear to reduce seedling establishment and growth, it may inhibit seedling persistance. Researchers recorded densities of 20 to 200 large (3- to 12-inch (7-30 cm) tall) common buckthorn seedlings/m² beneath the female trees near London, Ontario; however, few taller seedlings were recorded (Norman and others unpublished data cited by [175]). Many common buckthorn seedlings were observed growing under parent trees at the University of Wisconsin Arboretum; however, common buckthorn saplings seemed not to survive under parent trees, while saplings around the canopy perimeters did [74]. Differences among studies may be due to differences in stand structure and corresponding light levels experienced by the seedlings, or difference in other site characteristics that can influence common buckthorn seedling establishment, survival, and growth.

Common buckthorn seedling emergence may be better on bare soil than on soil with a dense litter or herbaceous layer, although persistence may be similar among microsites. In field tests, a higher percentage of common buckthorn seed germinated on bare soil than on soil with a dense litter or herbaceous layer. While germination was better on bare soil, survival to the next spring was similar among treatments with bare soil, bare and scratched soil, and dense herbaceous cover [74]. Fewer common buckthorn seedlings were observed in sites with thick red oak leaf litter than in sites with less leaf litter at Eagle Lake Park, Minnesota. Common buckthorn seedling emergence, height, and biomass decreased with increasing litter depth in both field (open oak woodlands) and greenhouse studies, but litter depths up to 2 inches (5.1 cm) did not prevent seedling emergence and survival [18].

Photos by S. Kelly Kearns

The effects of litter on common buckthorn seedling establishment may be related to reduced light and lower temperatures associated with litter. Regression analyses showed that common buckthorn seedling density decreased with lower light transmittance in both greenhouse and field studies, and increasing soil temperature increased common buckthorn seedling establishment in the greenhouse [18]. See Shade tolerance for more information on the effects of light on common buckthorn seedling establishment and growth.

Other site characteristics may influence common buckthorn seedling establishment and persistence. A regression model found a positive correlation between common buckthorn seedling density and soil cation exchange capacity and percent clay (P<0.05), both of which are related to soil water holding capacity [131]. Preliminary results suggest that North American soil biota may impact common buckthorn growth. European soil biota did not have a negative effect on common buckthorn, except in low light. North American soil biota had a large negative effect on common buckthorn in all light levels, which was consistent on common buckthorn individuals from 4 different populations [115].

Seedling mortality: Reported mortality rates of common buckthorn seedlings vary among studies and observations, likely a result of differences in site characteristics and plant and animal community compositions. Studies comparing establishment and survival of European shrub species found common buckthorn was among the species with the lowest mortality rates [80,119]. Researchers in London, Ontario, recorded high densities of common buckthorn seedlings under parent plants but noted that most seedlings died in their first summer, probably from drought, predation, and/or deep shade (Norman and others unpublished data cited by [175]). In Madison County, New York, common buckthorn seedlings in maple forest plots experienced higher mortality rates (>60%) than those in old field and plantation plots (~30% mortality). Causes of mortality were uncertain [143].

Mortality of common buckthorn seedlings may result from a variety of causes, including desiccation, frost, fungal pathogens, herbivory, and competition for resources from other plant species [65,119,143,175]. Common buckthorn seedling mortality due to frost damage has been observed in old fields in New York [65] and on peat soils in Europe [71]. Observations of common buckthorn seedlings in Ontario suggest that seedlings that emerged in spring were mature enough to withstand frost damage the following winter [175].

Herbivory may be a major cause of common buckthorn seedling mortality on some sites. In old fields in central New York, survival of common buckthorn seedlings was 5 times lower for seedlings growing under herbs than those growing in the open. During the growing season, herbivory by rodents (especially meadow voles) was the main source of mortality in both microsite types. Over winter, frost heaving caused 62% of seedling mortality in open microsites and 40% under herbs, while herbivory caused 60% of mortality of under herbs. Overall survivorship during the study was greatest in the open. The probability that seeds of common buckthorn landing in the open would produce seedlings that survived until the end of the 1st growing season was 0.23 and until the beginning of the 2nd season was 0.15. The probability that seeds under herbs would produce seedlings that survived to the end of the 1st growing season was 0.00012 and until the beginning of the 2nd season was 0.00007 [65]. Common buckthorn seedlings may be more vulnerable to herbivory in old fields than in plantations or sugar maple forests [143].

Plant growth: Common buckthorn's growth rate is described as medium to fast [48]. Seedling growth has been described as "comparatively rapid". Seedlings averaged about 2 inches (5.2 cm) tall 29 days after germination. Common buckthorn saplings may grow 6.5 feet (2 m) in height per year [175]. Common buckthorn had one of the highest relative growth rates among 10 European shrub species tested in Great Britain [80]. Growth characteristics of common buckthorn grown in a garden in southern England are shown in the table below. Plots were weeded frequently during the first 4 years after planting [79].

Mean values (SE) for common buckthorn characteristics after 2 and 12 years of growth in garden plots [79]					
End of year 2		End of year 12			
Height (cm)	Canopy diameter (cm)	Mean number of stems	Range of number of stems	Basal area (cm^2)	Height (cm)
73 (10.2)	24 (5.7)	4.2	2-14	68.0	352 (13)

Results of a greenhouse study led researchers to conclude that under favorable conditions, common buckthorn and North American native Carolina buckthorn establish similarly, but growth and photosynthesis of common buckthorn exceed those of Carolina buckthorn over time. Common buckthorn also produces more fruit than Carolina buckthorn [206].

Mean growth characteristics of common buckthorn over 98-days [206]								
	Day of harvest							
Characteristic	0	14	28	42	56	70	84	98
Aboveground dry mass (g)	0.38	1.50	1.82	3.44	4.70	8.41	10.08	9.69
Root dry mass (g)	0.07	0.26	0.38	0.71	1.32	2.98	4.33	4.28
Root length (cm)	321	1,018	1,400	2,071	3,478	7,063	8,667	8,689
Relative growth rate (g/g/day)	---	0.10	0.06	0.05	0.04	0.04	0.04	0.03

Growth characteristics of common buckthorn in invaded natural areas are likely to vary due to differences in site characteristics, especially light availability. Five and 17-month-old common buckthorn seedlings planted in old fields in New York had significantly greater dry mass in open microsites than under herbs ($P<0.025$) [65]. Common buckthorn growth rates tended to be higher on moist and open sites at the University of Wisconsin Arboretum [74,89].

Comparison of common buckthorn stem size and age on 3 sites at the University of Wisconsin Arboretum [74]			
Site	Mean (SD) age in years	Mean (SD) circumference in inches	Mean circumference growth (inches/year)
Oak woods	26.12 (8.43)	11.28 (5.82)	0.4319 (n=17)
Lowland forest	18.00 (6.19)	9.74 (4.03)	0.5411 (n=16)
Wetland	13.00 (5.22)	8.97 (5.36)	0.6900 (n=17)

At the University of Wisconsin Arboretum, common buckthorn aboveground growth rates were greater in open habitat (0.58 g/g/year) than in hardwood forest understory (0.23 g/g/year) ($P<0.0001$). The understory site was a restored hardwood forest with a mature, closed canopy; the open site was the edge of a hedgerow, 820 feet (250 m) from the understory site. Common buckthorn aboveground growth rate was significantly higher than those of Bell's honeysuckle, gray dogwood, and black cherry in the open habitat, but it did not differ in the understory habitat ($P=0.05$). Common buckthorn and black cherry had the highest annual net carbon gain in the open habitat, while Bell's honeysuckle had the highest in the understory habitat. Among the 4 shrub species, common buckthorn ranked second after black cherry for mean daily maximum photosynthesis [89].

Common and Dahurian buckthorn were planted and their growth and survival monitored in Mandan, North Dakota. Common buckthorn individuals were planted in 1918. They averaged 6.1 feet (1.9 m) tall after 10 years and 7.4 feet (2.3 m) after 32 years, with medium crown spread. Common buckthorn was described as having a shrubby, dense habit. Dahurian buckthorn individuals were planted in 1929. They averaged 7.4 feet (2.3 m) tall after 10 years and 14.1 feet (4.3 m) tall after 32 years. Dahurian buckthorn was described as having dense growth and a wide crown spread that can equal or exceed its height [63]. Another study in the northern Great Plains reports that of 15 Dahurian buckthorn plants planted, average height at 5 years was 3.3 feet (1 m), and crown spread averaged 3.1 feet (0.9 m) [62].

Vegetative regeneration: Common buckthorn does not reproduce or spread vegetatively, but it does regenerate by sprouting from cut or damaged stems [90] or from the root crown [18] following complete top-kill or partial removal from cutting, browsing, herbicide treatments, or burning [20,45,71,160] (see Control). Seedlings apparently do not sprout following top-kill [20]; however, it is not clear at what age or size common buckthorn seedlings attain the ability to sprout.

According to a review by Solecki [199], all nonnative buckthorns, including Dahurian buckthorn, sprout prolifically from cut or damaged stems. No additional information was available regarding vegetative regeneration in Dahurian buckthorn (as of 2010).

SITE CHARACTERISTICS:

- **Common buckthorn general site characteristics**
- **Dahurian buckthorn general site characteristics**
- **Climate**
- **Elevation, topography, and soil depth**
- **Soil nutrients, mineralogy, and parent material**
- **Soil moisture and texture**
- **Soil disturbance**

Common buckthorn general site characteristics: In its native range, common buckthorn occurs on hillsides, mountain tops, and valleys [120]. It grows in well-drained sand, clay, or poorly drained calcareous or alkaline soils, and it prefers neutral or alkaline soils. In Great Britain, common buckthorn may be more abundant at the foot of chalk escarpments than on the slope [71]. In Great Britain, common buckthorn often occurs in shrublands and wetlands on limestone soils, and as an understory shrub in open woodlands on limestone soils. It is particularly frequent in areas with big outcrops of calcareous rock, especially chalk and oolite, or in large alkaline fens, and it avoids dry exposed places on the chalk. Common buckthorn occurs on all soil types in Europe but grows best on limestone soils with pH 6.5 to 8.5. On alkaline fen peat it tolerates very high soil moisture, with the water table at or above soil level in winter and falling a few decimeters in summer. Humus content of fen peat averages 68% at 8 inches (20 cm); average calcium carbonate content in upper 8 inches is 0.25% [71]. In central Europe, common buckthorn occurs on dry and very dry calcareous slopes, floodplains, and in partially dried swamps [130].

Common buckthorn's distribution extends northward through the greater part of Europe to 60° 48' in Norway and 61° 41' in Sweden and is present sparingly at high altitudes in northern Africa. It is typically a lowland species and is an "index plant" for elevation zones up to 1,100 feet (335 m) in Great Britain; up to 5,300 feet (1,600 m) in Switzerland; and up to 5,900 feet (1,800 m) in Morocco [71].

In North America, distribution of common buckthorn seems to correspond with high human population density [74], and common buckthorn frequently occurs in human-modified environments including pastures [55,74,194,209,225] and field edges [12], along fence rows [55,74,209,225], roadsides [12,74,138,194,209,225], railroads [12,225], in vacant lots [225], hedgerows [35,194], clearings [225], "waste places" [138], woodlots and disturbed woods [35,74], cultivated areas, and around dwellings [74].

Common buckthorn is a wide ranging species, its environmental tolerances are great in terms of temperature, moisture, and substrate, and it is found in a "vast array" of plant communities [74]. In wildlands it is most common in disturbed areas [154,155], though it can establish in relatively undisturbed sites [50]. It is most commonly observed along rivers, streams [12,49,74,123,225], and ravines [209], in open woods [55,74,138,225], woodland edges [138,209,225], rocky woods [194], shrublands, hillsides, damp places, and nearly any habitat except where there is extreme shading or dryness [74]. It seems to have an affinity for disturbed, fertile, calcium-rich, open, moist areas [74], but it can tolerate both dry and partially flooded conditions [203].

Within these broad designations, common buckthorn is found most often on fertile, sunny, moist, and disturbed sites [74]. In a study of 25 fragments of riparian forest in an urban-rural gradient along the Assiniboine River in southern Manitoba, common buckthorn was most prevalent in urban and suburban sites with a high proportion of edge habitat, and it was rarely found in rural sites or reference (relatively undisturbed) forests [155]. Common buckthorn was significantly more likely to occur in urban and suburban sites ($P<0.005$) and was characterized as an opportunistic species and an indicator of disturbed forest; it was positively associated with disturbance measures (such as cover of garbage) and negatively associated with native and overall plant diversity [154]. Common buckthorn was found in both intact (forest, open woods, streams, wetlands) and disturbed (fields, pastures, roadsides, ditches, train tracks, urban sites) sites in forest fragment patches within and around Ottawa. It was not strongly associated with forested, agricultural, or urban landscapes [50]. Observations by Delanoy and Archibold [45] in the Saskatoon area indicate that common buckthorn density decreases with distance from the city and the South Saskatchewan River, and that it is mostly restricted to coulees and similar valley side features where colluvial deposits provide moist, yet well-drained conditions. Some of the densest common buckthorn stands in the area occur on river terraces within the city limits [45].

Wildland areas in urban settings commonly serve as fronts from which invasives can spread into other, more natural environments surrounding cities, and are therefore important places to monitor invasive species [226]. Along the Wisconsin River, increased edge habitat, higher road densities, and altered flood regimes seemed to facilitate shrub invasions, whereas unfragmented forest and intact flood regime limited invasion. Frequency and density of shrubs ≥1.6 feet (0.5 m) tall were measured in 100-year floodplain forests along 9 reaches of the Wisconsin River. Both common and glossy buckthorn were present, though common buckthorn was more frequently observed. Common and glossy buckthorn, which were not identified separately in the study results, occurred in 13% of plots and averaged 0.48 stem/m². They were more frequent and more abundant in reaches in south-central Wisconsin (an area with greater anthropogenic disturbance) than in reaches in north-central or southwestern Wisconsin ($P<0.0001$), and more frequent ($P=0.0134$) and abundant ($P=0.0311$) near roads [174].

Dahurian buckthorn general site characteristics: In its native range in China, Dahurian buckthorn occurs below 5,900 feet (1,800 m) in forests on slopes, forest margins, thickets, and wet places along canals [242]. According to Stephens [202], Dahurian buckthorn seldom escapes cultivation in North America except in the northern part of its nonnative range in North Dakota and, as of 1973, one location in South Dakota. It is rarely found in waste places and along roadsides in Rhode Island and Connecticut [138]. Dahurian buckthorn appears to grow well in any type of soil, especially when moist [202]; however, it may also grow well on dry soils (USDA FS 1948 as cited by [74]).

Very little additional information regarding site preferences for Dahurian buckthorn was found in the available literature as of 2010. Most of the following information applies to common buckthorn unless otherwise indicated.

Climate: Common buckthorn and Dahurian buckthorn are both described as very hardy and durable shrubs or trees. They can be grown under cultivation from USDA hardiness zone 3 (average minimum temperatures ranging from -40 to -30 °F (-40 to -34 °C)) to zone 6 (average minimum temperatures ranging from -10 to 0 °F (-23 to -18 °C)) or 7 (average minimum temperatures ranging from 0 to 10 °F (-18 to -12 °C)) [48].

In North America common buckthorn occurs in a wide range of climatic conditions [74], growing in nearly any climate except those in arid regions [202]. The climate within its primary, worldwide range of distribution is humid continental, where humid conditions occur throughout the year, summers are cool, temperatures average over 50 °F (10

°C) during at least 4 months, and the mean temperature of the warmest month is under 72 °F (22 °C). Common buckthorn seldom occurs in areas where the average January temperature falls below 0 °F (-18 °C); and most of common buckthorn's range lies within the 60 °F to 75 °F (20-24 °C) (July) isotherms [74]. However, a review by Qaderi and others [175] notes that common buckthorn populations in Canada tolerate temperature extremes from 104 °F (40 °C) (the highest temperature in Toronto) to - 53 °F (-47 °C) (the lowest temperature in Saskatoon). Stem samples of common buckthorn collected in midwinter and exposed to temperatures as low as -11 °F (-24 °C) showed 100% survival [205].

Common buckthorn tolerates a wide range of moisture conditions. Average annual precipitation in much of common buckthorn's range is between 20 and 40 inches (508-1,020 mm). The eastern portion of its native range and the western portion of its nonnative range, which includes North Dakota, Montana, Manitoba, and Saskatchewan, are drier (10-20 inches (250-510 mm) annual precipitation); and some parts within its US range are wetter, receiving 40 to 60 inches (1,020-1,500 mm) of annual rainfall [74].

In an effort to determine potential geographic extent of common buckthorn's spread in North America, Gourley [74] compared the distribution of common buckthorn outside cultivation in North America to climate, soil, and geological information in those areas. To the north, common buckthorn's range appeared to be limited by duration of temperatures too cold for flowering and seed set, possible winter-kill temperatures, and acidic soils. To the west, common buckthorn's range extends to the semiarid Great Plains and Rocky Mountains. The precise limits of common buckthorn's distribution probably involve a complex of factors [74].

In the early 1900s common buckthorn and Dahurian buckthorn were planted as potential shelterbelt species in Mandan, North Dakota, in the northern Great Plains. The test site was semiarid, with temperature extremes ranging from -63 °F to 121 °F (-53 to 49 °C), frost-free periods ranging from 89 to 161 days, and mean annual precipitation ranging from 9.39 to 24.20 inches (238.5-614.7 mm). Of 100 common buckthorn individuals planted in 1918, 100% survived 10 years and 98% survived 32 years. Common buckthorn was described as extremely cold and drought hardy, with only minor winter injury. Of 39 Dahurian buckthorn individuals planted on the site in 1929, 100% survived 1 year, and 33% survived 5 to 32 years. Dahurian buckthorn was described as cold and drought hardy, with only minor winter injury, although its stems and branches were easily broken by drifted snow [63]. Another study in the northern Great Plains reports 67.9% survival of 15 planted Dahurian buckthorn individuals after 5 years [62].

Elevation, topography, and soil depth: Few sources provide information on the elevational range of common buckthorn, and no information was available for Dahurian buckthorn (as of 2010). Common buckthorn may be an abundant shrub in disturbed settings within the eastern white pine-oak forest alliance of the northeastern United States, which occurs at elevations below 3,000 feet (915 m). In the northern glaciated portion of the range, the forest occurs on outwash plains or moraines, as well as along mid- and lower slopes and within protected ravines, and on protected ridges or upper slopes of shale, sandstone or other sedimentary rock, occasionally underlain by metamorphic or igneous rock. Along the unglaciated plateau, this community occurs on rolling topography underlain by sandstone [166]. The majority of common buckthorn at the University of Wisconsin Arboretum occurs in low-lying areas at 850 to 870 feet (260-265 m) near Lake Wingra [74]. One record reported a common buckthorn plant at 5,100 feet (1,550 m) in north-central Colorado, but it may have been cultivated [87]. In China, common buckthorn occurs in valleys and on slopes between 3,940 and 4,600 feet (1,200-1,400 m) [242]. In northern Africa it is restricted to high altitudes [71].

At the University of Wisconsin Arboretum common buckthorn is most abundant in nearly level areas and at the bases of areas with steep topography. It occurs to a limited extent in areas with 2% to 5% slope and some areas with as much as 12% slope [74]. The abundance of common buckthorn was examined at 3 locations on 3 site types (upland forests, river bluffs and ravine slopes, and floodplains) in the Thames River watershed in London, Ontario. Common buckthorn was found on all site types in each location, but was generally least abundant on upland sites [226]. In Europe common buckthorn shows a general preference for south and west slopes [71].

In the limestone woodlands at Chaumont Barrens Preserve in north-central New York, adult common buckthorn were found only on sites where soil depth exceeded 2.8 inches (7 cm), though seedlings and saplings were found at a wide range of soil depths. This suggests that common buckthorn seedlings can establish at a wide range of soil depths but cannot survive to adulthood at a soil depth less than 2.8 inches. In the calcareous pavement barrens, seedlings, saplings, and adults are found at all soil depths; one explanation for this is that the limestone bedrock contains many cracks that allow the roots of trees and shrubs to grow in seemingly little soil [188].

Soil nutrients, mineralogy, and parent material: While information on specific soil nutrient and pH preferences of common buckthorn in North America is sparse [120], several authors indicate that common buckthorn has an affinity for alkaline and calcareous soils or soils derived from limestone in both Europe and North America (e.g., [69,74,106,120,175], and there are several examples of its occurrence in such areas (e.g., [31,74,198]). Common buckthorn may have an affinity, though not a requirement, for alkaline and calcium-rich soils, and its distribution may be limited by acidic soils, deep shade, or aridity (see below) [74,131]. However, the fact that buckthorn tolerates association with conifers demonstrates some adaptability in soil requirements [74]. For example, common buckthorn is sometimes abundant in the shrub layer in disturbed settings within the eastern white pine-oak forest alliance of the northeastern United States, which occurs on acidic, nutrient-poor soils [166].

Soils under common buckthorn may have higher percentages of nitrogen and carbon, modified nitrogen mineralization rates, and modified microbial communities compared to soils without common buckthorn. See Influence on succession and plant community dynamics for more information on this topic.

Soil moisture and texture : A comprehensive review by Kurylo and others [120] indicates that soil-moisture preferences reported for common buckthorn range from dry to moist in both European and North American habitats. Some authors indicate that common buckthorn prefers moist soils in England [71], eastern Ontario [160], around Saskatoon, Saskatchewan [6], the northern Great Plains [202], west-central Minnesota [243], and the University of Wisconsin Arboretum [74,75]. Common buckthorn commonly occurs in wetland communities in the Great Lakes region (e.g., [40,52,74,133]), and it is often noted in riparian areas that experience regular spring flooding (e.g., [52,74,105,160]). Some studies have found that common buckthorn grows best on sites with high moisture availability (e.g., [74,140]). However, along the Wisconsin River, buckthorns (common and glossy combined) were more likely to occur on relatively high elevations (P=0.0446) and at distances farther from the river (P=0.0018), where flooding is less frequent [174]. Within Clark Reservation State Park in New York, common buckthorn occurs in an area with soils described as thin and drought-prone [196], and a study of common buckthorn in 28 upland, oak-dominated woodlots in southeastern Wisconsin found that common buckthorn density and importance values were highest in the more xeric bur oak communities and decreased in the more mesic sugar maple communities [131]. Site and microsite preferences may be affected by a combination of light availability, disturbance, and moisture availability (see Shade tolerance). Common buckthorn seedling densities had positive correlations with cation exchange capacity and percent clay and a negative correlation with percent organic matter and continuum index (i.e., shade) ($P \leq 0.002$). The author suggests that the bur oak savanna presents the ideal set of conditions for common buckthorn invasion and growth: relatively high light intensity and fertile, deep, humic soils [131].

In the northeastern United States, common buckthorn is classified as an upland species, suggesting that it rarely occurs in wetlands in that region. In the northern and central Great Plains, common buckthorn is classified as a facultative upland species: one that usually occurs in nonwetlands but is occasionally found in wetlands [178]. The 1996 draft revisions for wetland indicator statuses list common buckthorn as "facultative negative" in part of the Northeast Region (the Great Lakes Plain subregion of Ohio, Pennsylvania, and New York) and the whole of the North Central Region (covering Illinois, Iowa, Indiana, Michigan, Minnesota, Missouri, and Wisconsin), meaning that it is found in wetlands, but not as frequently as a facultative species [120]. Kurylo and others [120] raise some questions regarding common buckthorn based on these designations, particularly questioning whether common buckthorn populations in the northern and central Great Plains may be somehow ecologically distinct (e.g., an ecotype) from populations elsewhere within its invaded range, and whether these differences are attributable to a difference in native seed sources. For example, common buckthorn in England forms nearly monospecific stands in some fens, whereas it occurs in drier habitats in continental Europe [120].

A detailed survey at the University of Wisconsin Arboretum indicates that common buckthorn is most common and grows best on sites that are either open or moist or both [74,75] (see Shade tolerance). The greatest density of common buckthorn and the largest common buckthorn trees occurred in open-canopy wetlands in nearly level areas of deep, poorly to very poorly drained soils where the seasonal high water table is at or near the surface (<1 foot (0.3 m) deep). Common buckthorn also does well in wet and relatively shady areas. In one area with soils described as "extremely wet and mucky" and supporting the largest common buckthorn individuals found in the Arboretum (some measuring 37 inches (95 cm) in circumference), many of the large common buckthorn individuals have fallen over, suggesting that the trees may have grown too top-heavy for their shallow root system in this substrate [74]. Kurylo and others [120] cite evidence suggesting that common buckthorn may be limited by a high winter water table or more waterlogged parts of wetlands, preferring relatively drier microsites in some wetland areas. Drier soils in the Arboretum support common buckthorn growth, but to a more limited extent than wet areas. Prairie sites, which do not have common buckthorn, are drier upland areas with gently rolling or slightly irregular topography [74].

While common buckthorn often occurs on relatively wet sites, some evidence suggests that seedling establishment, growth, and frost resistance may be negatively impacted by prolonged flooding. At Chaumont Barrens Preserve in north-central New York, Samuels [188] suggested that the lack of common buckthorn seedlings, saplings, and adults in alvar grasslands may have been due to inhibition of common buckthorn seed germination by seasonal flooding. Common buckthorn occurs in both floodplain and basin forested wetlands dominated by silver maple in southeastern Wisconsin. The water table is at or near the soil surface most of the year in both site types, although basin soils always have 14 to 16 inches (35-40 cm) of standing water in spring, while floodplain soils are flooded every 2 to 3 years, usually in spring. Common buckthorn importance value (relative basal area+relative frequency+relative density) in the shrub layer was similar on floodplain sites (3.5) and basin sites (2.4). In the seedling layers, however, importance value was significantly greater on floodplain sites (17.9) than on basin sites (5.4) ($P<0.05$). Common buckthorn did not occur in the tree layer in either site type. Basin soils had significantly lower pH (6.5 versus 7.2), higher organic matter and higher calcium and magnesium content ($P<0.0001$) [52]. Common buckthorn individuals grown in a garden grew taller in well-drained (control) trenches than in trenches continuously flooded to a depth of 4 inches (10 cm) above the soil surface for 120 days [60]:

Common buckthorn height growth and diameter growth after 120 days under well-drained (control) or flooded conditions (n=20) [60]

Parameter	Initial height (cm)	Height growth (cm)	Diameter growth (cm)	Number surviving
Control	28.1	10.8*	0.05	16
Flooded	25.9	6.5	0.05	20

*Indicates a significant difference between flooded and control treatments (P=0.01).

When young trees were assessed the following year, common buckthorn individuals from the flooded treatment had significantly less height and diameter growth compared to controls (P=0.001). Fewer common buckthorn individuals survived in the second year after flooding (~78%), although differences were not significant. Previously flooded common buckthorn individuals also seemed more susceptible to frost injury during the period of recovery [60]. In a greenhouse study, common buckthorn initially showed reduced photosynthetic rates upon exposure to partial flooding; although photosynthetic rate recovered, plants remained significantly smaller than controls [203].

Common buckthorn often occurs on soils with relatively high percentages of organic matter (e.g., [184]), but its distribution does not seem to be correlated with particular soil textural classes (e.g., [226]). In Canada, common buckthorn frequently occurs on clays or loams [175]. Field observations of 24 oak woods in northwestern Indiana, northeastern Illinois, and southern Wisconsin found common buckthorn occurred on deep silty clay loams that are not frequently subject to extreme drying [83]. Common buckthorn may be an abundant shrub in disturbed settings within the eastern white pine-oak forest alliance of the northeastern United States, which occurs on dry-mesic to mesic, sandy loam to sandy soils [166]. Buckthorns (common and glossy combined) were most frequent in sandy soils ($P<0.0001$) along the Wisconsin River [174].

Soil disturbance: Areas of the heaviest concentrations of common buckthorn in the University of Wisconsin Arboretum are consistently places of soil disturbance such as trail and wood edges, dredge spoil sites, clearings, areas where Bell's honeysuckle was removed, streambanks, areas of steep topography with high erosion potential, excavated areas, an area directly under and around utility lines and poles, and deer yards [74]. Where common buckthorn occurs on dry sites in the Arboretum, Gourley [74] speculated that soil disturbance may have allowed it to establish. Prairie sites without common buckthorn were less disturbed than those with common buckthorn. Lack of perches to facilitate bird dispersal of seeds and interference from prairie grasses may also contribute to the rarity of common buckthorn in prairies [74].

Common buckthorn and Dahurian buckthorn were planted at 6 surface coal mine reclamation sites in Wyoming and Colorado. Both species survived and grew at 4 of the 6 sites during the first year after planting [102]. Site data from 2 of those sites are given in the table below:

Site characteristics and growth and survival of common buckthorn and Dahurian buckthorn at 2 coal mine reclamation sites in Wyoming and Colorado. All sites were surface-mined. Shrubs were planted in spring of 1976 and measurements taken at the end of the 1977 growing season [102].

Site		Gillette			Glenrock		
Elevation (feet)		4,500			6,000		
Mean annual precipitation (mm)		384.3			337.6		
Soil pH	Topsoil*	6.9			6.3		
	Subsoil	6.7			5.2		
Soil texture	Topsoil	Clay loam			Sandy loam		
	Subsoil	Clay loam			Sandy loam		
Electrical conductivity (mmhos/cm)	Topsoil	3.98			1.18		
	Subsoil	1.60			4.20		
Organic matter** (%)	Topsoil	4.32			1.25		
	Subsoil	3.30			2.00		
Survival and growth variables		Height (cm)	Spread (cm)	Survival (%)	Height (cm)	Spread (cm)	Survival (%)
Common buckthorn		24	14	67	21	17	100
Dahurian buckthorn		32	14	67	35	23	100

*Stockpiled or newly stripped, applied at depths of 6 to 18 inches.
**Soils at coal mine sites have various amounts of coal particles, which contribute to organic matter readings.

Data from 2 sites at Oak Creek are not included in the table because soil information is not clear. Common buckthorn had 100% survival and Dahurian buckthorn had 75% survival at both Oak Creek sites. Height and spread were about half as much for both species as at the other sites. Oak Creek sites were located at 7,500 feet (2,300 m) elevation, received 15.8 inches (401.7 mm) average annual precipitation, and soils were silt loams over clay loams, with a pH of 7.4 over 7.7, electrical conductivity of 2.00 mmhos/cm over 3.30 mmhos/cm, and organic matter of 6.5% to 3.7%. Neither common buckthorn nor Dahurian buckthorn survived at the Hanna or Kemmerer sites, which differed from other sites in terms of elevation (7,200-7,600 feet (2,200-2,300 m)), average annual precipitation (9.3-10.6 inches (235.2-270.5 mm)), and pH (7.3-8.0). Soils at the Hanna site also had the highest electrical conductivity (7.02 mmhos/cm), indicating a high salt content. Sites at Gillette and Glenrock were cultivated, while the other sites were planted and left to compete with the plants of natural succession [102]. Native vegetation at these sites is described in Habitat Types and Plant Communities: Western North America.

SUCCESSIONAL STATUS:
As of this writing (2010), no information was available regarding shade tolerance or successional status of Dahurian buckthorn. Information in the following sections applies to common buckthorn.

- **Shade tolerance**
- **Successional role**
    - Oak savannas and forests

    - Maple-beech, riparian, and coniferous ecosystems
    - Old-field succession
- **Influence on succession and plant community dynamics**

Shade tolerance: Common buckthorn tolerates shade [6,71] but may be more abundant and grow more quickly under intermediate levels of sunlight [4,74,89,131] if moisture is not limiting [120,243]. Heidorn [90] suggests that common buckthorn requires more light than Dahurian buckthorn, although the reasons for this assertion are unclear.

Throughout its worldwide distribution, common buckthorn does not typically occur in densely shaded communities [74]; however, qualitative descriptions of invaded communities suggest some shade tolerance in common buckthorn. In its native range, common buckthorn frequently occurs in open areas or forest edges [116]. It occurs in similar environments in its invaded range (see Habitat Types and Plant Communities), but it can also establish and persist in closed-canopy forests and is sometimes a dominant understory species in forests and woodlands [6,74,120,131,140,158,226]. In the Thames River watershed in London, Ontario, common buckthorn was positively correlated with canopy closure (P=0.002) [226]. Common buckthorn seedlings are common in low-light environments such as the shade of mature common buckthorn trees [6,74,243] (see Seedling establishment) and at the base of other shrubs and trees where birds perch and deposit seed (see Seed dispersal). Common buckthorn seedlings below a large common buckthorn shrub at Wicken Fen branched and produced leaves in the shade [69,72]. However, most common buckthorn seedlings observed in areas of deep shade in London, Ontario, died [175].

Several studies indicate higher densities and/or greater persistence and growth of common buckthorn at intermediate light levels. At 4 study sites in west-central Minnesota, common buckthorn did not grow well in light, dry microsites and grew in substantially darker microsites than bur oak did; however, common buckthorn seedling abundance peaked at intermediate light levels [243]. In an experiment where seedlings of common buckthorn were grown in a forest understory across a light gradient from 1% to 16% midsummer canopy openness, seedling biomass and survival were greater in the highest-light environments after 3 years (P<0.0001) [118]. In a greenhouse experiment, common buckthorn seedling survival and growth were best in 25% to 50% full light. The number of seedlings was reduced in 100% full light, but those that established grew well. Seedlings in the 12.5% light level grew slowly and were "quite sprawling" [74]. Survival of transplanted common buckthorn seedlings was lower in shadier maple forests than in old fields and plantations in central New York [143], and seedling abundance was significantly greater on sites with greater light at the forest floor (P=0.019) [144].

Common buckthorn can survive in deep shade in experimental settlings (e.g., [80]); however, growth and abundance tend to decrease with increased shade (e.g., [80,118,131]). Aboveground growth rates of common buckthorn were greater in an open habitat (0.58 g/g/year) than in a hardwood forest understory (0.23 g/g/year) in southern Wisconsin [89]. See Plant growth for more information on this study. In the greenhouse, Leitner [131] found a general decrease in common buckthorn growth as light decreased; this was especially pronounced under the greatest degree of shading (23% of total exterior solar radiation). In upland, oak woodlots in southeastern Wisconsin, common buckthorn tree/shrub and seedling densities appeared to decrease with shade, and tree/shrub density appeared to increase with canopy openness [131]. See Habitat Types and Plant Communities:Forest and woodland for further details from Leitner's study. In remnant oak savannas in southern Wisconsin [129] and old fields in southeastern New Hampshire [103], common buckthorn was associated with intermediate light levels [129]. In central New York, common buckthorn density was greater on plantation and old-field sites, which had intermediate light levels. Common buckthorn occurred in maple-beech forests, although it was closer to walking trails than expected in those forests (P<0.05), with a strong tendency to occur within 33 feet (10 m) of the trail [144].

Mean attributes of 4 plots in each of 3 site types in central New York. All woody plants >1 m in height and all common buckthorn individuals were censused at each plot. Values within columns followed by different letters are significantly different (P<0.05) [144].

Site type	Tree density/ha (all spp)	Shrub density/ha (all spp)	Herbaceous cover (%)	ISF*	DSF**	Common buckthorn density/ha
Maple-beech						

forest	2,802a	10a	18a	0.11a	0.11a	112a
Old field	365b	397ab	86b	0.79b	0.78b	5,912ab
Plantation	1,719a	794b	57b	0.20a	0.23a	7,717b
*Indirect site factors (ISF) is an estimate of the relative amount of diffuse radiation. **Direct site factors (DSF) is an estimate of the relative amount of direct sunlight given location-specific solar tracks. Both indices range from 0.0, which indicates no radiation, to 1.0, which indicates full and unobstructed sunlight.						

Common buckthorn is present in forests dominated by maple (*Acer* spp.), pine (*Pinus* spp.), or spruce (*Picea* spp.) and fir (*Abies* spp.), although it occurs at low densities and is typically confined to trail edges or gaps in the canopy. Reduced growth and abundance of common buckthorn at very low light levels suggests the very deep shade of these ecosystems may limit common buckthorn invasion as compared with other deciduous forests, shrublands, and grasslands where common buckthorn is common [74].

Common buckthorn reproduction may be best at intermediate light levels, and its shade tolerance may decrease with age. At the University of Wisconsin Arboretum, common buckthorn grew and reproduced in both open wetlands and oak woodlands, and similar numbers of seedlings occurred in each site type. In the open wetlands, common buckthorn trees were younger, larger, and produced more fruit, and common buckthorn seedlings produced fruit at an earlier age than in the oak woods. Shade in the oak woods ranged from 9% to 23% of total sunlight. Many common buckthorn seedlings were observed growing under parent trees in this study; however, common buckthorn saplings seemed not to survive there, but grew around the canopy perimeters [74].

Lower common buckthorn seedling establishment in areas with surface litter may be a function of light availability. Regression analyses showed that common buckthorn seedling density and biomass decreased with lower light transmittance at the soil surface in greenhouse and field experiments [18]. However, many common buckthorn seedlings survive in deep shade (1-2% of full light in midsummer) in the field [118].

Success of common buckthorn seedlings under parent shrubs may be related to factors other than light availability, such as reduced competition with herbaceous species for water and nutrients or facilitation from mature common buckthorn trees. In an oak-dominated forest in east-central Minnesota, common buckthorn seedlings growing near mature conspecifics exhibited greater growth and survival than seedlings far from mature conspecifics in similar light environments [118].

Competition for soil resources can affect common buckthorn seedling survival and growth in shade (e.g., [80,115]). A significant interaction between the effects of irradiance and nutrient supply was observed for common buckthorn (P<0.01) [80]:

Seedling mortality and total dry mass of seedlings of common buckthorn after 110 days in 4 shade treatments on soils with differing nutrient supply [80]								
	Numbers of plants dying				Mean (SE) dry mass (mg)			
% daylight	0.3%	1.6%	11%	63%	0.3%	1.6%	11%	63%
Grassland (low nutrient supply)	1	0	0	0	20 (3)	45(8)	366(40)	956(98)
Scrubland (high nutrient supply)	3	0	0	0	16 (1)	40(3)	458(52)	2145(252)

The number of common buckthorn leaves per plant, total leaf area, and shoot height increased significantly with higher irradiance (P<0.001) and was higher on nutrient-rich soil (P<0.05). Plants responded to increased shading with etoliated stems and decreased root length (P<0.001) [80]. Preliminary results from a field experiment at the Warner Nature Center in east-central Minnesota found that common buckthorn seedlings with no interference from understory plants showed a strong positive response to light with increased survival and growth. However, in subplots planted with native herbaceous plants (to create belowground competition), common buckthorn seedlings had only a small response to increased light [115]. Five- and 17-month-old, experimentally planted common buckthorn seedlings in old fields in New York had significantly greater dry mass in open microsites than under herbs. Growth was also greater for seedlings competing for soil resources than for those competing for light ($P<0.025$) [65]. These results are consistent with data that show decreased common buckthorn seedling abundance in areas with greater cover of understory herbaceous plants [117] and native shrubs [116].

Desiccation and competition from other plants in open areas may restrict common buckthorn to shaded areas in some habitats [120,243]. Within the grassland biome of North America, common buckthorn is associated with shrublands, hedgerows, lowland river vegetation, and open woods [74]. A detailed survey at the University of Wisconsin Arboretum indicates that common buckthorn is very rare in prairies and savannas, but it is most common and grows best on sites that are either open or moist or both [74,75]. At 4 study sites in west-central Minnesota, common buckthorn saplings were found in significantly darker microsites with higher soil moisture than those where bur oak occurred. Light and soil moisture explained approximately half of the variation in growth seen among common buckthorn saplings [243]. Common buckthorn was not common at Wolf Road Prairie Nature Preserve in Illinois, a rare savanna remnant with an open overstory of mature bur oak. However, it occurred most frequently on sites with lowest mean photosynthetically active radiation (PAR) (about 143.1 mol/m²/sec) and less frequently on sites with a mean PAR ranging from about 164.7 to 826.6 mol/m²/sec [23].

Establishment and persistence of common buckthorn in shade may depend on propagule pressure. Common buckthorn was artificially seeded at varied rates into 1-m² treatment plots with varied light and nutrient availability in a 60-year-old red pine plantation in Ontario. Percent cover of common buckthorn was dependent on both resource availability and propagule pressure (seeding rate). Common buckthorn had significantly greater average cover in shaded subplots (2.3%) than in unshaded subplots (1.3%) ($P=0.003$), and high propagule pressure subplots had significantly greater common buckthorn cover, density, and aboveground biomass than low or no pressure subplots ($P<0.001$) [212]. A roost area in a 16-acre (6.5-ha) forested wetland in New Jersey characterized by a dense, closed canopy with a sparse shrub layer of southern arrowwood and highbush blueberry (*Vaccinium corymbosum*) was first noted by Moskowitz [158] in August 1992. In August 1993, changes in the vegetative community beneath the roost were apparent. There was more than 50% mortality of highbush blueberry and a pronounced change in the species composition of the understory, including seedlings of 4 new species beneath the roost: common buckthorn, American black elderberry (*Sambucus nigra* subsp. *canadensis*), pokeweed (*Phytolacca americana*), and bittersweet nightshade (*Solanum dulcamara*). Common buckthorn increased from 0% cover on 6 August 1992 to 15% cover on 14 August 1993 [158], likely a result of high propagule pressure from seed in bird feces. No changes were observed in the vegetation of the wetland beyond the limits of the roost. Vegetation changes under the roost suggest a change toward more upland and facultative upland species and a loss of obligate and facultative wetland species [158].

Successional role: Little information was available regarding common buckthorn's successional role where it is native, with the exception of a detailed study at Wicken Fen in southern England. On alkaline peat at Wicken Fen, common buckthorn is characteristic of seral communities and codominates with glossy buckthorn, large gray willow, and other shrubs if left uncut. In the early stages of succession from mixed sedge communities to shrub carr after cessation of haying, glossy buckthorn is frequent. As carr ages, undergrowth is killed out and common buckthorn tends to replace both glossy buckthorn and large gray willow. Succession proceeds toward dense and widespread stands of common buckthorn about 50 years after cessation of haying [69,70,71,72]. The character of the shrub stages depends on initial densities of colonizing shrubs [69,70]. The rapid overtaking of glossy buckthorn by common buckthorn at Wicken Fen was apparently the result of severe and widespread fungal attack on glossy buckthorn [69] and may not represent the "typical" successional pattern. Godwin and others [72] provide further details of plant community changes over 50 years at Wicken Fen.

In its nonnative range, common buckthorn's successional role varies among plant communities and depends on the disturbance history of a given site. Its ability to establish and persist in low-light environments such as a deciduous forest understory suggests that it may occur in these communities during mid- to late-successional stages. However, it may be limited to forests where the native species are less adapted to such conditions or to canopy gaps. For example, invasive populations of common buckthorn often occur in the understory of oak forests that were maintained as oak savannas before fire exclusion began (e.g., [83,131,164,243]), but it rarely establishes in the understories of naturally occurring sugar maple forests, except in canopy gaps such as those occurring along walking trails (e.g., [144]) or following other types of disturbance (e.g., [44,140,246]). Common buckthorn also commonly establishes and persists in abandoned agricultural fields (e.g., [37,103,144,208]), especially former pastures (e.g., [17,193,208]).

The ability of common buckthorn to both tolerate shady conditions and grow quickly in open conditions may give it a successional advantage when canopy gaps are created in areas where it occurs in the understory [116]. Common buckthorn was the most responsive to light among 4 shade-tolerant, woody species tested in Europe [80]. In open woods in eastern Ontario, thousands of small common buckthorn saplings and seedlings covered the ground in shaded locations, and common buckthorn trees and large shrubs occurred in openings. When large common buckthorns were removed, small common buckthorn plants grew rapidly, forming a solid stand [160,175]. Three years after thinning treatments in pine plantations in the Oak Openings Preserve in northwestern Ohio, common buckthorn occurred in 10% of control plots and 36% of thinned plots. Common buckthorn cover and frequency increased after thinning, and common buckthorn and sheep sorrel (*Rumex acetosella*) were the most important nonnatives on thinned plots [1].

Oak savannas and forests: Much of the following information on succession and fire regimes in oak savannas was compiled from literature reviews in several papers: [4,22,23,24,113,125,131]. See Habitat Types and Plant Communities: Savanna for examples of savanna community composition.

Historical descriptions [23] and fire scars on old savanna oaks [83] suggest that savannas in the central United States were maintained by frequent fires, often set by humans [4,22,23,24,125,131]. See Fire regimes for more details. Frequent fires and moisture gradients resulted in communities ranging from xeric prairies, to savannas with an open understory, to relatively open oak woods, to shady, mesic stands dominated by maples [131]. The boundaries among these communities were neither discrete nor stationary but changed in response to climate fluctuations and the frequency and intensity of fires [113].

With postsettlement fire exclusion, some savannas succeeded to oak forests, sometimes with dense understories, as oak sprouts grew into oak trees (e.g., [23,59,113]), and native and nonnative woody species established, spread, and interfered with native savanna plants [4,5,83,125,131]. Common buckthorn was introduced to this landscape around the same time that fire exclusion began, as birds dispersed its seeds into a niche that was not suitable for native savanna species that were adapted to the frequent-fire regime [131]. Common buckthorn is now a common component in the understory of some oak forests and savannas [83,113,131]. It is often concentrated along edges of eastern oak forests that were forested at the time it was introduced, whereas some oak forests that originated as woodlands or savannas have common buckthorn throughout [59]. This suggests that common buckthorn established when the canopies were more open and has persisted as the canopies became more dense. While it has been suggested that fire exclusion along the prairie-forest border may increase common buckthorn invasion of prairies (e.g., Leitner 1984 personal communication cited by [36]), the limited success of common buckthorn in light, dry microsites within bur oak communities suggests that common buckthorn is not a pioneer species in fire-excluded prairies. However, it might establish after other pioneer woody species establish and provide some shade [243] and perches for bird dispersers [144].

According to Leitner [131], the most prevalent forms of anthropogenic disturbance in southern Wisconsin oak woodlots after the cessation of frequent fires were cattle grazing and timber cutting. Selective feeding by cows was thought to eliminate seedlings of desirable species such as maples, ashes, and basswoods while leaving the undesirable species such as hawthorns, barberries, and prickly-ashes. When cows were removed, the browse-resistant species had an initial advantage. While common buckthorn bears thorns, these seem to confer little protection from browsing, and common buckthorn was practically absent from the most heavily grazed oak woodlands studied in southeastern Wisconsin. However, common buckthorn can establish and spread in the openings created by browsing when cows are removed. A thick, sometimes impenetrable shrub layer developed in many of these woodlands following the cessation of grazing and fire. Over 50% of the stands in this study had shrub densities exceeding 10,000 shrubs/ha, with a high of 19,400 shrubs/ha, composed of native species such as gray dogwood and viburnum, nonnative species such as common buckthorn and honeysuckles, and survivors from the grazing period [131].

Several studies note dense and abundant common buckthorn populations in bur oak communities (e.g., [83,131,243]). Leitner's study of common buckthorn in 28 upland, oak-dominated woodlots in southeastern Wisconsin suggests that the bur oak savanna presents the ideal set of conditions for common buckthorn invasion and growth. However, the abundance of mesic species in the understory of all but the most xeric sites suggests that with continued exclusion of fire these communities may succeed to more mesic communities. These woodlots were never clearcut, so common buckthorn could not have been part of the pioneering vegetation on these sites, but instead invaded established forest or savanna [131]. Oak savanna remnants with canopy intercept of 40% to 70% may have been the vegetation types most vulnerable to common buckthorn invasion [4]. Field observations of 24 oak woods in northern Indiana and Illinois, and southern Wisconsin found common buckthorn was most common in tallgrass savanna dominated by bur oak, but also occurred in mesic savanna dominated by white oak and northern red oak. Fire exclusion from mesic savanna leads to increased abundace of sugar maple, red maple, and other hardwood species [83]. In several of the study areas surveyed in 1986, canopy oaks were nearly gone, oak seedling regeneration was poor to absent, and a dense understory of 16- to 26-foot (5-8 m) buckthorn shaded virtually bare ground [4]. In xeric, bur oak woodlots, common buckthorn produced denser shade than that of the surrounding forest matrix. Increased shade under common buckthorn may further reduce oak regeneration, reduce cover of native spring ephemerals, and favor more shade-tolerant tree species as succession proceeds [131]. See Influence on succession and plant community dynamics.

If oak forest and savanna sites are subjected to additional disturbances that open the canopy, such as fragmentation resulting from urbanization or logging operations, increased edge habitat and light penetration and simplified stand structure may result in a more xeric microclimate and favor continued dominance of common buckthorn [131].

Maple-beech, riparian, and coniferous ecosystems: Common buckthorn is less likely to establish in maple-beech and coniferous ecosystems than in oak-dominated ecosystems, and it seems to require some type of canopy-opening disturbance to establish. Once it has established, additional canopy disturbance may lead to increased growth and abundance of common buckthorn.

In Syracuse, New York, common buckthorn occurred in 78% of regenerated urban forest patches (had no canopy cover in 1939, but had canopy cover in 1978) and 100% of remnant urban forest patches (had canopy cover in both 1939 and 1978 aerial photos). In regenerated forest patches, it was sometimes dominant in communities characterized by sugar maple, Norway maple, or boxelder. In remnant forest patches, it had significantly greater average stem density and basal area in black oak communities (330 stems/ha and 0.58 m^2/ha, respectively) than in sugar maple communities (70.7 stems/ha and 0.11 m^2/ha) ($P<0.05$). The authors suggest that as gaps are formed in black oak canopies, common buckthorn can colonize available sites due to lack of oak regeneration in the absence of fire. Sugar maple, on the other hand, can establish beneath its own canopy, thus limiting recruitment sites for other species such as common buckthorn [246].

Results of studies in central New York suggest canopy openings or edges are important for common buckthorn establishment. Common buckthorn seed dispersal was lowest, seed predation highest, and seedling survival lowest in closed-canopy maple forests compared to plantations and old fields. A combination of low dispersal by frugivores, low seed survival due to predation, and low seedling survival due to dim light apparently prevents common buckthorn from invading intact maple forests [143]. These maple forests were free of anthropogenic disturbances for a century or more and had relatively intact canopies. The small populations of common buckthorn observed in these habitats were associated with walking trails and the canopy openings created by these trails. Disturbances that cause the opening of intact, closed-canopy forests in the Northeast will likely promote invasion by common buckthorn, as long as seed sources are nearby. Once common buckthorn is established, mature plants can serve as points of recruitment for new seedlings [144]. Common buckthorn occurred at the edge of a riparian forest along Little Otter Creek, a slow-moving stream in Vermont that floods each spring into the riparian forest to distances of about 328 feet (100 m) from the stream edge. Common buckthorn occurred in shrub-dominated plots 16 to 82 feet (5-25 m) from the stream edge; it did not occur in the forest understory plots 164 to 328 feet (50-100 m) from the stream edge [105].

Several studies provide examples of common buckthorn establishment following canopy-opening disturbances. Common buckthorn did not occur in an eastern white pine forest in Cedar Creek Natural History Area, east-central Minnesota, before or 2 weeks after a July 1983 storm that resulted in widespread windthrow with substantial tree mortality. However, 10 years later (1993) common buckthorn stems >1 inch (2.5 cm) DBH had a basal area of 0.01 m^2/ha and a density of 6.6 individuals/ha; in 1997, basal area was still 0.01 m^2/ha but density had increased to 9.9 individuals/ha [7]. In Ottawa, Ontario, common buckthorn was rare in maple-beech forest interior plots prior to an ice storm in January 1998, but it was abundant in the 4 years following the canopy-opening disturbance [44]. Common buckthorn seedling density was lower in undisturbed control plots than in treefall gaps created by severe windstorms in a mixed oak-Virginia pine (*Pinus virginiana*) forest in northern Virginia in July 1990. Although differences were not significant, common buckthorn averaged 347 seedlings/ha in gap plots and 55 seedlings/ha in control plots [163]. One common buckthorn stem, <6 inches (15 cm) DBH, was recorded in an American elm swamp where the elms had been killed by Dutch elm disease. It was not recorded in 2 similar swamps in the area [9]. Common buckthorn was recorded after flooding ceased in a green ash-red maple forest that had been flooded for waterfowl habitat management at Montezuma National Wildlife Refuge, central New York. It occurred in the ground layer 2 years after cessation of flooding and in the shrub layer 18 years after flood cessation. Densities of some native shrub species, green ash saplings, and overstory American elm were reduced during the same period, likely providing the openings for common buckthorn establishment. Common buckthorn was not mentioned as occurring in the control site (a swamp) [46].

Common buckthorn occurs in a variety of anthropogenically impacted and disturbed forests. It occurs in urban forests throughout its distribution in Canada [45,154,175,226], in the Great Lakes area (e.g., [74,97,133]) including Minnesota (e.g., [100,157,243]), and further east (e.g., [246]). Populations in urban forests can act as propagule sources for spread into wildlands and nature preserves. In central and western Massachusetts, common buckthorn was among several species associated with high-intensity tree harvest and not with low-intensity tree harvest in 4 forest types (mixed-hardwood, oak, eastern hemlock, and white pine forests). No comparison was made to unharvested forests [147]. Common buckthorn occurred in 8.1% of 148 randomly selected forest sites that had been harvested between 1984 and 2003. Though it was typically rare (1 individual) or uncommon (2-10 individuals) in these sites, it was common (>10 individuals) in 17% of invaded plots. Common buckthorn occurred most often on sites that were formerly plowed, and less often on former pastures or continuously forested woodlots [146]. Study results suggest that regional patterns of invasive species distribution are affected not only by disturbance but also by soil characteristics and "the current and historical landscape context" [146,147].

A comparison of historical data from a 1950 survey of floodplain forest vegetation on the Lower Wisconsin River [41] to data collected there in summer of 2001 [82] suggests that these forests are shifting to a later successional stage that is outside the historical range of variation. In the 1950s, floodplain forests in southern Wisconsin were typically colonized by black willow and eastern cottonwood on recently scoured or deposited substrates. River birch and swamp white oak (*Quercus bicolor*) were early-successional species in forest gaps. These communities typically succeeded to dominance by American elm, green ash, and silver maple, with a sparse woody understory. In the past, it was thought that regular flooding would typically prevent succession beyond this stage. Since the 1950s, however, the interaction of river regulation, elm mortality, increased browsing pressure from white-tailed deer, timber harvest, and invasive species establishment has led to changes in floodplain forest vegetation. The understories of 3 of the 5 study sites surveyed in 2001 were dominated by 2 invasive species: common prickly-ash and common buckthorn. Both species are thought to have established and spread in canopy gaps resulting from timber harvest and Dutch elm disease. Neither of these species is considered particularly flood tolerant, nor are they particularly palatable to white-tailed deer due to their thorns. Common buckthorn had the highest importance value of all understory species at Ferry Bluff, which is 1 of 2 sites that apparently experienced greater vegetation removal since the 1950 sampling. Common buckthorn was not recorded on this site in 1950 [82].

Mascaro and Schnitzer [140] found evidence that common buckthorn may attain its highest dominance in forests when it establishes prior to afforestation, then persists as forests develop. No examples were found of common buckthorn becoming a canopy dominant when colonizing intact, closed-canopy forest [140]. Eight forested sites where common buckthorn was a dominant species were studied in southern Wisconsin. The 3 mesic sites in this study—where common buckthorn ranks 1st or 2nd by basal area—were largely open areas in 1963. The 3 floodplain sites—where common buckthorn dominates the subcanopy—were completely forested in 1963, probably by native trees. The 2 swamp sites—which have the largest common buckthorn individuals encountered (>12 inches (30 cm) DBH)—were closed-canopy forest in 1963, probably with some common buckthorn present [140].

Site type, land cover history (as determined by inspection of aerial photography, or in the field for 2004), basal area of living stems, and generalized composition of dominant species on 8 forested study sites where common buckthorn was a dominant species in southern Wisconsin [140]

Site	Land cover history by year**	Basal area	Most dominant species*** (% relative basal area, % relative

type* and #								(m^2/ha)	density)		
	1963	1967	1970	1975	1985	2000	2004		1st	2nd	3rd
FP 1	F						F	49	SiM (44,4)	AM (29,10)	EC (14,2)
FP 2	F						F	68	EC (41,1)	SiM (40,3)	AM (14,7)
FP 3	F						F	42	EC (45,1)	GA (35,6)	CB (10,76)
Ms 4	A	A	A			F	F	25	CB (95,99)	AE (5,1)	--
Ms 5	S			O	F		F	10	CB (54,75)	WO (19,2)	WA (16,5)
Ms 6	S		S	O	O		F	36	WA (61,13)	CB (23,67)	BC (23,2)
Sw 7	F	F	F			F	F	48	CB (100,100)	--	--
Sw 8	F	F	F			F	F	29	CB (66,93)	BC (18,4)	GA (8,1)

*FP= floodplain, Ms= mesic, Sw= swamp.
**A= active agriculture, F= closed-canopy forest (ground not visible), O= open forest (ground visible, but trees touch each other), S= sparse trees (do not touch each other); blank cells indicate no data available for that site in that year.
***AB=American beech, AE= American elm, AM=boxelder, BA=basswood, BC=black cherry, BW=black walnut, CB=common buckthorn, EC=eastern cottonwood, GA=green ash, HA=hawthorn, RM=red maple, SH=shagbark hickory, SM=sugar maple, SiM=silver maple, WA=white ash, WO=white oak.

Old-field succession: Former agricultural fields throughout the eastern United States are undergoing succession to forest. No generalized pattern of old-field succession exists because of variability in agricultural use (e.g., cultivation, pasture), potential seed sources, and high variability in site conditions (review by [37]). Common buckthorn occurs on many former agricultural sites at various stages of succession (see below). As old fields in northeastern temperate forests undergo afforestation, there is potential for common buckthorn to become dominant in the plant community, alter successional trajectories, and have other adverse impacts on the invaded community [140].

Common buckthorn may establish in early succession after field abandonment. A study of seedling establishment suggests that common buckthorn establishes and persists better in open microsites than in those with herbaceous cover [65]. However, observations by Whitford and Whitford [236] suggest that dense, ungrazed bluegrass (*Poa* spp.) sod does not prevent establishment of common buckthorn. Common buckthorn and other woody species occurred as small and suppressed individuals beneath the herb canopy in a field in London, Ontario, that was mown yearly for at least 35 years until 2001. After annual mowing ceased, common buckthorn dominated the shrub layer within 5 years, and female trees produced large seed crops in 2006 (Cavers personal observations cited by [175]).

Some authors have suggested that common buckthorn does not establish in early old-field succession because these fields lack perches to aid in common buckthorn seed dispersal by birds [57]. In southwestern Michigan old fields, common buckthorn established 6 years after field abandonment. Common buckthorn stem density was 0.17 stem/200 m^2 in year 6 and 3.17 stems/200 m^2 the following year. The authors noted that at this time other woody species, especially staghorn sumac, had established and provided bird perches [57]. However, other authors observed common buckthorn establishment in fields without perches [236].

Many old fields in central and western New York have a similar land use history: a century of dairy farming followed by abandonment beginning during the 1930s. Similarities in old-field succession may be expected on these sites (Stanton and Bills 1996 as cited by [37]). In a chronosequence study of old fields in western New York, common buckthorn was dominant in early to middle succession but decreased in importance 70 years after abandonment. Common buckthorn averaged 20.3% cover and was among the dominant species on old fields 30 years after abandonment. Fifty years after abandonment, common buckthorn averaged 39.4% cover. On old fields in later succession (70 years after abandonment), common buckthorn averaged only 0.6% cover [37]. Common buckthorn population dynamics in old fields and abandoned plantations in central New York were studied by McCay and others [143,144,145]. Old fields were abandoned 10 to 30 years prior to the study; they had a dense cover of grasses and forbs and sparse cover of shrubs and small trees, of which common buckthorn was among the most abundant. The conifer plantations were planted 35 to 45 years prior and had not been thinned; before planting, they were in agricultural land use. Plantations had many canopy gaps and an "overwhelming number of buckthorn" [143]. Common buckthorn populations in plantations were larger, more evenly distributed, and more mature than populations in old fields or maple-beech forests in this landscape [144]. Common buckthorn is not a universal dominant in abandoned agricultural land, however. Of 483 mesic, abandoned pasture plots surveyed in the Bristol Hills in central New York, common buckthorn dominated 3 plots where quaking aspen and black cherry had high importance values. The author speculated that common buckthorn would eventually be replaced by quaking aspen and black cherry on these sites. Common buckthorn also occurred with hawthorn in shrub-dominated areas on mesic and dry-mesic fields. Most common buckthorn and hawthorn on these sites were in poor condition and shaded by eastern white pine, suggesting eventual replacement of these shrubs by eastern white pine [193].

A study of old-field succession comparing sites that were historically in pasture to those that were historically in cropland in Tompkins County, central New York, found that common buckthorn was more common in abandoned pastures than in abandoned cropland. Common buckthorn was among the most common species in the tree and shrub layer on former pasture sites, occurring in 4 of the 12 sites and contributing ≥20% of the basal area on 1 of those sites; it occurred on only 1 of the former crop sites. Common buckthorn occurred in the ground layer on 10 of the 12 pasture sites and on 5 of the 9 crop sites. The authors suggest that common buckthorn persisted on pasture sites because it is not commonly browsed by livestock (but see next paragraph). Crop sites ranged in age from 12 to about 40 years since abandonment; pasture sites were similar in age with the exception of 2 younger sites (age not given) [208]. A study of 36 farmlands abandoned in the 1970s in southwestern Quebec reveals 2 ecological groups: one comprised of former pasturelands and dominated by spiny shrub vegetation, including common buckthorn, and the other comprised of formerly cultivated fields dominated by either hydric herbs or shrubs. It is not clear whether common buckthorn occurred in the latter ecological group, but it was not among the dominant species. Differences in common buckthorn occurrence and plant community composition between sites was associated not only with land-use history and time since abandonment, but also with abiotic variables (e.g., slope, surface stoniness, drainage), which in turn influence how a parcel of land was most likely used [17].

Despite its common occurrence on abandoned pastureland, some authors indicate that common buckthorn is subject to browsing pressure by livestock and wildlife (e.g., [131,236]), and removal of browsing pressure may increase its importance. Observations in a small permanent pasture in Wisconsin with a history of use by both cattle and white-tailed deer suggest that common buckthorn establishment and persistence may have been facilitated by eastern redcedar acting as a nurse plant and protecting common buckthorn from browsing. Apparently common buckthorn was more palatable to browsers than eastern redcedar. Only the youngest tips of the eastern redcedars were browsed, and the common buckthorn seedlings were able to establish within the dense older growth of these eastern redcedars. Near the middle of each clump, the topmost buds of common buckthorn eventually grew above the reach of browsers and spread into normal crowns, overtopping the eastern redcedars. All common buckthorn individuals had been repeatedly browsed on all branches <4 feet (1.3 m) above the ground, such that remaining branches at that level were very short and densely branched. No other common buckthorn were found in this pasture except 2 individuals that were protected against rocks but were severely browsed and greatly suppressed [236].

Common buckthorn appears to be most abundant in midsuccessional old fields but may persist in later stages of succession on some sites. In a chronosequence study of old field succession in southwestern Ohio, common buckthorn did not occur in 2-year-old, 10-year-old, 90-year-old or 200+-year-old stands. It was present but not common (importance percentage or relative cover ≥5%) in 50-year-old stands dominated by goldenrod and with canopy tree cover of about 30% [222]. A 22-site chronosequence was used to study upland old-field succession in southeastern New Hampshire. Five woody community types were identified ranging from recently abandoned fields to eastern hemlock forests greater than 200 years old. Common buckthorn occurred at low densities in the tall shrub stratum in all types, with the highest relative importance values (<5%) in early- and midsuccessional types. Common buckthorn also occurred in the herb stratum in early-successional and midsuccessional community types [103].

Influence on succession and plant community dynamics: Persistence and spread of common buckthorn in native plant communities may alter plant community composition, stand structure, and successional trajectories in invaded communities. Hobbs [100] suggests that if invasive populations of common buckthorn suppress native tree regeneration, succession may tend toward a more open canopy; whereas, if tree regeneration is not suppressed, succession may lead to a more closed canopy and an eventual loss of common buckthorn. However, it is unclear how long common buckthorn can persist under a closed canopy, and observations of other authors (e.g., [6,74,120,131,140,158,226,243]) suggest that it tolerates substantial shading. Research in Chicago-area oak woodlands [95,96,97] and the University of Wisconsin Arboretum [137] showed altered soil properties under common buckthorn such as changes in soil chemistry, nutrient composition and cycling, and soil fauna and microbial communities, which are likely to impact plant community succession on invaded sites. These changes may have a "legacy effect" that impedes native plant establishment even after common buckthorn is removed [93].

Patches of common buckthorn likely interfere with the establishment and persistence of native shrubs, herbs, and tree seedlings. Alsum [3] found differences in woody species composition between invaded and uninvaded sites along the Lower Wisconsin River. Sites where common buckthorn was present also had higher density of woody seedlings (including common buckthorn), lower herbaceous cover, more weedy and nonnative species, fewer sensitive native plant species, lower density of several native woody species, and greater density of invasive honeysuckles than sites without common buckthorn [3]. While largely anecdotal, several other authors note impacts on native species in communities invaded by common buckthorn [20,31,59,74,90,131,144,232]. Observations by Gourley [74] in Wisconsin indicate that thickets of native shrubs generally had an herbaceous ground layer, whereas thickets of common buckthorn did not. She suggests that because common buckthorn leafs out early and retains leaves late in the season (see Phenological niche separation), there are no seasonal light fluctuations that would allow the germination and survival of tree seedlings, spring ephemerals, and understory shrubs [74]. Where common buckthorn occurs in wetlands, the understory tends to be completely devoid of any other vegetation. It is possible that dense common buckthorn shades out the understory or that white-tailed deer, which tend to congregate in these areas, impede vegetation growth. Areas within the wetland that contain the greatest common buckthorn seedling growth are usually the areas where the typical grass and sedge matrix is absent [74]. Catling and Brownell [31] examined 63 alvar sites in the Great Lakes region that had relatively high native plant diversity. Common buckthorn was especially common among invasive shrub species on the Napanee and Smith Falls plains, where it "has reduced native herbaceous flora" [31].

Dense shade under patches of common buckthorn may interfere with native plants [131,164]. Removal of common buckthorn from Chicago-area oak woodlands resulted in an increase of more than 10% in the openness of the canopy, measured at 5 feet (1.5 m) above the floor (Heneghan and Umek in prep cited by [93]). Packard [164] describes areas in Illinois that were dominated by tallgrass oak savanna in presettlement times and dominated by "an unbroken sea of buckthorn" in the early 1970s. Native plants were lacking and bare dirt was common under the buckthorn [164]. Measurements in oak woodlands at the University of Wisconsin Arboretum showed that light penetration was consistently lower under common buckthorn than in the surrounding forest matrix. However, decreases in native plant cover were not consistently associated with common buckthorn invasion. While herb cover was consistently lower in common buckthorn plots, differences were not significant. Similarly, numbers of woody seedlings were highly variable and showed no significant differences between plots with and without common buckthorn (P>0.05) [131]. Experimental studies of individual common buckthorn shrubs showed no negative effects on understory plants [118,119].

Areas where common buckthorn has invaded may be impacted by a variety of other disturbances that may also affect native plant populations. Study sites in common buckthorn-invaded oak woodlands in the Chicago area, for example, had "a depauperate herbaceous flora". The authors suggest that this was likely due to a combination of fire exclusion, dense shading from invasive woody species, a history of domestic livestock grazing, and an overabundant white-tailed deer population [97]. Along the Lower Wisconsin River, changes in plant community composition in the latter half of the 20th century may be attributed to changes in the flood regime, as well as death of overstory elms from Dutch elm disease, invasion of common buckthorn, changes in land use, and large populations of white-tailed deer [3]. Differential insect herbivory between native and nonnative species may also contribute to increases in common buckthorn associated with declines in native species abundance. Herbivory on 8 native species averaged 4.3% of leaf area lost, significantly more than the 0.8% loss to herbivory on common buckthorn [93].

Evidence of a synergy between common buckthorn and nonnative invasive earthworms, in which each invasive species positively reinforces the population of the other, has been observed in oak woodlands in the Chicago area [92,97] and at the University of Wisconsin Arboretum [137]. Nonnative invasive earthworms were most abundant and had the greatest biomass in subcommunities dominated by common buckthorn compared to those dominated by white oak, northern red oak, or sugar maple [97]. Earthworm populations are responsible for a very rapid incorporation of forest floor material into the soil [58], and earthworms showed a preference for common buckthorn litter in a decomposition experiment [92,97]. As keystone detritivores, invasive earthworms can change seedbed conditions, soil characteristics, plant-herbivore interactions, and flow of water, nutrients, and carbon ([58], review by [137]). Some earthworm species have been linked to declines in native plant diversity and declines in native soil micro- and mesofauna in northern hardwood forests (review by [137]).

Rapid decomposition of common buckthorn litter by earthworms and soil microbes may alter soil biochemistry in invaded sites. Common buckthorn litter decomposed much faster than litter from the native northern red oak overstory at the University of Wisconsin Arboretum [137] or litter from white oak, northern red oak, or sugar maple in Chicago-area woodlands [92,97]. Common buckthorn litter is high in nitrogen and has a low carbon:nitrogen ratio [95,96]. Soils under common buckthorn patches had higher percentages of nitrogen and carbon, modified nitrogen mineralization rates, elevated pH and gravimetric water content, and modified microbial communities compared to uninvaded parts of the woodland [94,95,96]. It has been suggested that these changes might promote growth of common buckthorn seedlings beneath the canopies of conspecifics [74,116,118], whereas the abundance of herbaceous plants in the genera *Aralia*, *Botrychium*, *Osmorhiza*, *Trillium*, *Uvularia*, and *Viola* can be reduced by invasive earthworm populations [58]. Additionally, loss of forest litter may result in the collapse of invertebrate populations that reside in the litter layer [93]. Because invertebrate populations support a large woodland foodweb that includes mammals and birds, the impacts of common buckthorn and nonnative earthworm invasion on native communities may be extensive [92]. Changes in the litter layer with common buckthorn invasion also impact surface fuel characteristics and may impede the use of prescribed fire for management of invaded communities.

A single removal of common buckthorn from invaded areas sometimes allows for native plant establishment (e.g., [20]). However, common buckthorn typically sprouts after top-kill (see Vegetative regeneration), and its seedlings establish from the soil seed bank in disturbed areas (see Germination and Seedling establishment), so it often reestablishes in areas after control efforts (see Control and Use of prescribed fire as a control agent). Other nonnative species may also establish (e.g., [20]). The positive feedback loop between common buckthorn and nonnative earthworms [97] and other changes in soil properties in invaded areas [92] may facilitate reestablishment of common buckthorn following its removal by cutting, chemical treatment, or prescribed fire [97] and retard restoration efforts [92]. After removal of common buckthorn in Chicago-area oak woodlands, populations of earthworms remained high (Heneghan and Umek personal observations cited by [97]), and common buckthorn reestablished and appeared to grow vigorously [97]. However, an experiment at the University of Wisconsin Arboretum in a mixed-hardwood stand dominated by northern red oak in the overstory and common buckthorn in the understory showed a 63% reduction in earthworm abundance the summer following common buckthorn removal (in September 2003 and spring 2004) compared to plots where no common buckthorn was removed. Common buckthorn aboveground biomass was removed again in the late spring of 2005 and 2006. Earthworm abundance in the common buckthorn removal treatments increased over time after the initial reduction, but it remained significantly lower than in control plots throughout the study period ($P<0.10$). However, no recruitment of native woody species was observed in any of the removal plots in 2004 or 2006 [137].

FIRE EFFECTS AND MANAGEMENT

SPECIES: Rhamnus cathartica, R. davurica

- FIRE EFFECTS
- FUELS AND FIRE REGIMES

- FIRE MANAGEMENT CONSIDERATIONS

FIRE EFFECTS:

- **Immediate fire effect on plant**
- **Postfire regeneration strategy**
- **Fire adaptations**
- **Plant response to fire**

Immediate fire effect on plant: Common buckthorn is difficult to burn and may be little affected by fire (e.g., [4,83,164]), especially in areas where surface fuels are too sparse or moist to carry fire. If surface fuels are sufficient, common buckthorn shrubs and trees are top-killed by fire [20,69]. Frequent or high-severity fire may kill common buckthorn shrubs and trees, although no examples of common buckthorn mortality from frequent or severe fire alone were found in the available literature as of 2010. Common buckthorn seedlings have "poorly developed" roots and are killed by fire. At Pipestone National Monument in southwestern Minnesota, spring (mid-April to mid-May) prescribed burning top-killed common buckthorn shrubs and killed common buckthorn seedlings [20].

Common buckthorn seedling establishment after fire [18] indicates that its seeds in the soil seed bank survive and may be scarified by fire. Germination and seedling establishment may increase after fire, possibly due to scarification by fire (although this has not been documented), or because common buckthorn seedling emergence is inhibited by a litter or herbaceous layer [18,65,118] and is increased by soil disturbance [18,65,74]. Prescribed burning in open oak woodlands following common buckthorn removal (by cutting and herbicide application to stumps) reduced common buckthorn sapling survival and plant height but increased common buckthorn seedling density compared to treatments without follow-up burning. Increased light and temperature at the soil surface, due to both litter removal and suppression of sprouting, likely facilitated postfire seedling emergence [18].

Postfire regeneration strategy [207]:
Tree with adventitious buds, a sprouting root crown
Tall shrub, adventitious buds and/or a sprouting root crown
Ground residual colonizer (on site, initial community)
Initial off-site colonizer (off site, initial community)
Secondary colonizer (on- or off-site seed sources)

Fire adaptations: Common buckthorn sprouts from cut or damaged stems [90] or from the root crown following complete top-kill or partial removal such as that resulting from cutting, browsing, herbicide treatments, or burning [4,18,20,71,83,160,181]. Common buckthorn seeds apparently survive and may be scarified by fire, and germination and seedling establishment are improved by postfire conditions (see Immediate fire effect on plant).

Plant response to fire: A single fire is not likely to kill common buckthorn, but its abundance may be reduced by frequent fires. Common buckthorn can be difficult to burn, however [4]. Common buckthorn typically sprouts from the root crown following top-kill from fire [4,20], and sprouts may be prolific [4]. Common buckthorn seedlings are killed by fire [4,20,214], although the age or size at which seedlings can survive and sprout is not clear. Common buckthorn seedling density may increase in the postfire environment. Bare soil and increased light after fire may facilitate common buckthorn seedling establishment [18].

Common buckthorn can persist or establish after a single fire and persists even after frequent fires, although its abundance may be reduced by frequent fires. Common buckthorn either established or persisted after a single fire in an Ontario woodland dominated by northern whitecedar. It occurred on 1 of 5 sites 100 days after a high-severity fire on 23 June 1999. No prefire information was provided [33]. Common buckthorn persisted, but at lower densities in all size classes, after 17 years of annual, dormant-season prescribed fire in an oak woodland at the Morton Arboretum, Illinois [22]. See the Research Paper by Bowles and others [22] for details.

Large common buckthorn individuals may survive fire, while smaller individuals may be top-killed and sprout from the root crown. In a mixed-hardwood forest that developed from a mesic savanna on the Reed Turner Nature Preserve in Illinois, common buckthorn was little affected by a single fire in autumn 1986. Stems larger than 2 inches (5 cm) in diameter showed little initial response to fire, either in mortality or sprouting. About 10% of common buckthorn individuals with 2- to 4-inch (10 cm) diameter stems were top-killed. The first season after fire, common buckthorn sprouting rate was 30 times greater in burned versus unburned plots [4,83]. At Pipestone National Monument, spring (mid-April to mid-May) prescribed burning top-killed common buckthorn but it sprouted [20].

Common buckthorn seedlings are susceptible to fire. Common buckthorn seedlings in the ground-layer vegetation decreased substantially (>50%) after a single fire in autumn 1986 in Illinois mixed-hardwood forest that developed from a mesic savanna [4,83]. Seedlings that survive or establish following removal of adults can be killed by heating until wilted with a propane torch. It is suggested that torching be done during the next growing season to be effective [214], implying that older seedlings may sprout (see Spot-burning). Spring burning at Pipestone National Monument killed common buckthorn seedlings [20].

Only one reference providing insight to Dahurian buckthorn's possible relationship to fire was found in the available literature as of 2010: A 150-foot² (14-m²) old field in the Spicebush Swamp Preserve in West Hartford, Connecticut, burned in 1969. When the area was observed in 1976, *R. davurica* subsp. *davurica* was especially dense and other woody and herbaceous plants were virtually excluded [173].

FUELS AND FIRE REGIMES:

- **Fuels**
- **Fire regimes**

Fuels: As of this writing (2010), none of the available literature specifically addressed fuel characteristics of common buckthorn or Dahurian buckthorn. However, observations and descriptions from study sites where common buckthorn forms invasive populations indicate changes in understory plant and litter composition and abundance (e.g., [3,6,20,31,67,74,85,94,96,97,99,131,164]), suggesting that surface fuel characteristics are altered in invaded stands. Shrub layer fuels may be altered by common buckthorn patches because common buckthorn can be difficult to burn (e.g., [121,164]). However, one study suggests that the shrub layer may become more flammable because of the abundance of dead stems in common buckthorn stands [140].

The understory of dense thickets of common buckthorn in oak-dominated ecosystems tends to have very little surface fuel. The lack of surface fuel impedes fire spread, making it difficult to use prescribed fire to manage these stands [164] (personal communications [67,85,99]). Initial attempts to use prescribed fire to enlarge prairie openings and reduce thickets of common buckthorn-dominated brush surrounding areas of former bur oak savanna in the Chicago area failed, because brush patches did not burn: "Ten-foot grass flames would sear the outer edges, but in the thicket where there was no grass, just green wood and matted leaves, the blaze quickly dwindled and flickered out." Most of the brush that did burn quickly grew back. In spring of 1984, experimental fires under the bur oak, where common buckthorn and Tatarian honeysuckle made up much of the dense understory, were characterized by 4- to 5-inch (10-13 cm) flames with occasional flare-ups in patches of dense fuel. Most of the common buckthorn and honeysuckle were top-killed and, aside from small sprouts, the understory was open: having bare soil and no shrubs. The author notes that compared to prairie, burning in degraded savanna communities with relatively little fuel may require drier, hotter, or windier weather [164].

Several authors have observed that fewer herbs grow beneath common buckthorn patches than beneath native shrubs [3,20,31,74,97,131,164]. Very little litter accumulates beneath common buckthorn patches [6,94,97,119] due to the high nitrogen content and ready decomposition of common buckthorn leaves [92,97], which is facilitated by a synergistic relationship between common buckthorn and nonnative earthworms [92,97,137]. See Influence on succession and plant community dynamics for more information on these topics. Heneghan and others [96] found that the litter layer in more open, buckthorn-free areas had 2 to 6 times greater biomass (depending on the season) than the litter under common buckthorn thickets. The understory of common buckthorn patches seems to be dominated by either common buckthorn seedlings [6,74,144,175,243] and/or bare soil [4,92,164].

Common buckthorn litter decomposes rapidly, and decomposition of mixed-leaf litter is accelerated when common buckthorn leaves are a component. Most common buckthorn litter disappears before it is replenished in fall [74,94] (Steffen and Heneghan personal observation cited by [97]). Under extensive common buckthorn thickets in woodlands around Chicago, the litter layer is typically gone and the mineral soil exposed within the first few weeks of spring [97]. Observations indicated that the forest floor in dense common buckthorn patches has only scattered oak litter. Earthworms showed a strong preference for common buckthorn litter in a decomposition experiment, and >90% of common buckthorn in litter bags allowing earthworm access was consumed in 3 months in areas with high earthworm abundance and biomass (e.g., under common buckthorn patches). Even in the absence of earthworms common buckthorn litter is readily broken down by microbial decomposers because of its unusually high nitrogen content [92]. Common buckthorn litter decomposed more rapidly than sugar maple, white oak, or northern red oak litter, with or without earthworms present [92,97]. Additionally, the presence of common buckthorn litter accelerated the disappearance of litter of other species when leaf litter from multiple species was mixed [94].

Common buckthorn invasion may alter fuel characteristics in the shrub layer. Mascaro and Schnitzer [140] found nearly 7 times the abundance of dead stems in common buckthorn-dominated sites compared to native-dominated sites ($P<0.05$) (see details of Mascaro and Schnitzer's study for descriptions of study sites). The authors suggest that common buckthorn stems are highly combustible and that the high abundance of dead stems may make common buckthorn-dominated sites more prone to fire. They suggest this may promote crown-fire development on some sites. Most of the sites described in their study were small, fragmented stands in close proximity to roads where the risk of human-caused fires may be especially high [140]. Managers at the University of Wisconsin Arboretum, however, have not observed common buckthorn acting as a ladder fuel (personal communication [85]), and instead find that prescribed fire is impeded in common buckthorn patches (personal communications [67,99]). Similar observations were made in invaded prairie and savanna sites in Illinois [121,164].

Fire regimes: Information on fire regimes in plant communities where common buckthorn is native was not found in the available literature as of 2010. Based on its regeneration strategies and observations and studies of invasive populations in North America, common buckthorn is well adapted to survive fire (see Plant response to fire and Use of prescribed fire as a control agent) and persists even when subjected to a regime of frequent, low-severity fires (e.g., [22]).

Much of the following information on fire regimes in oak savannas was compiled from literature reviews in several papers: [4,22,23,24,83,113,125,131].

Common buckthorn seems to be most invasive and/or best studied in oak savannas. Before European settlement, oaks grew in a continuum of fire-adapted communities in central North America [41], and tree densities varied from open prairie with less than 2.5 trees/ha to oak forests with more than 250 trees/ha. Savannas were intermediate along this continuum, and savanna boundaries were dynamically driven by long and short-term climate fluctuations and the frequency and intensity of fires [113]. Fire regimes and postfire successional patterns in oak savannas are complex and difficult to characterize due to variations in stand structures and plant community compositions, which are driven by a number of factors including substrate, geography, climate, and site disturbance history. However, historical accounts and fire scars on old oaks indicate that these communities were maintained by a regime of frequent, low-severity fires in presettlement times. Some presettlement fires in these communities were lightning-caused, but many were probably human-caused [4,22,23,24,83,113,125,131]. Low-severity fire may have occurred nearly every year in dry savannas, but age distribution of trees in distinct cohorts suggests that periodic severe fires were interspersed with several years of low-severity or no fire, allowing recruitment of canopy cohorts [4]. Because young oaks are susceptible to fire, absence of fire for 10 to 20 years may be required for recruitment; mesic species that are more susceptible to fire would not persist in this fire regime [83]. The best example of relict, Midwestern tallgrass savanna found by Haney and Apfelbaum [83] was in a Chicago suburb along a railroad where frequent fire apparently maintained the savanna.

With postsettlement fire exclusion, some savanna types became oak forests, sometimes with dense understories, as oak sprouts grew into trees (e.g., [23,59,113]), and native and nonnative woody species including common buckthorn established, spread, and interfered with native understory plants [4,5,83,113,125,131]. Spread and dominance of mesic trees and shrubs eventually reduces or prevents recruitment of oaks, even from root sprouts [83]. Common buckthorn was introduced to this landscape as a horticultural plant around the same time that fire exclusion began, and its seed was dispersed into these communities by birds that ate common buckthorn fruit and deposited its seed under perch trees and shrubs into a niche that was not suitable for native savanna species that were adapted to the freqent-fire regime [131]. Common buckthorn has established, persisted, and often spread to become a dominant understory shrub in savanna communities where fire has been excluded in the Great Lakes area (e.g., [23,83,113,131]). See Successional Status for more information on common buckthorn's successional role in oak savannas and forests.

When fire is returned to these communities with management programs that include frequent prescribed fire, the abundance of nonnative and native mesic species is typically reduced, and native prairie and savanna associates are favored (e.g., [4,164]). However, additional control measures such as cutting of nonnative shrubs and/or planting of desirable native species is needed to best approximate desired species compositions and stand structures (see Use of prescribed fire as a control agent). Packard [164] declares that tallgrass savanna is a "classic example of a community whose continued existence depends almost entirely on a program of active restoration." Nonnative species such as common buckthorn and garlic mustard (*Alliaria petiolata*) may continue to persist and have the potential to spread without ongoing management (e.g., [22]).

Common buckthorn is sometimes invasive in prairie communities where fire has been excluded (e.g., [15,24,74]). Frequent fires in presettlement times maintained prairie communities by reducing or excluding woody species and favoring native graminoids and forbs, and fire exclusion has allowed native and nonnative woody species to establish and spread in some areas (e.g., [4,5,83,113,125,131]). Prairies managed with frequent prescribed fire are less likely to have established common buckthorn individuals or populations [24,36,74].

See the Fire Regime Table for additional information on fire regimes of vegetation communities in which common buckthorn may occur.

No information was available regarding fire regimes in plant communities invaded by Dahurian buckthorn. Only one description of an invasive population of Dahurian buckthorn was found in the literature available as of 2010, where it occurred in a red maple swamp [173]. Historical fire regimes have not been described for this plant community, but are likely characterized by mixed-severity fires with very long return intervals.

FIRE MANAGEMENT CONSIDERATIONS:

Preventing postfire establishment and spread: In areas where common buckthorn is established, it is likely to persist after fire by sprouting and seedling establishment. Information regarding postfire establishment of common buckthorn in areas where it did not occur before fire is lacking. According to a Vermont Agency for Natural Resources fact sheet, fire may "encourage buckthorn infestation" in some cases [223]; however, no details are provided. Common buckthorn may be dispersed from nearby, off-site sources after fire, especially if perches are available to facilitate dispersal by birds.

Preventing invasive plants from establishing in weed-free burned areas is the most effective and least costly management method. This may be accomplished through early detection and eradication, careful monitoring and follow-up, and limiting dispersal of invasive plant propagules into burned areas. General recommendations for preventing postfire establishment and spread of invasive plants include:

- Incorporate cost of weed prevention and management into fire rehabilitation plans
- Acquire restoration funding
- Include weed prevention education in fire training
- Minimize soil disturbance and vegetation removal during fire suppression and rehabilitation activities
- Minimize the use of retardants that may alter soil nutrient availability, such as those containing nitrogen and phosphorus
- Avoid areas dominated by high priority invasive plants when locating firelines, monitoring camps, staging areas, and helibases
- Clean equipment and vehicles prior to entering burned areas
- Regulate or prevent human and livestock entry into burned areas until desirable site vegetation has recovered sufficiently to resist invasion by undesirable vegetation
- Monitor burned areas and areas of significant disturbance or traffic from management activity

- Detect weeds early and eradicate before vegetative spread and/or seed dispersal
- Eradicate small patches and contain or control large infestations within or adjacent to the burned area
- Reestablish vegetation on bare ground as soon as possible
- Avoid use of fertilizers in postfire rehabilitation and restoration
- Use only certified weed-free seed mixes when revegetation is necessary

For more detailed information on these topics, see the following publications: [27,73,218].

Use of prescribed fire as a control agent: In fire-adapted communities where fire has been excluded and common buckthorn has invaded, repeated prescribed fires may help restore presettlement fire regimes and stand structures and encourage reproduction and persistence of fire-adapted native species. It is often suggested that a regime of frequent fires can reduce common buckthorn abundance in invaded communities [78,90,199], and this has been demonstrated in a former bur oak-white oak savanna community in the East Woods of the Morton Arboretum, Illinois [22]. Adequate fuels must exist for prescribed burning to impact common buckthorn (see Immediate fire effect on plant). Unfortunately, changes in invaded communities due, in part, to common buckthorn invasion may make them difficult to burn (see Fuels and Fire regimes). A fact sheet suggests that seedlings and saplings in dense common buckthorn stands may be cut and left on site, creating fuel for future fires [237]. Repeated fires may facilitate development of the herbaceous fuel layer in some fire-adapted plant communities [76,113], either through establishment from the soil seed bank or with postfire seeding of desirable species. Fire frequency is an important consideration, as annual fires may not allow adequate build-up of surface fuels and may have adverse impacts on litter invertebrates [25]. When used as part of an integrated management approach, fire may help reduce common buckthorn abundance by top-killing existing shrubs and trees and by depleting the common buckthorn seed bank (see Integrated management with prescribed fire).

While some common buckthorn control may be evident after one fire [90], a single fire does not provide effective control [4,20,83,164] unless used in combination with other control efforts (see below). A spring fire in an oak savanna in Minnesota killed common buckthorn seedlings, which were unable to sprout after fire. However, mature trees were only top-killed and survived by sprouting [20]. The first season after a fall prescribed fire in a mixed-hardwood forest (developed from a mesic savanna) in Illinois, common buckthorn seedlings were reduced by more than 50%, but only 10% of 2- to 4-inch (5-10 cm) diameter common buckthorn stems were top-killed. Common buckthorn sprouting rate was 30 times greater in burned versus unburned plots based on averages per tree stem [4,83]. Information on postfire seedling establishment of common buckthorn was not given in this study.

Published management guidelines recommend repeated annual or biennial prescribed fires for 5 to 6 years or more for control of common buckthorn [15,78,90,113,199,237], although none of these authors provide specific examples to demonstrate that frequent fire alone provides effective control of common buckthorn. It is also recommended that frequent fire not be used if the native community would be adversely affected [90]. Prescribed fires can kill common buckthorn seedlings and stimulate the native herbaceous understory. Fire may kill larger common buckthorn saplings, but they typically sprout. Burns conducted on a 2- to 3-year cycle may control common buckthorn but can also kill native woody seedlings [157]. Research in oak woodlands at the Morton Arboretum in Illinois shows that common buckthorn was among the most abundant woody species before and after 17 years of annual, dormant-season prescribed fire. However, density of common buckthorn in smaller size classes was substantially lower on burned sites [22]:

Prefire (1986) and postfire (2002) stem densities of common buckthorn in small size classes in annually burned plots of the East Woods of the Morton Arboretum. Stems <2.5 cm diameter were >1 m tall [22].

Year	Size class		
	<2.5 cm	≥2.5-5 cm	>5-10 cm
1986	1,200	1,680	40
2002	42	20	54

Common buckthorn was among the dominant groundlayer plants in pretreatment plots, with a mean relative cover of 3.24% on burn plots in 1986 (prefire). It was not among the dominant species in the ground layer of burned plots in 2002 [22], suggesting that seedlings were killed and unable to establish in a regime of annual fires. Results of this research indicate that annual prescribed fires can eliminate most shrub and small sapling canopy cover, increase canopy openness, and promote greater richness and cover of forbs. Tradeoffs include a loss of native vines, shrubs, understory trees and forest interior bird habitat, as well as persistence of nonnative plants including common buckthorn and garlic mustard. See the Research Paper by Bowles and others [22] for details of this study. Additional research in the same study sites shows significantly fewer springtail species in areas burned annually for 16 years ($P<0.01$), though the effects of fire on springtail density varied among individual species. To maintain the richness of litter invertebrates in areas where prescribed fire is used, the author suggests burning every 2 or 3 years instead of annually, and/or creating refuge areas (unburned patches) to enhance invertebrate survival [25]. After 10 years of adaptive management using prescribed fire and seeding of native species, Packard [164] notes that frequent fire is an essential part of savanna restoration, but many sites need to be seeded with desirable native species because the native seed bank is depleted (see Integrated management with prescribed fire for details).

Few examples were available in the published literature (as of 2010) of the effects of frequent prescribed fire alone to reduce common buckthorn abundance. In several historic oak savannas in northern Illinois, Indiana, and southern Wisconsin, controlled fires reduced the number of nonnative or mesic species and favored occurrence of prairie and savanna associates. Shrubs and mesic trees were reduced, and cover and richness of herbaceous ground layer species increased. Periodic fire also appeared to favor richness of birds, insects, and spiders. For savanna restoration, the authors suggest relatively frequent fires for several years followed by less frequent burning, with a 5- to 10-year gap, to allow recruitment of new canopy cohorts and to maintain savanna species [4]. At Pipestone National Monument, backfires in early May 1985 injured some small common buckthorn trees (10-15 feet (3-4.5 m) tall and ≤1 inch (2.5 cm) in diameter). The authors suggest that repeated burning would eventually eliminate most common buckthorn in rock outcrop areas [15]. However, prescribed spring burns conducted annually for 5 years from mid- to late April (when cool-season grasses had initiated growth) resulted in no appreciable change in common buckthorn cover, although a few individual common buckthorns were sensitive to fire. Cover of common buckthorn was as follows:

1983: spring 1.4%, summer 2.0%
1984: spring 0.9%, summer 3.0%
1985: spring 2.6%
1987: summer 2.4% [14].

At the Grady Knolls Forest (dominated at the time by hybrid black oak (*Q. velutina* × *Q. ellipsoidalis*)) in the University of Wisconsin Arboretum, 2 consecutive years of prescribed fires followed by a year with no fire resulted in a decrease in cover of common buckthorn in each of the burn years, followed by a slight increase in the no-burn year. The prefire shrub layer consisted of nearly continuous, almost impenetrable Bell's honeysuckle and common buckthorn, and the ground layer was sparse. Prescribed fires were carried out under the following conditions [113]:

Burn date	16 April 1990	17 April 1991
Air temperature	50 °F (10 °C)	50 °F (10 °C)
Relative humidity (%)	50 to 55	50 to 55
Wind direction/speed	SW 5 to 12 mph	NE 5 mph
Flame heights	15 to 30 cm	15 to 30 cm
Area burned (%)	50	60-70

Before the first prescribed fire, mean cover of common buckthorn and Bell's honeysuckle (combined) was 85%. The 1st fire reduced nonnative shrub cover to 56% and the 2nd to 38%. The following year there was a slight increase, to 41%. Most of the nonnative shrubs sprouted from the base, but the sprouts were not very "vigorous". Some dead honeysuckles were observed in 1992, but no dead common buckthorn were reported. Hybrid black oak density decreased; there was a large reduction in the number of black oak, white oak, and black cherry saplings; and diversity of the ground layer increased. The authors concluded that prescribed fire can suppress common buckthorn and Bell's honeysuckle, and encourage a more diverse ground layer dominated by native species with enough biomass to help fuel the fires. Eventually, repeated prescribed fires may deplete the root reserves of common buckthorn and Bell's honeysuckle (see Fire timing below), so that sprouting will be the exception. The management plan is to continue prescribed burns to mimic natural processes in oak woodland, not necessarily for eradication of nonnative shrubs [113].

Fire timing: Control treatments for common buckthorn, including prescribed fires, may be most effective if timed to correspond to periods of low levels of root carbohydrates (see Underground phenology). Personal communications from county park managers in Minnesota suggest that the best time to conduct prescribed burning in oak-dominated woodlands where common buckthorn occurs is between late March and early May, when weather conditions are conducive for burning (i.e., low soil moisture, high litter density, less windy conditions, lower native plant density) (Moriarty and Evenson 2001 personal communication cited by [18]). It has been suggested that because common buckthorn's leaves emerge earlier than most native species, and root carbohydrate levels are assumed to be low at that time, a late April or May prescribed fire (when common buckthorn is actively growing, but most native plants are not) is most effective for common buckthorn control (e.g., [15,36]). However, burning may not be possible at these times because groundlayer fuels are sparse [15]. When control treatments (cutting plus herbicide, or cutting alone) were compared across seasons, spring and summer treatments resulted in 4 to 8 times more common buckthorn sprouts in July than when treatments were applied in either fall or winter ($P<0.05$). Common buckthorn seedling densities in July were similar. Based on reports of seasonal changes in total nonstructural carbohydrates in root tissues, the author suggests cutting during flowering or early fruit development, when carbohydrates are sequestered in these structures. Cutting also interrupts fruit development, thereby reducing seed dispersal and input into the seed bank [18].

Integrated management with prescribed fire: Fire alone, even when repeated annually, does not seem to provide adequate control of common buckthorn. Control may be improved by seeding of native species after prescribed fire, or by using prescribed fire in conjunction with cutting and herbicide treatments.

In areas where dense patches of common buckthorn and other woody species have persisted for many decades, it is likely that the native seed bank has been depleted and that native species will not establish after brush removal. Packard [164] reports on 10 years of work to restore native tallgrass prairie and oak savanna communities in the Chicago area. In spring of 1984, burning in the understory of a bur oak grove, composed mostly of common buckthorn and Tatarian honeysuckle, resulted in top-kill of most common buckthorn and Tatarian honeysuckle. Aside from small sprouts, the understory was entirely open. However, very few seedlings established from the seed bank that summer. After a second, "much hotter" fire and a second summer, only a few seedlings of weedy forbs such as Canada thistle (*Cirsium arvense*), bull thistle (*C. vulgare*), dandelion (*Taraxacum* spp.), and burdock (*Arctium* spp.), established, and they were "increasing exponentially". Seeding native species after fire, using different seed mixes each year until the best mix was found, eventually gave desired results. After 10 years of adaptive management using prescribed fire and seeding of native species, Packard [164] notes that burning once or twice every 3 years is important in the early years of savanna restoration, and that many sites must also be seeded with desirable native species.

A combination of cutting and prescribed burning may control common buckthorn better than prescribed burning alone [78], although common buckthorn may persist indefinitely even with this intensive management approach (e.g., [112]). In plots where common buckthorn was removed and annual prescribed fires were used to control common buckthorn seedlings, herbaceous diversity was twice that of unmanipulated plots. However, some native woody plants were negatively impacted by fire (Moriarty personal communication cited by [116]). Common buckthorn occurred with multiflora rose and gray dogwood in old fields that were being maintained as grassland bird habitat at the Montezuma National Wildlife Refuge in Seneca Falls, New York. A treatment that reduced common buckthorn in grasslands consisted of a late spring mowing, allowing cut fuels to cure, and then a late summer fire. Growth rate of common buckthorn sprouts was slower on August-burned plots than on unburned plots or spring-burned plots. Effects may be short-lived, however. Nonstructural carbohydrates in common buckthorn declined after cutting, mowing, or burning treatments but recovered within 1 year [181]. At Wolf Road Prairie, an 82-acre (33 ha) native tallgrass prairie in suburban Chicago, prescribed fires are conducted periodically in spring and fall to control woody shrubs such as common and glossy buckthorn, gray dogwood, and boxelder; and to clear dead winter underbrush, release minerals, and "stimulate" prairie plants. Common buckthorn, Japanese honeysuckle, gray dogwood, and boxelder "do not burn very well", so they are cut with a sickle bar mower before burning. Observations suggest that the diversity and numbers of prairie forbs and grasses have increased in response to these and other management actions begun in the

1970s [121]. Common buckthorn persisted in bur oak savanna in central Minnesota that was managed for 20 to 30 years with a combination of prescribed burning and physical and/or chemical removal of common buckthorn, eastern redcedar, and American elm [112]. No data on common buckthorn abundance were provided, and it is unclear when common buckthorn established on this site.

Management initiated in 1989 on oak woodland sites in Cook County, Illinois, included prescribed burning and cutting and removal of woody plants. Prescribed fires were applied to the site at irregular intervals in either fall or spring. The season of the fire was held constant for each area. Half the study areas were burned once in 7 years; the remaining areas were burned either 2 or 4 times in 7 years. Vegetation was surveyed in 1988 and 1995. On managed sites, nonnative shrubs decreased by 3,139 stems/ha, and native shrubs decreased by 2,635 stems/ha. Common buckthorn decreased from an average of 292 stems/ha in 1988 to 33 stems/ha in 1995. Common buckthorn was not as abundant on the unmanaged site, where common and glossy buckthorns were recorded at the genus level. Density of woody species in all size classes increased and invasive shrubs increased substantially. In the suppressed layer (stems <4.6 feet (1.4 m tall), there were 1,090 buckthorn stems/ha in 1992, and 5,590 buckthorn stems/ha in 1995. The authors note that all were glossy buckthorn in this layer in 1995. In the intermediate layer (stems >4.6 feet (1.4 m) tall but <4.3 inches (11 cm) DBH), 31 buckthorn stems/ha were recorded in 1992, and 205 stems/ha were recorded in 1995. Of those recorded in 1995, 9 were common buckthorn and 196 were glossy buckthorn [122].

Studies on 2 sites at the University of Wisconsin Arboretum [191,192,238] followed the response of common buckthorn and other invasive shrubs to various combinations of prescribed burning, cutting, herbicide application, and planting of native species. Invasive shrubs were removed by cutting and herbicide application on both sites between 1992 and 1996. A case study from Lost City Woods suggests that a combination of prescribed burning and planting of groundlayer species may limit common buckthorn reestablishment after removal with cutting and herbicide. Three treatments were evaluated to control common buckthorn reestablishment after initial removal: 1) burning followed by planting with groundlayer species, 2) burning only, and 3) planting only. On 12 November 1996, low-intensity prescribed fires were conducted in burn plots; 2 weeks later, a woodland-savanna mix was hand-seeded into planting plots. That winter, midstory trees were removed to increase the amount of light reaching the ground. In September 1997 burned and planted plots had the fewest common buckthorn seedlings and the greatest abundance of ground-layer species. The untreated control plot had 191 common buckthorn seedlings, the planted-only plot had 143, the burned-only plot had 99, and the burned and planted plot had 6 common buckthorn seedlings. These results suggest that common buckthorn seedlings are susceptible to burning and that fire may facilitate establishment of planted native species. The planted native species also provide surface fuel for future fires [192].

Two additional studies were conducted on the Lost City site and another site, the Grady Kettle Hole Forest, where invasive shrubs had been removed by cutting and herbicide application between 1992 and 1996 [191,238]. Common buckthorn cover and abundance did not differ among 4 treatments (thinning, prescribed burning, deer exclosure, and planting native herbs) at the Lost City and Grady sites, although a combination of thinning and burning was potentially more effective at reducing common buckthorn cover than thinning alone. Thinning alone resulted in the greatest height of nonnative woody seedlings ($P<0.05$), while other treatments produced results similar to those of controls. Percent cover of planted grasses and forbs was significantly greater in thinned-and-burned plots compared to thinned-and-unburned and control plots ($P<0.01$) [238].

Using the same plots and similar treatments as Willert [238], Scriver [191] found similar results. Plots were burned in fall of 1997 and 1998 at both sites [238] and in spring of 2000 at Lost City and spring of 2000 and 2001 at Grady, and vegetation was sampled from July to September 2000 and 2001. Fire details were as follows [191]:

Site	Lost City	Grady Kettle Hole	
Burn date	3 May 2000	3 May 2000	2 May 2001
Air temperature (°F)	mid 70s	mid 70s	81
Relative humidity (%)	38	38	63
Wind direction and speed	SW at 5 to 10 mph	SW at 5 to 10 mph	no data
Flame heights	2 feet	4 feet	no data

Fuel consumption	90% of the fuel consumed in 81.3% of the plots	100% of the fuel in 15 of the 16 subplots, and 95% in the remaining subplot	90-100% of the fuel consumed in 38% of the subplots and 65-90% of the fuel consumed in 31% of the subplots

None of the restoration techniques studied, alone or in combination, prevented reinvasion of common buckthorn. Tree-canopy thinning was the most likely to lead to common buckthorn reinvasion: the average percent cover and average maximum height of common buckthorn increased in thinned plots. Prescribed burning reduced average common buckthorn cover and height on the Grady site in both years ($P<0.05$). Differences in stem density were not significant at either site in either year. Planting and white-tailed deer exclusion had no significant influence on common buckthorn reinvasion [191].

Prescribed burning in April 2001 following cutting and treating stumps of seed-bearing common buckthorn shrubs with triclopyr in winter 2000 reduced common buckthorn sapling survival and plant height but increased common buckthorn seedling density during the first posttreatment growing season at Battle Creek Regional Park, Minnesota. However, removal of seed-bearing common buckthorn shrubs without follow-up burning also increased common buckthorn seedling densities. Results of additional studies from 2002 to 2004 at Battle Creek and Eagle Lake regional parks suggest that burning in addition to cutting with and without herbicide treatment suppressed common buckthorn sprouting but increased common buckthorn seedling establishment. The author suggests that because burning removed surface litter and suppressed sprouting, soil temperatures and light availability to the soil surface were increased, and this facilitated seedling emergence [18].

Common buckthorn seedling density, sprouts, and density of other species about 15 months after control treatments. Data are means averaged across 2 sites [18]

Treatments	Common buckthorn seedling density (plants/ha)	Common buckthorn sprouts (#/root crown)	Density of other species (plants/ha)
Treated in spring 2002 and measured in July 2003			
C+S+B*	3,226a**	0.0a	6,720
C+B	2,957b	0.6c	3,226
C+S	1,075c	0.0a	2,151
C	1,075c	1.7d	2,151
Untreated	1,075c	0.5b	2,151
Treated in spring 2003 and measured in July 2004			
C+S+B	5,376a	0.0a	20,296a
C+B	4,301b	1.8c	13,710b
C+S	2,688c	0.0a	5,376c
C	1,075d	4.6d	5,376c
Untreated	1,075d	0.5b	5,376c

*C=cutting, S=stump treatment with triclopyr, B=burning
**Values within the same column in the same treatment year followed by different letters are significantly different ($P<0.05$).

Common buckthorn was the dominant nonnative plant species at both Battle Creek and Eagle Lake sites, comprising 75% of all understory species before control treatments. Plots treated with prescribed fire had higher seedling densities of both common buckthorn and other plant species (including herbaceous weeds and native species) than those that were not burned. Native seedlings that emerged after burning included oak, white birch (*Betula papyrifera*), pin cherry (*Prunus pensylvanica*), and black cherry [18].

Common buckthorn response to integrated management with prescribed fire is likely to vary among sites. Restoration efforts at Santa Fe Prairie, a prairie remnant in northeastern Illinois, included fire management and herbicide application to cut stems. In 2003, after 5 years of restoration efforts, common buckthorn frequency did not change on dry-mesic prairie sites. Common buckthorn occurred at 23.81% frequency in 1998 and 25.0% frequency in 2003. However, common buckthorn frequency decreased slightly on mesic prairie sites, from 12.5% frequency in 1998 to 5% frequency in 2003 [24].

Spot-burning: Common buckthorn seedlings, saplings, and sprouts may be controlled by spot-burning with a propane torch the first growing season after dormant-season removal of mature plants [214]. However, spot-burning immediately after cutting does not prevent sprouting [6]. A 5 to 10 second flame torch application around the common buckthorn stem kills the cambium of stems less than 1.8 inches (4.5 cm) in diameter [15]. Once adult common buckthorn have been removed from an area it is likely that large numbers of seedlings, a few saplings that were missed, and some sprouts from cut-stumps will establish or persist in the next growing season. Spot-burning individual plants or groups of plants (or a small area) has 2 advantages: 1) the torches can be used in areas where there is little or no fine fuel to carry prescribed fire, and 2) the torches can be used during wet or otherwise unsuitable weather for prescribed burning. Torching seedlings until wilting occurs is usually sufficient to kill them; it is not usually necessary to torch seedlings to ash (although this is more satisfying). Torching seedlings and saplings at the stem base rather than the entire plant may be most efficient. Usually one treatment removes most seedlings/saplings, but repeated treatments in the same or next growing season may be necessary due to seed bank input or sapling sprouts. Seedlings are not usually capable of sprouting if torched in the first growing season (before August) [214]. An experiment near Saskatoon, Saskatchewan, compared follow-up treatment of stumps with herbicide to follow-up treatment with a propane torch immediately after cutting aboveground stems. Each of 120 randomly selected common buckthorn shrubs or trees was cut off at the base and subsequently girdled with a propane torch for 2 to 3 minutes. The propane torch applied a temperature of approximately 1,800 °F (1,000 °C) to the cambium layer. Sprouts emerged from fire-treated stumps in the spring and developed "vigorously". The new leaves were larger than those on untreated shrubs, and the crown was also denser than on untreated individuals of similar size. Some of the chemicals tested were more effective than burning [6]. See Chemical control for more details on this method. Detailed operational guidelines for use of propane torches are provided in the Weed Control Methods Handbook, Appendix 2.3 [214].

Altered fuel characteristics: A lack of groundlayer herbaceous species under dense common buckthorn patches and the rapid decomposition of common buckthorn leaf litter due, in part, to its association with nonnative earthworms, often results in bare ground under invasive patches of common buckthorn (see Fuels and Influence on succession and plant community dynamics). In oak-dominated ecosystems that were once maintained by frequent fires, surface fuels consisted largely of oak leaves. In invaded oak stands, common buckthorn leaf litter decomposes much more rapidly than oak leaf litter and increases the decomposition rate of mixed-species litter when it is a litter component [94], especially in the presence of nonnative earthworms [92,97,137]. These changes in surface fuel characteristics brought about by common buckthorn invasion make invaded communities very difficult to burn. Managers at the University of Wisconsin Arboretum report that fire does not carry well in areas where common buckthorn has invaded, largely because of the lack of surface fuels and the generally cooler, moister microclimate under the dense shade of common buckthorn thickets (personal communications [67,85,99]). Differences in phenology between common buckthorn and native species could theoretically affect fire seasonality, rendering a community more or less flammable during particular seasons. For example, common buckthorn leafs out earlier than native vegetation and retains its leaves later into autumn. This topic deserves further study [47].

MANAGEMENT CONSIDERATIONS

SPECIES: Rhamnus cathartica, R. davurica

- FEDERAL LEGAL STATUS
- OTHER STATUS

- IMPORTANCE TO WILDLIFE AND LIVESTOCK
- OTHER USES
- IMPACTS
- CONTROL

Three extensive literature reviews on common buckthorn [116,120,175] provided substantial information on its distribution, biology, ecology, and management and were used throughout this review. Some information in the following sections was also compiled from reviews in the following manuscripts: [43,74].

FEDERAL LEGAL STATUS:
None

OTHER STATUS:
As of 2010, common buckthorn was listed as a noxious weed in Connecticut, Iowa, Massachusetts, Minnesota, New Hampshire, and Vermont in the United States, and in Ontario and Manitoba in Canada [175]. Information on state-level noxious weed status of plants in the United States is available at Plants Database.

IMPORTANCE TO WILDLIFE AND LIVESTOCK:
Common buckthorn is not a preferred browse species for wildlife and livestock, partly because of its spine-tipped branches [175], but it may be heavily browsed in some plant communities (e.g., [236]). Obvious avoidance of common buckthorn by native wildlife was noted at Sutherland Beach in Saskatoon. Although common buckthorn stems greatly outnumbered native stems, they remained untouched while 32 chokecherry stems and 2 Saskatoon serviceberry stems had been girdled over the winter [45].

Mammals:

Food: Common buckthorn does not appear to be a major food source for mammalian herbivores [116], but it may be used in some plant communities. Common buckthorn was not used by white-tailed deer in a deer yard in southwestern Quebec from 1985 to 1986, when several other deciduous hardwood shrubs were available for browse [28]. Common buckthorn occurred in browsed, but not in fenced areas in Sharon Woods Metro Park, Ohio [8]. However, observations in Wisconsin suggest that white-tailed deer, and probably cattle, preferred common buckthorn over eastern redcedar [236] (see Old-field succession for details).

A review by Knight and others [116] notes cases where common buckthorn saplings were avoided by eastern cottontail and American beavers. On a 3-acre (1.2 ha) site in western Massachusetts, common buckthorn received only a trace amount of feeding injury from eastern cottontail during the winter of 1947 to 1948 [211]. Common buckthorn seedlings were damaged or killed by unknown herbivores in old fields in New York [65] and by spring browsing by rabbits in England; few common buckthorn individuals were damaged in summer and fall [79]. Mice and other rodents may consume common buckthorn seeds in some locations (see Seed predation).

Cover: Common buckthorn thickets in wetlands at the University of Wisconsin Arboretum appear to be favored places for white-tailed deer [74]. Apparently, buckthorn thickets are favored places for deer herding in Europe, too. It is thought that the name buckthorn may have arisen in Europe, where it provides shelter for the male deer or bucks (USDA Forest Service 1937 as cited by [74]).

Birds:

Food: Accounts of the palatability and consumption of common buckthorn fruits vary. Consumption likely depends on availability of other food sources. Some authors suggest that common buckthorn fruits are readily eaten [90] and quickly scattered [55] by birds, while others note that common buckthorn fruits persist on bushes and may be unpalatable [70]. Observations of dried fruits remaining on shrubs until late winter or spring when all more palatable fruits of other species have been consumed [71,175] suggest that common buckthorn fruit is used as a food of last resort [175]. The rate of common buckthorn fruit removal by birds is related to their preference for its fruit relative to that of cooccurring shrubs. For example, the order of preference in old fields in Tompkins County, New York, is Allegheny blackberry>gray dogwood>southern arrowwood (*Viburnum dentatum*)>>>common buckthorn>staghorn sumac (*Rhus typhina*) [65] (see Seed dispersal).

Several species of birds consume common buckthorn fruits and disperse its seeds. Lindsey (1939 as cited by [32]) reported that common buckthorn formed 8.3% of the food of European starlings in New York in November. Cedar waxwings are potential dispersers around Saskatoon [6], while American robins and cedar waxwings appear to be the main dispersal agents of common buckthorn in the University of Wisconsin Arboretum [74]. Common buckthorn seeds occurred in feces of thrush in New Jersey; seed viability was not reported. Common buckthorn did not occur in stomach samples of any bird species [233], and no feeding was observed on common buckthorn in this study [234]. Knight [118] provides a list of birds observed feeding on or nesting in common buckthorn in Europe and North America.

Cover: Common buckthorn growth form includes many, more or less horizontal branches and twigs that are likely to be attractive to perching birds [119] or suitable for nest construction for many songbird species. In a wooded habitat at the Morton Arboretum in Lisle, Illinois, nests of several birds including wood thrushes, catbirds, American robins, northern cardinals, rose-breasted grosbeaks, blue jays, and red-eyed vireos occurred in either common buckthorn or nonnative honeysuckles. The authors speculated the nonnative shrubs were chosen for nest sites because the height and branch structure were suitable for nest building, and because there was a lack of native shrubs [231]. In eastern Canada, loggerhead shrike nests were located in common buckthorn, although infrequently (<10% of nests observed) [34]. Common buckthorn was one of the most common plant species used in nests of European starlings in a study in southern Germany [81]. The only 2 bird nests in the hundreds of common buckthorn trees observed in the University of Wisconsin Arboretum appeared to be those of the marsh wren [74]. Nests in common buckthorn may experience higher rates of predation than nests in native shrubs (e.g., [190], see Impacts). Although common buckthorn has dense growth to the ground level and does not provide "the best" cover for northern bobwhite, it is listed among plants "potentially useful" for improving northern bobwhite habitat in northwestern Oklahoma [86].

Insects: Many species of insects associate with common buckthorn in Europe, and several species of moths and psyllids seem to use it exclusively. In North America some generalist insects feed on common buckthorn [116], but common buckthorn seems to experience less herbivory than cooccurring native plants [93]. More insect herbivores were associated with common buckthorn in Europe than in Canada. Nearly all herbivorous insects associated with Rhamnaceae in Europe and Canada were either Lepidopterans or Hemipterans; Coleoptera found on Rhamnaceae were not usually species-specific. Plant feeders such as Say's stink bug and the eastern tent caterpillar were observed feeding on leaves of common buckthorn at 3 locations in London, Ontario, in 1995 [175]. Green stink bugs use common buckthorn for food and habitat. They lay eggs on the undersides of the leaves and spend a large part of their life cycle on common buckthorn plants. For more information on the life cycle and phenology of green stink bugs on common buckthorn and other hosts in Quebec, see Javahery [107]. Van Veldhuizen and others [221] provide a survey of insect fauna on common buckthorn in 7 sites in southeastern Minnesota. Many insects may be deterred by the emodin content in the roots, fruits, seeds, bark, and foliage of common buckthorn [175].

Earthworms: Large densities of the European nightcrawler (*Lumbricus terrestris*) may be related to the presence of common buckthorn. See Fuels and Influence on succession and plant community dynamics for more information on this topic.

Nutritional value: Very little information was found in the available literature regarding the nutritional value of common buckthorn. The chemical composition of common buckthorn fruits was described as follows [86]:

Chemical composition (%) of common buckthorn fruits in western Oklahoma [86]						
Ash	Protein	Fat	Fiber	Nitrogen-free extract	Calcium	Phosphorus
2.58	21.79	23.88	20.16	31.59	0.55	0.248

The emodin content in the roots, fruits, seeds, bark, and foliage of common buckthorn has a laxative effect and may deter herbivores and frugivores [175].

OTHER USES:

Both common buckthorn and Dahurian buckthorn have historically been used medicinally and as a source of dye [242]. Substances in the bark, leaves, and fruits of common buckthorn are known to have strong purgative effects if eaten [200], and the fruit has been used for treating constipation [159,242]. A review by Qaderi and others [175] notes that parts of the common buckthorn plant have historically been used medicinally as a laxative and cathartic and to treat a number of other ailments including dropsy, gout, rheumatism, chronic skin diseases, and liver disorders; and extracts of common buckthorn exhibited antibacterial properties.

The bark and dried fruits of common buckthorn have been used as a source of yellow and saffron-colored dyes, and the fruit juice, when combined with alum, produces a green dye, once used by water-color artists [74,159,175]. The bark and fruit of Dahurian buckthorn are used for making a yellow dye [242].

The bark of common buckthorn is rich in tannin and was used as a tanning agent. The wood is marble-like with close grains and reddish veins. It is used in woodwork and carpentry. In Russia it has been used for ornamental art wares and plywood [74,175]. Common buckthorn wood is marketed in the United States because the yellow sapwood encircling rich orange heartwood has ornamental value [45]. The hard wood of Dahurian buckthorn has also been used for making furniture, and oil has been extracted from the seeds for lubricating oil [242].

Common buckthorn has been used as an ornamental in gardens, parks, and hedges [175], and both common buckthorn and Dahurian buckthorn were once recommended for shelterbelts because they are hardy and grow well on a variety of soil types [62,63]. Additionally, common buckthorn was recommended because it holds its leaves late in the fall, tolerates some shading, grows fast and produces an attractive hedge that is easy to culture [74].

IMPACTS:
Invasive populations of common buckthorn may impact plant community composition and structure, leaf litter decomposition, nutrient cycling, and soil biota. See Influence on succession and plant community dynamics for more information on these topics. Knight and others [116] suggest that the magnitude and direction of effects of common buckthorn on native plants and animals in invaded ecosystems in North America are not well understood, and more research is needed in this area. Isolating and quantifying the effects of common buckthorn invasion is complicated by the impacts of other changes in invaded communities including anthropogenic disturbances, the presence of other nonnative invasive plants, Dutch elm disease, white-tailed deer overpopulation, nonnative earthworm invasion, altered flooding regimes, and climate change [3,82,97,116]. Although Dirr [48] has seen Dahurian buckthorn "literally consume waste areas", no information was available as of this writing (2010) on the impacts of Dahurian buckthorn on native communities.

Invasive populations of common buckthorn may impact native animals, especially birds. Although birds consume common buckthorn fruits and the shrubs provide nesting sites (see Birds), similar native shrubs likely provide better nesting sites. On a site in an urban reserve outside Chicago, American robin nests in common buckthorn experienced higher rates of predation than nests in hawthorns. Common buckthorn lacks the sharp thorns that characterize hawthorn, which may increase nest predation. Predation of wood thrush nests was lower in common buckthorn than in native viburnum, but predation was similar to that in hawthorns and native tree species such as maples, hophornbeam, and plums [190].

Common buckthorn is considered a poisonous plant in the United States and Canada [175], and Dahurian buckthorn is also said to be toxic if ingested [43]. Common buckthorn bark, leaves, and fruits are strongly purgative when consumed. Other effects include nausea, stomach cramps, gastroenteritis, diarrhea, and irritation of the gastrointestinal mucosa to the point of bleeding. Poisoning is rare but has been reported in Europe. Consumption of common buckthorn in sufficient quantity causes poisoning in cattle, reduces milk quantity and quality, and even affects the meat [175]. Following an outbreak of an idiopathic neurological disease in horses in Illinois, common buckthorn was identified as a possible cause, and a study was undertaken to assess its toxicity in mice. Researchers found that compounds in common buckthorn interfered with glycogen metabolism, causing abnormal changes in liver cells. The authors concluded that common buckthorn could not be ruled out as a cause of the neurologic disorder in the horses, and that further research was needed to determine whether liver injury in mice would progress [132]. No additional studies on this topic were found as of 2010.

Common buckthorn is an overwintering host for 2 invasive crop pests, oat crown rust (*Puccinea coronata*) and the soybean aphid (*Aphis glycines*). Oat crown rust infestations tend to be more severe in oat crops located near common buckthorn plants, and removal of common buckthorn in the vicinity of oat fields has long been recommended for reducing the severity of rust infection [175]. The nonnative soybean aphid first appeared in Wisconsin in 2000, and within 4 years, it spread to 21 states and 3 Canadian provinces, putting more than 60 million acres (24 million ha) of soybean at risk to crop injury. Common buckthorn occurs over much of this area. In China and Japan, the most common overwintering hosts for the soybean aphid are Dahurian buckthorn and Japanese buckthorn (*Rhamnus japonica*). Dahurian buckthorn would likely be a primary host for soybean aphid in North America; however, Dahurian buckthorn is so uncommon in the soybean production areas that it is unlikely to be an important host [176]. Heimpel and others [91] provide a detailed discussion on the interactions of common buckthorn and the soybean aphid, discuss how these 2 organisms are components of an extensive invasional meltdown in North America, and discuss management issues surrounding these and 9 other cofacilitating Eurasian species.

Based on perceived or observed impacts, common buckthorn has been classified as a pest plant in several states and provinces:

Pest plant classification of common buckthorn in several US locations		
Location	Classification	Definition
Minnesota	Restricted noxious weed	Importation, sale, and transportation of plants or propagating parts is illegal in the state [151]
Missouri	Category A-3 plant	Plant species that are invading and disrupting native plant communities in 10 or fewer Missouri counties [152]
Tennessee	Watch List B	Nonnative plant species that are severe problems in surrounding states but not yet reported in Tennessee as of 2001 [213]
Vermont	Class B noxious weed	Nonnative species that are known to occur in Vermont and are considered to pose a serious threat. The movement, sale, and/or distribution of these plants are prohibited [223]
Eastern Region	Category 1 plant	Nonnative, highly invasive plants which invade natural habitats and replace native species [216]

In a survey of 60 land managers in Wisconsin, common buckthorn was one of the most frequently reported nonnative plants, and it was ranked among those having the greatest impact (3rd out of 66). It was perceived to be difficult to control and spreading on both recently disturbed and relatively undisturbed sites [179]. Common buckthorn was considered a "high" priority on the Ottawa National Forest in northern Michigan, where it occurred on 14 known sites with a total known infested area of 3 acres as of May 2005 [217]. Common buckthorn was rated among the "3 most important established and widespread invasive plants that warrants research" by 13% of land managers surveyed in the Midwest (Iowa, Illinois, Indiana, Michigan, Minnesota, Missouri, Ohio, and Wisconsin); however, less than 7% of researchers surveyed included common buckthorn in the top 3 [180]. Common buckthorn is one of several plants "voted as" invasive by the Massachusetts Invasive Plant Advisory Group [141].

Allelopathy: Secondary compounds, particularly emodin, have been found in many buckthorn species including common buckthorn [116]. It has been suggested that these compounds may contribute to invasion success. For example, emodin may deter insects and other herbivores from eating common buckthorn leaves, bark, and fruits, protect plants from pathogens and high light levels, have allelopathic effects on nearby plants, affect soil microorganisms, and affect fruit consumption and digestion by birds (Izhaki 2002 as cited by [116]).

Evidence for allelopathy from common buckthorn exudates is not consistent. Archibold and others [6] found no reduction in germination of crop seeds exposed to leachates from common buckthorn leaves. Conversely, Seltzner and Eddy (2003 as cited by [116]) found that common buckthorn leaf exudates reduced alfalfa (*Medicago sativa*) seed germination by 42%, and fruit exudates reduced germination to <1%; and Vincent (2006 as cited by [175]) found that common buckthorn fruit extracts reduced germination in crop seeds, and common buckthorn fruit debris reduced growth of crop seedlings. It has been suggested that emodin in common buckthorn fruits could adversely affect growth of native plants beneath common buckthorn canopies and that these effects may vary seasonally as well as among individual common buckthorn trees (Wilson personal communication cited by [116]). A review by Knight and others [116] suggests that more research is needed to understand the ecological significance of secondary chemicals in common buckthorn.

No information was available regarding allelopathy in Dahurian buckthorn (as of 2010).

CONTROL:
Common buckthorn management efforts in Minnesota, which may be applicable throughout its distribution, indicate that treating a site to control common buckthorn using one or a combination of control methods is the first step in a long, continual process. Sites need to be visited on an annual basis, checked for missed trees, and searched for reestablished saplings and seedlings. The amount of time and effort needed for retreatments will decline over time, but common buckthorn is likely to reestablish if not monitored and controlled. Common buckthorn cannot be eliminated from all areas, and sites should be prioritized so that the highest quality habitats are treated first [157]. Low-density stands of common buckthorn are not only less expensive to treat, but treatments are likely to yield better results (i.e., better recruitment of natives with less effort and/or expense) [45]. Similarly, Samuels [188] emphasizes the importance of controlling satellite populations of common buckthorn, because each outlying reproductive adult becomes an "establishment front" with greater potential to increase the area of infestation than a thicket of reproductive adults. A commonly used control method for common buckthorn involves either basal-bark spraying with herbicide or cutting followed by herbicide treatment of the cut stump (see Chemical control). These methods kill existing common buckthorn trees and saplings but must be repeated due to sprouting and rapid seedling establishment. Planting of desirable species may prevent or reduce common buckthorn seedling establishment, and prescribed burning or spot burning can be used as a follow-up treatment to kill sprouts and seedlings [192,214]. At the University of Wisconsin Arboretum, common buckthorn continually invades remnants of oak forest and areas planted to sugar maple, and these areas require continual maintenance with clearing, herbicide treatment, and prescribed burning [133].

Initial efforts concentrated on removing female common buckthorn shrubs can reduce the number of seeds in the seed bank [6,45] and allow retention of nesting habitat in the absence of a native shrub stratum [231,239]. In many small, fragmented woodlands invaded by common buckthorn, native shrubs may be absent or nearly so. Consequently, removing all nonnative invasive shrubs at once could lead to local extirpation of the bird species using those shrubs. Male common buckthorn plants can be left standing for a number of years while female plants are removed and native shrubs planted. Once native shrubs are large enough to provide nesting habitat, male trees can be removed [231].

Control treatments for common buckthorn may be most effective if timed to correspond to periods of low carbohydrate reserves (see Underground phenology and Fire timing).

Any control efforts that disturb the soil are likely to result in common buckthorn seedling establishment from the soil seed bank (e.g., [237]), and follow-up treatments will be necessary to control seedlings (see Use of prescribed fire as a control agent). See Germination and Seedling establishment for more information. Effective long-term control of common buckthorn may need to focus on conspecific seedling emergence for at least 2 years following control of existing shrubs [165].

Prevention: It is commonly argued that the most cost-efficient and effective method of managing invasive species is to prevent their establishment and spread by maintaining "healthy" natural communities [136,197]. For example, maintaining the integrity of animal communities including native seed predators may be an important aspect of supporting the biological resistance of natural areas to invasion by nonnative plants such as common buckthorn [143]. Managing to maintain the integrity of the native community and mitigate the factors enhancing ecosystem invasibility is likely to be more effective than managing solely to control the invader [101].

Monitoring potentially vulnerable communities several times each year is important for preventing establishment and spread of invasive species [108]. For example, Archibold and others [6] recommend careful monitoring of areas with perch trees and adjoining fencelines to help reduce common buckthorn establishment and spread.

Weed prevention and control can be incorporated into many types of management plans, including those for logging and site preparation, grazing allotments, recreation management, research projects, road building and maintenance, and fire management [218]. See the Guide to noxious weed prevention practices [218] for specific guidelines in preventing the spread of weed seeds and propagules under different management conditions.

Fire: For information on the use of prescribed fire to control buckthorns, see Fire Management Considerations.

Cultural control: Information on cultural control of common buckthorn comes primarily from studies that include planting of native species following other control efforts. See Integrated management and Integrated management with prescribed fire for more information on these studies.

A review by Converse [36] suggests that "underplanting" disturbed woods with native woody species is potentially effective to prevent primary invasion or reinvasion of buckthorns.

Physical or mechanical control: Physical control of common buckthorn typically involves cutting or girdling saplings and adult plants or hand-pulling seedlings. Cutting does not kill common buckthorn, and sprouts must be clipped as they occur [90]. Stumps can also be treated with herbicide to prevent or minimize sprouting (see Chemical control). Small plants may be uprooted using a weed wrench [214,237]. In Vermont, flooding was used successfully to kill common buckthorn seeds and seedlings [214].

Cutting common buckthorn plants typically results in abundant and vigorous sprouting (e.g., [157]), so follow-up treatments are needed. Plants that were cut had 36% and 75% more sprouts in 2003 and 2004, respectively, compared to untreated controls. Fewer sprouts in 2003 were likely due to below-average precipitation that year [18]. In the United Kingdom, a hedge management regime involving annual cutting (in either September or February) had a substantial negative impact on fruit production and growth of common buckthorn. Cessation of annual cutting for 3 years increased common buckthorn relative abundance about 250% [142]. In a preliminary study at the University of Wisconsin Arboretum, 73% of common buckthorn plants sprouted following a single cutting after fruiting in July. Only 53% sprouted if the first cut was followed by a second 4 hours later [75]. Double-cutting also reduces the vigor of sprouts over the single-cut method. Although the double-cut technique is more labor intensive, it may be useful in wetlands or other areas where herbicides are restricted [74]. Pergams and Norton [165] found that neither cutting nor girdling alone was optimal for controlling common buckthorn in northeastern Illinois. See Chemical control for more details of this study.

Girdling and repeated cutting of sprouts may be somewhat effective for controlling common buckthorn, although it is time- and labor-intensive [78,90]. Girdled large stems take time to die and the results may not be seen until a year later. Heidorn [90] provides guidelines to increase effectiveness of girdling.

Uprooting common buckthorn seedlings by hand, and uprooting plants up to about 2 inches (5 cm) in diameter using a weed wrench may be effective [157,214,237]. However, hand-pulling is labor- and time-intensive and not always effective. For example, on 1 work day in June 1996 it took 8 volunteers 2 hours to remove about 125,000 seedlings from a 538-foot² (50-m²) area. This area was soon revegetated with common buckthorn seedlings from the disturbed seed bank and missed seedlings [214]. Hand-pulling of small (<0.5-inch (1 cm) stem diameter) common buckthorn saplings or seedlings is effective as a follow-up to large tree removal in small areas (<5 acres (2 ha)), or when abundant laborers are available. Pulled stems can be left on site. Hand-pulling is an important tool in areas where prescribed fires are not allowed. Root wrenches can be used to pull up larger common buckthorn (up to about 2 inches (5 cm) DBH) in relatively small areas. However, common buckthorn root systems are large enough that pulling and uprooting plants can result in substantial soil disturbance [157], possibly increasing invasibility of the site.

Biological control: Biological control of invasive species has a long history that indicates many factors must be considered before using biological controls. Refer to these sources: [220,240] and the Weed control methods handbook [214] for background information and important considerations for developing and implementing biological control programs.

A literature review and results from field surveys in Europe provide information on potential biological control of buckthorns in North America and on the specialized herbivorous arthropods on common and glossy buckthorn. As of this writing (2010), no insects had been released for biological control of common buckthorn. The most promising insects for biological control of common buckthorn, as of 2008, were the leaf-margin curled gall phylloid (*Trichochermes walkeri*), the leaf-feeding geometrid (*Philereme vetulata*), and the seed-feeding gall midge (*Wachtiella krumbholzi*) [61].

Observations in Wisconsin suggest that livestock may be used to help control common buckthorn in some areas under some conditions [236]. Preliminary observations indicate that domestic sheep readily browse tall common buckthorn but strongly avoid short stems in the ground layer [45]. Managing the browsing intensity would likely be difficult, as would preventing damage to associated desirable native plants. The authors suggest that a properly timed, brief period of controlled animal use might control common buckthorn invasion in early stages, when it is less than 3 feet (1 m) tall. It may also control sprouting after cutting, but experiments and monitoring would be needed to determine proper timing and intensity. The authors conclude that hand-cutting and spot use of chemicals would be simpler, safer, and more cost-effective than using livestock [236].

Chemical control: Management guidelines recommend a combination of cutting and prescribed burning for controlling common buckthorn in fire-adapted communities (see Integrated management with prescribed fire), and in areas where burning is not feasible they recommend basal-bark chemical girdling or treating cut stems with herbicide to improve control [78,90]. Several studies demonstrate the efficacy of these approaches using various chemicals (see below), with triclopyr and glyphosate being the most common [157]. Control may be improved when treatment is timed to correspond with common buckthorn's translocation of carbohydrates to the roots (see Underground phenology), although no studies were found to document this. Treatments may need to be repeated numerous times to control sprouts, and follow-up treatments are needed to control seedlings [45,78,165]. Care should be taken to avoid herbicide contact with nontarget plants, which are important for recolonizing the site after buckthorn is removed [90].

Herbicides are effective in gaining initial control of a new invasion or a severe infestation, but they are rarely a complete or long-term solution to weed management [29]. See the Weed control methods handbook [214] for considerations on the use of herbicides in natural areas and detailed information on specific chemicals, and see Heidorn [90] for specific recommendations and cautions for using herbicides to control buckthorns in wildlands.

Glyphosate and triclopyr appear to result in the highest mortality rates and least sprouting of common buckthorn when used in chemical girdling or cut-stem applications. A benefit of this method is that it minimizes damage to associated vegetation [114]. For more details on studies using these herbicides, see the review by Qaderi and others [165] and the following publications by location: Minnesota [18,20,21,237], Wisconsin [114], Saskatchewan [6,45].

Management guidelines recommend a formulation of triclopyr applied to cut stems or as a basal-bark treatment on large common buckthorn stems and sprouts less than 6 inches (15 cm) diameter [90]. Management efforts in Minnesota parks indicate that this approach works well on common buckthorn trees from 1 to 15 inches (2.5-28 cm) DBH [157].

Strategic timing of herbicide application may improve herbicide translocation and efficacy, and one author suggests that herbicide be applied during the fall when carbohydrates are being translocated to the roots [18]. Archibold and others [6] indicate that triclopyr can be used well into the dormant season, and when used at this time it eliminates the unsightly "brown-out " phase and prepares the stand for a subsequent burn intended to kill seedlings. Others also suggest that fall is the best time to find and treat common buckthorn. It is easier to locate then, because it stays green longer than natives and the black fruit clusters are highly visible even after leaves have dropped [45,90]. Because natives are dormant at this time, they are less likely to be damaged by herbicide [90,189]. However, foliar treatment in June killed more common buckthorn sprouts than foliar treatment in September, although neither was 100% effective [21].

Monitoring and follow-up treatments of common buckthorn sprouts and seedlings are likely necessary for several years [18,165]. Common buckthorn seedlings may also establish following herbicide applications to control other nonnative species, as was observed following efforts to control swallow-wort (*Cynanchum* spp.) at 3 sites in central New York [128]. Plots in Minnesota where common buckthorn plants were cut and treated with triclopyr had no sprouts but had 40% more common buckthorn seedlings than cut-only plots [18]. Similarly, common buckthorn seedlings were more numerous in plots where large common buckthorn shrubs were killed by chemical spraying than in plots where the shrubs were left untouched (Moriarty personal communication cited by [116]). Following herbicide treatments in the densest common buckthorn stands in riparian communities near Saskatoon, the ground layer was still dominated by common buckthorn. The authors recommend either foliar spraying, mowing, prescribed fire (if fuels are sufficient), or spot burning with a propane torch to kill common buckthorn seedlings. They note that controlling common buckthorn in the ground layer may not result in recruitment of native plants. The stand had few native woody seedlings or saplings, and the only herbaceous plant found in the groundlayer of their sample plots was the native Sprengel's sedge (*Carex sprenglii*), which is typically one of the dominant plants in native shrub stands in the region. At this study site, it was sparsely distributed with no visible seed production [45]. These results highlight the need for integrating native planting or seeding with common buckthorn removal.

Integrated management: Because the native seed bank is often depleted in areas where common buckthorn has invaded, it is important to plant native species after common buckthorn removal to achieve desired results. Some authors have noted a lack of natural regeneration following overstory and/or nonnative shrub removal in common buckthorn-invaded stands (e.g., [45,66,164]). Therefore a management approach that includes seeding or planting of native species may produce better results. Dealanoy and Archibold [45] outline a 4-phase approach to restoring native plant communities where common buckthorn has invaded: 1) remove fruiting common buckthorn stems using 3 to 5 chemical girdling passes; 2) remove common buckthorn from the ground layer using burning, mechanical, chemical or browsing methods, or girdle fruiting stems with herbicide as they mature; 3) remove male stems using chemical girdling; and 4) restore native plants using seeding or planting of native species as needed. Fire and browsing may be required to ensure long-term restoration success, depending on native fire regimes [45]. See Integrated management with prescribed fire for more information on this topic.

APPENDIX: FIRE REGIME TABLE

SPECIES: Rhamnus cathartica, R. davurica

The following table provides fire regime information that may be relevant to common buckthorn or Dahurian buckthorn habitats. Follow the links in the table to documents that provide more detailed information on these fire regimes.

Fire regime information on vegetation communities in which common buckthorn or Dahurian buckthorn may occur. This information is taken from the LANDFIRE Rapid Assessment Vegetation Models [127], which were developed by local experts using available literature, local data, and/or expert opinion. This table summarizes fire regime characteristics for each plant community listed. The PDF file linked from each plant community name describes the model and synthesizes the knowledge available on vegetation composition, structure, and dynamics in that community. Cells are blank where information is not available in the Rapid Assessment Vegetation Model.

Northern Great Plains | Great Lakes | Northeast

Northern Great Plains

- Northern Plains Grassland
- Northern Plains Woodland

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

Northern Plains Grassland					
Central tallgrass prairie	Replacement	75%	5	3	5
	Mixed	11%	34	1	100
	Surface or low	13%	28	1	50
Northern tallgrass prairie	Replacement	90%	6.5	1	25
	Mixed	9%	63		
	Surface or low	2%	303		
Southern tallgrass prairie (East)	Replacement	96%	4	1	10
	Mixed	1%	277		
	Surface or low	3%	135		
Oak savanna	Replacement	7%	44		
	Mixed	17%	18		
	Surface or low	76%	4		
Northern Plains Woodland					
Oak woodland	Replacement	2%	450		
	Surface or low	98%	7.5		
Northern Great Plains wooded draws and ravines	Replacement	38%	45	30	100
	Mixed	18%	94		
	Surface or low	43%	40	10	
Great Plains floodplain	Replacement	100%	500		

Great Lakes

- Great Lakes Grassland
- 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		
Great Lakes floodplain forest	Mixed	7%	833		
	Surface or low	93%	61		
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 (less frequent fire)	Replacement	30%	166		
	Mixed	47%	105		
	Surface or low	23%	220		
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
Oak-pine (eastern dry-xeric)	Replacement	4%	185		
	Mixed	7%	110		
	Surface or low	90%	8		
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		

*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 [84,127].

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