SPECIES: Celastrus orbiculatus

INTRODUCTORY

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AUTHORSHIP AND CITATION:
Howard, Janet L. 2005. Celastrus orbiculatus. 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/ [2007, September 24].

FEIS ABBREVIATION:
CELORB

SYNONYMS:
Celastrus orbiculata Thunb. [56,118]

NRCS PLANT CODE [113]:
CEOR

COMMON NAMES:
Oriental bittersweet
Asian bittersweet
climbing spindleberry
round-leaved bittersweet

TAXONOMY:
The scientific name of Oriental bittersweet is *Celastrus orbiculatus* Thunb. [35,50,78,82,91,123]. It is in the stafftree (Celastraceae) family. Three varieties are described from southeastern Asia [15,82], but none are distinguished in North America [53].

Hybrids: Prior to Oriental bittersweet's introduction, American bittersweet (*C. scandens*) was the only North American representative of the stafftree family north of Mexico. Oriental and American bittersweet have the same number of chromosomes (n=23) and the potential to hybridize. Oriental bittersweet and American bittersweet are cross-fertile in the laboratory [122,125], although the current extent of Oriental bittersweet × American bittersweet hybridization is unknown. Hybrids are not widely reported in the field; however, this may be due to the difficulty in identifying bittersweet hybrids. Dreyer and others [21] noted a bittersweet plant in Connecticut that produced 2 distinct types of pollen. Both species of bittersweet were present in the study area, and the authors speculated that the individual may have been a hybrid. Genetic studies of field specimens are needed to determine levels of hybridization and introgression in the 2 bittersweet congeners.

LIFE FORM:
Vine-liana

FEDERAL LEGAL STATUS:
None

OTHER STATUS:
Oriental bittersweet is classified as an invasive species in several states and Regions. Rankings are:

Area	Rank
Connecticut	Invasive [113]
Tennessee	Rank 1: severe threat [103]
Vermont	Category 2: potential to displace native plants [115]
Virginia	Highly invasive [116]
US Forest Service, Eastern Region	Category 1: highly invasive [110]
US Forest Service, Southern Region	Category 1: highly invasive [111]

DISTRIBUTION AND OCCURRENCE

SPECIES: Celastrus orbiculatus

GENERAL DISTRIBUTION:

Oriental bittersweet is native to Korea, China, and Japan [82]. Its southern limit in southeastern Asia is along the Yangtze River watershed (Cheng and Huang, cited in [67]). Oriental bittersweet is nonnative in the United States, Canada, [35,50,56,78,91,118,124], and New Zealand [123].

In North America, Oriental bittersweet is sporadically distributed from Ontario and Quebec south through the Great Lakes states, New England, and the Southeast to Arkansas, Tennessee, Florida, Louisiana, and the southeastern edge of the Great Plains [7,19,38,56]. Oriental bittersweet was 1st introduced in North America in1860 as an ornamental [93]. It has escaped from cultivation, showing a scattered distribution in the Great Lakes [78] and northern New England [4,35] states. Oriental bittersweet is most common and invasive in New York state, coastal Connecticut, and the southern Appalachians [19]. Based upon its native range and habitat preferences, it can be expected to expand its range in the United States and Canada [64]. Plants database provides a distributional map of Oriental bittersweet in the United States.

The following lists give biogeographic classifications where Oriental bittersweet is known to be present or invasive, or is likely to be invasive based upon current knowledge of Oriental bittersweet's geographical distribution and habitat preferences. Precise distribution information is unavailable for all locations where Oriental bittersweet may be invasive. The following lists are therefore speculative and not exhaustive, and Oriental bittersweet may be present and possibly invasive in vegetation types not listed below.

ECOSYSTEMS [33]:
FRES10 White-red-jack pine
FRES11 Spruce-fir
FRES13 Loblolly-shortleaf pine
FRES14 Oak-pine
FRES15 Oak-hickory
FRES16 Oak-gum-cypress
FRES17 Elm-ash-cottonwood
FRES18 Maple-beech-birch
FRES39 Prairie

STATES/PROVINCES: (key to state/province abbreviations)

UNITED STATES

AR	CT	DE	FL	GA	IL	IN
IA	KY	LA	ME	MD	MA	MI
MO	NH	NJ	NY	NC	OH	PA
RI	SC	TN	VT	VA	WV	WI
DC						

CANADA

ON	PQ

BLM PHYSIOGRAPHIC REGIONS [10]:
None

KUCHLER [63] PLANT ASSOCIATIONS:
K095 Great Lakes pine forest
K097 Southeastern spruce-fir forest
K099 Maple-basswood forest
K100 Oak-hickory forest
K101 Elm-ash forest
K102 Beech-maple forest

K103 Mixed mesophytic forest
K104 Appalachian oak forest
K106 Northern hardwoods
K109 Transition between K104 and K106
K110 Northeastern oak-pine forest
K111 Oak-hickory-pine
K112 Southern mixed forest
K113 Southern floodplain forest

SAF COVER TYPES [26]:
14 Northern pin oak
15 Red pine
17 Pin cherry
20 White pine-northern red oak-red maple
21 Eastern white pine
22 White pine-hemlock
23 Eastern hemlock
24 Hemlock-yellow birch
25 Sugar maple-beech-yellow birch
26 Sugar maple-basswood
27 Sugar maple
28 Black cherry-maple
30 Red spruce-yellow birch
31 Red spruce-sugar maple-beech
32 Red spruce
33 Red spruce-balsam fir
34 Red spruce-Fraser fir
39 Black ash-American elm-red maple
40 Post oak-blackjack oak
43 Bear oak
44 Chestnut oak
45 Pitch pine
46 Eastern redcedar
51 White pine-chestnut oak
52 White oak-black oak-northern red oak
53 White oak
55 Northern red oak
57 Yellow-poplar
58 Yellow-poplar-eastern hemlock
59 Yellow-poplar-white oak-northern red oak
60 Beech-sugar maple
61 River birch-sycamore
65 Pin oak-sweetgum
71 Longleaf pine-scrub oak
72 Southern scrub oak
73 Southern redcedar
74 Cabbage palmetto
75 Shortleaf pine
76 Shortleaf pine-oak
78 Virginia pine-oak
79 Virginia pine
80 Loblolly pine-shortleaf pine

81 Loblolly pine
85 Slash pine-hardwood
87 Sweetgum-yellow-poplar
103 Water tupelo-swamp tupelo
108 Red maple
110 Black oak

SRM (RANGELAND) COVER TYPES [100]:
None identified in the literature.

HABITAT TYPES AND PLANT COMMUNITIES:
Oriental bittersweet is most common in mesic mixed-hardwood eastern forests [58,74,95,120], although it also occurs in some conifer forests [39,74,83]. Descriptions of plant community composition for mixed-hardwood forests with Oriental bittersweet follow. Detailed descriptions of plant community composition in northern coniferous and southern pine forest types with Oriental bittersweet were not found in the literature.

In Amherst, **Massachusetts**, Oriental bittersweet occurs in the understory of northern red oak-hickory-red maple (*Quercus rubra-Carya* spp.-*Acer rubrum*) forest. Native and nonnative honeysuckles (*Lonicera* spp.) dominate the shrub layer [24]. On riparian floodplains forests of Massachusetts, Oriental bittersweet occurs in the understory of sugar maple-eastern cottonwood (*Populus deltoides* ssp. *deltoides*) forest. Sycamore (*Platanus occidentalis*) and white ash (*Fraxinus americana*) are occasional in the canopy. Slippery elm (*Ulmus rubra*), hackberry (*Celtis occidentalis*), and boxelder (*A. negundo*) occur in the subcanopy. Other riparian species occurring with Oriental bittersweet in the understory are staghorn sumac (*Rhus typhina*), nonnative multiflora rose (*Rosa multiflora*), and nonnative Japanese barberry (*Berberis thunbergii)*, with Japanese barberry most common. Ostrich fern (*Matteuccia struthiopteris*) dominates the herb layer [58].

In the Pennyback Wilderness of southeastern **Pennsylvania**, Oriental bittersweet occurs in mixed-mesophytic woodland and forest, riparian, and old-field communities. American beech (*Fagus grandifolia*), oaks, yellow-poplar (*Liriodendron tulipifera*), white ash, red maple, and black walnut (*Juglans nigra*) dominate the woodland and forest overstories. Flowering dogwood (*Cornus florida*), black cherry (*Prunus serotina*), sweet cherry (*P. avium*), poison-ivy (*Toxicodendron radicans*), Canadian woodnettle (*Laportea canadensis*), goldenrods (*Solidago* spp.), and nonnative Nepalese browntop (*Microstegium vimineum*) are common understory components. Boxelder, sycamore, green ash (*F. pennsylvanica*), and silver maple (*A. saccharinum*) dominate riparian zones. Blackberries (*Rubus* spp.) dominate old fields. Little bluestem (*Schizachyrium scoparium*), milkweeds (*Asclepias* spp.), and Indianhemp (*Apocynum cannabinum*) are common old-field components. Japanese honeysuckle (*L. japonica*), a nonnative, associates with Oriental bittersweet in each of the 4 community types [95].

On the George Washington Memorial Parkway in **Virginia**, Oriental bittersweet occurs on late-successional oak-hickory forest edges. White oak (*Q. alba*), scarlet oak (*Q. coccinea*), chestnut oak (*Q. prinus*), pignut hickory (*Carya glabra*), and mockernut hickory (*C. tomentosa*) dominate the interior forest overstory. The forest edge community is composed of a mixture of nonnative and native lianas and herbs including Japanese honeysuckle, summer grape (*Vitis aestivalis*), riverbank grape (*V. riparia*), white clover (*Trifolium repens*), Kentucky bluegrass (*Poa pratensis*), common velvetgrass (*Holcus lanatus*), and broomsedge bluestem (*Andropogon virginicus*) [120].

On the Bent Creek Experimental Forest near Asheville, **North Carolina**, Oriental bittersweet occurs in the understory of a mixed-hardwood forest. Yellow-poplar and sweet birch (*Betula lenta)* dominate on mesic sites, where Oriental bittersweet is most common. Oriental bittersweet is less common on dry sites where scarlet, chestnut, and black (*Q. velutina*) oaks are mixed with occasional shortleaf pines (*Pinus echinata*). Red maple, hickories, and white oak are scattered throughout the mixed-hardwood community [39,74]. Midstory species in the Experimental Forest include red maple, sourwood (*Oxydendrum arboreum*), and flowering dogwood.

Rosebay (*Rhododendron maximum*), blueberries (*Vaccinium spp.*), and huckleberries (*Gaylussacia* spp.) occur in the shrub layer. Oriental bittersweet does not associate with mountain-laurel (*Kalmia latifolia*), which is common on the Experimental Forest but tends to occupy relatively dry soils [74].

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

SPECIES: Celastrus orbiculatus

August root sprouts. Photo by
James H. Miller, USDA Forest Service

GENERAL BOTANICAL CHARACTERISTICS:
This description provides characteristics that may be relevant to fire ecology, and is not meant for identification. Oriental bittersweet is commonly mistaken for the relatively rare, native American bittersweet [21]. The 2 bittersweets are distinguished primarily by location of female flowers and fruits, with terminal reproductive organs on American bittersweet and axillary organs on Oriental bittersweet. Identification may be difficult for male plants and female plants without flowers or fruits [19]. Gleason [34] and NcNab and Meeker [75] provide illustrative keys for distinguishing between the 2 bittersweet species.

Morphology:

Oriental bittersweet is a nonnative liana. The leaves are oblong, 2 to 5 inches (4-12 cm) long, and 1.4 to 2 inches (3.5-5 cm) wide [21,35,50,78,82]. Leaf morphology is plastic, with Oriental bittersweet showing reduced leaf mass area and increased leaf area ratios under shaded conditions [25]. Stems are woody with deciduous, alternate leaves and a twining habit [35,82,91]. They may reach 66 feet (20 m) in length and 3.9 inches (10 cm) in width [7,20,102], depending upon supporting vegetation [7]. Oriental bittersweet produces aerial climbing stems, stolons, and rhizomes [9,10,118]. The roots are spreading, and may be as much as 0.8 inch (2 cm) thick [67]. Oriental bittersweet is functionally dioecious (see Breeding system). Flowers are sparse, occurring in 3-flowered, axillary cymes [21,35,50,78,82]. Outer vegetative bud scales may be spiny [19]. Fruits develop next to the vegetative buds [21]. A typical plant bears upwards of 370 fruits [123]. Fruits are dehiscent, 3-valved capsules about 0.4 inch (1 cm) in diameter. Each valve contains 1 or 2 seeds covered by

fleshy, yellowish-red arils [35,82,91]. The capsules are relatively large [24,86]. Fukui [32] recorded mean seed and capsule sizes of Oriental bittersweet in Japan as 3.8 mm in seed length, 0.023 mm in seed width, and 7.5 mm in capsule length. Similar capsule sizes occur on plants in the United States (range, 1.5-1.6 mm in width; 6-8 mm in diameter) [15,19].

Stand structure and age class:

Growth habit is sprawling and climbing. Oriental bittersweet uses woody shrubs and trees for structural support, intertwining its branches around support trunks. It may eventually overtop or shade out the support plant. Sprawling Oriental bittersweet branches may form impenetrable thickets [3,21]. In Rock Creek Park, Washington DC, Oriental bittersweet used bole-climbing vines and lianas including English ivy (*Hedera helix*), Virginia creeper (*Parthenocissus quinquefolia*), and poison-ivy for initial structural support. After twining around associated vines, the Oriental bittersweet branches grew into and twined around tree tops. This climbing habit enabled Oriental bittersweet to grow above other vines and access the tops of the largest trees (44.1 inches (112 cm dbh)) in the Park [90].

On the Pleasant Valley Wildlife Sanctuary, Massachusetts, age of Oriental bittersweet plants was determined 13 years after logging and underbrush removal. Mean basal stem age was 3.4 years (range 1-12 years, $s_{\bar{x}}$ =0.2). Mean plant length was 138.9 cm (range 1-200 cm, $s_{\bar{x}}$ =27.0 cm). Some Oriental bittersweet just outside the Sanctuary (the likely seed sources for the infestation) were 35 years old [102].

RAUNKIAER [92] LIFE FORM:
Hemicryptophyte
Geophyte

REGENERATION PROCESSES:
Oriental bittersweet regenerates from seed and by sprouting. Its invasiveness is due, in part, to its superior ability to establish from seeds and sprouts compared to native lianas and other associated native woody species [39,68,76,86,91,102].

Breeding system:

This species is "functionally dioecious" because early abortion of either male or female organs makes individual plants unisexual [11]. Plants occasionally develop both unisexual and perfect flowers, becoming polygamodioecious [35,91]. Monoecious plants are also reported [48].

Pollination:

Hymenoptera, especially bees, pollinate Oriental bittersweet flowers. Wind pollination also occurs [7]. Four Oriental bittersweet populations from Connecticut were studied for pollen viability. Mean pollen viability across populations was 67%. Viability was significantly different among populations ($p<0.05$), varying from 17.3% to 74.3%. Oriental bittersweet × American bittersweet hybrids had low pollen viability [21].

Seed production is "prolific" [9] (see right-hand photo in Management Considerations). In the greenhouse, both male and female plants produced flowers in their 2nd year [125].

Seed dispersal:

Animals, water, and humans disperse Oriental bittersweet seed. The seed is dispersed after the 3-valved capsules splits open and expose the arils [91]. The brightly colored, fleshy arils attract birds and small mammals, which disperse most of the seed after ingesting the arils [39,68,76,86,102]. Oriental bittersweet frequently establishes along fencelines and other sites where birds perch [75]. A North Carolina study in undisturbed oak forest showed small animals removed 75% of the total Oriental bittersweet seed crop [39]. Roads may act as a corridor for seed dispersal. Oriental bittersweet has been used in roadside plantings in the Northeast. It is common along roadsides, especially interstate highways in New England. Some seed may be transported by water [21]. Humans, who collect the fruiting branches for ornaments, disperse seeds when

collecting and disposing of the branches [7,21]. They facilitate animal dispersal of Oriental bittersweet seed by planting Oriental bittersweet as an ornamental [20].

Frugivorous birds are probably the most important vectors for Oriental bittersweet seed dispersal because they are highly mobile, travel in flocks, and often eat voraciously [20,39,121]. Northern flickers, yellow-rumpled warblers, American robins and other thrushes (Turdidae), mockingbirds and catbirds (Mimidae), and European starlings and mynas (Sturnidae) are the primary Oriental bittersweet seed dispersers [121]. In Japan, Oriental bittersweet seed retention time in the digestive tracts of brown-eared bulbuls (*Hypsipetes amaurotis*, a native Japanese Passerine) ranged from 14 to 42 days (μ=27). That was one of the longest retention times recorded among 16 bird-dispersed plant species. Long retention times can result in long Oriental bittersweet dispersal distances when birds migrate [32].

Near Asheville, North Carolina, birds and small mammals dispersed Oriental bittersweet seeds in large numbers. Greater than 80% of Oriental bittersweet arils remained on the parent plant until December, and >50% remained until mid-January. Some arils not harvested by animals fell near the parent plant. Such seeds (with undigested arils) showed reduced germination rates (51%) compared to ingested seeds (82%); however, a 51% germination rate is high enough to substantially contribute to Oriental bittersweet regeneration. Seeds still on the vine in February were damaged and unviable [39].

Seed banking:

Oriental bittersweet has a short-lived seed bank. Laboratory seed viability studies suggest that Oriental bittersweet seed does not remain viable for more than 1 growing season [24]; however, some land managers report that soil-stored Oriental bittersweet seed remains viable for several years [108]. Field and soil sample studies suggest that seed remaining in seed banks for more than 1 year contributes little to Oriental bittersweet regeneration [24,62]. A 3-year field study in New Jersey showed a 90% germination rate of Oriental bittersweet seed the 1st spring after a winter planting. There was no "appreciable" Oriental bittersweet germination in the 2nd or 3rd years of the study [114]. In a 2-year study in an Oriental bittersweet-infested Massachusetts field, Oriental bittersweet seedling emergence from the seed bank averaged 0.9 seedling/m² (n=15 plots). All seedlings emerged in the 1st year of the study. Another facet of the Massachusetts field experiment involved measuring seedling recruitment following artificial (hand-sown) seed rain onto exclosed plots. Density of Oriental bittersweet seedling recruits closely matched the density of seeds sown. Seed rain ranged from 14 seeds/m² to 826 seeds/m² (μ=168 seeds/m²), and seedling recruitment ranged from 11 seedlings/m² to 532 seedlings/m² (μ=107 seedlings/m²) [24]. Field managers in Great Smoky National Park report substantial Oriental bittersweet seedling regeneration during the first 6 years of a grubbing and herbicide control program involving "complete removal and rootkill" of Oriental bittersweet (Langon 1993, cited in [7]). Seedling establishment dropped greatly after 6 years, however, suggesting either that the soil seed bank depleted and/or that off-site seed sources had been eliminated. Because Oriental bittersweet is such a prolific seed producer, its seed bank is quickly replenished when seed sources remain on-site or nearby [7].

In a green ash-yellow-poplar forest near Philadelphia, Pennsylvania, Oriental bittersweet seedlings emerged from the seed bank following herbicide treatment of Nepalese browntop (*Microstegium vimineum*) [37].

Germination rate of Oriental bittersweet seed is high [7,9], showing as much as 95% germination in the laboratory [7]. Light is not required [21,102], and germination may occur under a wide range of light conditions [85]. Patterson [86] found best germination occurred under low-light conditions; however, Greenberg and others [39] found seed germination and seedling survival rates in the greenhouse were similar from 20% photosynthetically active radiation (PAR) to full sunlight conditions. Stratification improves germination rates [21]. Mechanical or chemical scarification of the seed is not necessary for germination [24,39,86]; however, germination in the laboratory is delayed or reduced if the fleshy aril remains attached to the seeds [39]. This suggests that animal ingestion of Oriental bittersweet arils may enhance Oriental bittersweet seedling emergence.

Some water-dispersed seed may establish on floodplains. In Connecticut, Oriental bittersweet seed viability was tested for floating vs. sinking seeds. Mean viability was 41% for floating seeds and 88% for sinking seeds [21].

Seedling establishment: Seedling emergence is high [75,86], but survivorship may vary greatly depending upon field conditions and population differences. Survivorship of field-germinated seedlings in Massachusetts ranged from 0% to 88% (μ=17%) [24]. Patterson [86] reported densities of 60/m² for Oriental bittersweet emergents in Connecticut; however, seedling density declined over the growing season. Patterson attributed seedling mortality to drought. In the laboratory, establishment rate differed significantly ($p<0.001$) among 2 Oriental bittersweet populations in Connecticut. Percent germination after 21 days was 59% and 82% [21].

Oak litter may retard Oriental bittersweet seedling emergence. A study on the Bent Creek Experimental Forest found Oriental bittersweet was significantly less abundant ($p\leq0.005$) on oak cover types compared to yellow-poplar-sweet birch types [74]. A greenhouse study showed that intact oak litter physically impeded seedling emergence, although hypocotyls grew as much as 4 inches (9 cm) to find a point of reduced litter (in this case, the pot edge), and then emerged. Seedlings in deep litter tended to allocate more growth to hypocotyls, while seedlings in fragmented litter tended to allocated more growth to cotyledons. The authors concluded that Oriental bittersweet seedlings would probably find litter patches thin enough for emergence in all but the deepest of oak litter layers, but that pine litter may be more conducive to Oriental bittersweet establishment [24].

Oriental bittersweet seedlings may persist in a densely shaded understory for many years, then respond with rapid growth when disturbance opens the canopy [73,86].

Growth Oriental bittersweet shows rapid growth under partial to full sun [3,73]. In Massachusetts, artificially shaded Oriental bittersweet transplants showed best biomass gain under 28% of full sunlight. Mean aboveground biomass 1 year after transplanting was significantly different ($p=0.002$) under 100% full sunlight (μ=0.9 g), 28% of full sunlight (μ=14.4 g), and 2% of full sunlight (μ=0.33 g). Oriental bittersweet growing in partial to full sun can overtop 3- to 7-foot- (1-2 m) tall associated vegetation after 1 growing season [25]. On mesic sites in full sunlight, Oriental bittersweet can grow 10 to 12 feet (3-3.7 m) per year [73]. The Tennessee Exotic Plant Pest Council reports annual growth rates of 1 to 12 feet (0.3-3.0 m) in the first 7 years, with little growth thereafter. Patterson [86] reports annual Oriental bittersweet growth rates of 10 feet (3 m), with no time or age restrictions on cessation of topgrowth. Oriental bittersweet has shown faster growth rates than associated native lianas. On a Michigan site, Oriental bittersweet plants were younger than native riverbank grapes (μ=3.7 vs. 4.2 years, respectively) but were 8% wider in stem diameter compared to riverbank grape plants [109].

Asexual regeneration: Oriental bittersweet sprouts from roots, root fragments, and the root crown [3,9,21,24]. It also spreads from stolons and rhizomes (collectively called "runners") [7,9]. Cloning is a highly effective method of regeneration for Oriental bittersweet. In a greenhouse study using soil samples collected from an infested Massachusetts field, no Oriental bittersweet seedlings emerged from the soil, but Oriental bittersweet root fragments in the soil samples sprouted. Sprouts were distinguished by their lack of cotyledons [24].
Damage to the branches, root crowns, runners, or roots encourages sprouting. Clonal growth can result in large patches of Oriental bittersweet that originate from a few seedlings [7]. On a Connecticut site, Patterson [86] reported that Oriental bittersweet cover over a 600-m² area increased from 5% to 100% within 5 years.

SITE CHARACTERISTICS:
In its native Japan, Oriental bittersweet occurs in lowland and mountainous thickets and grassy slopes [82]. In the United States, Oriental bittersweet grows on forest edges [3,69,70], in forests, woods, and thickets [3,35,78,91,118], coastal areas, beaches, and salt marsh edges [7]. Oriental bittersweet is common on disturbed

sites such as roadsides, logged forests, and old fields [3,91]. It is reported on woodland ecotones in the Blue Ridge Mountains [124]. It is also common in urban areas, where it may disperse onto wildlands. Oriental bittersweet in West Virginia herbaria collections came from the following sites [49]:

Roads	Streamsides	Closed forests	Open forests	RR tracks	Trails	Old fields	Residential	Other	Total plants
23%	3%	6%	31%	11%	6%	3%	3%	14%	26

McNab and Loftis [74] found that on Bent Creek Experimental Forest, Oriental bittersweet was most common at relatively high elevations (μ=2,460 ft (749 m)), on steep slopes (μ=36% slope), and on concave landforms. It was significantly associated with mesic soils, soils disturbed by animal scarification, and logged sites. Significant stand structure variables for Oriental bittersweet occurrence were canopy gaps, dense midstories, and hardwood overstories other than oak. The 2 variables of strongest significance were lack of an oak overstory (p=0.001) and presence of animal-scarified soils (p=0.001). Oriental bittersweet was weakly associated (p<0.157) with sites where Hurricane Opal had uprooted trees. McNab and Loftis present a model to predict Oriental bittersweet presence or absence based on 5 variables obtainable through quick stand examinations [74].

Soils: Oriental bittersweet grows on forest, alluvial and floodplain [91,95], and glacial till soils [40]. Soil textures include sand and silt [40,95] derived from sandstone, granite, hornblende, and gneiss parent materials. Soil pH is generally moderately to mildly acidic (pH 5.6-6.5 [95], although Oriental bittersweet is reported on gneiss and schist parent materials <5.5 in pH [74]. Silveri and others [102] found Oriental bittersweet occurred on acidic (4.9-5.3 pH) soils in Massachusetts, with best establishment and growth on the relatively less acidic soils. Nutrient content of soils with Oriental bittersweet varies widely [95]. Oriental bittersweet is most common on mesic soils, and is apparently intolerant of saturated or droughty soils [9,51,102,123]. Information on moisture regimes for Oriental bittersweet soils is sparse, and research is needed on moisture requirements for Oriental bittersweet [74].

Climate and elevation: Oriental bittersweet appears to tolerate a wide range of climatic conditions [51,81,86]. Elevational range is from sea level to 4,600 feet (0-1,400 m) in the United States [7,74,96] and from sea level to 1,800 feet (0-540 m) in New Zealand [123]. Oriental bittersweet occurs from 1,500 to 7,200 feet (450-2,200 m) elevation in its native range of southeast Asia (Cheng and Huang, cited in [67]).

SUCCESSIONAL STATUS:
Oriental bittersweet occurs in all stages of succession. It colonizes forest edges and canopy gaps [25], and occurs in all stages of old-field succession [3]. It has colonized canopy gaps in eastern hemlock (*Tsuga canadensis*) forest in Connecticut following deforestation by woolly adelgids [83]. After establishing on woodland and forest ecotones, Oriental bittersweet vines invaded 2nd growth or late-successional, closed-canopy forests [69,70]. Oriental bittersweet was found in all stages of succession (riparian zones, old fields, thickets, woodlands, and forests) in mixed mesophytic oak (*Quercus* spp.)-American beech and riparian cover types of southeastern Pennsylvania. Oriental bittersweet frequency in each cover type was [95]:

Riparian	Old field	Thicket	Woodland	Forest
24%	41%	37%	26%	39%

Bird dispersal is an important factor in Oriental bittersweet's ability to rapidly colonize a site. Oriental bittersweet seedlings were noted the 1st year following restoration treatments to a landfill on Staten Island, New York. Minimum mean travel distance to the nearest Oriental bittersweet seed source was 430 feet (131 m) [96]. Long-distance dispersal of seed by birds may promote faster rates of Oriental bittersweet migration onto new sites compared to other plant species, particularly late-successional herbs with seeds that are primarily

dispersed by ants [69].

Shade tolerance: Oriental bittersweet is shade tolerant at all life stages [25,39]. In the greenhouse, varying light intensities did not produce significant differences in number of days until Oriental bittersweet germination, its seed germination rate, root:shoot weight, or root:shoot length. However, seedlings exposed to 70% or more PAR tended to produce more leaves, heavier leaves, and longer, heavier roots compared to more shaded seedlings [39]. In a Massachusetts field, artificially shaded Oriental bittersweet transplants showed good survivorship over a large range of sunlight conditions. Survivorship from mid-summer transplanting in 2000 to final field measurements in fall 2001 was [25]:

Treatment (% sun)	Transplant survival (%)	Winter survival (%)	Growing season survival (%)	Cumulative survival after 1 year (%)
100	96 (3)*	49 (21)^{b}	90 (9)^{ab}	43 (20)
28	87 (19)	84 (12)^{a}	96 (4)^{a}	70 (21)
2	94(7)	60 (12)^{ab}	76 (5)^{b}	43 (11)
P value	ns	0.031	0.029	ns

*Data are means and 1 standard deviation. Means with the same letter are not significantly different ($p<0.05$) among treatments.

Oriental bittersweet employs what Greenberg and others [39] call a "sit and wait" strategy: it can establish, grow slowly, and persist indefinitely in late-seral, closed-canopy communities. When disturbance opens the canopy, Oriental bittersweet responds with rapid growth [39,75]. Patterson [86] found Oriental bittersweet seedlings grown under low PAR nearly doubled their photosynthetic rate after 8 days of exposure to high light. Oriental bittersweet's climbing habit enables it to shade out, overtop, and eventually kill supporting vegetation [3,21].

Disturbance ecology: Although it invades undisturbed old growth [69,70], field studies show Oriental bittersweet is more common on disturbed sites such as roads [102] and sites disturbed by logging, windthrow, or animal foraging [74,102] (see Disturbance
in Management Considerations for further discussion). Further ecological studies are needed on Oriental bittersweet response to various types of disturbance under differing soil moisture and light regimes [74].

Nutrient flushes, which are sometimes associated with fire and other disturbances, may alter the course of succession and encourage establishment of Oriental bittersweet and other invasive species. In Massachusetts, a black oak-white oak/black huckleberry-low sweet blueberry (*Gaylussacia baccata-Vaccinium angustifolium*) forest irrigated with nitrogen-enriched wastewater was initially invaded with old-field herbs including pokeweed (*Phytolacca americana*) and tangled bindweed (*Polygonum concolculus*). After 9 years of irrigation pokeweed was still abundant, but Oriental bittersweet had replaced the tangled bindweed. Woody nightshade (*Solanum dulcamera*), Tatarian honeysuckle (*Lonicera tatarica*), Virginia creeper (*Parthenocissus quinquefolia*), and poison-ivy were also more abundant after 9 years of nitrogen addendum compared to unirrigated control plots [55].

Old fields:

Oriental bittersweet can change old-field successional pathways. In southeastern Connecticut, old field vegetation, surrounded by late-successional oak-hickory forest, was measured approximately every 10 years from 1954 to 1992. The old field burned just prior to the 1954 survey. In 1954, field cover was primarily Kentucky bluegrass (*Poa pratensis*), redtop (*Agrostis gigantea*), and wrinkleleaf goldenrod (*Solidago rugosa*). Allegheny blackberry (*Rubus allegheniensis*) and northern bayberry (*Morella pennsylvanica*) had scattered

occurrence. Black cherry (*Prunus serotina*) and black oak established by 1960. A thicket of shrubs and trees had developed by the 1970s; important new woody species included common greenbrier (*Smilax rotundifolia*) and flameleaf sumac (*Rhus copallinum*). Oriental bittersweet, 2 exotic shrubs (Morrow's honeysuckle (*Lonicera morrowii*) and multiflora rose), and a native liana (Virginia creeper) were noted for the 1st time. By the early 1980s, 2 distinct plant communities were described. The eastern portion of the field was a young hardwood forest dominated by black cherry, red maple, and black tupelo (*Nyssa sylvatica*). Southern arrowwood (*Viburnum dentatum*), Morrow's honeysuckle, and common greenbrier dominated the midstory. Woody vines <2 feet (0.5 m) tall, including Oriental bittersweet, Virginia creeper, and poison-ivy, dominated the lowest strata. The western portion of the old field was an "almost impenetrable" woody vine community dominated by Oriental bittersweet. Fox grape, (*Vitis labrusca*), a native liana, was increasing in cover and spreading into the canopy by using Oriental bittersweet for support. Scattered woody species on the western field were covered by exotic and native lianas. Trees were suffering branch breakage and low reproduction; shrubs were suppressed or killed. The authors speculated that the initial Oriental bittersweet invasion was facilitated by an Oriental bittersweet vine at the edge of the field, which provided perching support and food for frugivorous birds. The pioneering vine was 2 inches (5 cm) in basal diameter by 1992. Oriental bittersweet did not invade sites where common greenbrier dominated the initial community [28].

SEASONAL DEVELOPMENT:
Oriental bittersweet starts growth in mid-spring and flowers soon after [7,20]. Pollen sheds about 2 weeks after flowers open [89]. Leaves abscise in late fall, usually later than associated native species [7,109]. Oriental bittersweet in Michigan, for example, retained leaves for a month after the 1st October frost [109]. Arils and seeds mature in autumn and remain on the vine all winter unless harvested. Animals disperse the seeds throughout autumn, winter, and into early spring [24,39,86,102]. Most seeds are dispersed after leaf drop [39]. Plants are dormant in winter [19]. Seasonal phenology for Oriental bittersweet is given below.

Area	Event	Season
Connecticut	flowers	May-June
	fruits & arils ripen	Sept. [7]
Illinois	flowers	May-June [78]
New York	flowers	May-June
	fruits & arils develop	July-Oct. [15]
Tennessee	germinates	mid- to late spring
	flowers	May
	arils mature	Aug.-Sept. [7]
Blue Ridge Mts.	flowers	May-June [124]
Carolinas	flowers	mostly in May; extends to Aug. or Sept. [91]
	seed disperses	Nov.-Jan. [39]
Japan	flowers	May-June [82]

FIRE ECOLOGY

SPECIES: Celastrus orbiculatus

FIRE ECOLOGY OR ADAPTATIONS:

Fire adaptations: Oriental bittersweet sprouts from the root crown, roots, root fragments, and runners [3,9,21,24]. Additionally, it produces abundant, bird-dispersed seed and shows rapid growth on open sites [9,20,39,96,121]. Although there is no literature suggesting that these regeneration strategies evolved in response to fire disturbances in southeast Asia, sprouting, bird dispersal of off-site seed, and rapid growth would favor Oriental bittersweet regeneration in postfire environments of the eastern United States.

Fuels:

Oriental bittersweet can act as a ladder fuel by growing up to and over supporting shrubs and trees. It can also support later-successional vines and lianas [28], enabling other species to become ladder fuels.

Fire regimes vary across Oriental bittersweet's range. In northeastern maple-birch-beech (*Acer-Betula-Fagus* spp.) forests, historic fire return intervals were highly variable, depending upon microclimate, topography, and soil. Fires were mostly of mixed severity. Stand-replacing, medium-interval (~ 80-yr) fires were most common in forests dominated by birches, while long-interval (≥300 years), mixed-severity or stand-replacing fires occurred in forests dominated by maple and/or beech [27,30,43,98,119]. Oak-hickory (*Quercus-Carya* spp.), oak-pine (*Quercus-Pinus* spp.), and pine (*Pinus* spp.) forests of the Northeast and Southeast had mostly short-return interval, understory surface fires [107,119]. Oriental bittersweet was not present in these forests while historic fire regimes were still operating. The fire ecology of Oriental bittersweet is poorly understood [94]. It is unclear how Oriental bittersweet may affect or alter fire regimes in plant communities where it is present because as of this writing (2005), fire ecology studies are lacking for Oriental bittersweet. Oriental bittersweet's climbing habit alters forest structure [21,28,66], and it is likely that Oriental bittersweet will increase fire severity on sites where it is abundant. High Oriental bittersweet cover and biomass on badly infested sites creates heavy ladder fuels that may carry fire into the canopies of forests that historically did not experience crown fires. Fire ecology studies are needed to determine Oriental bittersweet's impact on fire behavior and severity.

The following table provides fire return intervals for plant communities and ecosystems where Oriental bittersweet is important. For further information, see the FEIS review of the dominant species listed below. This list may not be inclusive for all plant communities where Oriental bittersweet may occur. If you are interested in plant communities or ecosystems that are not listed below, see the complete FEIS Fire Regime Table.

Community or Ecosystem	Dominant Species	Fire Return Interval Range (years)
maple-beech	*Acer-Fagus* spp.	684-1,385 [14,119]
silver maple-American elm	*A. saccharinum-Ulmus americana*	< 35 to 200
sugar maple	*A. saccharum*	> 1,000
sugar maple-basswood	*A. saccharum-Tilia americana*	> 1,000 [119]
birch	*Betula* spp.	80-230 [14]
sugarberry-America elm-green ash	*Celtis laevigata-Ulmus americana-Fraxinus pennsylvanica*	< 35 to 200
beech-sugar maple	*Fagus* spp.-*Acer saccharum*	> 1,000

black ash	*Fraxinus nigra*	< 35 to 200 [119]
cedar glades	*Juniperus virginiana*	3-22 [42,87]
yellow-poplar	*Liriodendron tulipifera*	< 35 [119]
Great Lakes spruce-fir	*Picea-Abies* spp.	35 to > 200
northeastern spruce-fir	*Picea-Abies* spp.	35-200 [23]
southeastern spruce-fir	*Picea-Abies* spp.	35 to > 200 [119]
red spruce*	*P. rubens*	35-200 [23]
shortleaf pine	*Pinus echinata*	2-15
shortleaf pine-oak	*P. echinata-Quercus* spp.	< 10
slash pine	*P. elliottii*	3-8
slash pine-hardwood	*P. elliottii*-variable	< 35
sand pine	*P. elliottii* var. *elliottii*	25-45 [119]
longleaf-slash pine	*P. palustris-P. elliottii*	1-4 [80,119]
longleaf pine-scrub oak	*P. palustris-Quercus* spp.	6-10 [119]
red-white-jack pine*	*P. resinosa-P. strobus-P. banksiana*	10-300 [23,45]
pitch pine	*P. rigida*	6-25 [12,46]
eastern white pine	*P. strobus*	35-200
eastern white pine-eastern hemlock	*P. strobus-Tsuga canadensis*	35-200
eastern white pine-northern red oak-red maple	*P. strobus-Quercus rubra-Acer rubrum*	35-200
loblolly pine	*P. taeda*	3-8
loblolly-shortleaf pine	*P. taeda-P. echinata*	10 to < 35
sycamore-sweetgum-American elm	*Platanus occidentalis-Liquidambar styraciflua-Ulmus americana*	< 35 to 200
black cherry-sugar maple	*Prunus serotina-Acer saccharum*	> 1,000
oak-hickory	*Quercus-Carya* spp.	< 35
northeastern oak-pine	*Quercus-Pinus* spp.	10 to < 35 [119]
oak-gum-cypress	*Quercus-Nyssa*-spp.-*Taxodium distichum*	35 to > 200 [80]
southeastern oak-pine	*Quercus-Pinus* spp.	< 10
white oak-black oak-northern red oak	*Q. alba-Q. velutina-Q. rubra*	< 35
northern pin oak	*Q. ellipsoidalis*	< 35
chestnut oak	*Q. prinus*	3-8
northern red oak	*Q. rubra*	10 to < 35
post oak-blackjack oak	*Q. stellata-Q. marilandica*	< 10
black oak	*Q. velutina*	< 35 [119]
elm-ash-cottonwood	*Ulmus-Fraxinus-Populus* spp.	< 35 to 200 [23,119]

*fire return interval varies widely; trends in variation are noted in the species review

POSTFIRE REGENERATION STRATEGY [105]:
Geophyte, growing points deep in soil
Initial off-site colonizer (off-site, initial community)
Secondary colonizer (on-site or off-site seed sources)

FIRE EFFECTS

SPECIES: Celastrus orbiculatus

IMMEDIATE FIRE EFFECT ON PLANT:
As of this writing (2005), there is no published information on the effects of fire on Oriental bittersweet. As a root, root crown, and runner sprouter [3,9,21,24], it is likely that fire only top-kills Oriental bittersweet.

DISCUSSION AND QUALIFICATION OF FIRE EFFECT:
Sprouting species with deeply buried perennating buds are most likely to survive severe fire. Species with large carbohydrate reserves in the roots are most likely to show rapid postfire growth [59,105]. Since descriptions of Oriental bittersweet's root and rhizome system are lacking (as of 2005), it is difficult to assess Oriental bittersweet's capacity to survive fire and sprout. However, since Oriental bittersweet is widely described as a vigorous root sprouter following other types of disturbance that can kill aboveground portions of the plant (e.g., logging) [3,7,9,21,24], Oriental bittersweet probably survives most fires. Descriptions of Oriental bittersweet's root system are needed to further understand Oriental bittersweet's ability to survive and grow following fire under various site, fuel, and weather conditions.

PLANT RESPONSE TO FIRE:
Published accounts of Oriental bittersweet's response to fire are lacking as of this writing (2005); however, Oriental bittersweet can sprout from roots, runners, and root crown following other types of top-killing disturbance [3,9,21,24]. It is likely that Oriental bittersweet is favored by fire, establishing from sprouts and seed. Both sprouts and seedlings respond to canopy release with rapid growth [39,75]. Beyond light release, Oriental bittersweet shows an even greater growth response from nutrient flushes, which often occur after fire [1,2,55].

DISCUSSION AND QUALIFICATION OF PLANT RESPONSE:

Seedling establishment:

New burns may favor Oriental bittersweet establishment. Laboratory studies suggest that open conditions and mineral soil favor Oriental bittersweet seedling establishment on mesic sites [24]. Plants with bird-dispersed seed have good opportunities for short- and long-distance seed transport after fire [65]. Birds are known to disperse Oriental bittersweet seeds from nearby seed sources onto old fields and other disturbed sites, where seedlings can easily establish and grow [28,75,96]. Long gut retention times for Oriental bittersweet seed can facilitate long-distance bird dispersal of Oriental bittersweet seed [32] onto burns and other disturbed sites where birds congregate.

Because most Oriental bittersweet seed remains viable in the seed bank for only 1 year [24,114], fire that kills a year's cohort of Oriental bittersweet seedlings and any seeds remaining on vines, will remove most of the

Oriental bittersweet seed bank. Even with severe fire, however, it is unlikely that a single fire will kill all Oriental bittersweet seed sources on a site. Because Oriental bittersweet is such a prolific seed producer, its seed bank can be quickly replenished by on-site, unburned vines or nearby seed sources [7].

Sprouting: For plants that sprout (see Asexual regeneration), root sprouting is less common than rhizome and root crown sprouting [59]. Plants capable of sprouting from the roots can be powerful competitors for space, light, and nutrients in early postfire environments [57,59,71,97]. Roots are less susceptible to fire damage, and often capable of greater carbohydrate storage, compared to rhizomes and root crowns. Although many of Oriental bittersweet's associates in eastern mixed hardwood forests are capable of sprouting, Oriental bittersweet may have a competitive edge over associated species that cannot root sprout after fire damage.

FIRE MANAGEMENT CONSIDERATIONS:
As of this writing (2005), there is no literature suggesting that fire be used as a management tool to control Oriental bittersweet. Given the potential for rapid Oriental bittersweet growth in early postfire environments, prescribed fire use cannot be recommended without further knowledge of Oriental bittersweet's response to fire under different site, fuel, and weather conditions, in different seasons, and in various plant communities. However, wildfire that removes much of Oriental bittersweet's aboveground biomass may provide opportunities for other control measures.

If burning is prescribed to meet management objectives other than control of Oriental bittersweet, burning should be done either very early or very late in the burning season if Oriental bittersweet is present on the site. Either early spring burning or late fall burning, when most associated plant species are dormant, lowers Oriental bittersweet's carbohydrate reserves [9,94]. Small burns will allow managers to assess Oriental bittersweet's response over a small area, where it will be easier to monitor for Oriental bittersweet seedlings and sprouts. Postfire follow-up measures such as grubbing or spraying are needed to control new Oriental bittersweet growth (see Control). The following paragraphs provide some general guidelines for invasive species management after fire. See Integrated Noxious Weed Management after Wildfires for a more detailed source of this information.

Preventing postfire establishment and spread: More research is needed to determine fire tolerance and response of Oriental bittersweet on specific sites and ecosystems in which it occurs. The USDA Forest Service's "Guide to Noxious Weed Prevention Practices" [112] provides several fire management considerations for weed prevention in general that apply to Oriental bittersweet. Guidelines for determining burn severity, revegetation necessity, and establishing and managing competitive plants are available [5,36]. The following paragraphs provide some general guidelines for invasive species management after fire. See Integrated Noxious Weed Management after Wildfires for a more detailed source of this information.

When planning a prescribed burn, preinventory the project area to evaluate cover and phenology of any Oriental bittersweet or other invasive plants present on or adjacent to the site, and avoid ignition and burning in areas at high risk for Oriental bittersweet establishment or spread due to fire effects. Avoid creating soil conditions that promote weed germination and establishment. Areas of soil disturbance (e.g., those brought about by fire suppression activities) are especially susceptible to invasive plant establishment. Weed status, risks, and prevention must be incorporated in fire rehabilitation plans. Also, wildfire managers might consider including weed prevention education and providing weed identification aids during fire training; avoiding known weed infestations when locating fire lines, monitoring camps, staging areas, helibases, etc., to be sure they are kept weed free; taking care that equipment is weed free; and acquiring restoration funding. Additional guidelines and specific recommendations and requirements are available [36,112].

Preventing invasive plants from establishing in weed-free burned areas is the most effective and least costly management method. This can be accomplished through early detection and eradication, careful monitoring, and by limiting invasive plant seed dispersal into burned areas by [5,36,112]:

- re-establishing vegetation on bare ground as soon as possible
- using only certified weed-free seed mixes when revegetation is necessary
- cleaning equipment and vehicles prior to entering burned areas
- regulating or preventing human and livestock entry into burned areas until desirable site vegetation has recovered sufficiently to resist invasion by undesirable vegetation
- detecting weeds early and eradicating before vegetative spread and/or seed dispersal
- eradicating small patches and containing or controlling large infestations within or adjacent to the burned area

In general, early detection is critical for preventing establishment of large populations of invasive plants. Monitoring in spring, summer, and fall is imperative. Eradicate established Oriental bittersweet plants and small patches adjacent to burned areas to prevent or limit seed dispersal into the site [5,36,112].

The need for revegetation after fire can be assessed on the basis of the degree of desirable vegetation displaced by invasive plants prior to burning, and on postfire survival of desirable vegetation. Revegetation necessity can also be related to invasive plant survival as viable seeds, root crowns, or rhizomes capable of reproduction. In general, postfire revegetation should be considered when desirable vegetation cover is less than about 30% [36].

MANAGEMENT CONSIDERATIONS

SPECIES: Celastrus orbiculatus

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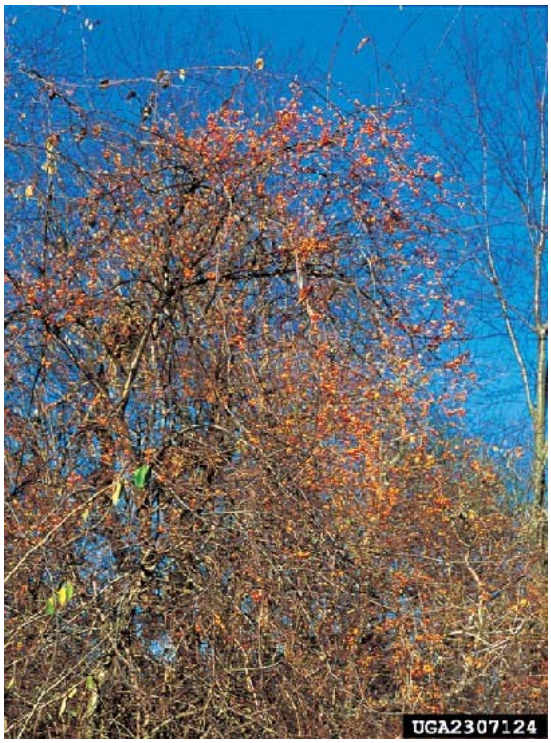
- IMPORTANCE TO LIVESTOCK AND WILDLIFE
- OTHER USES
- IMPACTS AND CONTROL



James H. Miller, USDA Forest Service

IMPORTANCE TO LIVESTOCK AND WILDLIFE:

Oriental bittersweet arils provide winter food for small mammals and birds [39] including black-capped chickadees, northern mockingbirds, European starlings, blue jays, eastern bluebirds, and ruffed grouse [7,88,106].

Palatability/nutritional value:

Oriental bittersweet browse is apparently unpalatable to herbivores. Cattle, white-tailed deer, and lagomorphs browse American bittersweet, which helps keep American bittersweet growth in check [17]. Oriental bittersweet is not similarly utilized by browsing animals [22].

Oriental bittersweet arils are 71% water [32]. Further nutritional information on Oriental bittersweet is not available as of this writing (2005).

Cover value:

Information on how Oriental bittersweet affects cover quality for native wildlife is largely unknown. Because Oriental bittersweet alters forest structure, it probably favors thicket-dwelling animals at the expense of animals requiring more open habitats. On a Nature Conservancy Preserve on Long Island Sound, Connecticut, Oriental bittersweet poses a threat in dune nesting areas of the piping plover, a state-threatened bird. Managers are concerned that Oriental bittersweet will either spread onto and overtake nesting areas, or alter dune erosion and formation dynamics (Lapin 1992, cited in [7]). Investigations comparing animal community composition on sites with and without Oriental bittersweet are needed.

OTHER USES:

Medical:

Oriental bittersweet may prove valuable for medical treatments. It is an Asian folk medicine used for treating rheumatoid arthritis and bacterial infections. Medical and pharmacological studies show that Oriental bittersweet derivatives have antitumor, anti-inflammatory, antioxidant, antibacterial, and insecticidal properties [52,54,77]. One Oriental bittersweet derivative shows ability to reverse cancer-cell multidrug resistance to cancer treatment drugs [60,61].

Food products:

Enzymes in Oriental bittersweet leaves can clot milk. These leaf extracts may provide an alternative to calf rennet enzymes used in making cheese [84].

Ornamental/rehabilitation use: Oriental bittersweet is planted as a hedge in Japan [82]. In the United States, it is commercially available and widely planted and harvested as an ornamental. Oriental bittersweet has also been widely planted in highway and "conservation" plantings, but it is not recommended for plantings of any kind (e.g., ornamental, landscape, wildlife, and rehabilitation) [41,44,73]. Alternative native lianas recommended for ornamental and restoration plantings include American bittersweet, trumpet-creeper (*Campsis radicans*), yellow passionflower (*Passiflora lutea*), pipevine (*Aristolochia macrophylla*), and American wisteria (*Wisteria frutescens*) [9]. For wildlife plantings, American bittersweet can be used on sites where more fruit-bearing species are needed for frugivorous animals [73]. Oriental bittersweet is sometimes mistaken for, mislabeled, and/or planted as American bittersweet in wildlife cover and erosion projects. Correct identification of American bittersweet is needed to meet restoration goals [7].

IMPACTS AND CONTROL:

Impacts:

Oriental bittersweet competes with native vegetation for light, threatening native plant community diversity and modifying stand structure and plant succession [7,8,117]. The southern Appalachians are currently most affected by Oriental bittersweet invasion [7,64]; however, the ease of seed dispersal and horticultural interest in Oriental bittersweet in the eastern United States and elsewhere creates a large geographic area of potential invasion [7]. Invasion strategies of Oriental bittersweet include:

- ability to regenerate by cloning
- abundant seed production
- wide-ranging seed dispersal by animal and human vectors [39,68,76,86,91,102]
- ability to germinate under a wide range of light conditions
- ability to acclimate photosynthetic capacity and persist a wide range of light conditions [85,86]
- rapid growth after release [3,73]
- ability to climb supports of varying sizes [3,21,90]

Site diversity:
Oriental bittersweet thickets are too densely shaded for most native herbaceous species to establish and grow [75]. For example, Oriental bittersweet canopies inhibit establishment of understory spring ephemerals [51]. Oriental bittersweet is interfering with growth of native wild grapes on the Pisgah National Forest, North Carolina [75].

Oriental bittersweet appears to be expanding its range at the expense of American bittersweet [104]. The same characteristics that make Oriental bittersweet a preferred ornamental plant compared to American bittersweet: faster growth, greater fecundity, and a greater tolerance to varying environmental conditions, are the same characteristics that have enabled Oriental bittersweet to be a successful invader [64]. Oriental bittersweet has superior ability to regenerate under a wide range of light conditions compared to American bittersweet. A field experiment showed Oriental bittersweet increased its photosynthetic rate with increasing light intensity, while American bittersweet's photosynthetic rate tended to saturate under low light conditions [16]. Floral inventories generally show that Oriental bittersweet is more common than its native congener. In a Connecticut study, Dreyer and others [21] found Oriental bittersweet showed significantly ($p<0.001$) greater pollen and seed viability compared to American bittersweet. While recognizing that many environmental and genetic factors ultimately affect seedling establishment, the authors stated that these 2 factors could be important in determining relative cover of the 2 bittersweet species [21]. A New Jersey study showed a 90% germination rate for 1st-year, soil-stored Oriental bittersweet seed compared to a 65% germination rate for 1st-year, soil-stored American bittersweet seed [114]. American bittersweet is further threatened by hybridization. The potential for hybridization and introgression of American bittersweet with Oriental bittersweet has prompted the state of Connecticut to list American bittersweet as a Species of Special Concern, and Great Smoky National Park to list American bittersweet as a Nonreproducing Rare Plant [7].

Oriental bittersweet's growth habit of blanketing and shading out support species affects both stand structure and plant succession [21,28,66]. Twining Oriental bittersweet vines girdle support vegetation, restricting sap and water flow. Damaged support plants are at increased risk for breakage or uprooting from ice- and windstorms [7,9,20,21,75]. Photosynthesis of support and understory plants is reduced or prevented in Oriental bittersweet thickets. Patterson [86] noted the scarcity of other plant species beneath Oriental bittersweet canopies, and attributed it to shading. In Connecticut, Oriental bittersweet altered old-field-to-hardwood forest succession by decreasing diversity, inhibiting reproduction and growth of native shrubs and trees, and facilitating growth of fox grape, a late-successional native liana, into the canopy (see Old fields) [28].

Reports of Oriental bittersweet's invasiveness vary. Voss [118] describes it as "sometimes aggressive" when escaped from cultivation in Michigan. Others classify it as invasive [31] to highly invasive [7]. On the Energy Oak Ridge National Environmental Research Park, Tennessee, Oriental bittersweet was ranked the 5th most invasive nonnative dicot in the Park, and the 9th most invasive nonnative plant species overall [18]. In Farmington, Maine, a survey of invasive nonnatives in mixed hardwood-spruce (*Picea* spp.) forests ranked Oriental bittersweet as intermediate in abundance, behind Japanese knotweed (*Polygonum cuspidatum*) and

nonnative bush honeysuckles (*Lonicera morrowi, L. tatarica,* and their hybrids). In this survey, Oriental bittersweet often occurred as large, escaped populations that were "largely independent" of ornamental Oriental bittersweet seed sources [6].

Disturbance increases the likelihood of successful Oriental bittersweet establishment [24]. As of this writing (2005), there are few studies seeking to identify specific disturbance factors that may foster Oriental bittersweet invasion. On the Pleasantville Valley Wildlife Sanctuary, Massachusetts, Oriental bittersweet density was correlated with level of past site disturbance. Sites with a known history of farming or logging tended to have moderate to heavy infestations, with heaviest infestation on logging roads. On logged sites, plots where horse logging had been conducted were less infested than plots where mechanized equipment was used. Oriental bittersweet did not occur on undisturbed plots. Oriental bittersweet seedling establishment on logged plots occurred 2 or more years after logging ceased. The authors speculated that the Oriental bittersweet establishment lag was due to reluctance of bird dispersers to forage or perch in exposed openings and/or the more favorably mesic conditions for Oriental bittersweet germination and establishment that occurred after initial colonization of other plant species. Oriental bittersweet was positively correlated with percent exposed mineral soil and sites with relatively less acidic soil pH, a combination of which was most common on logging roads and least common on undisturbed sites [102].

Oriental bittersweet does invade undisturbed mesic to dry-mesic forests [9,51], however. Silveri and others [102] noted that although it did not occur on their undisturbed plots, small but apparently healthy Oriental bittersweet seedlings were present in late-successional deciduous and conifer forests elsewhere on the Wildlife Sanctuary, growing through an intact litter layer on a well-shaded forest floor. Further investigations into site conditions fostering Oriental bittersweet invasion onto both undisturbed and disturbed sites are needed.

Silvicultural:

After tree harvest or fire, Oriental bittersweet sprouts may outgrow and overtop competing sprouts of native trees and shrubs. Girdling and stem damage from Oriental bittersweet vines lowers the value of timber species infested with Oriental bittersweet. On the Pisgah National Forest, Oriental bittersweet has covered sapling-sized hardwood and eastern white pine (*Pinus strobiformis*) regeneration on small clearcuts [75].

Where it is present before harvest, Oriental bittersweet can rapidly overtake a site after tree harvest. In a Massachusetts clipping experiment, Oriental bittersweet growth ranged from 6.9 to 15 feet (2.1-4.7 m) in 1 year. In contrast, bigtooth aspen (*Populus grandidentata*) sprout growth ranged from 3 to 5.9 feet (0.9-1.8 m) in 1 year, and yellow-poplar sprouts averaged 4.6 feet (1.4 m) of growth in 1 year ([25] and references therein). On the Bent Creek Experimental Forest, a high-quality stand of upland oaks was clearcut in the summer of 1977. Oak site index before harvest was above 80, with a basal overstory area of 120 ft². Preharvest Oriental bittersweet density was 830 seedlings/acre and 27 saplings/acre (Oriental bittersweet seedlings were < 0.6 dbh; saplings were >0.6 dbh). Seven years after tree harvest, the canopy was nearly 100% Oriental bittersweet [75].

Agricultural: Oriental bittersweet is an alternate host for *Xylella fastidiosa.* This bacterium is responsible for several crop diseases including Pierce's grapevine (*Vitis* spp.) disease, periwinkle (*Vinca* spp.) wilt, plum leaf scorch and phony peach (*Prunus* spp.) disease, and variegated chlorosis (affects several genera including oaks, elms, sycamores, citrus (*Citrus* spp.), and mulberries (*Morus* spp.)) [72].

Control: The Southeast Exotic Pest Plant Council [7] recommends that Rank 1 and Rank 2 species such as Oriental bittersweet (see Other Status) be controlled and managed in the early stages of infestation whenever possible. Because Oriental bittersweet appears to build only a short-term seed bank [24], there are better opportunities for control and a higher probability of success than if seeds were longer lived. If established plants and nearby seed sources are killed before fruits mature, subsequent seedling establishment may primarily come from long-distant seed sources, with little seedling emergence from the seed bank [7,24]. Vigilant monitoring and early control of new outbreaks can then help control Oriental bittersweet [7,19].

Since Oriental bittersweet resembles native American bittersweet, it is important to correctly identify Oriental bittersweet before control measures begin [9] (see General Botanical Characteristics).

Prevention:

The most efficient and effective method of managing invasive species such as Oriental bittersweet is to prevent their invasion and spread [99]. Preventing the establishment of nonnative invasive plants in wildlands is achieved by maintaining native communities and conducting aggressive surveying, monitoring, and any needed control measures several times each year. Preventing the introduction of Oriental bittersweet into uninfested areas, and early control of small infestations, should be a priority [19]. Monitoring efforts are best concentrated on the most likely sites of Oriental bittersweet invasion: disturbed soil, roadsides, old fields, woodlands, and waterways. Uninvaded sites should be periodically surveyed to detect new invasions. The Center for Invasive Plant Management provides an online guide to noxious weed prevention practices.

Monitoring is an important part of an integrated program for Oriental bittersweet control [102]. Because Oriental bittersweet retains its leaves longer than most associated native species, its yellow leaves are easy to spot in late fall, even from a distance. Consistent fall monitoring can identify new infestations, allowing managers to implement control programs and prevent new infestations from spreading. Managers in Great Smoky National Park recommend scouting for infestations every 2 weeks after most native species have dropped their leaves, which is approximately November 10th in Great Smoky National Park. [7].

It is important to identify areas that are at high risk for Oriental bittersweet invasion, and monitor such areas regularly [102]. Silveri and others [102] conducted field transplanting experiments 13 years after logging on the Pleasantville Valley Wildlife Sanctuary. Variables that were positively correlated to Oriental bittersweet's invasion success were soil moisture, soil pH, and irradiance. For mountainous terrain in the southern the Appalachians, NcNab and Loftis [74] describe a rapid survey technique for hazard rating, and provide a model for estimating probability of Oriental bittersweet occurrence based on environmental, competitive, and disturbance factors.

Inventories to establish Oriental bittersweet presence and densities are needed before control programs, or any silvicultural treatment that opens the canopy, begin. McNab [73] cautions that if Oriental bittersweet is present in the understory, canopy disturbance will stimulate its growth.

Integrated management:

No single treatment provides effective, long-term control of Oriental bittersweet. Managing Oriental bittersweet requires an integrated strategy. Integrated management includes early detection, assessment, and containment of infestations before they spread. Factors to be addressed before a management decision is made also include assessment of nontarget vegetation, soil types, climatic conditions and important water resources; and an evaluation of the benefits and limitations of all control methods [79]. Hobbs and Humphries [47] advocate an integrated approach to the management of plant invasions that includes "a focus on the invaded system and its management, rather than on the invader" and "identification of the causal factors enhancing ecosystem invasibility" as an effective approach to controlling invasive species. This type of "ecological control" puts an emphasis on removing the ecological stressors that may be underlying the causes of invasion, rather than on direct control of invasive species [47].

Few studies investigate multiple control methods for Oriental bittersweet control. Hutchison [51] recommends either grubbing or a combination of cutting and herbicide treatment. When practical, he recommends uprooting and removing individual Oriental bittersweet stems from infested sites. In other situations he recommends hand cutting after the 1st killing frost, then spot-treating cut stems with glyphosate. Large populations can also be treated with foliar application of glyphosate alone, triclopyr alone, or a combination of 2,4-D and triclopyr. Small infestations should be eradicated from the treatment site and surrounding vicinity. To maintain control, invading individuals should be immediately pulled and removed off-site [51].

Physical/mechanical:
Frequent cutting, mowing, or grubbing controls small Oriental bittersweet populations. Grubbed roots and runners sprout unless they are completely removed, so treatment must be frequent enough to eventually exhaust the underground carbohydrate supply. This is accomplished by cutting or mowing every 2 weeks. Occasional mowing, cutting, or grubbing only encourages Oriental bittersweet root sprouting, and is therefore not recommended [7,9,22,74]. Climbing or trailing vines should be cut as close to the root crown as possible [7]. When grubbing, underground reproductive organs should be bagged and removed from the site or allowed to sit in the sun until the bagged plants and seeds have died [7,9]. To prevent posttreatment seedling establishment, it is most effective to implement mechanical treatments before Oriental bittersweet is in fruit [9].

Fire: See the Fire Management Considerations section of this summary.

Biological: Oriental bittersweet has no known pathogens in North America [9]. A leaf spot fungus (*Marssonina celastri*) causes defoliation of Oriental bittersweet in Korea, where Oriental bittersweet is native [101]; however, pathogens from Oriental bittersweet's native range have not been approved for use in the United States [9].

Chemical: Oriental bittersweet can be controlled with herbicides [7,9]. Herbicides may provide initial control of a new invasion or a severe infestation, but used alone, they are rarely a complete or long-term solution to invasive species management [13]. Herbicides are most effective on large infestations when incorporated into long-term management plans that include replacement of weeds with desirable species, careful land use management, and prevention of new infestations. Control with herbicides is temporary, as it does not change the conditions that allowed the invasion to occur (e.g. [126]). See The Nature Conservancy's Weed Control Methods Handbook
for considerations on the use of herbicides in Natural Areas and detailed information on specific chemicals.

Oriental bittersweet can be controlled using herbicides applied as either cut-stem or foliar treatment. Systemic herbicides (e.g., triclopyr or glyphosate) is recommended for Oriental bittersweet [7,9]. Triclopyr is a broadleaf-specific herbicide, and glyphosate is a nonselective herbicide (kills all plants). Care must be taken to avoid drift onto desirable native species.

Effective use of herbicides requires appropriate herbicide concentration, application technique, and timing. For cut-stem treatments, best control occurs when the herbicide is applied after stems are cut or mowed [7,9]. Cut the stems about 2 inches (5 cm) above the root crown. A 2nd treatment may be needed to control sprouts. Herbicide applications in early spring, before native herbs have emerged, or in late fall when natives are dormant but Oriental bittersweet is still green, can minimize effects to nontarget plants [9]. Bean [7] provides further details on herbicide control of Oriental bittersweet.

In red pine (*Pinus resinosa*) forests in Connecticut, late-summer (17-18 Sept.) herbicide treatments gave fair to good control of Oriental bittersweet. Fourteen treatments involving four different herbicides, used alone or in combination, at varying application rates were used. One year after treatments, imazapyr and triclopyr gave best results with low concentrations. Results for unmixed herbicide treatments are given below. See Ahrens [3] for details of herbicide combinations, concentrations, and other treatment results.

Herbicide	Control
imazapyr	~100%
triclopyr	~100%
glyphosate	80%
sulfometuron	0%

Cultural: There is no information on using plantings of other species to control Oriental bittersweet.

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