Cirsium palustre

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INTRODUCTORY

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AUTHORSHIP AND CITATION:
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FEIS ABBREVIATION:
CIRPAL

NRCS PLANT CODE [69]:
CIPA6

COMMON NAMES:
marsh thistle
European swamp thistle

TAXONOMY:
The scientific name of marsh thistle is *Cirsium palustre* (L.) Scop. (Asteraceae) [17,19,30,36,54].

Hybrids: Natural *C. palustre* × *C. arvense* hybrids occur in England and other European countries (Sledge 1975 cited in [17]). These hybrids are possible where these species grow together in North America [17].

SYNONYMS:

None

LIFE FORM:
Forb

FEDERAL LEGAL STATUS:
None

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

DISTRIBUTION AND OCCURRENCE

SPECIES: Cirsium palustre

- GENERAL DISTRIBUTION
- HABITAT TYPES AND PLANT COMMUNITIES

GENERAL DISTRIBUTION:
Marsh thistle occurs as a nonnative species in Wisconsin, Michigan, New York, Massachusetts, and New Hampshire in the United States and north to Newfoundland, Nova Scotia, Quebec, Ontario, and British Columbia in Canada [37,56,69]. It is native to Europe [17] and was first reported in North America in the early 1900s [79]. In the Great Lakes area, marsh thistle populations are considered "vastly under reported", although marsh thistle was reported in 10 northeastern counties in Wisconsin as of 2007 and is considered well established in Michigan. Populations in Canadian provinces and northeastern US states are scattered [56]. Plants Database provides a distributional map of marsh thistle.

Marsh thistle was reported in New England by 1902 and in the Great Lakes area by 1934 (review by [56]). In New Hampshire, marsh thistle was first reported from East Andover in 1902. Plants occurred over a nearly 20-acre (8 ha) area in a "moist forest tangle" that was more than a mile (1.6 km) from the nearest town or cultivated area. Method of introduction was unknown. Marsh thistle was reported in South Boston in 1908 and in Newfoundland in 1910 [37]. In 1944, marsh thistle was reported in several communities near Halifax, Nova Scotia [54]. In Michigan, marsh thistle was first collected from Marquette County in 1934 [79]. It was first recorded in Wisconsin in 1961 [56]. In British Columbia, marsh thistle was first reported in 1954 [41]. Marsh thistle was reported during a 1964 survey of a ponderosa pine (*Pinus ponderosa*) forest in northwestern Nebraska [40]. However, no other sources reported marsh thistle in Nebraska as of 2009, suggesting that this population was transient or incorrectly identified.

Local distribution changes: The range of marsh thistle in North America is "rapidly expanding". Marsh thistle populations in Europe occur almost as far north as the Arctic Circle, suggesting marsh thistle could grow and spread throughout the boreal forest regions of North America [17]. In Wisconsin and Michigan, the area occupied by and the abundance of marsh thistle have increased since its introduction and continue to increase [56]. Marsh thistle was first recorded in Michigan in 1934 and by 1956 was considered locally frequent and common in Michigan's Upper Peninsula and on islands in the Straits of Mackinac [78,79]. By 1959, marsh thistle spread to the Lower Peninsula, and it continues to spread south. "Dense, ungainly colonies" occupy miles of ditch banks in Michigan, and populations have spread into adjacent natural areas [79]. Although marsh thistle has occurred in British Columbia since the 1950s, its spread has been more recent. A "diminutive patch" of marsh thistle west of McBride, British Columbia, was reported in 1991, but marsh thistle had spread at least 130 miles (210 km) by early 2000. Spread occurred primarily along roadways and through river valleys [41]. For more on the potential impacts of marsh thistle persistence and spread, see Impacts and Control.

HABITAT TYPES AND PLANT COMMUNITIES:

European habitats and plant communities: In Europe, marsh thistle occurs in fens, sedge (*Carex* spp.) meadows, and moist grasslands and woodlands. In Suffolk, England, the bluntflower rush (*Juncus subnodulosus*)-marsh thistle fen occurred where shrub vegetation was cleared [18]. Marsh thistle also occurs in the understory of mires at Holmsley Bog in Hampshire, England. Overstory species, which may reach 12 feet (3.7 m) tall, often include English oak (*Quercus robur*) and/or English yew (*Taxus baccata*) [20]. In the British Plant Communities books, marsh thistle is reported in:

- willow (*Salix* spp.), downy birch (*Betula pubescens*), European alder (*Alnus glutinosa*), and/or European ash (*Fraxinus excelsior*) woodlands
- shrubby blackberry (*Rubus fruticosus*) communities [51]
- mires, pastures, and fen meadows [52]
- creeping willow-calliergon moss (*S. repens-Calliergon cuspidatum*) dune-slack communities (in the swales between sand dunes)
- willowherb (*Epilobium* spp.) communities [53]

In southeastern Scotland, marsh thistle is common in colonial bentgrass (*Agrostis tenuis*) grasslands on poorly drained sites [31]. On coastal dunes in the Netherlands, marsh thistle is common in oneseed hawthorn-European white birch (*Crataegus monogyna-Betula pendula*) woodlands with ground water at or near the soil surface [70]. Marsh thistle is also described in surface water-fed sedge fens [7], bare sandy sites, and open sites with chee reedgrass (*Calamagrostis epigejos*) and seaberry (*Hippophae rhamnoides*) [73].

North American habitats and plant communities: In North America, marsh thistle occurs in wetlands, moist meadows, and forest openings [17,41]. In Wisconsin, it occurs in sphagnum (*Sphagnum* spp.) bogs, wet roadside communities, sedge marshes, and black spruce (*Picea mariana*) swamp openings [56]. In Michigan, marsh thistle populations along ditch banks have spread into adjacent northern whitecedar (*Thuja occidentalis*) swamps and shaded fens [79]. In New England, marsh thistle is reported from coastal beach and dune communities, coastal grasslands, early-seral forests, forest edges, floodplain forests, herbaceous wetlands, and other disturbed areas [37]. Additional information on common marsh thistle habitats is reported in Site Characteristics.

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

SPECIES: Cirsium palustre

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

GENERAL BOTANICAL CHARACTERISTICS:

- **Botanical description**
- **Raunkiaer life form**

Photo © J.C. Schou; Biopix.dk

Botanical description: This description covers characteristics that may be relevant to fire ecology and is not meant for identification. Keys for identification are available (e.g., [17,19,36,54]).

At maturity, marsh thistle is generally an erect forb with a single branching stem. Plants may reach 6 feet (2 m) when flowering [17]. Stems are spiny and winged because a portion of the leaf blade is attached to the stem. Most plant parts are covered with long sticky hairs [37,54].

Marsh thistle is best described as a monocarpic perennial. Plants often reproduce within 2 years but may take longer [19,36,56]. Rosette leaves are long, spiny, and deeply lobed [17,83]. In Jutland, Denmark, many marsh thistle plants remained vegetative for 2 or more years. All plants died after flowering, unless they were damaged during the flowering stage, in which case they regrew the next year [4]. Another researcher reported that marsh thistle generally flowered at 4 years old in its native range (Linkola 1935 cited in [6]). In 2 seashore meadows in Tullgarn, Sweden, most (68-86%) marsh thistles flowered 3 years after germination, while the rest flowered later. In this area, the researcher noted a small number of marsh thistle plants flowering twice [48]. Damage to these plants was not reported, but grazing and trampling were common in the area. (See Vegetative regeneration for another report of marsh thistle flowering in successive years.)

On flowering stems, alternate leaves are 6 to 12 inches (15-30 cm) long near the base but shorter near the top. Leaf spacing is generally much wider near the top than at the base of the plant [17,83]. Spines up to 6 mm long occur along leaf margin lobes [17].

Marsh thistle flower heads also appear spiny [83]. Perfect disk florets occur in heads that develop on short branches at the end of the stem [19,36,36,79]. Few to many flower heads

Photos ©Steve Garske, Great Lakes Indian Fish & Wildlife Commission

may be produced [17]. Heads typically measure 0.4 to 0.6 inch (1-1.5 cm) across [79].

Marsh thistle produces achenes that measure between 2.5 and 3.5 mm and are attached to a feathery pappus of fine cottony hairs [17,19,37,83]. The pappus is typically less than 0.4 inch (1 cm) long [37], and achenes average 2 mg (Grime and others 1988 cited in [28]).

Marsh thistle produces a taproot with clusters of fibrous roots [17,36]. It lacks rhizomes [54]. In Jutland, Denmark, root development of vegetative marsh thistles was described in detail. Increased root growth coincided with increased leaf growth and increased flowering probability. Twenty-three percent of plants in the 3rd vegetative life stage (described in the table below) flowered the next year, while 79% or more plants in 4th vegetative life stage flowered the next year. All plants died after flowering [4].

Below- and aboveground growth of marsh thistle in Denmark [4]			
Stage of vegetative development	2nd vegetative life stage	3rd vegetative life stage	4th vegetative life stage
Number of rosette leaves	3-4	3-5	8-18
Leaf width (mm)	19-45	35-73	85-123
Leaf length (mm)	150-360	180-400	300-600
Diameter of taproot (mm)	3.1-5.0	5.5-8.0	11.0-22.0
Length of taproot (mm)	30-50	20-50	30-40
Number of lateral roots	9-18	15-30	30

Similar native species: In the Great Lakes, New England, and eastern Canada, marsh thistle occupies habitat similar to that of the native swamp thistle (*Cirsium muticum*). Swamp thistle lacks stem spines and produces less spiny-looking flower heads than marsh thistle [83].

Raunkiaer [49] life form:
Hemicryptophyte

SEASONAL DEVELOPMENT:
Marsh thistle flowers are generally present from June to August in North America [17,19,36]. In seashore meadow habitats in Tullgarn, Sweden, marsh thistle flowered in the summer (flowering dates were not reported). Flowering dates for early- and late-flowering plants were not reported [48]. In Wisconsin, seeds are produced by late summer [83]. In central Jutland, Denmark, seed germination occurred in spring and fall [4]. Seedlings emerged from April through October in Poland's Bialowieza Primeval Forest, although most emergence occurred in June or July [15].

REGENERATION PROCESSES:
Marsh thistle reproduces by seed. Although plants damaged in the flowering stage may regenerate and flower the following year, undamaged plants die after flowering. Sprouting is restricted to overwintering rosettes or cut or damaged plants (see Vegetative regeneration).

- **Pollination and breeding system**
- **Seed production**

- **Seed dispersal**
- **Seed banking**
- **Germination**
- **Seedling establishment and growth**
- **Plant development and survival**
- **Vegetative regeneration**

Pollination and breeding system: Marsh thistle flowers are self-compatible, but most are cross-pollinated by insects. In meadows in Tullgarn, Sweden, marsh thistle flowers were primarily pollinated by bumblebees [48]. In mountain and sea cliff habitats in England, bees were the dominant daytime pollinators [39].

Seeds from self-pollinated plants may have lower viability than seeds from cross-pollinated plants. Self-pollinated marsh thistle plants from mountain habitats in Monmouthshire and sea cliff habitats in Gower, England, produced significantly less viable seed than cross-pollinated plants [39]. Field experiments in 3 marsh thistle populations north of The Hague in the Netherlands revealed no significant differences in the germination of seed from cross-pollinated plants and plants protected from insects. Marsh thistle populations occurred in a dense birch (*Betula* spp.) woodland, a grassland, and a bare sandy site. Seeds produced by cross-pollinated plants weighed significantly ($P<0.01$) less than those produced by protected plants. Although some dispersal had occurred by the time production was evaluated, seed production of cross-pollinated plants exceeded that of protected plants by as much as 58.9%. Production differences were not significant [73]. Germination, seedling establishment, and plant survival based on pollination method are discussed more in the sections below.

Seed production: Reviews report that a single marsh thistle plant may produce up to 2,000 seeds [41,56]. A vernalization period is considered necessary for flowering [44]. Flowering date, flowering stem height, site conditions, and predation may affect marsh thistle seed production. In seashore meadow habitats in Tullgarn, Sweden, late-flowering marsh thistle plants produced more flower heads and generally had greater reproductive output than early-flowering plants. Reproductive output also increased with increasing height of the flowering stem (R^2 =0.646, $P<0.0001$) [48]. In a dune area north of The Hague, marsh thistle populations averaged 24.1 seed-producing flower heads/plant and produced between 300 and 2,000 seeds/plant. There were many undeveloped seeds in the flower heads; the largest percentage of undeveloped seeds occurred in populations that were inundated for parts of the summer. Shade did not impact seed development [75,76], although other research suggests that shading can limit seed production (see Shade tolerance).

Field observations made near The Hague showed that moth (*Epiblema scutulana*) larvae and rabbits that fed on marsh thistle stems reduced flower head production by an average of 25.2% and 31.8%, respectively [74]. When seeds were sown in dune areas near The Hague, counts 2 weeks later suggested seed predation levels of 60% to 80% [75].

Seed dispersal: Wind is likely the most common dispersal mechanism for marsh thistle seeds, but seeds may also be dispersed by gravity, in water runoff, or by animals and equipment [41,42]. Marsh thistle seeds are attached to a "thistle-down" pappus that aids in wind dispersal [83]. A review reports that while most marsh thistle seeds fall within 33 feet (10 m) of the parent plant, high winds may carry seeds several kilometers [41]. Wind dispersal distances may be reduced by increased densities and heights of neighboring plants [57], decreased heights of marsh thistle plants [74], and increased seed weights [73].

From laboratory experiments and achene and pappus measurements, researchers calculated that marsh thistle seeds could be dispersed a maximum of 22 feet (6.8 m) in 10 mile (16.4 km)/hour winds. Seeds released from a 36-inch (90 cm) height traveled a maximum of 7.5 feet (2.3 m) and 15 feet (4.5 m) in wind speeds of 3.4 miles (5.5 km)/hour and 6.8 miles (10.9 km)/hour, respectively. Researchers noted that dispersal distances would likely be less in dense stands, where wind speeds are reduced and obstructions are increased [57]. Based on these calculations, researchers suggested seed dispersal distances could be reduced 35% to 50% when marsh thistle plant heights were reduced 16% by larval insects feeding on plant stems [74]. Dispersal distance changes as a result of the greater seed weights of self-pollinated plants were not calculated, but researchers suggested that heavier seeds fell closer to the parent plants [73].

During seed trapping studies conducted in peat-harvested areas in Finland, marsh thistle seeds may have dispersed distances of 160 feet (50 m) or more. In one area, 1 marsh thistle seed/m² was recovered from seed traps located 820 feet (250 m) from the forest edge. There were no mature marsh thistle plants reported in the trapping area. Seed traps 160 feet (50 m) from the forest edge collected 16 marsh thistle seeds/m² [55]. This study, however, was not designed to directly estimate seed dispersal distances. In another seed-trapping study in an eastern Scotland grassland, marsh thistle was collected from traps but not from soil in plots where vegetation was herbicide-killed. Traps contained less than 10 marsh thistle seeds/m², and the distance to the nearest mature plants was not reported. Researchers indicated that seeds were likely transported by wind, but may have been transported in surface water runoff or in animal fur or feathers [42].

It is likely that marsh thistle seeds are transported by equipment, but direct evidence is lacking. A review suggests that logging equipment may have transported marsh thistle seed. In British Columbia, new marsh thistle populations have been reported on mechanically-disturbed sites hundreds of kilometers from existing populations [41]. In hay fields in the northern Netherlands, marsh thistle was present but its seed was not collected from haying equipment used for mowing in August [62]. Although seeds were not recovered from mowing machinery, haying equipment may still have contributed to marsh thistle seed dispersal. It is possible that seeds had fallen off before counts were made or that seed was dispersed in the mowed area by blowing motors.

Seed banking: Although many have studied marsh thistle seed bank dynamics and attempted to determine the longevity and persistence of seed in the soil, findings and conclusions from these studies disagree. Some suggest a short-lived seed bank [50], while others suggest a persistent seed bank [46,63]. Methodology and scope of marsh thistle seed bank studies differ, making them difficult to compare and evaluate. It is possible that a portion of marsh thistle seed germinates immediately following dispersal [50], but a smaller portion fails to germinate, becomes dormant, and develops germination requirements different from those of fresh seed [46]. Of seeds collected from plants near The Hague, 40% germinated after 1 year of burial [76].

Experiments conducted in Wellesbourne, England, suggested that seeds did not persist more than 3 years in the soil. Marsh thistle seeds were mixed with soil and put in a container that was sunk into the ground in September. Soil was mixed 3 times/year and emergence monitored. Most seeds germinated within a year and most germinated in the spring, although some fall germination occurred. Not all sown seeds were recovered, and the researcher suspected that seeds covered by 3 inches (7.5 cm) of soil germinated but failed to emerge [50].

Emergence of marsh thistle seeds over time in England [50]

Time in the ground	4 months	1 year	2 years	3 years	4 years	5 years
Percentage of seeds emerging	8.8%	33.3%	0.2%	0.1%	0	0

Increasing depth of burial increased the survival of buried marsh thistle seed in the Netherlands. In a field experiment, 4% of marsh thistle seeds survived 27 months of burial at 2- to 5-inch (5-10 cm) depths, and 40% of seeds survived the same amount of time at 6- to 8-inch (15-20 cm) depths [75].

Soil samples collected from 95- to 150-year-old European beech (*Fagus sylvatica*) woodlands in southern Sweden rarely contained marsh thistle seed. Soil samples were collected in April at least 330 feet (100 m) inside the woodland edge. Surveys revealed no marsh thistle seedlings in the woodland. Fourteen marsh thistle seedlings/m² emerged from the top 2 inches (5 cm) of mineral soil collected from 1 of the 7 sampled sites. Researchers noted that after clearcutting, marsh thistle was common in the area. Because marsh thistle did not emerge from all soil samples, researchers supposed that emergence on cleared sites resulted from recent long-distance seed dispersal and not a persistent seed bank [60].

Based on several field and greenhouse observations and experiments, Pons [46] concluded that marsh thistle seed does persist in the soil seed bank. In the Netherlands, marsh thistle is common following cutting in ash (*Fraxinus* spp.) stands. Marsh thistle seedling emergence was compared in soil samples taken from sites cut 7 years earlier. Soil was collected from an undisturbed site and a site where soil had been artificially disturbed. Just 19 marsh thistle seedlings/m² emerged from undisturbed soils, and 497 marsh thistle seedlings/m² emerged from disturbed soils,

suggesting that emergence was not limited to wind-dispersed seed on the soil surface but also came from soil-stored seed that was encouraged to germinate by the soil disturbance. In multiple follow-up experiments, Pons concluded that dormancy in marsh thistle seeds was triggered by high temperatures and reduced light levels. Exposure to light was the principal stimulus for germination of soil-stored seed, and brief light exposure during winter harvesting could allow for emergence several months later [46].

In a meadow in Poland's Bialowieza Primeval Forest, the density of marsh thistle in the soil and in aboveground vegetation generally decreased as succession progressed. The meadow was managed with regular mowing that was discontinued when the study began. Marsh thistle plants and seeds occurred in all stages of succession, 0 to 20 years since the last mowing, but density generally decreased as time since last mowing increased [16]. Marsh thistle survival, growth, and development were also studied as succession progressed in this meadow (see Plant development and survival).

Density of marsh thistle seed in the soil from a meadow as time since last mowing increased [16]

Time since last mowing (years)	0	5	10	15	20
Dominant vegetation	Grasses	Grasses, increased proportion of tall forbs	Forbs	Sedges, some willow clumps	Willow clumps, still some tall herbs and sedges
Marsh thistle seed bank density (seed/m²)*	320	393	217	144	50

*Determined by separating seeds from soil; 40 samples (10×10×3 cm) were collected at each 5-year interval.

Germination: Marsh thistle seeds generally germinate best in warm temperatures and full light after cold stratification. However, some germination occurs without stratification, in cool temperatures, and in the dark. Pollination method and parent plant litter can also affect germination.

During field studies in Tullgarn, Sweden, germination percentages for marsh thistle were very low; 0.2% to 0.4% germination in one meadow population and 9% to 17% germination in another meadow population [48].

Temperature, light, and moisture effects: Cold stratification and high light and moisture levels may produce the highest germination percentages for marsh thistle seeds, but seeds may also germinate without cold stratification and in the dark. Warm temperatures (=54 °F (12° C)) are typically best for germination regardless of prior chilling and light conditions [24,45,75].

Increasingly cold temperatures significantly (P<0.001) increased the germination of marsh thistle seeds collected from a wet meadow in the Czech Republic. Germination was highest but was still less than 40% after 30 days at 6.8 °F (-14° C). At 68 °F (20° C), germination was less than 20% [32]. Marsh thistle seeds collected from plants in the Netherlands, however, "gave no problems in germination", although other species required winter temperatures before germinating [43]. Marsh thistle seeds collected in August from a sphagnum bog in England's Sheffield area also germinated well (91%) without cold stratification. After 3, 6, and 12 months of storage at 41 °F (5° C), germination was 50%, 88%, and 79%, respectively. In full light, germination was 90%; in the shade (2.4% of full light), germination was 86%. In the dark, germination was 36% [24]. In other laboratory studies, germination of freshly collected marsh thistle seed ranged from 32% to 72% in the light and 0.8% to 20.7% in the dark. Storage at 39 °F (4 °C) reduced germination in the light and dark [75].

Laboratory findings suggested that marsh thistle seeds could germinate beneath ash canopies, but seedlings were rare in the understory. At low red/far red (R/FR) light levels that were slightly lower than those penetrating ash thickets in

the Netherlands, freshly harvested or dry-stored marsh thistle seed germination was lower than at high R/FR light levels. Cold stratification increased germination at low R/FR light levels and at low temperatures. Germination failed even with stratification at a R/FR level of less than 0.2 [45].

Marsh thistle seeds failed to germinate at water stress levels of 0.25 MPa in the laboratory. Germination ranged from 69% to 57% up to water stress levels of 0.1 MPa but was reduced to 3.8% at 0.2 MPa [75].

Timing and parent plant effects: Researchers found that in a spring area in central Jutland, Denmark, marsh thistle seedlings from fall-germinating seeds were generally larger than those from spring-germinating seeds [4]. Seedlings were rare beneath flowering marsh thistles or in the immediate vicinity of marsh thistle rosettes. In the laboratory, germination of marsh thistle seeds was significantly (P<0.05) lower when treated with extracts of marsh thistle leaf material than when untreated [3]. Seedling growth may also be reduced in soil with marsh thistle leaf litter (see Seedling establishment, growth, and survival).

Pollination method effects: In the Netherlands, marsh thistle seeds from plants protected from insects germinated at a greater percentage and rate than seeds from cross-pollinated plants. After 4 days, germination of seeds from cross-pollinated plants (1.6%) was significantly (P<0.01) less than that of seeds from protected plants (19.7%). After 14 days, germination differences were still significant (P<0.05); 77.4% of seeds from cross-pollinated plants and 87.7% of seeds from protected plants germinated [73]. Seedling emergence and survival may also be reduced in cross-pollinated plants (see Seedling establishment, growth, and survival).

Seedling establishment and growth: Open sites are likely best for marsh thistle seedling emergence and establishment. Seedling growth and survival may be impacted by timing of germination, pollination of the parent plant, and presence of marsh thistle plant material in the soil. Growth, development, and reproductive success of plants 1 year or older are discussed in Plant development and survival.

Bare sites may favor seedling establishment. In a low-nutrient, species-rich meadow in the Czech Republic, almost no marsh thistle seedlings emerged from treatment plots where mosses, litter, and/or existing vegetation were left intact. Marsh thistle seedling emergence was greatest in plots where mosses and litter were removed [59]. In England, gaps created by domestic sheep grazing were considered important to marsh thistle seedling establishment [26].

In a spring area in central Jutland, Denmark, seedling mortality was high (85%) regardless of emergence timing, but seedlings that survived their first winter had a high probability of surviving to reproductive age [4]. Growth, reproduction, and survival of these seedlings were monitored in later life stages (see Botanical description), but spring- and fall-emerging cohorts were not studied separately [4].

Characteristics of fall- and spring-emerging seedlings in Jutland, Denmark [4]		
Measured (mm) or counted attribute	Spring emergence	Fall emergence
Number of rosette leaves	2-3	2-3
Leaf width	7-11	13-23
Leaf length	40-80	90-200
Diameter of taproot	0.8-1.2	1.5-2.5
Length of taproot	20-30	20-30
Number of lateral roots	4	7-8

In the Netherlands, seedlings from seeds produced by cross-pollination had significantly (P<0.05) lower overall emergence, fall emergence, and survival to 1 year old than seedlings produced by plants protected from insects. There were 100 seeds from protected plants and 100 seeds from cross-pollinated plants sown and monitored in the field [73].

Fate of cross-pollinated and noncrossed seed sown in the Netherlands [73]		
Seed type	Cross-pollinated seed	Noncrossed seed
Total number of seedlings observed	44.3	57.0
Number of fall-emerging seedlings	8.7	17.2
Number of 1-year-old plants	10.5	15.8
All differences between cross-pollinated and noncrossed seeds were significant (P<0.05).		

Marsh thistle seedling growth may be reduced in the presence of marsh thistle leaf litter. Field observations in central Jutland, Denmark, revealed a rarity of seedlings beneath marsh thistle flowering plants or near marsh thistle rosettes. In a controlled study, marsh thistle seedling growth was monitored after 5 weeks in soils mixed with marsh thistle foliage. At a 0.25% foliage concentration, marsh thistle seedling growth was reduced by 52%, and at a concentration of 1.25%, was reduced by 65% [3].

Plant development and survival: Marsh thistle rosette diameter and probability of flowering are positively correlated. Rosette diameter and probability of flowering generally decrease as densities or canopy cover of associated vegetation increase.

In a greenhouse study, marsh thistle flowering was positively correlated with rosette size (r =0.40, P<0.05), and rosette size was negatively correlated with marsh thistle plant density (r =-0.38, P<0.05). The percentage of flowering plants was greatest when plant density was lowest and rosette diameter was greatest. Marsh thistle plants at the lowest density produced significantly (P<0.05) more fruits than those at moderate and high densities [15].

Growth and reproductive fate of marsh thistle plants grown in different densities in the greenhouse [15]			
Density (plants/0.25 m²)	1	2	4
Average rosette diameter (cm)	34.8*	25.6*	20.6
Percentage of individuals flowering in 2nd year	90	60	25
Height of flowering shoot (cm)	139.7*	116.9*	102.2
*Values within the row are significantly different (P<0.05).			

In field studies in the Reski Range of Poland's Bialowieza Primeval Forest, marsh thistle population dynamics were studied within a single cohort and for many cohorts within different vegetation types. In a grassland area, a spring-emerging marsh thistle cohort was studied for 5 years. No plants flowered in their 1st year, and only 30% flowered in their 2nd year. The highest percentage of plants flowered in their 4th year [15].

Fate of a marsh thistle seedling cohort monitored over 5 years in a grassland in Poland [15]				
Plant age (years)	Survival (%)	Flowering (%)	Rosette diameter (cm) of nonflowering	Rosette diameter (cm) of flowering
1	---	0	14.9	---
2	63	30	22.4	29.6
3	70	50	24.6	32.1
4	30	90	18.5	31.8

As succession proceeded to grass-, forb-, patchy sedge-, and willow-dominated vegetation (5, 10, and 15 years after mowing) in the Bialowieza Primeval Forest, Falinska [15] conducted many studies and made several observations on marsh thistle populations, concluding that:

- Marsh thistle seedlings emerged from April through October, although most emerged in June or July
- Typically, marsh thistle was the only species to colonize gaps left after the death of reproductive marsh thistle plants
- Fewer than 10% of rosettes <8 inches (20 cm) in diameter flowered
- About 75% of rosettes 8 to 16 inches (20-40 cm) in diameter flowered
- 90% to 100% of rosettes >16 inches (40 cm) in diameter flowered
- Regardless of plant age, rosettes of flowering individuals were larger than those of nonflowering individuals
- Rosette size was generally smallest in willow patches
- Only in willow patches were marsh thistle populations eliminated
- In recently mowed grassland plots, marsh thistle generally flowered at 2 or 3 years old
- In later-seral plots, marsh thistle generally flowered at 3 to 6 years old
- Seed production was greatest in the earliest seral stage (grass-dominated vegetation), although only 5% to 10% of seeds developed into seedlings
- In May and June, there were 107, 125, and 40 marsh thistle seedlings/m² in grass-, forb-, and willow dominated plots, respectively
- Within a year of mowing in any vegetation type, the number of marsh thistle seedlings increased and
- After mowing, marsh thistle population size increased for up to 5 years
- Mowing in forb-dominated and sedge-dominated vegetation led to a doubling of marsh thistle's rosette size [15]

Vegetative regeneration: Marsh thistle does not reproduce vegetatively, but it may regenerate vegetatively following damage. Marsh thistle plants generally sprout following cutting [56]. In Jutland, Denmark, if the inflorescence of flowering plants was damaged before ripe seed was produced, marsh thistle sprouted from rosette buds later in the season or in the next year [4].

SITE CHARACTERISTICS:
Throughout its range, marsh thistle is common in disturbed habitats including roadsides, fields, yards, gardens, and early-seral forests or clearings [36,37,83]. In New England, marsh thistle is considered possible in any moist disturbed area [37]. Marsh thistle also occurs in less disturbed habitats including thickets, damp woods, forest edges, and wetlands [36,37,83].

Climate: In North America, marsh thistle is most common in moist areas with long cold winters [56]. During a survey of major roadways in South Island, New Zealand, marsh thistle was generally restricted to cool, wet areas in a zone where the annual water deficit was less than 2 inches (50 mm) [81].

Climates are described from several European marsh thistle habitats, which may allow for a better prediction of its spread potential in North America. In Europe, marsh thistle populations occur almost as far north as the Arctic Circle, suggesting populations in North America could potentially spread through the boreal forest zone [17]. In southeastern Scotland, marsh thistle is common in grasslands where the average February and July temperatures are 34.2° F (1.2° C) and 57° F (13.9 °C), respectively, and annual precipitation averages 35.2 inches (894 mm) [31]. In south Wales, the climate is mild and oceanic. Temperatures average 39° F (4° C) in February and 59° F (15° C) in July [26]. In the central and northeastern Netherlands, marsh thistle is common in sedge fens where annual precipitation averages 30.1 to 31.7 inches (765-806 mm) [7]. In wet meadow marsh thistle habitats in Ceske Budejovice, Czech Republic, annual precipitation averages 24.4 inches (620 mm), and minimum and maximum temperature averages for July are 52.9° F (11.6° C) and 75.4° F (24.1° C) and for January are 20.8° F (-6.2° C) and 33.1° F (0.6° C) [32].

Elevation: Marsh thistle occurs at elevations from 30 to 2,600 feet (10-800 m) in North America [17].

Soils: In marsh thistle habitats in North America, soils were rarely described in detail. In Canada, marsh thistle grew in organic wetland soils and in coarse gravelly soils along roadsides. Large populations and high densities were often associated with high water tables [41]. Marsh thistle is common in moist, acidic soils in New England [37] and Wisconsin [83].

In Europe, studies of soils in marsh thistle habitats suggest a wider tolerance of soil textures and pH levels than those

evident from the few North American studies and sources available as of 2009. In southeastern Scotland, marsh thistle was most common on poorly to very poorly drained, acidic (pH 5-5.5), clay soils [31]. In southwestern England, marsh thistle seedlings emerged from basic soil samples collected from a 45-year-old oak woodland but not from acidic soils collected from the same woodland [80]. However, this study does not necessarily imply an establishment preference for basic soils and could simply be a result of uneven seed dispersal. In an old field in the Geescroft Wilderness area of England, marsh thistle occurred in damp, cool, acidic heavy loams but not in a field described as wet and alkaline [8]. This finding could also be the result of dispersal and not preference. In the western part of the Utrecht Province in the Netherlands, marsh thistle was significantly (P<0.01) more frequent on ditch banks adjacent to fields fertilized with low levels of nitrogen (0-250 kg N/ha/year) than on fields fertilized with high levels of nitrogen (250-500 kg N/ha/year) [77]. Marsh thistle emerged from all organic peat soil samples taken from a "recently" clearcut birch woodland in Germany. Soils were fed with calcium-rich groundwater [5].

Moist conditions are typical in marsh thistle's native habitats, but plants may not tolerate long-term flooding or saturation. In the coastal dune areas of the Netherlands, marsh thistle is common in oneseed hawthorn-European white birch woodlands where ground water occurs at or near the soil surface [70]. In a spring area of Jutland, Denmark, marsh thistle plants did not grow in the wettest areas or on "regularly flushed" springs [4]. Marsh thistle's drought tolerance is likely low. After a 3-month drought, leaves from marsh thistle plants growing in a species-rich, calcareous grassland in Derbyshire, England, had low relative water content. Of leaves of the 31 plant species evaluated, marsh thistle leaves were ranked 6th lowest in relative water content. Monthly precipitation during the drought averaged 43%, 84%, and 26% of long-term monthly averages [11].

SUCCESSIONAL STATUS:
In Europe, marsh thistle is most common in early-seral communities and generally decreases as time since disturbance and canopy closure increase. Marsh thistle emergence is common and typically rapid following disturbances in grasslands and woodlands.

Shade tolerance: A review reports that marsh thistle is somewhat shade tolerant in North America [37]. In Canada, marsh thistle populations tend to be replaced in late-seral, densely shaded forests, but "flourishing" populations have been reported in underbrush and "heavily canopied" sites (Minor and Nordin 2002 cited in [41]).

In Europe, marsh thistle is reported in shaded areas, although research suggests that reproduction and growth may be limited on shaded sites. During surveys of 4 river catchments in Wales, marsh thistle occurred in open and shaded damp sites throughout the study area [14]. In Holmsley Bog in England, marsh thistle was frequent in the understory of mire vegetation where overstory species were up to 12 feet (3.7 m) tall [20]. Cover of marsh thistle was generally low (1%) on floating peat woodlands at Westbroek Polder, Utrecht, the Netherlands [71]. In the central Netherlands, marsh thistle seedlings were generally abundant in the 1st year after cutting in ash stands. Flower production was typically abundant in the 2nd year after cutting but decreased as time since cutting increased. Photosynthetically active radiation (PAR) transmission averaged 66.3% in the 1st year after cutting, 64.2% in 2nd year after cutting, and 2.5% in 4th year after cutting. On a 0.5-m² plot, there were 33 vegetative marsh thistles in 1st year after cutting. In the 2nd year after cutting, there were 5 vegetative and 5 flowering marsh thistles [47].

Experiments suggest that marsh thistle growth and reproduction may be reduced by shading. In England, marsh thistle was grown in shaded cold frames that received 1%, 4.5%, 20%, and 90% PAR. All marsh thistle plants receiving only 1% PAR died within a year; plants getting 4.5% PAR produced leaf numbers and lengths that were about half those produced at 20% and 90%. Only those plants receiving 20% or 90% PAR flowered in their 2nd year. Experiments did not continue beyond the 2nd year of growth [38]. In the Netherlands, marsh thistle leaf production, relative growth rate, and rosette dry-weight production all generally decreased with increased shading. Marsh thistle growth was monitored beneath 1.2%, 4.6%, 13%, 32%, and 100% of daylight [43]. In constant 100% light, plants grew to about 5 feet (1.5 m), developed many branches, and produced abundant seed. Plants in constant 4.6% light, and plants transferred to 4.6% light after developing rosettes in 100% light, produced few branches and little to no seed. Most plants in 4.6% light had to be staked so that stems did not fall and break [44].

General succession information and disturbance response: Marsh thistle's place in the succession of woodlands and old fields is described in studies conducted in England. In the Wicken Fen in Cambridgeshire, marsh

thistle generally persists throughout the succession from mixed-sedge vegetation to glossy buckthorn (*Frangula alnus*) dominance and eventual development of the oldest mire vegetation, dominated by common buckthorn (*Rhamnus cathartica*). Researchers noted marsh thistle could "persist thinly in a vegetative state" in the oldest mire [21]. In the Geescroft area, marsh thistle was first recorded in an old field about 20 years after abandonment, when it was described as scarce; 30 years after abandonment it was described as occasional [8].

Based on studies in its native habitats, marsh thistle is generally more abundant on grazed than ungrazed areas. In Westerholt, the Netherlands, marsh thistle cover was greatest after the introduction of domestic sheep into common velvetgrass (*Holcus lanatus*)-dominated grasslands. Before domestic sheep grazing, the grassland was primarily harvested for hay, and marsh thistle cover was about 0.5%. Nine years after grazing, marsh thistle cover was 3.5% in lightly grazed areas, 3.2% on moderately grazed areas, and 2% on heavily grazed areas. Litter was greatest on the lightly grazed and least on the heavily grazed areas [2]. When domestic sheep were removed from hill pastures in Snowdonia, South Wales, England, marsh thistle abundance decreased dramatically, and marsh thistle plants were restricted to steep, unstable ground. Researchers suggested marsh thistle in the steep areas may have established from seed produced on nearby grazed areas. Researchers indicated that the absence of gaps in the ungrazed turf canopy likely restricted marsh thistle reproduction [26]. Although marsh thistle's spines suggest it would be avoided by herbivores, cattle in Tullgarn, Sweden, grazed plants [48].

In a field experiment in a moist grassland on Harpur Hill in Derbyshire, England, disturbances increased marsh thistle abundance more than fertilization treatments. On control plots, the average cover of marsh thistle was 0.3%. On fertilized and undisturbed plots, the average cover of marsh thistle was 0.17%. Cover was 0.52% on unfertilized and disturbed plots and 0.56% on fertilized and disturbed plots. Disturbances were artificially created circular gaps with diameters of up to 4.7 inches (12 cm) and mechanically disturbed soil to depths up to 2 inches (5 cm). Plots were fertilized and disturbed twice before cover was estimated [12].

FIRE EFFECTS AND MANAGEMENT

SPECIES: Cirsium palustre

- FIRE EFFECTS
- FUELS AND FIRE REGIMES
- FIRE MANAGEMENT CONSIDERATIONS

FIRE EFFECTS:

Immediate fire effect on plant: Fire effects studies on marsh thistle seeds and plants were lacking as of 2009. A low-severity fire may only top-kill marsh thistle, since this species often regenerates following aboveground damage (review by [56]).

Postfire regeneration strategy [61]:

Unknown

Fire adaptations and plant response to fire:

Fire adaptations: On sites with established marsh thistle plants, postfire sprouting from the root crown may occur. Because open sites are likely best for marsh thistle seedling emergence [59], burned areas could provide suitable establishment sites, given a seed source. See Germination and Seedling establishment and growth for more on these topics.

Plant response to fire: Studies documenting marsh thistle recovery, establishment, and increases or decreases in abundance on burned sites are lacking. Marsh thistle frequency was 9% in the aboveground vegetation in a "derelict", species-rich, tall herb community in northern England that was occasionally burned, although time since the last fire

was not reported in this study. Marsh thistles seeds did not emerge from soil samples collected from the site, although it emerged from soil samples collected in other vegetation types with similar aboveground marsh thistle frequencies [63]. Because this study was not designed to study marsh thistle's response, recovery, or reproduction on a burned site, findings presented here may or may not provide useful information on marsh thistle's postfire seed production.

FUELS AND FIRE REGIMES:

Fuels: Marsh thistle fuel characteristics and influences on native fuel beds were not described in the available literature (2009).

Fire regimes: Marsh thistle is most common in moist to wet habitats (see Site Characteristics), where fires may be rare and/or burn with low severity. However, on sites with deep organic soils, fires may be infrequent but severe. Altered fire regimes in areas invaded by marsh thistle habitats were not reported. Fire studies in sites invaded by marsh thistle are needed.

See the Fire Regime Table for further information on fire regimes of vegetation communities in which marsh thistle may occur.

FIRE MANAGEMENT CONSIDERATIONS:

Potential for postfire establishment and spread: Open sites are considered best for marsh thistle seedling emergence and establishment [59]. Given a seed source, burned sites may be suitable for establishment. Long-distance seed dispersal by wind, animals, or equipment is also possible. See Seed dispersal, Germination, and Seedling establishment and growth for more information on these topics.

Preventing postfire establishment and spread: Preventing invasive plants from establishing in weed-free burned areas is likely the most effective and least costly management method. This can be accomplished through early detection and eradication, careful monitoring and follow-up, and limiting dispersal of invasive plant seed 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: [1,9,23,68].

Use of prescribed fire as a control agent: There were no studies on the use of prescribed fire to control marsh thistle. While fire alone is unlikely to control marsh thistle, it could be useful in conjunction with other control methods. Fire could be useful in removing last year's stems and increasing plant exposure to other treatments. Fire may also be useful in the disposal of cut stems with seeds or flowers that could provide for reinvasion [83].

MANAGEMENT CONSIDERATIONS

SPECIES: Cirsium palustre

- IMPORTANCE TO WILDLIFE AND LIVESTOCK
- IMPACTS AND CONTROL

IMPORTANCE TO WILDLIFE AND LIVESTOCK:
Wildlife and livestock use or avoidance of marsh thistle was not discussed in the available literature (2009). Marsh thistle spines are likely a defense against many herbivores, but cattle grazed marsh thistle in sea shore meadows in Tullgarn, Sweden [48]. In the Netherlands [2] and England [26], marsh thistle was more abundant on sites grazed by domestic sheep than ungrazed sites.

IMPACTS AND CONTROL:
Impacts: Although several sources suggest that marsh thistle may spread rapidly and negatively impact native vegetation, detailed study and documentation were lacking as of 2009. In its North American range, marsh thistle is described as "rapidly expanding", spreading "invasively" through wetlands, and sometimes forming "impenetrable spiny stands" that replace native species [17]. In 2003 on Michigan's Ottawa National Forest, marsh thistle was listed among the Forest's moderate priority weeds [67], but by 2005, marsh thistle was listed as a high priority and was reported from more than 87 Forest sites [66]. In other parts of Michigan, marsh thistle has been described as "aggressive". Marsh thistle occupies miles of ditch banks, and populations have spread into adjacent natural areas, which include northern whitecedar swamps and shaded fens [79]. In the Great Lakes region, marsh thistle commonly invades bogs and fens, which are often conservation priorities. Habitats invaded by marsh thistle are similar to habitats occupied by native swamp thistle. Dense marsh thistle stands, which may be more than 7 feet (2 m) tall, likely displace shorter native plants as well as swamp thistle. In British Columbia, marsh thistle has been "implicated in the degradation of sedge meadows" (review by [56]). For more on past and recent marsh thistle spread, see Local distribution changes.

Control: Few studies provide guidelines for control of marsh thistle. Provided below are general guidelines and practices useful to the avoidance, control, and management of invasive species. When invasive species are targeted for control, there is potential for another invasive species to fill their void no matter what method is used [10]. Often control of invasive species is most effective when a long-term, ecosystem-wide approach is used rather than a tactical approach focused on individual species control [35].

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

Prevention: Management practices that prevent the establishment of marsh thistle on uninvaded sites are considered best. Cleaning equipment used in marsh thistle populations before it enters uninvaded habitats is important in prevention (see Seed dispersal) [41].

Preventing establishment and spread of invasive species through the maintenance of "healthy" natural communities is often the most cost-efficient and effective management method [35,58]. Prevention methods could include avoiding new road construction in wildlands [65]) and consistent monitoring for invasive species [29]. Managing to maintain the integrity of native plant communities and minimizing those practices that increase ecosystem invasibility will likely be more effective than managing solely to control the invader [27].

Weed prevention and control can be incorporated into land management plans, including site preparation and logging, grazing allotments, recreation management, research projects, road building and maintenance, and fire management [68]. See the Guide to noxious weed prevention practices [68] for specific guidelines in preventing the spread of weed seeds and propagules during land management operations.

Physical or mechanical control: Hand-pulling of small marsh thistle populations may provide successful control [41]. Mowing or cutting may provide control when done repeatedly or combined with other control methods. After 3 to 4 years of repeated mowing or cutting near ground level, the size of marsh thistle populations may decrease. If plants are cut when flowers are present, it is recommended that stems be destroyed [83]. If plants are flowering at the time of mowing, most will sprout in the next growing season, often producing more seed than undisturbed plants [41].

Biological control: As of 2009, there were no insect biological controls released for control of marsh thistle. Many factors need to be considered when determining the agents for biological control and the potential release of biological controls. Refer to these sources: [72,82] and the Weed control methods handbook [64] for background information and important considerations for developing and implementing biological control programs.

Chemical control: Herbicides may be effective in gaining initial control of a new invasion or a severe infestation, but rarely are they a complete or long-term solution to weed management [13]. For marsh thistle, herbicide applications on cut hollow stems may be more effective than those on intact plants [56].

See the Weed control methods handbook[64] for considerations on the use of herbicides in natural areas and detailed information on specific chemicals. Herbicide use may be restricted in wetland areas, where marsh thistle is common [83].

Integrated management: Integrating control methods could increase the effectiveness of individual methods and the management of invasive species populations; however, studies involving or discussing this type of management in marsh thistle populations were lacking in the available literature (2009).

APPENDIX: FIRE REGIME TABLE

SPECIES: Cirsium palustre

The following table provides fire regime information that may be relevant to marsh thistle 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 marsh thistle may occur. This information is taken from the LANDFIRE Rapid Assessment Vegetation Models [34], 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.

Great Lakes Northeast

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		
Conifer lowland (embedded in fire-prone system)	Replacement	45%	120	90	220
	Mixed	55%	100		
Conifer lowland (embedded in fire-resistant ecosystem)	Replacement	36%	540	220	≥1,000
	Mixed	64%	300		
Great Lakes floodplain forest	Mixed	7%	833		
	Surface or low	93%	61		
Great Lakes spruce-fir	Replacement	100%	85	50	200
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		
Red pine-eastern white pine (frequent fire)	Replacement	38%	56		
	Mixed	36%	60		
	Surface or	26%	84		

	low				
Red pine-eastern white pine (less frequent fire)	Replacement	30%	166		
	Mixed	47%	105		
	Surface or low	23%	220		
Great Lakes pine forest, eastern white pine-eastern hemlock (frequent fire)	Replacement	52%	260		
	Mixed	12%	>1,000		
	Surface or low	35%	385		
Eastern white pine-eastern hemlock	Replacement	54%	370		
	Mixed	12%	>1,000		
	Surface or low	34%	588		

Northeast

- Northeast Grassland
- 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 Grassland					
Northern coastal marsh	Replacement	97%	7	2	50
	Mixed	3%	265	20	
Northeast Woodland					
Eastern woodland mosaic	Replacement	2%	200	100	300
	Mixed	9%	40	20	60
	Surface or low	89%	4	1	7
Northeast Forested					
Northern hardwoods (Northeast)	Replacement	39%	≥1,000		
	Mixed	61%	650		
Eastern white pine-northern hardwoods	Replacement	72%	475		
	Surface or low	28%	>1,000		
Northern hardwoods-eastern hemlock	Replacement	50%	≥1,000		
	Surface or low	50%	≥1,000		

Northern hardwoods-spruce	Replacement	100%	≥1,000	400	>1,000
Beech-maple	Replacement	100%	>1,000		
Northeast spruce-fir forest	Replacement	100%	265	150	300

*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 [25, 33].

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