SPECIES: Cynoglossum officinale

INTRODUCTORY

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AUTHORSHIP AND CITATION:
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FEIS ABBREVIATION:
CYNOFF

SYNONYMS:
No entry

NRCS PLANT CODE [96]:
CYOF

COMMON NAMES:
houndstongue

gypsyflower

TAXONOMY:
The currently accepted scientific name for houndstongue is *Cynoglossum officinale* L. (Boraginaceae) [17,35,37,42,43,63,76,104,107]. Hybridization of houndstongue has been reported in Europe [26], but not in North America [99].

LIFE FORM:
Forb

FEDERAL LEGAL STATUS:
No special status

OTHER STATUS:
At the time of this writing (2002), houndstongue is classified as a noxious, restricted or prohibited weed or weed seed in 6 states in the United States and 2 Canadian provinces [97]. See the Invaders or Plants databases for more information.

DISTRIBUTION AND OCCURRENCE

SPECIES: Cynoglossum officinale

GENERAL DISTRIBUTION:
The center of origin of houndstongue is thought to be the mountains of western Asia and eastern Europe. Houndstongue also occurs in apparently natural communities in Great Britain. It is widely distributed through Europe, where its northern limit is approximately 60°N, though there are isolated occurrences up to 68°N in Sweden. Towards the Mediterranean region it becomes rare. Houndstongue does not grow in the southernmost regions of Europe [26].

A review by Upadhyaya and others [99] suggests houndstongue was introduced to North America as a crop seed contaminant from Europe. Herbarium specimens of houndstongue were collected in Ontario as early as 1859 and in the western provinces between 1922 and 1934. Houndstongue was noted in 1884 as "common" around Montreal, and as "a pest" in Ontario. As of 1988, houndstongue occurred in all provinces in Canada except Prince Edward Island and Newfoundland, and appeared to be most abundant in southern British Columbia and Ontario. Houndstongue occurs throughout the contiguous U.S., in all but 6 southern states. Its occurrence has not been reported in Alaska or Hawaii [96]. Houndstongue is reported as a problem plant in natural areas and parks in several states including Michigan, Missouri, Indiana [73], Colorado, and Oregon [80]. The Plants database provides a distribution map of houndstongue in the United States.

The following biogeographic classification systems are presented as a guide to demonstrate where houndstongue may be found. Precise distribution information is limited. Because it is so widespread and has broad ecological tolerances, it is difficult to exclude many ecosystems as potential hosts of houndstongue plants or populations.

Therefore, these lists are speculative and not necessarily exhaustive.

ECOSYSTEMS [34]:
FRES10 White-red-jack pine
FRES11 Spruce-fir
FRES14 Oak-pine
FRES15 Oak-hickory
FRES16 Oak-gum-cypress
FRES17 Elm-ash-cottonwood
FRES18 Maple-beech-birch
FRES19 Aspen-birch
FRES20 Douglas-fir
FRES21 Ponderosa pine
FRES22 Western white pine
FRES23 Fir-spruce
FRES24 Hemlock-Sitka spruce
FRES25 Larch
FRES26 Lodgepole pine
FRES27 Redwood
FRES28 Western hardwoods
FRES29 Sagebrush
FRES30 Desert shrub
FRES33 Southwestern shrubsteppe
FRES34 Chaparral-mountain shrub
FRES35 Pinyon-juniper
FRES36 Mountain grasslands
FRES37 Mountain meadows
FRES38 Plains grasslands
FRES39 Prairie
FRES40 Desert grasslands
FRES42 Annual grasslands
FRES44 Alpine

STATES [49]:

AL	AZ	AR	CA	CO	CT	DE	GA
ID	IL	IN	IA	KS	KY	ME	MD
MA	MI	MN	MO	MT	NE	NV	NH
NJ	NM	NY	NC	ND	OH	OR	PA
RI	SD	TN	UT	VT	VA	WA	WV
WI	WY	DC					
AB	BC	MB	NB	NS	ON	PQ	SK

BLM PHYSIOGRAPHIC REGIONS [10]:
1 Northern Pacific Border
2 Cascade Mountains
3 Southern Pacific Border
4 Sierra Mountains

5 Columbia Plateau
6 Upper Basin and Range
7 Lower Basin and Range
8 Northern Rocky Mountains
9 Middle Rocky Mountains
10 Wyoming Basin
11 Southern Rocky Mountains
12 Colorado Plateau
13 Rocky Mountain Piedmont
14 Great Plains
15 Black Hills Uplift
16 Upper Missouri Basin and Broken Lands

KUCHLER [56] PLANT ASSOCIATIONS:
K001 Spruce-cedar-hemlock forest
K002 Cedar-hemlock-Douglas-fir forest
K003 Silver fir-Douglas-fir forest
K004 Fir-hemlock forest
K005 Mixed conifer forest
K006 Redwood forest
K007 Red fir forest
K008 Lodgepole pine-subalpine forest
K009 Pine-cypress forest
K010 Ponderosa shrub forest
K011 Western ponderosa forest
K012 Douglas-fir forest
K013 Cedar-hemlock-pine forest
K014 Grand fir-Douglas-fir forest
K015 Western spruce-fir forest
K016 Eastern ponderosa forest
K017 Black Hills pine forest
K018 Pine-Douglas-fir forest
K019 Arizona pine forest
K020 Spruce-fir-Douglas-fir forest
K021 Southwestern spruce-fir forest
K022 Great Basin pine forest
K023 Juniper-pinyon woodland
K024 Juniper steppe woodland
K025 Alder-ash forest
K026 Oregon oakwoods
K027 Mesquite bosques
K028 Mosaic of K002 and K026
K029 California mixed evergreen forest
K030 California oakwoods
K031 Oak-juniper woodland
K032 Transition between K031 and K037
K033 Chaparral
K034 Montane chaparral
K035 Coastal sagebrush
K036 Mosaic of K030 and K035
K037 Mountain-mahogany-oak scrub
K038 Great Basin sagebrush
K039 Blackbrush

K040 Saltbush-greasewood
K041 Creosote bush
K042 Creosote bush-bur sage
K043 Paloverde-cactus shrub
K044 Creosote bush-tarbush
K045 Cenzia shrub
K046 Desert: vegetation largely lacking
K047 Fescue-oatgrass
K048 California steppe
K050 Fescue-wheatgrass
K051 Wheatgrass-bluegrass
K052 Alpine meadows and barren
K053 Grama-galleta steppe
K054 Grama-tobosa prairie
K055 Sagebrush steppe
K056 Wheatgrass-needlegrass shrubsteppe
K057 Galleta-threeawn shrubsteppe
K058 Grama-tobosa shrubsteppe
K059 Trans-Pecos shrub savanna
K063 Foothills prairie
K064 Grama-needlegrass-wheatgrass
K065 Grama-buffalo grass
K066 Wheatgrass-needlegrass
K067 Wheatgrass-bluestem-needlegrass
K068 Wheatgrass-grama-buffalo grass
K069 Bluestem-grama prairie
K070 Sandsage-bluestem prairie
K072 Sea oats prairie
K074 Bluestem prairie
K075 Nebraska Sandhills prairie
K076 Blackland prairie
K077 Bluestem-sacahuista prairie
K081 Oak savanna
K082 Mosaic of K074 and K100
K083 Cedar glades
K084 Cross Timbers
K085 Mesquite-buffalo grass
K088 Fayette prairie
K089 Black Belt
K093 Great Lakes spruce-fir forest
K095 Great Lakes pine forest
K096 Northeastern spruce-fir forest
K097 Southeastern spruce-fir forest
K098 Northern floodplain 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
K107 Northern hardwoods-fir forest
K108 Northern hardwoods-spruce forest

K109 Transition between K104 and K106
K110 Northeastern oak-pine forest

SAF COVER TYPES [31]:
1 Jack pine
5 Balsam fir
12 Black spruce
13 Black spruce-tamarack
14 Northern pin oak
15 Red pine
16 Aspen
17 Pin cherry
18 Paper birch
19 Gray birch-red maple
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
35 Paper birch-red spruce-balsam fir
37 Northern white-cedar
38 Tamarack
39 Black ash-American elm-red maple
40 Post oak-blackjack oak
42 Bur oak
43 Bear oak
44 Chestnut oak
46 Eastern redcedar
49 Pitch pine
50 Black locust
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
62 Silver maple-American elm
63 Cottonwood
64 Sassafras-persimmon
65 Pin oak-sweetgum
71 Longleaf pine-scrub oak

72 Southern scrub oak
78 Virginia pine-oak
82 Loblolly pine-hardwood
85 Slash pine-hardwood
93 Sugarberry-American elm-green ash
94 Sycamore-sweetgum-American elm
95 Black willow
107 White spruce
108 Red maple
109 Hawthorn
110 Black oak
201 White spruce
202 White spruce-paper birch
203 Balsam poplar
204 Black spruce
205 Mountain hemlock
206 Engelmann spruce-subalpine fir
207 Red fir
208 Whitebark pine
209 Bristlecone pine
210 Interior Douglas-fir
211 White fir
212 Western larch
213 Grand fir
215 Western white pine
216 Blue spruce
217 Aspen
218 Lodgepole pine
219 Limber pine
220 Rocky Mountain juniper
221 Red alder
222 Black cottonwood-willow
223 Sitka spruce
224 Western hemlock
225 Western hemlock-Sitka spruce
226 Coastal true fir-hemlock
227 Western redcedar-western hemlock
228 Western redcedar
229 Pacific Douglas-fir
230 Douglas-fir-western hemlock
231 Port-Orford-cedar
232 Redwood
233 Oregon white oak
234 Douglas-fir-tanoak-Pacific madrone
235 Cottonwood-willow
236 Bur oak
237 Interior ponderosa pine
238 Western juniper
239 Pinyon-juniper
240 Arizona cypress
241 Western live oak
243 Sierra Nevada mixed conifer
244 Pacific ponderosa pine-Douglas-fir

245 Pacific ponderosa pine
246 California black oak
247 Jeffrey pine
248 Knobcone pine
249 Canyon live oak
250 Blue oak-foothills pine
251 White spruce-aspen
252 Paper birch
253 Black spruce-white spruce
254 Black spruce-paper birch
255 California coast live oak
256 California mixed subalpine

SRM (RANGELAND) COVER TYPES [89]:
101 Bluebunch wheatgrass
102 Idaho fescue
103 Green fescue
104 Antelope bitterbrush-bluebunch wheatgrass
105 Antelope bitterbrush-Idaho fescue
106 Bluegrass scabland
107 Western juniper/big sagebrush/bluebunch wheatgrass
108 Alpine Idaho fescue
109 Ponderosa pine shrubland
110 Ponderosa pine-grassland
201 Blue oak woodland
202 Coast live oak woodland
203 Riparian woodland
204 North coastal shrub
205 Coastal sage shrub
206 Chamise chaparral
207 Scrub oak mixed chaparral
208 Ceanothus mixed chaparral
209 Montane shrubland
210 Bitterbrush
211 Creosote bush scrub
212 Blackbush
213 Alpine grassland
214 Coastal prairie
215 Valley grassland
216 Montane meadows
301 Bluebunch wheatgrass-blue grama
302 Bluebunch wheatgrass-Sandberg bluegrass
303 Bluebunch wheatgrass-western wheatgrass
304 Idaho fescue-bluebunch wheatgrass
305 Idaho fescue-Richardson needlegrass
306 Idaho fescue-slender wheatgrass
307 Idaho fescue-threadleaf sedge
308 Idaho fescue-tufted hairgrass
309 Idaho fescue-western wheatgrass
310 Needle-and-thread-blue grama
311 Rough fescue-bluebunch wheatgrass
312 Rough fescue-Idaho fescue
313 Tufted hairgrass-sedge

314 Big sagebrush-bluebunch wheatgrass
315 Big sagebrush-Idaho fescue
316 Big sagebrush-rough fescue
317 Bitterbrush-bluebunch wheatgrass
318 Bitterbrush-Idaho fescue
319 Bitterbrush-rough fescue
320 Black sagebrush-bluebunch wheatgrass
321 Black sagebrush-Idaho fescue
322 Curlleaf mountain-mahogany-bluebunch wheatgrass
323 Shrubby cinquefoil-rough fescue
324 Threetip sagebrush-Idaho fescue
401 Basin big sagebrush
402 Mountain big sagebrush
403 Wyoming big sagebrush
404 Threetip sagebrush
405 Black sagebrush
406 Low sagebrush
407 Stiff sagebrush
408 Other sagebrush types
409 Tall forb
410 Alpine rangeland
411 Aspen woodland
412 Juniper-pinyon woodland
413 Gambel oak
414 Salt desert shrub
415 Curlleaf mountain-mahogany
416 True mountain-mahogany
417 Littleleaf mountain-mahogany
418 Bigtooth maple
419 Bittercherry
420 Snowbrush
421 Chokecherry-serviceberry-rose
422 Riparian
501 Saltbush-greasewood
502 Grama-galleta
503 Arizona chaparral
504 Juniper-pinyon pine woodland
505 Grama-tobosa shrub
506 Creosotebush-bursage
507 Palo verde-cactus
508 Creosotebush-tarbush
509 Transition between oak-juniper woodland and mahogany-oak association
601 Bluestem prairie
602 Bluestem-prairie sandreed
603 Prairie sandreed-needlegrass
604 Bluestem-grama prairie
605 Sandsage prairie
606 Wheatgrass-bluestem-needlegrass
607 Wheatgrass-needlegrass
608 Wheatgrass-grama-needlegrass
609 Wheatgrass-grama
610 Wheatgrass
611 Blue grama-buffalo grass

612 Sagebrush-grass
613 Fescue grassland
614 Crested wheatgrass
615 Wheatgrass-saltgrass-grama
701 Alkali sacaton-tobosagrass
702 Black grama-alkali sacaton
703 Black grama-sideoats grama
704 Blue grama-western wheatgrass
705 Blue grama-galleta
706 Blue grama-sideoats grama
707 Blue grama-sideoats grama-black grama
708 Bluestem-dropseed
709 Bluestem-grama
710 Bluestem prairie
711 Bluestem-sacahuista prairie
712 Galleta-alkali sacaton
713 Grama-muhly-threeawn
714 Grama-bluestem
715 Grama-buffalo grass
716 Grama-feathergrass
717 Little bluestem-Indiangrass-Texas wintergrass
718 Mesquite-grama
720 Sand bluestem-little bluestem (dunes)
721 Sand bluestem-little bluestem (plains)
722 Sand sagebrush-mixed prairie
723 Sea oats
724 Sideoats grama-New Mexico feathergrass-winterfat
725 Vine mesquite-alkali sacaton
727 Mesquite-buffalo grass
729 Mesquite
733 Juniper-oak
801 Savanna
802 Missouri prairie
803 Missouri glades
804 Tall fescue
805 Riparian
809 Mixed hardwood and pine

HABITAT TYPES AND PLANT COMMUNITIES:
In British Columbia, houndstongue occurs predominantly in the Interior Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*)-bunchgrass biogeoclimatic zones [99].

In Utah, houndstongue may be found in sagebrush (*Artemisia* spp.), pinyon-juniper (*Pinus* spp.-*Juniperus* spp.), cottonwood (*Populus* spp.), mountain brush, quaking aspen (*Populus tremuloides*), ponderosa pine, and spruce-fir (*Picea* spp.-*Abies* spp.) communities [107]. It is a minor component in Gambel oak (*Quercus gambelii*) communities in central and northern Utah [58]. On preserves in Colorado, houndstongue has been reported in shortgrass prairie, narrowleaf cottonwood/red-osier dogwood (*Populus angustifolia*/*Cornus sericea*) riparian forests, and riparian meadows.

In northeastern Oregon, houndstongue invades Idaho fescue (*Festuca idahoensis*), bluebunch wheatgrass (*Pseudoroegneria spicata*), and prairie Junegrass (*Koeleria macrantha*) grasslands, and riparian habitats [80].

In Iowa, houndstongue was found on an upland site dominated by white oak (*Q. alba*), northern red oak (*Q. rubra*), and shagbark hickory (*Carya ovata*) [54].

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

SPECIES: Cynoglossum officinale

GENERAL BOTANICAL CHARACTERISTICS:
Houndstongue is a biennial or short-lived perennial forb. The following description of houndstongue is based on reviews by Upadhyaya and others [99] and de Jong and others [26]. It presents characteristics of houndstongue that may be relevant to fire ecology, and is not meant to be used for identification. Keys for identification are available [17,35,37,42,43,63,104,107]. A detailed discussion of the biology of houndstongue is provided by de Jong and others [26].

Houndstongue forms a rosette in its 1st year with softly pubescent leaves 4 to 12 inches (10-30 cm) long and 0.8 to 2 inches (2-5 cm) wide. It has a thick, black, branching taproot, extending to depths > 40 inches (100 cm). An individual plant consists of 1 or several rosettes on a single root system. Flower stems, 12 to 48 inches (30-120 cm) tall, are produced the 2nd year, or sometimes later. The upper part of the stem is branching. Stem leaves are generally broadest near the base and narrower towards the tip. Houndstongue inflorescences have up to 35 but usually no more than 10 flowers each and are axillary to leaves or terminating short branches. Each flower can produce up to 4 fruits. The fruits are nutlets, the surfaces of which are flat and densely covered with small, barbed hooks (glochidia) that facilitate dispersal by animals.

Houndstongue rosettes can withstand drought stress, enabling the plant to survive water deficits and to delay flowering until conditions are favorable. The thick, deep taproot can exploit lower soil strata for water and nutrients. The root also serves as an underground food reserve which may offer protection against winter injury [11,98,99].

Houndstongue often occurs in dense stands, but may also occur as a small but regular proportion of regional flora. Seedlings are usually strongly clustered around parent plants in densities of up to 405 seedlings per ft^2 ($4500/m^2$) [26]. Houndstongue may grow as an isolated plant or at densities up to 1 individual per ft^2 ($8/m^2$) on dunes in England. On coastal dunes in the Netherlands, its abundance ranges from rare to abundant. Vesicular-arbuscular mycorrhizae are usually present on houndstongue roots [26,39].

RAUNKIAER [77] LIFE FORM:
Hemicryptophyte

REGENERATION PROCESSES:
Houndstongue is a biennial or short-lived perennial that reproduces only by seed. An annual life cycle apparently does not occur anywhere in the entire range of the species [26]. The following discussion of the regeneration processes in houndstongue derives primarily from research in British and Dutch coastal dune areas. More research is needed on houndstongue regeneration on sites where it is invasive in North America.

Breeding system: A review by Upadhyaya and others [99] suggests that houndstongue flowers are perfect (having both male and female parts), and that seed production occurs via autogamy. However, de Jong and others [26] report that houndstongue plants produce only very few nutlets if pollinators are excluded, and that bagging inflorescences in the field generally results in reduced seed set per flower. This suggests some mechanism that

prevents self-pollination within the flower. Seed set per flower is greatly increased by exchanging pollen between flowers on the same plant.

Pollination: Houndstongue is pollinated by bumblebees [75]. Flowers are also visited by other bees, thrips, and butterflies [26].

Seed production: Estimates of total seed number per plant in houndstongue range from 50 to more than 2,000 [99]. In Montana, houndstongue seed production ranges from 300-675 seeds per plant [50].

Houndstongue plants typically have 1 or 2 stems, although up to 8 stems per plant have been reported on plants growing in dune grasslands in England. In this ecosystem, a single stem could produce around 300 seeds, and seed number per stem was correlated with stem basal diameter ($r=0.84$, $p<0.01$) [11]. In a sand dune area in the Netherlands, larger plants produce more seed per flower, and smaller plants produce more flowers per plant [51]. Researchers there found that watering houndstongue plants had a positive effect on seed set [26].

Each flower has the potential to produce 4 nutlets. A review by Upadhyaya and others [99] reports an average 2.75 nutlets per flower. In Dutch sand dunes, 5.2 to 7.8% of the nutlets produced in a population formed seedlings in the following spring [26]. Boorman and Fuller [11] estimated this figure at 25% on coastal dunes in England.

Seed dispersal:
Houndstongue seeds are covered in a spiny husk and possess a protruding barb that enables the seed to adhere to wild and domestic animals thus promoting long-distance dispersal [50]. European studies, however, suggest that animal dispersal is rare in houndstongue [11,26], and wind is considered to be the primary dispersal mechanism [100]. In one study, the majority of houndstongue seeds (75%) fell into an area of radius 5 inches (12 cm) around the parent plant. The greatest recorded dispersal distance was 4.6 feet (1.4 m). With such limited primary dispersal range, even rare dispersal events by animals could be important [11].

It has been proposed that the presence of houndstongue around rabbit warrens in European ecosystems is the result of rabbits cleaning seeds off their fur before entering the warrens. However, seeds do not adhere well to fine rabbit fur [11]. Evidence from a study in British Columbia indicates that cattle are important dispersers of houndstongue seed, picking up about 65% of seeds per stalk in grazed paddocks [23]. Some houndstongue seeds remain on plants well into the winter [11,23,26]. These seeds are dispersed slowly over time by attaching to animal wool and hair. Dispersal via streams and irrigation ditches is unlikely due to the high specific gravity of houndstongue seeds [99]. Although seed dispersal occurs slowly over time, colonization of disturbed sites can take place very quickly [50].

Seed banking: A review by Upadhyaya and others [99] cites several studies that indicate that houndstongue does not produce a large, persistent bank of buried seeds, and that seeds remain viable no longer than 2-3 years. Newly ripened seeds of houndstongue exhibit an innate dormancy [26,99]. Most seeds fall from the plant soon after ripening; however, some seeds remain on plants for up to 2 years, especially in sheltered habitats (e.g. scrub), thus creating an above-ground seed bank. A fraction (less than 5 to 10% in exposed habitats) of seeds that fall to the ground do not germinate in the 1st year [11,100]. A small percentage of these seeds (4-7 %) may remain viable after 1 year [26]. In the Netherlands, viable seeds were found to occur almost entirely within the top 0.4 inch (1 cm) of soil, and viable seeds did not occur deeper than 2 inches (5 cm). Experimentally, all buried seeds had germinated within 9 months at both 0.8-inch (2 cm) and 6-inch (15 cm) depths [100].

Germination:
Seed burial depth, ambient temperature, moisture, soil nitrate levels, and light have been shown to affect seed germination in houndstongue (reviews by [26,99]).

The viability of freshly harvested houndstongue seeds exceeds 90%, although newly ripened seeds of houndstongue exhibit an innate dormancy [26,99]. Thus, houndstongue seeds remain ungerminated throughout the fall and winter and germinate uniformly in the spring, suggesting a vernalization requirement for dormancy release. In Dutch coastal dunes, almost all houndstongue seedlings emerge in March and April, the main

germination period being March, with very little to no germination in any other month [11,100].

Germination in houndstongue generally requires some form of scarification or softening of the seed coat. Seeds are likely to remain dormant until they can take up sufficient water [11]. Nitrate also breaks seed dormancy [11,100]. In laboratory studies, germination rate was highest after 6-12 weeks of moist-chilling at 32 to 50 degrees Fahrenheit (0-10 ºC). Germination of dispersed seeds depends strongly on burial. Of the viable houndstongue seeds buried 0.4 inch (1 cm) in sand, almost 100% germinated before and during the 1st spring, while germination on the surface was less than 4% [26,100]. Darkness may either stimulate or have no effect on germination of houndstongue seeds [100].

Seedling establishment/growth:
Large temporal and spatial variation in the number of surviving seedlings per reproductive individual has been observed for houndstongue [24]. It is estimated that less than 1% of dispersed seed survives to produce more seed (review by [26]). Reports of 7 to 40% of dispersed houndstongue seeds were retrieved as seedlings in spring. The remaining seeds may have been dispersed secondarily or lost through predation, although death of seeds or seedlings immediately after germination was the most plausible explanation [24,75]. First year survival of seedlings from spring to fall ranged from 22 to over 50% on Dutch coastal dunes [24].

Houndstongue seedlings have a low growth rate and are not strongly competitive. Plants do well when their competitors are kept in check (e.g. grazed by rabbits) [11]. Small-scale disturbances are important for houndstongue establishment. Houndstongue occurs only in areas of the Dutch coastal dunes where grazing by horses and cows is allowed [20]. Prins and Nell [74] compared population dynamics of houndstongue with and without protection from generalist herbivores (insects, rabbits and mice). Houndstongue mortality was significantly higher in protected populations for 3 consecutive years ($p<0.05$). Germination, seedling establishment and number of flowering plants were also lower inside exclosures. Similar results were observed in exclosure studies in northeastern Oregon, where percent canopy cover of houndstongue increased over a 30 year period under grazing pressure from both cattle and wildlife [81]. Generalist herbivores seem to play a positive role in the population dynamics of houndstongue by reducing competition from grasses [74]. Seedling growth and survival are also reduced by intraspecific competition at high population densities [26].

Seeds of houndstongue have large nutrient reserves that allow rapid seedling root growth so that plants can be well established before drier weather begins (reviews by [26,99]). Most seedling mortality, however, is attributed to water deficit in the early summer months, before the development of a deep and extensive root system [11,20]. Seedling survival is lowest in dry summers and on exposed sites [24]. Seedling mortality was negatively correlated with the water content in the top 4 inches (10 cm) of soil ($r=-0.65$, $p<0.001$) in Dutch coastal dunes. Early seedling mortality (April to May) was also negatively correlated with the cover of shrubs and trees ($r=-0.70$, $p<0.001$) and soil humus content, ($r=-0.63$, $p<0.01$). Variation in rainfall may cause yearly differences in houndstongue survival and growth, and also affects its distribution over shaded and exposed habitats on dune sites [25]. A large proportion of houndstongue rosettes that delayed reproduction buffered the population against low seedling recruitment in some years (a bud bank versus a seed bank) [24].

Asexual regeneration: Houndstongue reproduces only by seed.

SITE CHARACTERISTICS:
In North America, houndstongue often occurs in "waste" areas [63,104] and disturbed sites (especially roadsides) [17,37,42,67], including logging roads and heavily grazed areas [20,60], disturbed woods and forest clearings [104,106], and lake shores [104]. Dense infestations of houndstongue are found in clearcut areas in northern British Columbia [99], and Upadhyaya and Cranston [98] suggest that houndstongue thrives and has great potential for spread in areas disturbed by logging operations and road construction.

Houndstongue is most abundant in areas with more than 10% bare ground (review by [99]). Studies in Europe also indicate that houndstongue requires open, disturbed ground and that it is most common in dry, open habitats [26], such as the dune grasslands in England. Houndstongue can exploit bare ground around rabbit warrens, benefiting from the high nitrogen levels from rabbit excreta, and the fact that rabbits do not usually eat

houndstongue. Houndstongue is often found in areas grazed by livestock and wildlife [20,74,81].

In England and in the Netherlands, houndstongue occurs on sand dunes and calcareous substrates. These calcareous, sandy soils have high nitrate levels that favor houndstongue establishment, and abundant calcium that houndstongue accumulates to a marked degree, especially in its leaves [11]. Houndstongue is absent from acid coastal dunes and from acid sandy soils and does not occur on peat or clay soils [99]. In Germany houndstongue grows on both calcium-rich and weakly-acid soil, and is classified as both a drought and nitrogen indicator [26]. In British Columbia it is found on soils ranging from well-drained, relatively coarse material to clay subsoils in the open coniferous and deciduous forests. In Eastern Canada, houndstongue is often associated with rocky pastures in limestone regions [98].

Houndstongue is found in temperate regions. In British Columbia it is found on sites that are characterized by hot, dry summers and cold winters, with annual precipitation in the range of 11 to 18 inches (268-448 mm), and mean January and July temperatures of approximately 21 and 72 degrees Fahrenheit (-6 and 22 ºC), respectively. In Ontario, houndstongue-infested regions have annual precipitation and mean January and July temperature variations in the range of 31 to 41 inches (770-1020 mm), 39 to 52 degrees Fahrenheit (3.9-10.9 ºC) and 67 to 72 degrees Fahrenheit (19.2-22.2 ºC), respectively [99]. On droughty sand dunes in the Netherlands, the amount of rainfall during the growing season greatly affects growth, survival and seed production in houndstongue. Here the species may disappear from the most exposed sites after several dry years, and recolonize these areas again after a number of wet years. Plants grow poorly and eventually die after waterlogging [26]. Houndstongue is not well adapted to dry grassland sites with less than 12 inches (300 mm) annual precipitation in British Columbia. It survives well in wetter grasslands and moist draws in drier sites [98].

The distribution pattern of houndstongue in Europe suggests that at its northern limits its temperature requirements during the growing season, rather than the occurrence of winter frost, restrict the species to warmer microsites. On sand dunes in England, it occurs mostly on south or south-east facing slopes [26]. Houndstongue is completely absent from areas above 495 feet (150 m) in England. In continental Europe, it reaches the subalpine but only rarely the alpine (4,950 to 7,920 feet (1,500-2,400 m)). Some elevational ranges at which houndstongue occurs are given below:

Area	Elevation range	Reference
UT	4,880 to 9,900 feet (1,480-3,000 m)	[107]
CA	2,800 to 3,300 feet (850-1,000 m)	[42]
NM	5,000 to 8,000 feet (1,500-2,400 m)	[63]

SUCCESSIONAL STATUS:
Houndstongue is an opportunistic species that exploits conditions suitable for its establishment and growth. In the variable environment of dune habitats, houndstongue populations are usually in decline, and only in rare years are conditions favorable for growth and/or seed production. For this reason, one may see large fluctuations in population density in a single locality [24]. As is typical of biennials, large population increases are observed following reproductive success and large decreases or even local extinctions following reproductive failure. Annual disturbances as well as absence of disturbance can be fatal for biennial plant development; therefore most habitats are only temporarily suitable for biennials. Grazed range provides an environment where gaps are repeatedly created and therefore suitable sites for establishment are usually available [101]. Where it has established on disturbed sites such as roads and around old buildings, it may persist indefinitely, as is evidenced by its continued presence in abandoned mining towns in southwestern Montana, even after 45 to 77 years of recovery [52].

Houndstongue is shade tolerant [98] but grows best in full sunlight, if sufficient water and nutrients are available. In sand dunes it may occur in both open and shaded sites (5-10% of full daylight). Its establishment in open sites may depend on spring and summer rainfall. In half-open habitats, at the edges of the canopies of shrubs or trees, plants are less susceptible to drought [26]. Houndstongue was significantly ($p<0.05$) positively associated with

closed canopies at Mammoth campground in Yellowstone National Park. Here it was more consistently found under high canopy cover than any other nonnative species. Similarly, Lacey and Lacey [59] describe occurrences of houndstongue in areas of thick litter accumulation (as might be found under a forest with high canopy cover) [1].

SEASONAL DEVELOPMENT:
Houndstongue seeds overwinter predominantly in the top (1 cm) of soil, although some seeds may remain attached to the parent plant throughout the winter [99]. Houndstongue germination starts in late winter and early spring, when soil temperature rises above the freezing point. Houndstongue plants then develop from seedling to rosette within the 1st year of growth. When night frosts begin in autumn, rosette leaves die back and the taproot remains. Houndstongue requires a vernalization period before stem elongation can occur. Stem elongation is probably stimulated by day length [26]. Flowering is strongly size-dependent, with the probability of flowering increasing with the size of the plant. There may also be a critical size below which plants do not flower [27]. The main period of flowering is about 55 days, with seed ripening requiring an additional 70 days. Most ripened seeds fall to the ground within 4 months of ripening [99].

Typical flowering dates are reported by area as follows:

Area	Flowering dates	Reference
Carolinas	May-July	[76]
Great Plains	May to July	[37]
IL	May-July	[67]
Intermountain region	May to July	[17]
IA	May-June	[54]
MT	mid-June	[50]
NM	May-August	[63]
BC	May-July	[98]

Although usually a biennial, houndstongue can behave as a short-lived perennial. Under fertile conditions plants typically flower in their 2nd year. Under adverse environmental conditions, flowering can be delayed until the plants reach a sufficient size for vernalization [26]. Delay of flowering is common in natural populations of houndstongue on Dutch coastal dunes. Over a 7-year period, the percentage of rosettes that flowered ranged from 2 to 25%. The proportion of rosettes flowering was positively correlated (r=0.62, p=0.05) with rainfall in the previous year and was reduced after a very cold winter [27].

While most houndstongue plants die after flowering, houndstongue is not strictly monocarpic. Of 55 houndstongue plants studied, 7 flowered again in both the 2nd and 3rd years and 2 in their 3rd and 4th years [11]. Repeated flowering has also been observed in houndstongue not only after damage to the flowering plant, but also in undamaged plants under both natural and garden conditions [26].

FIRE ECOLOGY

SPECIES: Cynoglossum officinale

FIRE ECOLOGY OR ADAPTATIONS:

Fire adaptations:
Houndstongue reproduces by seed, some of which may be dispersed over moderate to long distances by animals. Fire creates conditions that are favorable for establishment of houndstongue (i.e. open canopy, reduced competition, areas of bare soil), so if houndstongue seeds are present and competition minimal, it may be favored in the postfire community. Houndstongue plants may also survive fire, since nutrient reserves in the taproot acquired during the 1st year are sufficient for normal seed production the following year, even if the plants are completely defoliated early in the spring [11,98]. More research is needed regarding adaptations of houndstongue to fire.

Fire regimes:
Introduced species can alter the rate of spread of fire, the probability of occurrence of fire, and the intensity of fire in an ecosystem [18]. It is unclear how the presence of houndstongue may alter the fire regime of a given site, and it is unclear how a historical fire regime might affect the presence or abundance of houndstongue at a given site. It has been suggested that the exclusion or alteration of natural processes, such as fire and flooding, can encourage the establishment and persistence of houndstongue on prairie sites in Colorado [80]. Houndstongue did not occur in any of these communities at the time in which historic fire regimes were functioning, but has established since fire exclusion began. More information is needed about ecosystems in which houndstongue is likely to be invasive in North America.

The following table provides some fire return intervals for communities or ecosystems in which houndstongue may be found. Because houndstongue is widespread, it is difficult to exclude many ecosystems as potential hosts of houndstongue plants or populations.

Community or Ecosystem	Dominant Species	Fire Return Interval Range (years)
silver fir-Douglas-fir	*Abies amabilis-Pseudotsuga menziesii* var. *menziesii*	> 200
grand fir	*A. grandis*	35-200 [3]
maple-beech-birch	*Acer-Fagus-Betula*	> 1000
silver maple-American elm	*A. saccharinum-Ulmus americana*	< 35 to 200
sugar maple	*A. saccharum*	> 1000
sugar maple-basswood	*A. s.-Tilia americana*	> 1000 [105]
California chaparral	*Adenostoma* and/or *Arctostaphylos* spp.	< 35 to < 100 [72]
bluestem prairie	*Andropogon gerardii* var. *gerardii-Schizachyrium scoparium*	< 10 [55,72]
Nebraska sandhills prairie	*A. g.* var. *paucipilus-S. s.*	< 10
bluestem-Sacahuista prairie	*A. littoralis-Spartina spartinae*	< 10
sagebrush steppe	*Artemisia tridentata/Pseudoroegneria spicata*	20-70 [72]

basin big sagebrush	*A. t.* var. *tridentata*	12-43 [84]
mountain big sagebrush	*A. t.* var. *vaseyana*	15-40 [4,13,66]
Wyoming big sagebrush	*A. t.* var. *wyomingensis*	10-70 (40**) [103,109]
coastal sagebrush	*A. californica*	< 35 to < 100
desert grasslands	*Bouteloua eriopoda* and/or *Pleuraphis mutica*	5-100
plains grasslands	*Bouteloua* spp.	< 35
blue grama-needle-and-thread grass-western wheatgrass	*B. gracilis-Hesperostipa comata-Pascopyrum smithii*	< 35
blue grama-buffalo grass	*B. g.-Buchloe dactyloides*	< 35
grama-galleta steppe	*B. g.-Pleuraphis jamesii*	< 35 to < 100
blue grama-tobosa prairie	*B. g.-P. mutica*	< 35 to < 100
cheatgrass	*Bromus tectorum*	< 10
California montane chaparral	*Ceanothus* and/or *Arctostaphylos* spp.	50-100 [72]
sugarberry-America elm-green ash	*Celtis laevigata-Ulmus americana-Fraxinus pennsylvanica*	< 35 to 200 [105]
paloverde-cactus shrub	*Cercidium microphyllum/Opuntia* spp.	< 35 to < 100 [72]
curlleaf mountain-mahogany*	*Cercocarpus ledifolius*	13-1000 [6,85]
mountain-mahogany-Gambel oak scrub	*C. l.-Quercus gambelii*	< 35 to < 100
blackbrush	*Coleogyne ramosissima*	< 35 to < 100
Arizona cypress	*Cupressus arizonica*	< 35 to 200
northern cordgrass prairie	*Distichlis spicata-Spartina* spp.	1-3 [72]
beech-sugar maple	*Fagus* spp.-*Acer saccharum*	> 1000 [105]
California steppe	*Festuca-Danthonia* spp.	< 35 [72]
black ash	*Fraxinus nigra*	< 35 to 200 [105]
juniper-oak savanna	*Juniperus ashei-Quercus virginiana*	< 35
Ashe juniper	*J. a.*	< 35
western juniper	*J. occidentalis*	20-70
Rocky Mountain juniper	*J. scopulorum*	< 35
tamarack	*Larix laricina*	35-200 [72]
western larch	*L. occidentalis*	25-100 [3]
creosotebush	*Larrea tridentata*	< 35 to < 100

Ceniza shrub	*L. t.-Leucophyllum frutescens-Prosopis glandulosa*	< 35 [72]
yellow-poplar	*Liriodendron tulipifera*	< 35 [105]
wheatgrass plains grasslands	*Pascopyrum smithii*	< 35 [72]
Great Lakes spruce-fir	*Picea-Abies* spp.	35 to > 200
northeastern spruce-fir	*Picea-Abies* spp.	35-200 [30]
Engelmann spruce-subalpine fir	*P. engelmannii-A. lasiocarpa*	35 to > 200 [3]
black spruce	*P. mariana*	35-200 [30]
blue spruce*	*P. pungens*	35-200 [3]
red spruce*	*P. rubens*	35-200 [30]
pine-cypress forest	*Pinus-Cupressus* spp.	< 35 to 200 [3]
pinyon-juniper	*Pinus-Juniperus* spp.	< 35 [72]
whitebark pine*	*P. albicaulis*	50-200 [3]
jack pine	*P. banksiana*	<35 to 200 [30]
Mexican pinyon	*P. cembroides*	20-70 [68,93]
Rocky Mountain lodgepole pine*	*P. contorta* var. *latifolia*	25-300+ [2,3,83]
Sierra lodgepole pine*	*P. c.* var. *murrayana*	35-200 [3]
shortleaf pine	*P. echinata*	2-15
shortleaf pine-oak	*P. e.-Quercus* spp.	< 10 [105]
Colorado pinyon	*P. edulis*	10-49 [72]
slash pine	*P. elliottii*	3-8 [105]
Jeffrey pine	*P. jeffreyi*	5-30
western white pine*	*P. monticola*	50-200
Pacific ponderosa pine*	*P. ponderosa* var. *ponderosa*	1-47 [3]
interior ponderosa pine*	*P. p.* var. *scopulorum*	2-30 [3,8,61]
Arizona pine	*P. p.* var. *arizonica*	2-15 [8,16,86]
Table Mountain pine	*P. pungens*	< 35 to 200 [105]
red pine (Great Lakes region)	*P. resinosa*	10-200 (10**) [30,33]
red-white-jack pine*	*P. r.-P. strobus-P. banksiana*	10-300 [30,40]
pitch pine	*P. rigida*	6-25 [12,41]
pocosin	*P. serotina*	3-8
eastern white pine	*P. strobus*	35-200

eastern white pine-eastern hemlock	*P. s.-Tsuga canadensis*	35-200
eastern white pine-northern red oak-red maple	*P. s.-Quercus rubra-Acer rubrum*	35-200
loblolly pine	*P. taeda*	3-8
Virginia pine	*P. virginiana*	10 to < 35
sycamore-sweetgum-American elm	*Platanus occidentalis-Liquidambar styraciflua-Ulmus americana*	< 35 to 200 [105]
galleta-threeawn shrubsteppe	*Pleuraphis jamesii-Aristida purpurea*	< 35 to < 100
eastern cottonwood	*Populus deltoides*	< 35 to 200 [72]
aspen-birch	*P. tremuloides-Betula papyrifera*	35-200 [30,105]
quaking aspen (west of the Great Plains)	*P. t.*	7-120 [3,38,65]
mesquite	*Prosopis glandulosa*	< 35 to < 100 [64,72]
black cherry-sugar maple	*Prunus serotina-Acer saccharum*	> 1000 [105]
mountain grasslands	*Pseudoroegneria spicata*	3-40 (10**) [2,3]
Rocky Mountain Douglas-fir*	*Pseudotsuga menziesii* var. *glauca*	25-100 [3,4,5]
coastal Douglas-fir*	*P. m.* var. *menziesii*	40-240 [3,69,82]
California mixed evergreen	*P. m.* var. *m.-Lithocarpus densiflorus-Arbutus menziesii*	< 35
California oakwoods	*Quercus* spp.	< 35 [3]
oak-hickory	*Q.-Carya* spp.	< 35[105]
oak-juniper woodland (Southwest)	*Q.-Juniperus* spp.	< 35 to < 200 [72]
northeastern oak-pine	*Q.-Pinus* spp.	10 to < 35 [105]
coast live oak	*Q. agrifolia*	<35 to 200 [3]
white oak-black oak-northern red oak	*Q. alba-Q. velutina-Q. rubra*	< 35 [105]
canyon live oak	*Q. chrysolepis*	<35 to 200
blue oak-foothills pine	*Q. douglasii-Pinus sabiniana*	<35 [3]
northern pin oak	*Q. ellipsoidalis*	< 35 [105]
Oregon white oak	*Q. garryana*	< 35 [3]

bear oak	*Q. ilicifolia*	< 35 >[105]
California black oak	*Q. kelloggii*	5-30 [72]
bur oak	*Q. macrocarpa*	< 10 [105]
oak savanna	*Q. m./Andropogon gerardii-Schizachyrium scoparium*	2-14 [72,105]
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
live oak	*Q virginiana*	10 to< 100 [105]
interior live oak	*Q. wislizenii*	< 35 [3]
blackland prairie	*Schizachyrium scoparium-Nassella leucotricha*	< 10
little bluestem-grama prairie	*S. s.-Bouteloua* spp.	< 35 [72]
redwood	*Sequoia sempervirens*	5-200 [3,32,92]
pondcypress	*Taxodium distichum* var. *nutans*	< 35 [70]
western redcedar-western hemlock	*Thuja plicata-Tsuga heterophylla*	> 200 [3]
eastern hemlock-yellow birch	*Tsuga canadensis-Betula alleghaniensis*	> 200 [105]
western hemlock-Sitka spruce	*T. heterophylla-Picea sitchensis*	> 200
mountain hemlock*	*T. mertensiana*	35 to > 200 [3]
elm-ash-cottonwood	*Ulmus-Fraxinus-Populus* spp.	< 35 to 200 [30,105]

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

POSTFIRE REGENERATION STRATEGY [91]:
Ground residual colonizer (on-site, initial community)
Crown residual colonizer (on-site, initial community)
Initial off-site colonizer (off-site, initial community)
Secondary colonizer (on-site or off-site seed sources)

FIRE EFFECTS

SPECIES: Cynoglossum officinale

- IMMEDIATE FIRE EFFECT ON PLANT
- DISCUSSION AND QUALIFICATION OF FIRE EFFECT

IMMEDIATE FIRE EFFECT ON PLANT:
Fire probably top-kills houndstongue plants. A high severity fire would probably be necessary to kill houndstongue because of its hardy taproot. Research is needed regarding the effects of fire on both houndstongue plants and seeds.

DISCUSSION AND QUALIFICATION OF FIRE EFFECT:
No entry

PLANT RESPONSE TO FIRE:
Response of houndstongue to fire will depend on the conditions of the fire such as fire severity, time of burning, prior and subsequent weather conditions [18], and composition of the preburn community and seed bank. Fire creates conditions that are suitable to houndstongue establishment; however, it is unclear how houndstongue plants or populations would respond to historic fire regimes on sites where it occurs. On a western juniper (*J. occidentalis*)/mountain mahogany (*Cercocarpus* spp.)/bluebunch wheatgrass site in northeastern Oregon, houndstongue established 5 years after a wildfire of moderate severity, and did not establish on a similar site that was severely burned [46].

DISCUSSION AND QUALIFICATION OF PLANT RESPONSE:
The Research Project Summary
Vegetation response to restoration treatments in ponderosa pine-Douglas-fir forests of western Montana provides information on prescribed fire and postfire response of plant community species including houndstongue.

FIRE MANAGEMENT CONSIDERATIONS:
Fire as a control agent: The lack of normal ecological processes such as fire and flood can promote establishment by invasive plants such as houndstongue [80]. In some ecosystems, re-establishing historic fire regimes can be effective at controlling invasive species by encouraging growth and vigor of native species (e.g. [19,29,44,79]). Research is needed regarding the potential of prescribed burning to control houndstongue.

Postfire colonization potential: General precautions should be followed to prevent houndstongue establishment after fire. The USDA Forest Service's "Guide to noxious weed prevention practices" [95] provides several fire management considerations for weed prevention in general that can be applied to houndstongue. Wildfire managers might consider including weed prevention education and providing weed identification aids during fire training; avoiding known weed infestations when locating firelines, monitoring camps, staging areas, and helibases to be sure they are kept weed free; taking care that equipment is weed free; incorporating the cost of weed prevention and management into fire rehabilitation plans; and acquiring restoration funding. Careful postfire vigilance to identify and record the establishment of new populations is critical. About 1 month after fire, survey for signs of new or resprouting weeds. Repeat surveys will be needed, with the frequency and intensity of the survey guided by local conditions [7].

Potential weed problems must be addressed during prefire planning of prescribed burns, and following both wild and prescribed fires. When planning a prescribed burn, preinventory the project area, evaluate cover and phenology of any houndstongue present on or adjacent to the site, and evaluate the potential for increased houndstongue populations in the area [7]. Avoid ignition and burning in areas at high risk for weed establishment or spread, and/or plan for follow-up treatments in succeeding years. Avoid creating soil conditions that promote weed germination and establishment. Discuss weed status and risks in burn rehabilitation plans [95].

To prevent new infestations, re-establish vegetation on bare ground as soon after fire as possible, using either natural recovery or artificial techniques as appropriate to site conditions and objectives. When reseeding after wildfires and prescribed burns, use only certified weed-free seed. Monitor the burn site and associated disturbed areas after the fire and the following spring for emergence of houndstongue, and treat to eradicate any emergent

houndstongue or other pestiferous plants. Regulate human, pack animal, and livestock entry into burned areas at risk for weed invasion until desirable site vegetation has recovered sufficiently to resist weed invasion. Additional guidelines and specific recommendations and requirements are available [7,36,95].

MANAGEMENT CONSIDERATIONS

SPECIES: Cynoglossum officinale

IMPORTANCE TO LIVESTOCK AND WILDLIFE:
Houndstongue causes poisoning in horses and cattle [9,14,48,53,90]. Houndstongue contains various pyrrolizidine alkaloids (PAs), whose concentrations are highest during its rosette stage and decrease as the plant matures [9,53]. PAs are known to cause liver damage or failure in livestock [90]. Kedzie-Webb and Sheley [50] suggest that PAs are toxic to horses and cattle but not to domestic sheep. Poisoning can occur when houndstongue is cut and dried with harvested hay, or when animals are confined to a small area lacking desirable forage. Most livestock poisonings occur from ingestion of contaminated hay or feed [90]. The acute or chronic nature of poisoning depends on the PA concentration, amount eaten, and rate of ingestion [9,50]. Any level of houndstongue contamination in feed should be considered potentially lethal for all livestock [90].

Kufeld and others [57] report light use of houndstongue by Rocky Mountain mule deer in winter in Montana. Domestic sheep commonly graze houndstongue leaves [26]. There are few direct effects of herbivores on houndstongue where it occurs on coastal dunes in England and the Netherlands. It is not normally eaten by rabbits [11], although rabbits have been observed digging up taproots in winter [26]. A 3-year study by Prins and Nell [74] indicates only low levels of leaf herbivory on houndstongue in coastal dunes in the Netherlands. Rabbits caused some leaf damage in early spring, and no root consumption by rabbits was found. From June to November, larvae of the oligophagous Lepidopteran, *Ethmia bipunctella*, are the most important herbivores on houndstongue. Captive mice eat nutlets, but it is unknown whether this occurs in the field. Ring-necked pheasants graze on the cotyledons and on whole seedlings of houndstongue (review by [26]).

Palatability/nutritional value:
Green houndstongue plants have a distinctive odor that discourages animals from eating it, but when dried it becomes more palatable [9,53].

Cover value: No information

OTHER USES:
A review by Upadhyaya and others [99] suggests the following traditional uses of plants in the borage family such as houndstongue. Extracts of Boraginaceous roots have been used for centuries as "folk" remedies for a variety of disorders such as eczema, fever, acne, corn callus, dermatophytosis, burns and hemorrhoids. Lipophilic red pigments associated with the outer surface of the roots of many members of the Boraginaceae are antibacterial, antitumorogenic and possess wound-healing activity. These pigments have also been used as food and wine colorants in at least 12 European countries. Roots and leaves of houndstongue have been used as "folk" pesticides; their herbage has been reported to repel moles in gardens and to protect stored fruits and vegetables from rodents.

IMPACTS AND CONTROL:
Impacts:
Houndstongue can establish rapidly and form dense monocultures in disturbed habitats. Populations of houndstongue displace native plant species and hinder the re-establishment of valuable range species, thereby decreasing availability of forage to wildlife and livestock [80]. It is most detrimental on rangelands and hayfields

because of its toxicity to livestock, although, in most cases, the fresh plant is considered unpalatable by livestock and is generally avoided (see Importance to Livestock and Wildlife) [50,99].

The barbed seeds of houndstongue readily attach to wool and fur. This can create marketing problems and require extra time and money for removal, thus reducing the value of livestock. The seeds can also attach to the eyelashes of animals and cause eye damage, and the foliage may cause dermatitis [50,99].

Control:
Houndstongue can be controlled by killing plants and/or preventing seed production. Long-term control of houndstongue requires an integrated management approach [50].

Prevention: Prevention is the most effective method for managing invasive species, including houndstongue [50,88]. Preventing or dramatically reducing seed production and dispersal, detecting and eradicating weed introductions early, containing current infestations, minimizing soil disturbances, establishing competitive grasses, and managing grazing properly will all help decrease the spread of infestations.

Cleaning livestock when they are moved from an infested area to an uninfested area is critical to prevent seed spread [23]. Houndstongue seeds also readily adhere to shoes and clothing and need to be removed and carefully disposed of (burned or bagged). It is important to clean mowers, vehicles, and tillage equipment after operating in an infested area. When seeding is necessary, use clean, certified weed-free seed and mulch to ensure that these or other weeds are not being sown.

Place a priority on controlling small infestations so they do not expand. Conducting aggressive monitoring and treatment several times each year can help with early detection and containment of infestations when they are small. Monitoring efforts are best concentrated on the most disturbed areas in a site, particularly along roadsides, parking lots, fencelines, and waterways. When an infestation is found, the location can be recorded and the surrounding area surveyed to determine the size and extent of the infestation, so these sites can be revisited on follow-up surveys. For more on monitoring see Johnson [47].

Historic overgrazing by livestock and native ungulates encourages invasion by houndstongue [80]. In areas susceptible to invasion, proper livestock grazing should include altering timing, frequency and level of defoliation to allow a full recovery of desirable grass species. This grazing regime promotes litter accumulation to allow proper nutrient cycling and enhances vigor of desirable grasses which limits invasion by rangeland weeds [50]. For more information on grazing management for weed control see Olson [71].

Weed prevention and control can be incorporated into all types of management plans, including logging and site preparation, management of grazing allotments, recreation management, research projects, road building and maintenance, and fire management. See the "Guide to noxious weed prevention practices" [95] for specific guidelines in preventing the spread of weed seeds and propagules under different management conditions.

Integrated management:
The goal of any management plan should be to not only control invasive plants, but also to improve the affected community by maximizing forage quality and quantity and/or preserving ecosystem integrity, and preventing reinvasion or invasion by other invasive species. This must be done in a way that is complementary to the ecology and economics of the site [28,45]. Effective long-term control requires that invasive plants be removed and replaced by more desirable and weed-resistant plant communities [45]. Once the desired plant community has been determined, an integrated weed management strategy can be developed to direct succession toward that plant community by identifying key mechanisms and processes directing plant community dynamics (site availability, species availability, and species performance) and predicting plant community response to control measures [87]. This requires a long-term integrated management plan.

Most often, a single method is not effective for controlling an invasive plant, but there are many possible combinations of methods that can achieve the desired objectives. Methods selected for removal or control of houndstongue on a specific site will be determined by land use objectives, desired plant community, extent and

nature of the infestation(s), environmental factors (nontarget vegetation, soil types, climatic conditions, important water resources), economics, and effectiveness and limitations of available control techniques [78].

Managers are encouraged to use combinations of control techniques in a manner that is appropriate to the site objectives, desired plant community, available resources, and timing of application. For information on integrated weed management without herbicides, see the Bio-Integral Resource Center (BIRC) website.

Physical/mechanical:
Tillage, hoeing, and hand-pulling may provide effective control of houndstongue, providing these operations are done before the reproductive growth stages to prevent seed production. Mechanical methods may not be practical on rangeland and natural areas, but could be useful in improved pastures or roadsides.

First-year houndstongue plants are difficult to control by aboveground cutting, as the prostrate rosette resists mowing and grazing [99], and nutrient reserves of the taproot acquired during the 1st year are sufficient for normal seed production the following year, even if the plants are completely defoliated early in the spring [11,98]. Furthermore, defoliation at the rosette stage may cause the plant to delay flowering for a year and thus result in a larger plant with a greater seed output [102]. Mowing or clipping 2nd year plants can reduce seed production in houndstongue provided that it is done before seeds are formed and that defoliation is severe enough to prevent regrowth and subsequent flowering [80]. Clipping 2nd year houndstongue plants 0 to 3 inches (0-7 cm) above ground in late June reduced but did not eliminate seed production in houndstongue (Dickerson and Fay 1982, as cited by [26,98]). Sixty percent of cut plants failed to regrow, and seed production of the plants that resumed growth declined to about 25 seeds per plant compared to 364 seeds per plant in the unclipped controls. Boorman and Fuller [11], on the other hand, found that removing the leaves from 2nd year plants had little effect on seed number or seed weight. Additionally, if the flowering stalk is cut off or if flower buds are removed, axillary buds lower on the stem may be activated and develop into cymes; or the plant may respond by forming vegetative side-rosettes from the axils of old leaf-bases [26]. Response of houndstongue after serious defoliation depends on the vigor of plants and the fertility of the site, especially nitrogen availability. Plants with low growth rates respond quite poorly to defoliation, while vigorous plants may recover and set seed [102].

Plowing is said to control houndstongue [99]. However, tillage is not usually appropriate in wildlands and rangelands since it can damage important desirable species, increase erosion, alter soil structure, and expose the soil for rapid reinfestation by houndstongue and other invasive species [62]. Cutting the root crown of either young rosettes or older houndstongue plants (before seed set) 1 to 2 inches (2.5-5 cm) below the soil surface in autumn or early spring and removing top-growth can be effective in controlling small infestations [50,99]. Hand-pulling of houndstongue on the Dunstan Homestead in northeastern Oregon reduced houndstongue populations by 85% [80]. For very large infestations, it may be difficult to get enough labor for cutting or hand-pulling. The Salmon River Restoration Council (SRRC) provides an example of watershed-scale weed control using primarily mechanical control methods and volunteer labor.

Fire: See Fire Management Considerations.

Biological:
Biological control of invasive species has a long history; many important considerations need to be made before implementation of a biological control program. The reader is referred to other sources [78,108] and the Weed Control Methods Handbook [94] for background information on biological control. Additionally, Cornell University and NAPIS websites offer information on biological control.

As of 1999, 5 biological control agents were being screened for their potential use on houndstongue. These include a root weevil (*Mogulones cruciger*), a seed weevil (*M. borreginis*), a stem weevil (*M. trisignatus*), a root beetle (*Longitarsus quadriguttatus*), and a root fly (*Cheilosia pasquorum*) [50]. Recent research on the host specificity of *Mogulones cruciger*
indicates that this agent can complete full development on several plant species within closely related genera in the Boraginaceae, but prefers houndstongue as a host. This is a matter of concern since at least one species in the genus *Cryptantha* (*C. crassipes*) is listed as endangered in the U.S., and 6 of the 12 *Cryptantha* species tested

supported full development of the root weevil (*C. crassipes* was not tested) [22]. As of the time of this writing, no further information is available regarding the status of the other biocontrol agents. *Erysiphe cynoglossi* is a commonly encountered pathogen on houndstongue in western North America that is being studied for its impact on vegetative plant growth and reproduction [21].

Chemical:
Herbicides are effective in gaining initial control of a new invasion or a severe infestation, but are rarely a complete or long-term solution to weed management [15]. Herbicides are more 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 those conditions that allow infestations to occur [110]. See the Weed Control Methods Handbook for considerations on the use of herbicides in natural areas and detailed information on specific chemicals.

Picloram, dicamba, chlorsulfuron, metsulfuron and 2,4-D amine can kill houndstongue plants. Repeated applications may be necessary for several years to maintain adequate control [50,59,99]. Herbicide choice and rates are influenced by growth stage, stand density, and environmental conditions (e.g. drought or cold temperatures). Check with state or county weed specialists for appropriate local use rates and timing.

Cultural:
No matter what method is used to kill weeds, re-establishment of competitive, desirable plant cover is imperative for long-term control. Fertilization and reseeding with competitive, adapted species is often necessary in areas without a residual understory of desirable plants [78].

Houndstongue seedlings have a comparatively low growth rate and are not strongly competitive. Interspecific competition severely reduces the dry weight of 1st and 2nd year houndstongue plants [99]. Generalist herbivores play a positive role in the population dynamics of houndstongue by reducing competition from grasses in coastal dunes in the Netherlands [20,74]. Similarly, in exclosure studies in northeastern Oregon, percent canopy cover houndstongue increased over a 30-year period under grazing pressure from both cattle and wildlife [81]. These studies suggest, therefore, that planting and maintaining competitive species can effectively control houndstongue, although more research is needed.

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