Broadleaf Pepperweed (*Lepidium latifolium*)

Ecological Risk Screening Summary

U.S. Fish & Wildlife Service, March 2011
Revised, July 2019
Web Version, 2/25/2021

Organism Type: Plant
Overall Risk Assessment Category: High

Photo: Malte. Licensed under Wikimedia Commons. Available: https://commons.wikimedia.org/wiki/File:20130704-Lepidium_latifolium.jpg (June 2019).

1 Native Range and Status in the United States

Native Range

From EDDMapS (2019):

"*Lepidium latifolium* is native to southeast Europe, North Africa and southwest Asia."

Status in the United States

From Francis and Warwick (2007):

"In the United States, *L. latifolium* is locally persistent and spreading in Connecticut and Massachusetts (Mehrhoff et al. 2003; Forman Orth et al. 2006), and is established in New York State (Mitchell and Tucker 1997). *Lepidium latifolium* is established and invasive in western non-forested coastal regions from Washington to California north of the Sonoran Desert; and inland along waterways, irrigation systems and montane wetlands from Washington, Idaho and Montana to New Mexico (Grayum and Koutnik 1982; Zouhar 2004; Anonymous 2005; Invaders Database System 2005a, b; […]). It is present but not invasive in a few mid-western states (Young et al. 1997a; Zouhar 2004; USDA-NRCS 2006)."

"In the United States, *L. latifolium* is not listed on the federal Noxious Weed List, but is listed as "invasive and banned" in Connecticut; a "regulated non-native plant species" in South Dakota; a "noxious weed" in Colorado, Idaho, Nevada, Utah and Wyoming, and although not present in either state, as "noxious" in Alaska and Hawaii; a "Class A noxious weed" in New Mexico; and a "B list or Category 2 noxious weed" in California, Montana, Oregon and Washington (USDA-NRCS 2006). *Lepidium latifolium* is also subject to "quarantine" in Oregon and to "seed and plant quarantine" in Washington State (USDA-NRCS 2006)."

Lepidium latifolium is listed as a prohibited species in New York (New York Senate 2014). "Prohibited invasive species cannot be knowingly possessed with the intent to sell, import, purchase, transport or introduce. In addition, no person shall sell, import, purchase, transport, introduce or propagate prohibited invasive species."

From California Department of Food and Agriculture (2015):

"It has been determined that the following species of plants are noxious weeds within the meaning of Section 5004 of the Food and Agricultural Code:
[…] *Lepidium latifolium* (perennial peppercress)"

The extract of *L. latifolium* is sold in the United States by Alibaba.com (2019): "1-24 kilograms $16.50"

Means of Introductions in the United States

From CABI (2016):

"It is possible that some introductions occurred via botanic gardens or nurseries, but there are suggestions that several separate introductions may have been involved, some involving contaminated *Beta vulgaris* (sugar beet) seed (Zouhar, 2004)."

From Francis and Warwick (2007):

"In the United States, *L. latifolium* was first reported in 1924 from Peabody, MA as naturalized near a glue factory where it may have been introduced as a contaminant of factory materials (Morse 1924) […] It is believed to have arrived originally in the Yolo County delta lands of

California in contaminated sugar beet (*Beta vulgaris* L.) seed (Robbins et al. 1951), but may have had multiple introductions prior to World War II, when such imports from eastern Europe were common (Young et al. 1997a)."

"Transported along rivers and irrigation canals, seeds and easily fragmented rhizomes of *L. latifolium* from eroded banks established new colonies, and flood irrigation carried plant propagules into hay meadows, pastures and other irrigated lands (Donaldson and Johnson 1999; Krueger and Sheley 2004)."

"The use of the flowers and fruiting stalks in dried arrangements in the United States is believed to contribute to long-distance spread of viable seeds (Krueger and Sheley 2004)."

Remarks

ITIS (2019) lists the following common names: perennial pepperweed, broadleaved peppergrass, tall whitetop, Virginia pepperweed, broadleaf pepperweed, perennial peppercress, peppergrass mustard, broadleaved pepperweed.

2 Biology and Ecology

Taxonomic Hierarchy and Taxonomic Standing

World Flora Online (2021) lists *Lepidium latifolium* L. as the accepted name of this species.

From ITIS (2019):

Kingdom Plantae
Subkingdom Viridiplantae
Infrakingdom Streptophyta
Superdivision Embryophyta
Division Tracheophyta
Subdivision Spermatophytina
Class Magnoliopsida
Superorder Rosanae
Order Brassicales
Family Brassicaceae
Genus *Lepidium* L.
Species *Lepidium latifolium* L.

Size, Weight, and Age Range

From CABI (2016):

"L. latifolium is a perennial herb 1-2 m high"

"Seeds have no innate dormancy and are not known to persist beyond two years in the soil (Zouhar, 2004). Stands of established *L. latifolium* have been observed to persist for at least 15 years (Blank et al., 2002)."

Environment

From CABI (2016):

"*L. latifolium* is a plant of wet places, especially coastal saline wetlands, but also non-saline stream-sides, marshes, roadsides, railways, waste ground, ditches and irrigated cropland; also non-irrigated cereal, lucerne, hay and pasture crops (Francis and Warwick, 2007)."

"It grows under a wide range of environmental conditions from saline to brackish to fresh and from very wet to quite dry; also in inland alkaline soils. Although it may occur under fully saline conditions it is generally most vigorous in less saline, brackish soils at -0.02 MPa soil matric water potential (Blank et al., 2002). Although thriving in wet conditions and surviving under temporary flooding, *L. latifolium* is not fully adapted to anaerobic soil conditions and growth is reduced. The plant survives continuous flooding for at least 50 days but photosynthesis is reduced by 60-70% (Chen et al., 2005) and it is eventually killed.

Roots of *L. latifolium* have metabolically adaptive strategies to anoxia, but there is evidence of oxidative stress under anoxia and of post-anoxic injury from free radicals upon re-exposure to air (Chen et al., 2002; Chen and Qualls, 2003).

Although mainly a lowland/wetland species it does also occur at high altitudes, up to 2000 m in the USA and in India an ecotype apparently adapted to cold conditions has been the subject of molecular studies (Mohammad Aslam et al., 2010; Mohammad Aslam et al., 2011)."

Climate

CABI (2016) reports a temperate latitude range of 70°N to 30°S, preferring temperatures > 10°C with a cold tolerance limit of ~0°C.

From Francis and Warwick (2007):

"*Lepidium latifolium* occurs in areas with a Mediterranean climate, but has adapted to more temperate maritime climates as in countries bordering the North Sea in Europe and the New England and British Columbia coasts in North America, as well as to interior alpine and continental climates in eastern Eurasia, along the St. Lawrence in Quebec, in the inter-montane regions of British Columbia, the western United States and Mexico, and east of the Rocky Mountains from southern Alberta to New Mexico. […] The moderating climatic effects of nearby water, whether from oceans, rivers and lakes, or from irrigation systems, are evident in all climate zones where the plant is found, and the presence of *L. latifolium* is generally restricted to latitudes where there are pronounced seasons […]."

Distribution Outside the United States

Native

From EDDMapS (2019):

"*Lepidium latifolium* is native to southeast Europe, North Africa and southwest Asia."

Introduced
CABI (2016) reports introductions in Canada, Mexico, Japan, Bolivia, Belarus, Norway, and Australia.

From Francis and Warwick (2007):

"In Canada, *L. latifolium* has been reported in Quebec, Alberta and British Columbia […]."

"*Lepidium latifolium* is also established in parts of south central and northeastern Mexico (Villaseñor Ríos and Espinosa García 1998) and has been spreading in the Valley of Mexico (Vibrans 2003)."

"*Lepidium latifolium* has spread beyond its purported eastern Mediterranean origins into other areas with Mediterranean climates, including the Black Sea and western Mediterranean regions of Europe and North Africa, and the coasts of California (Rollins 1993) and southern Australia (Hewson 1981). It is widespread in the Mediterranean, Atlantic, Black and Caspian Sea regions of Europe (Jalas et al. 1996), and in North Africa and west Asia (Schultze-Motel 1986). *Lepidium latifolium* has been spreading in western and northern Europe (e.g. Lundqvist 1979; Schultze-Motel 1986; Herrero-Cembranos et al. 1988; Hämet-Ahti et al. 1998); northeast into Siberia (Gusev 1976, 1977; Pyak 1991); and, eastwards through west and central Asia into northwest and north central China (Cheo et al. 2001)."

According to Darias et al. (2001), *Lepidium latifolium* is naturalized in the Canary Islands.

According to Al-Shehbaz (2010), *L. latifolium* is naturalized in Argentina.

Means of Introduction Outside the United States
From CABI (2016):

"In Australia, it is thought to have been introduced via contaminated sugar beet seed (Kloot, 1973). The earliest herbarium specimen recorded by GBIF (2012) is from 1972.

In Norway the earliest herbarium specimen recorded by GBIF (2012) is from 1921. It is now of increasing concern as it is spreading, perhaps via soil introduced as ballast (Halvorsen and Grøstad, 1998) or in seaweed or seawater after storms (Størmer, 2011)."

Short Description
From CABI (2016):

"*L. latifolium* is a perennial herb 1-2 m high, with a creeping root system emanating from a semi-woody crown. Francis and Warwick (2007) describe the underground structures as both rhizomes and roots. Other authors quoted by Zouhar (2004) conclude otherwise, that they are all true roots. It seems likely that both types of structure can occur – short rhizomes (horizontal stems from which buds develop at the nodes) and much longer horizontal roots 10-20 cm deep,

on which adventitious buds can develop at any point, especially when fragmented. Other roots can occur much more deeply, even down to 3 m (Zouhar, 2004). A number of erect stems arise from the crown, and are much branched above. Lower leaves are up to 30 cm long by 5-8 cm wide on petioles up to 10 cm long, elliptic-ovate or oblong, finely serrate on the margins and with a whitish mid-rib. Upper leaves are smaller up to 10 cm long, sessile, with entire margins, cuneate base and acute apex. Leaf surfaces may have some hairs, but are generally glabrous, leathery and glaucous.

Francis and Warwick (2007) describe the inflorescence as 'paniculate, terminating in numerous, many-flowered, often compounded racemes; sparsely pubescent or glabrous; pedicels slender, 2–5 mm long. Sepals deciduous, oblong, suborbicular, 1–1.4 mm long by 0.8–0.9 mm wide, glabrous or pubescent, white at margin and apex. Petals milky white, obovate, 1.8–2.5 mm long by (0.8)1–1.3 mm wide, apex rounded. Stamens 6, with 4 long and 2 short filaments 0.9–1.4 mm long; anthers ovate, 0.4–0.5 mm long. Pistil 2 mm long, style nearly obsolete (scarcely visible), stigma prominent, sessile, 2–3 times broader than sepals, persistent on fruit. Fruits (silicules) 2-chambered, slightly flattened, oblong ellipsoid to oval-ellipsoid, or suborbicular, (1.6)1.8–2.4(2.7) mm long by about 1.3 mm wide, sparsely hairy with soft, crinkly hairs or glabrous, not emarginate or very minutely so. Seeds 1 per chamber, light reddish brown, flattened, wingless, finely papillate (with small swellings) with long, simple hairs; oblong-ovoid, (0.8)1–1.3 mm long by 0.7–0.9 mm wide."

Biology

From CABI (2016):

"Reproductive Biology

L. latifolium may spread by seed and also vegetatively via its spreading root system. Seed production is potentially very high but Zouhar (2004) notes that seeds may fail to mature in dry years and under wet conditions they may be damaged by the oomycete, *Albugo* sp. Leininger and Foin (2009) found that while inflorescence size was not affected by salinity, seed production was much higher in dry, non-saline conditions. Seed production at a high salinity site was reduced by 29% from a freshwater site and seed production at the wettest site in this San Francisco Bay study had an 87% reduction from the driest site.

Plants can self- and cross-pollinate (Brown, 2005; Gaskin et al., 2012). Pollination is believed to occur by insects (Zouhar, 2004). Most authors however comment that germination is rarely observed in the field and most local spread apparently occurs vegetatively. New shoots can arise from anywhere on the undisturbed superficial root system, effectively establishing new plants. After fragmentation by cultivation or by wave or current action, root regeneration can occur from root fragments as small as 2-3 cm long (Wotring et al., 1997).

Physiology and Phenology

Seed germination requires light and is inhibited by high salinity, though some germination still occurs at 16 dS/m (Larson and Kiemnec, 2005). Germination is generally low at constant

temperatures and requires alternating temperatures, anywhere between 0 and 40°C. Ahmed and Khan (2010) found the optimum temperature regime to be alternating between 20/30°C.

Newly-established plants can flower in their first season. Regrowth from existing crowns begins in early spring, with the development of a basal rosette of leaves, followed by flowering shoots. In Europe and North America flowering may occur from May in low-lying coastal areas but later inland, e.g. from August in New England. In the absence of frost, some basal leaves may persist through the winter, but above-ground growth normally dies down in the winter and forms a layer of litter.

Once established, a young colony of *L. latifolium* may expand by 1-3 m per year as new shoots emerge from the peripheral root system (Zouhar, 2004). However, longer-established patches were found to expand by only 0.85 m per annum (Renz et al., 2012).

The seasonal flux of photosynthate between roots and shoots has been described in some detail by Renz (2000a). *L. latifolium has* the ability to make available and take up more nitrogen than the vegetation it is replacing (Blank, 2002)."

Human Uses

From CABI (2016):

"*L. latifolium* may be grazed by cattle, sheep and goats but is not considered a useful forage (Zouhar, 2004)"

"*L. latifolium* has been widely used medicinally, especially as a diuretic. Wright et al. (2007) concluded that it was among the more effective herbal diuretic preparations. It has been found to have a hypotensive effect due to its diuretic action in rats. The aqueous leaf extract given in doses of 50 and 100 mg/kg through intraperitoneal and oral routes, respectively, produced significant and dose-dependent diuretic and hypotensive activities. Attempts to extrapolate the diuretic action of *L. latifolium* extracts from rats to man led to the recommended daily dose of 3-5 g *L. latifolium* extract per man per day, administered as tea, which is equivalent to 43 to 71 mg/kg body weight in a 70 kg subject (Navarro et al., 1994). *L. latifolium* has also been used as a folk medicine in the Canary Islands for renal lithiasis and six months of oral treatment with a suspension of *L. latifolium* significantly reduced prostate size and volume in castrated rats where the hyperplasia was induced by steroid treatment (Martínez Caballero et al., 2004). *L. latifolium* is also used in India both medicinally and as a food (Rana et al., 2012) and in the Ladakh Himalayas there is interest in it as forage (Anju Verma et al., 2008)."

The extract of *L. latifolium* is sold in the United States by Alibaba.com (2019): "1-24 kilograms $16.50"

From Francis and Warwick (2007):

"The use of the flowers and fruiting stalks in dried arrangements in the United States is believed to contribute to long-distance spread of viable seeds (Krueger and Sheley 2004)."

"*Lepidium latifolium* has shown potential as a tool in the restoration of mesic silty clay calcareous soils rich in sodium (Na) through alteration of soil chemical properties (Renz and Blank 2004)."

Diseases

From Francis and Warwick (2007):

"[…] although Young et al. (1997a) reported the presence of white rust (*Albugo* sp.?) on *L. latifolium* […]; and a high incidence of white mould (*Sclerotinia* sp.) was observed on plants in Wyoming, but with no associated plant injury (Baker 1997). All other reports on *L. latifolium* (Farr et al., undated) are from Europe and Asia. These include: *Albugo candida* (Pers.: Fr.) Kuntze from Bulgaria; *Ascospora lepidii* Nasyrov from the former USSR; *Cercospora bizzozeriana* Sacc. & Berl. from Cyprus and Italy; *Cystopus candidus* Lév. from Cyprus; *Erysiphe communis* (Wallr.: Fr.) Link (= *Erysiphe pisi* DC. var. *pisi*) from Uzbekistan and Central Asia; *Erysiphe cruciferarum* Opiz ex L. Junell from Afghanistan, China, Iran, Romania, Turkey and the former USSR; *Erysiphe polygoni* DC. from the former USSR; *Hyaloperonospora parasitica* (Pers.: Fr.) Fr. from Romania and Russia; *Leveillula taurica* (Lév.) Arn. from Turkestan, Turkmenistan and the former USSR; *Oidium* sp. from China; *Peronospora lepidii* (McAlpine) G.W. Wilson (= *Perofascia lepidii* (McAlpine) Constant from Central Asia; *Peronospora lepidii-sativii* Gäum from the former USSR; *Puccinia isiacae* (Thum.) G. Winter from Central Asia; and, *Septoria lepidii* Desm. from Romania. Wang et al. (1998) listed *L. latifolium* as a host of *Albugo macrospora* (Togashi) S. Ito in Ningxia, China."

"*Lepidium latifolium*, one of the weeds examined in experimental virus-infected potato fields in Washington State, was not susceptible to the potato viruses PVS, PLRV and PVY (Thomas et al. 2003)."

Threat to Humans

CABI (2016) reports threats to humans in the form of decreased land values post invasion and loss of forage quantity and quality for livestock.

From Francis and Warwick (2007):

"In tidal marshes in the San Francisco Bay estuary, *L. latifolium* was among the invasive weeds that not only contributed to a reduction in native marsh plants but impeded tidal circulation, with a resulting increase in mosquito populations (Kramer et al. 1995). […] later invaded land along the river infested by encephalitis-bearing mosquitoes where the dense canopy and height of *L. latifolium* reduced the efficacy of insecticide applications."

3 Impacts of Introductions

From Young et al. (1995a):

"This [*Lepidium latifolium*] is a very competitive species that occurs in dense patches that are almost complete mono-cultures. […] An indication of the competitiveness of this species is provided by several examples of where it has replaced quackgrass."

"The greatest threat posed by perennial pepperweed [*Lepidium latifolium*] is to native hay meadows. The weed is invading these meadows in areas such as the Humboldt River Valley of Nevada. The mode of invasion is along irrigation ditches from riparian areas. In the hay meadows perennial pepperweed lowers the quality of hay in terms of protein content and digestibility. In areas of meadows that are not mowed annually the accumulation of stems inhibits grazing. If grazing in the early spring is used to help suppress this weed the accumulations of old stems must be reduced by mowing, brush beating, or burning."

"Among livestock producers in areas infested with perennial pepperweed there have been persistent rumors that the weed may be poisonous. Most cases of suspected poisoning have occurred with horses being fed hay containing perennial pepperweed under confined conditions."

"There is limited evidence that plants related to perennial pepperweed may be poisonous. *Lepidium latifolium* or shieldcress, is suspected of being poisonous to horses. A large number of horses became ill and many died in Utah after being fed hay consisting largely of shieldcress.

Based on the evidence of toxicity from other members of the mustard family and the persistent rumors of animal poisoning associated with perennial pepperweed it is worthwhile to investigate the toxic properties of the species under controlled feeding conditions."

From Francis and Warwick (2007):

"In Canada, *L. latifolium* was first identified as invasive in the late 1990s in British Columbia, where it represents a threat to croplands, rangelands, and riparian areas in the south-central region (Anonymous 2004; Weeds BC 2006; British Columbia Government Ministry of Agriculture and Food 2006). In Alberta, where *L. latifolium* has been established around Lethbridge for over half a century, it has become a problem in hay crops, and is among weeds considered undesirable in a new certified weed free hay program (Alberta Government Agriculture, Food and Rural Development 2006)."

"In Connecticut and Massachusetts *L. latifolium* began spreading rapidly in the 1990s (Pau and Smith 2005) from long-persistent stands in coastal marshes, where it frequently displaced such plants as marsh elder (*Iva frutescens* L.), salt grass [*Distichlis spicata* (L.) Greene] and saltmeadow cord grass [*Spartina patens* (Aiton) Muhl.], to roadsides, fields, pastures and gardens, and is now being treated as an invasive weed (Mehrhoff et al. 2003; USDA-NRCS 2006; Forman Orth et al. 2006)."

"In northeastern California, invasions of *L. latifolium* moved beyond the irrigated meadows used as winter forage into intensive agricultural crops such as cereal grains and alfalfa, where infestations led to depreciation in land values for affected farms (Young et al. 1995[a], 1997a, 2005). In Nevada and other western states, Eiswerth et al. (2005) calculated that losses from *L. latifolium* infestation on land used for grazing plus hay harvest were high enough that investment in control measures would have a payback period of 4 to 5 yr, whereas such investment on land used solely for grazing was of less economic benefit with a payback period of 15 yr."

"On a wildlife refuge in Oregon, *L. latifolium* displaced 5 and 10% of the native vegetation in the meadow and grass/shrub uplands, respectively; both are critical habitats for nesting aquatic birds and because hay from infested meadows is not marketable, contamination by *L. latifolium* has jeopardized haying programs on the refuge, which is also required to maintain a supply of short and medium grasses for sandhill cranes (*Grus canadensis* L.), shorebirds and waterfowl (Kilbride et al. 1997). The greatest damage from displacement of high quality forage grasses and sedges in western United States rangelands has been a reduction in protein content and digestibility of hay; while in unmowed areas the accumulation of persistent non-degraded dead stalks from previous seasons has both inhibited grazing, and had a negative impact on nesting sites (Young et al. 1995a, b; Renz 2000[b]; Krueger and Sheley 2004). *Lepidium latifolium* also acts as a "salt pump", transporting salt ions through the roots and depositing them near the surface in dead leaves and stalks, creating a hyper-saline soil environment (Blank and Young 1997[a]; […])."

"Results from studies on the impact of *L. latifolium* on wildlife habitats in California and adjacent western states vary, ranging from none, to positive, to deleterious effects. *Lepidium latifolium* was observed to have completely altered the species diversity and structure and function of riparian areas in those states. The main competitive features of *L. latifolium* are large underground reserves, shading by a closed canopy of tall, robust plants, and accumulation of litter (Blank and Young 1997a, b). In such areas *L. latifolium* has interfered with regeneration of willow (*Salix* spp.) and cottonwood (*Populus* spp.) and in wetland areas has affected the species composition and productivity of key herbaceous species (Young et al. 1995[a]; Renz 2000[b]). In California, a stand of *L. latifolium* in a hay meadow was seen to almost completely replace native sedges (*Carex* spp.), native grasses, and a suite of adventitious grasses (Young et al. 1997b), and in estuarine and other aquatic environments displaced rare native marsh grasses (Cohen and Moyle 2004)."

"In tidal marshes in the San Francisco Bay estuary, *L. latifolium* was among the invasive weeds that not only contributed to a reduction in native marsh plants but impeded tidal circulation, with a resulting increase in mosquito populations (Kramer et al. 1995). Control problems arose along waterways in Utah after *L. latifolium* first became abundant following heavy flooding of the Green River in 1983 (Reid et al. 1997). Initially, *L. latifolium* could not be controlled effectively in the pastures and hayfields after flooding subsided, and later invaded land along the river infested by encephalitis-bearing mosquitoes where the dense canopy and height of *L. latifolium* reduced the efficacy of insecticide applications. *Lepidium latifolium* also interfered with a recovery plan for endangered fishes of the Upper Colorado watershed because the flooding needed to create backwaters for fish spawning also furthered the spread of the weed (Reid et al. 1997)."

"In Canada, *L. latifolium* is presently regulated only in British Columbia. […] In Alberta, *L. latifolium* is on a designated weed and undesirable plant species list of the Alberta Certified Weed Free Hay Program (Alberta Government Agriculture, Food and Rural Development 2006)."

From U.S. Fish and Wildlife Service (2010):

"Dense patches of invasive *Lepidium latifolium* (perennial pepperweed) appear to displace tidal marsh vegetation positively associated with *Cirsium hydrophilum* (B. Grewell pers. comm. 2000; P. Baye pers. observ. 1994-1998)."

"Rapid invasion of brackish tidal marsh by *Lepidium latifolium* is a very significant threat to the persistence of *Cirsium hydrophilum* var. *hydrophilum* [Suisun thistle, federally endangered] colonies. *Lepidium latifolium* can readily invade both diked and tidal brackish marshes with low salinity during the growing season, and its colonies are especially dense and vigorous in better-drained marsh areas where *Cirsium hydrophilum* var. *hydrophilum* is most likely to occur. *Lepidium latifolium* is especially invasive on physically disturbed marsh soils and where vegetation cover has been reduced. It can permanently establish a continuous leaf canopy, eliminating the vegetation gaps that may be essential for seedling establishment of *Cirsium hydrophilum* var. *hydrophilum*. Dense, tall stands of *Lepidium latifolium* appear to inhibit survival and growth of juvenile thistles as well. Colonies of *Cirsium hydrophilum* var. *hydrophilum* have not been observed to persist in colonies of this invasive brackish marsh species (B. Grewell and P. Baye pers. observ.)."

"The most significant threats to remaining *Cordylanthus mollis* ssp. *mollis* [soft bird's-beak, federally endangered] populations are region-wide. One of the most potentially detrimental is the invasion of the middle and upper brackish tidal marsh zones by non-native *Lepidium latifolium*, a tall clonal herb in the mustard family that establishes in dense stands. *Lepidium latifolium* generally excludes *Cordylanthus mollis* ssp. *mollis*. There are no reports of its populations regenerating annually under spreading tall canopies of *Lepidium latifolium*. The invasion of brackish tidal marshes by *Lepidium latifolium* has proceeded rapidly in the last two decades. It currently threatens at least portions of *Cordylanthus mollis* ssp. *mollis* populations at Rush Ranch and Southampton Marsh where it has spread rapidly in the last decade, particularly in high rainfall years (B. Grewell, P. Baye pers. observ. 1991-1999)."

"Some introduced plants, particularly *Lepidium latifolium* (perennial pepperweed) and *Spartina alterniflora*, appear to pose threats to habitat quality for clapper rails [*Rallus crepitans*]. The rapid spread of *Lepidium latifolium* throughout thousands of acres of brackish marshes and brackish high marsh edges in Suisun, San Pablo, and south San Francisco bays may interfere with seedling establishment of Grindelia, a tall native evergreen sub-shrub used by clapper rails for high tide cover and nesting substrate in high marsh. *Lepidium latifolium* establishes poor above-ground winter cover as it is leafless and provides little cover during high winter tides. Spreading rhizomatously and by seed, it may displace *Sarcocornia pacifica* and other plants in some locations. The extent to which this species may affect clapper rails and other native species has not been investigated. Further study is needed to assess the effects of *Lepidium latifolium* in the marshes of San Francisco Bay."

"*Lepidium latifolium* (perennial pepperweed) readily invades brackish middle marsh plains that support significant proportions of *Sarcocornia* vegetation and associated native salt marsh plants. It can overtop and shade a *Sarcocornia* understory, and displace all other tidal brackish marsh

vegetation (P. Baye pers. observ. 1990-2000). *Lepidium latifolium* can form dense, often monotypic stands in high tidal marsh zones and terrestrial ecotones."

"The perennial depression of channel water salinity during high freshwater flows has caused conversion of middle tidalmarsh plains from salt marsh to brackish marsh dominated by species with very low or negative habitat value to the salt marsh harvest mouse (*Scirpus maritimus* [alkali bulrush], *Lepidium latifolium*), and reduced marsh salinity (H.T. Harvey and Associates 1997)."

From Zouhar (2004):

"Observed differences between broadleaved pepperweed-invaded sites and similar, noninvaded sites include a thick, nitrogen-rich litter layer; greater nitrogen availability and nitrogen-mineralization potentials; increased enzyme activities; increased biogeochemical fluxes of carbon, nitrogen, phosphorus, calcium, magnesium, and sulfur; lower sodium absorption ratios; and less compact, more friable natric horizons in sites occupied by broadleaved pepperweed as compared to sites dominated by tall wheatgrass [Blank and Young 1997a, 2002; Blank 2002]. Amelioration of sodic soils, including those with hard and compact subsoils (natric horizons) could give these soils greater effective rooting depth and more favorable physical properties that would make them likely to support a richer, more productive plant community if broadleaved pepperweed is controlled. The potential for excessive salt accumulation at the soil surface via litter decomposition cautions that long-term invasion by broadleaved pepperweed may increase the osmotic potential of the soil surface, thereby reducing seed germination and growth of salt-intolerant species [Blank and Young 2002]."

"All differences in soil attributes observed between broadleaved pepperweed invaded and uninvaded sites are difficult to attribute solely to broadleaved pepperweed invasion. It is possible that antecedent soil differences favored invasion by broadleaved pepperweed in particular areas. However, the case can be made that some differences in soils occupied by broadleaved pepperweed are a direct consequence of plant invasion through a combination of differential biogeochemical cycling and rhizosphere interactions. Where broadleaved pepperweed has converted diverse plant communities to monocultures, it is reasonable to conjecture that this conversion will promote divergent soil evolution [Blank and Young 2002]."

"However, if broadleaved pepperweed is qualitatively unique to the invaded ecosystem, it has the potential to completely alter the fire regime [D'Antonio 2000]. No examples of fire regimes altered by broadleaved pepperweed invasion are described in the available literature."

"Observations of researchers in Nevada suggest that cattle and domestic sheep will graze it when it grows amid other plants, but they do not eat broadleaved pepperweed growing in pure dense stands [Wood 1998]. According to Baker [1997], in Wyoming, pastures with broadleaved pepperweed rapidly become useless to cows and horses, but sheep readily eat broadleaved pepperweed, and even heavily infested pastures appear weed free when grazed by domestic sheep. In Montana, horses and mules were observed eating around broadleaved pepperweed leaf and seed flakes in grass hay [JL Fryer 2013, personal observation, U.S. Forest Service, Missoula, Montana]."

"Broadleaved pepperweed is listed by the California Invasive Plant Council (Cal-IPC) on List A-1: a widespread, aggressive invader that displaces natives and disrupts natural habitats. These are the most invasive wildland pest plants in their classification [Cal-IPC 1999]. Little research is available documenting or quantifying impacts of broadleaved pepperweed. However, several authors indicate observed impacts, especially in wetland and riparian settings. Observed and/or suggested impacts include altered species diversity, structure and function [Trumbo 1994; Blank and Young 1997b; Reid et al. 1997; Young et al. 1997b], displaced native species [Trumbo 1994; Rice and Randall 2003] including rare plant populations (Skinner and Pavlik 1994, as cited by [Howald 2000]), decreased food and habitat for several wildlife species [Trumbo 1994; Young et al. 1995[a], 1998; Kilbride et al. 1997; Howald 2000], changes in biogeochemical cycles [Blank and Young 1997a, 2002; Blank 2002] including emission of mercury from contaminated soils into the atmosphere [Leonard et al. 1998a], increased streamside soil erosion (personal communications with Susan Donaldson and Jim Young, as cited by [Renz 2000b]), and economic losses through reduced forage quantity and hay quality [Young et al. 1995[a], 1997b, 1998; Baker 1997; Kilbride et al. 1997; Howald 2000; JL Fryer 2013, personal observation, U.S. Forest Service, Missoula, Montana]."

"Observations of researchers and managers (e.g. [Trumbo 1994; Young et al. 1995[a], 1997b; Blank and Young 1997b; Rice and Randall 2003]) suggest that broadleaved pepperweed has altered species diversity, structure, function, and succession in many wetland and riparian areas in the western U.S. Because broadleaved pepperweed is highly competitive, grows in dense patches that are near monocultures, and results in a buildup of heavy thatch and litter that may be rich in salts (depending on the site), seedling recruitment and productivity of important, native species may be adversely affected [Young et al. 1995[a], 1997b; Blank and Young 1997b;]. Few data are available to support these observations. […] An inventory of rare and endangered plants in California indicates that broadleaved pepperweed is encroaching on several rare plant populations at Grizzly Island Wildlife Area in Suisun Marsh, including soft bird's-beak (*Cordylanthus mollis* ssp. *mollis*), Suisun thistle (*Cirsium hydrophilum* var. *hydrophilum*), and Suisun Marsh aster (*Symphyotrichum lentum*) (Skinner and Pavlik 1994 as cited by [Howald 2000])."

"Changes in vegetation structure caused by broadleaved pepperweed may interfere with management objectives and reduce habitat for various wildlife species. For example, observations along the Green River in Utah indicate that because of broadleaved pepperweed's increased canopy height and density as compared to native vegetation, it directly interferes with mosquito control efforts in the area (Steven V. Romney, personal communication as cited by [Reid et al. 1997]). Broadleaved pepperweed's tall stature, dense growth pattern, and accumulations of semiwoody stems […] are also purported to negatively impact nesting habitat for wildlife [Trumbo 1994; Young et al. 1995[a], 1998]. Observations by Blank and Young [2002] suggest that when broadleaved pepperweed populations reach a density of 50 stems per m^2, no waterfowl nesting occurs. According to Howald [2000], broadleaved pepperweed outcompetes grasses that provide food for waterfowl. Broadleaved pepperweed has invaded pickleweed-dominated marshes in some areas in California, and thus poses a threat to the habitat of the endangered salt marsh harvest mouse, California black rail, and California clapper rail [Trumbo 1994; Howald 2000]. No data are provided to support these observations. At the

Malheur National Wildlife Refuge in Oregon, broadleaved pepperweed has displaced 5 and 10% of the meadow and grass/shrub uplands, respectively, that are critical habitats for nesting aquatic and neotropical birds (US Fish and Wildlife Service, unpublished data, as cited by [Kilbride et al. 1997]). Because broadleaved pepperweed makes hay from infested pastures unmarketable, broadleaved pepperweed jeopardizes the haying program on the Malheur National Wildlife Refuge, which provides short and medium grasses for sandhill cranes, shorebirds, and waterfowl [Kilbride et al. 1997]."

"Observations at the Honey Lake Wildlife Refuge in northeastern California, indicated "striking differences" in soil profiles in broadleaved pepperweed infested areas compared with soils in similar, noninvaded areas of native hayland [Blank and Young 1997b]. These observations led to a series of research projects that indicated many differences in soil physical and chemical properties between broadleaved pepperweed infested sites and similar noninvaded sites [Blank and Young 1997a, b, 2002; Blank 2002] […]."

"Broadleaved pepperweed can take up mercury from contaminated soils and emit about 70% of that taken up during the growing season into the atmosphere (for every one molecule retained in broadleaved pepperweed foliage, 12 molecules were emitted) [Leonard et al. 1998a]. The most critical factors governing mercury flux from plants are mercury concentration in the soil, leaf area index, temperature, and irradiance [Leonard et al. 1998b]."

"The combination of low root density and easily-fragmented perennial roots allows soil erosion to occur during flooding events or other high waterflow events along riverbanks infested with broadleaved pepperweed. The water will also carry root pieces (which float) downstream where they can establish new populations (personal communications with Susan Donaldson and Jim Young as cited by [Renz 2000b])."

"Fence rows and "waste areas" within fields may become dense, impermeable thickets of broadleaved pepperweed [Young et al. 1998]."

From CABI (2016):

"Blank and Young (1997a) have shown that *L. latifolium* can act as a 'salt pump' which brings salt ions from deep in the soil profile and deposits them near the surface. This can favour halophytes and put other species at a disadvantage, thereby shifting plant composition and diversity. Conversely, Reynolds and Boyer (2010) recorded lower salinities under *L. latifolium* compared with those under *Sarcocornia pacifica*. *L. latifolium* was also shown to elevate soil solution levels of Mg^{+2} and Ca^{+2}, thereby reducing sodium adsorption ratios that could lead to sodic soil amelioration (Blank and Young, 2002; Blank and Young, 2004). […] Invasion by *L. latifolium* thus has the potential to alter soil properties and processes, thereby altering the trajectory of soil evolution. These effects may be exaggerated under elevated carbon dioxide conditions (Blank and Denner, 2004)."

Lepidium latifolium is regulated in multiple States, see Section 1.

4 History of Invasiveness

The U.S. Fish and Wildlife Service has determined that *Lepidium latifolium* is a threat to two federally listed, endangered native species of plants and is a possible threat to other native species. *L. latifolium* impacts the listed species by preventing seedling establishment, juvenile growth, and exclusion. This determination is made mostly on the basis of reports sent directly to the assessors and not on peer-reviewed information that can be accessed for this screening. However, there are many reports that *L. latifolium* impacts other species though changes in soil chemistry, may alter fire regimes, and may be a hazard to some livestock if ingested. Most of the information available to use for this screening came from scientific databases and white papers instead of peer-reviewed literature. There is enough information however to determine that *Lepidium latifolium* has a high history of invasiveness based on a preponderance of evidence.

5 Global Distribution

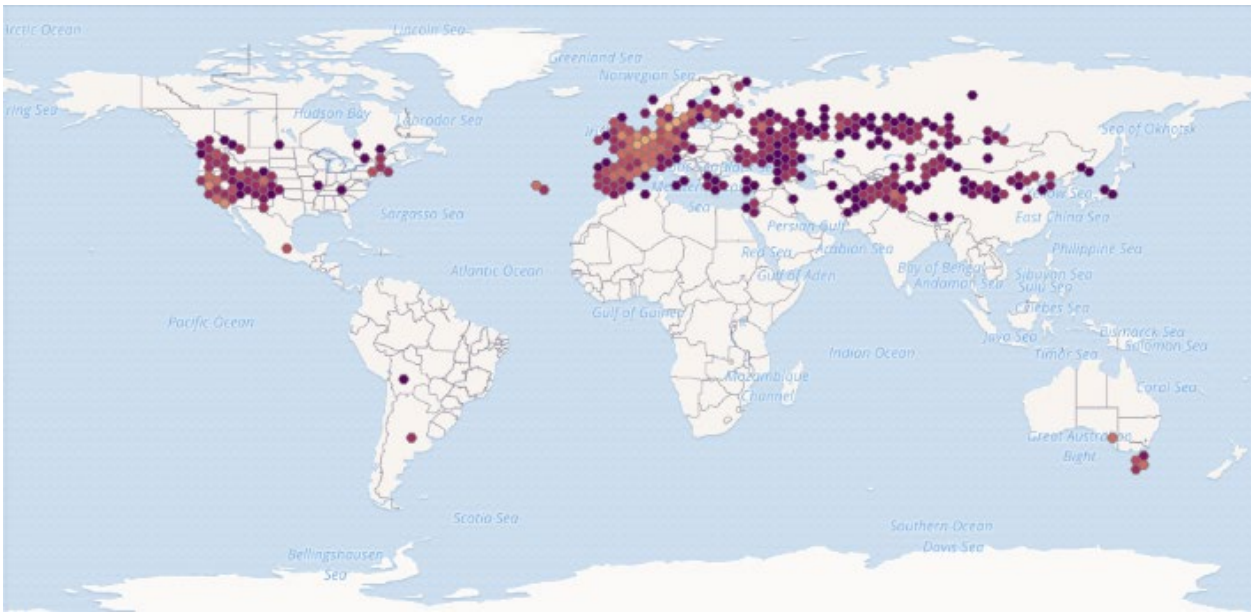

Figure 1. Known global distribution of *Lepidium latifolium*. Map from GBIF Secretariat (2021). Points that appear to be in the ocean are present on islands and were used to select source points for the climate match. Few observations were available from the Mediterranean areas of northern Africa where *Lepidium latifolium* is reported to be native (Francis and Warwick 2007; EDDMapS 2019).

6 Distribution Within the United States

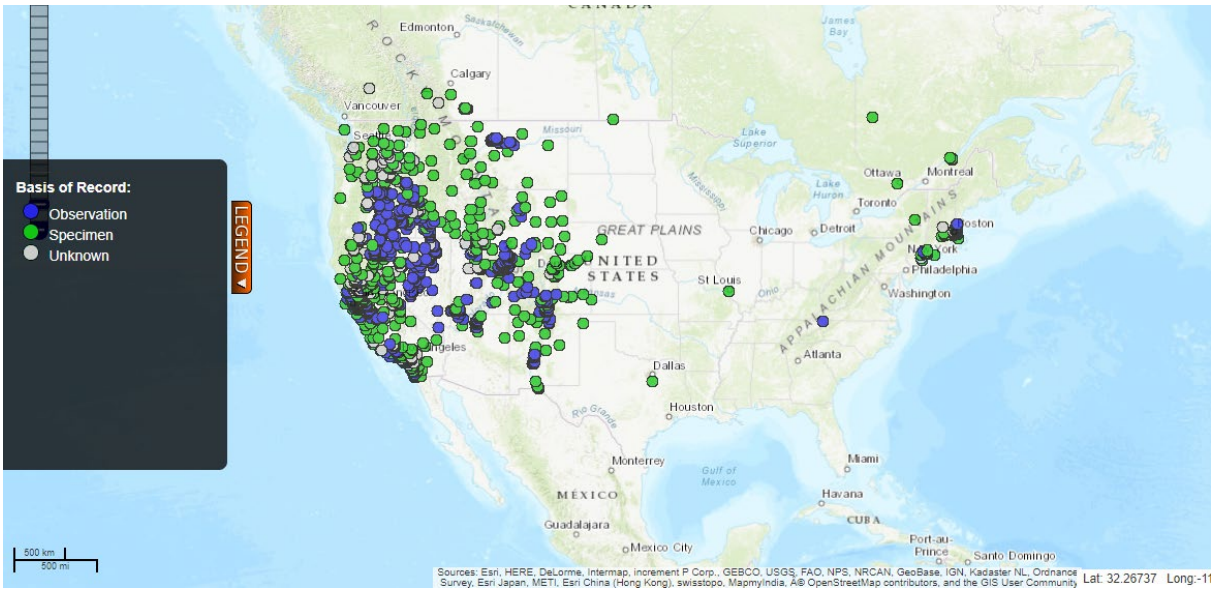

Figure 2. Known distribution of *Lepidium latifolium* in the United States. Map from BISON (2021).

7 Climate Matching

Summary of Climate Matching Analysis

The climate match for *Lepidium latifolium* was mainly high across the contiguous United States. There were areas of low match along the Gulf Coast and in a small area of coastal Pacific Northwest. Areas of medium match were found mostly in coastal areas of the Pacific Northwest, along the Gulf Coast where the match was not low, and inland from the Gulf Coast. Everywhere else had a high match. The Climate 6 score (Sanders et al. 2018; 16 climate variables; Euclidean distance) for the contiguous United States was 0.909, high (scores 0.103 or greater are classified as high). A majority of the States had high individual Climate 6 scores, except Alabama, which had a medium score, and Florida, which had a low score.

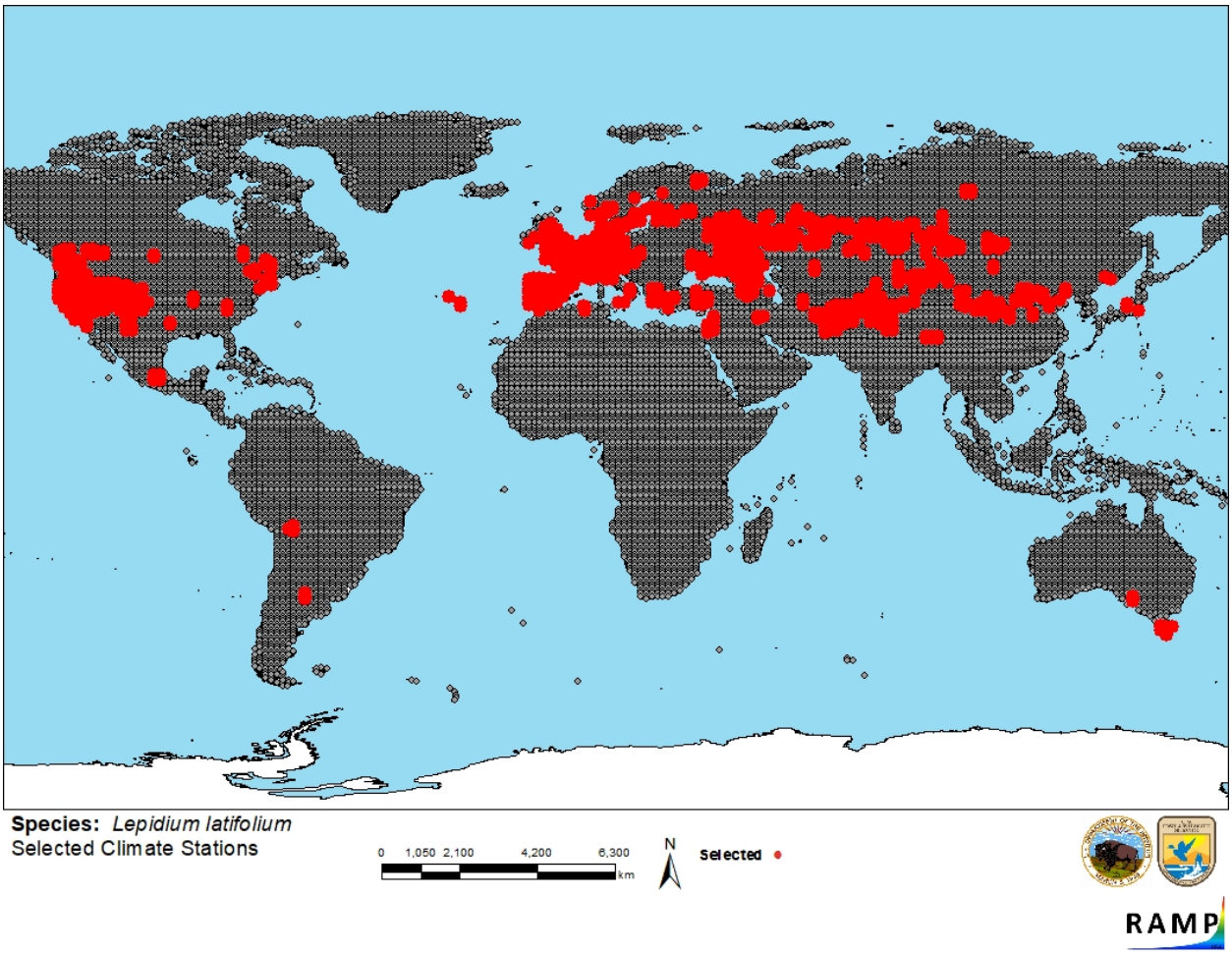

Figure 3. RAMP (Sanders et al. 2018) source map showing weather stations selected as source locations (red; North and South America, Africa, Europe, Asia, Australia) and non-source locations (gray) for *Lepidium latifolium* climate matching. Source locations from GBIF Secretariat (2021). Selected source locations are within 100 km of one or more species occurrences, and do not necessarily represent the locations of occurrences themselves.

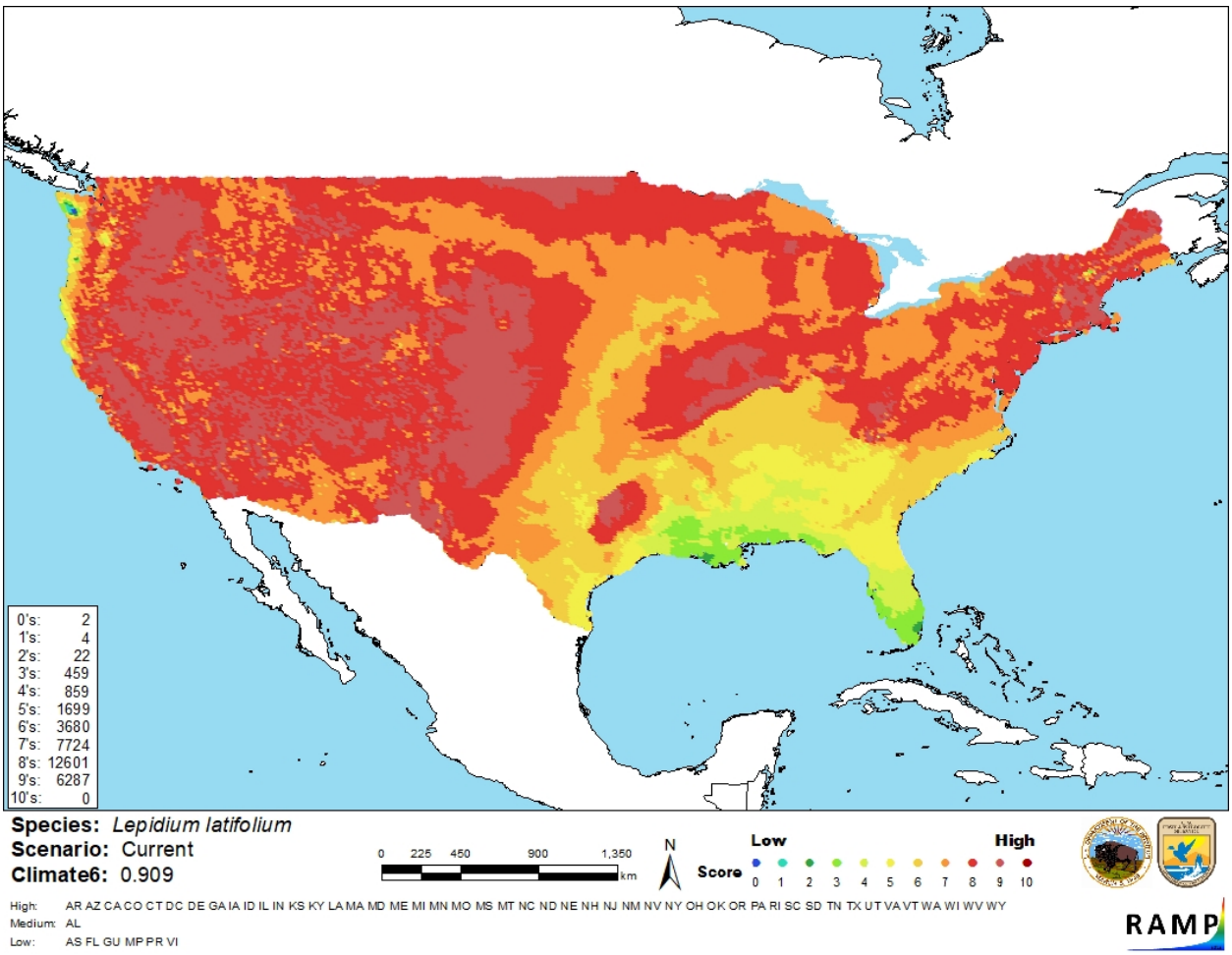

Figure 4. Map of RAMP (Sanders et al. 2018) climate matching for *Lepidium latifolium* in the contiguous United States based on source locations reported by GBIF Secretariat (2021). Counts of climate match scores are tabulated on the left. 0/Blue = Lowest match, 10/Red = Highest match.

The "High", "Medium", and "Low" climate match categories are based on the following table:

Climate 6: (Count of target points with target climate scores 6-10)/(Count of all target points)	Overall Climate Match Category
0.000≤X≤0.005	Low
0.005<X<0.103	Medium
≥0.103	High

8 Certainty of Assessment

There is an abundance of information on *Lepidium latifolium* from multiple sources, including information on its invasiveness and associated impacts. While some information was available from peer-reviewed literature the information regarding impacts of introduction was primarily

available from scientific databases and white papers. Due to the abundance of information, but lack of impact information from peer-review sources, the certainty of this assessment is medium.

9 Risk Assessment

Summary of Risk to the Contiguous United States

Broadleaf pepperweed (*Lepidium latifolium*) is an herbaceous perennial plant native to Mediterranean areas of Southeast Europe, North Africa and Southwest Asia, but has been spread to and become established in the United States, Canada, Mexico, Bolivia, Argentina, most of western and northern Europe, and from western Asia into China and Japan. It is also established in Australia and the Canary Islands. This species is believed to have been introduced through contaminated plant shipments, and possibly other vectors including ballast and storm water. It also has a long history of human use as medicine and a food source which may have contributed to its spread. Secondary spread can be easily achieved through vegetative reproduction from plant fragments. When introduced, impacts are widely reported and include altered trophic level, ecosystem change, habitat alteration, modification of nutrient regime, modification of successional patterns, monoculture formation, negative impacts to agriculture, and reduced native biodiversity. *L. latifolium* is potentially a threat to endangered species. Human impacts are realized through effects on agricultural lands including contamination of hay field and loss of forage land for livestock. *L. latifolium* is regulated in multiple States. The history of invasiveness for *L. latifolium* is classified as High. *L. latifolium* is regulated in multiple States. The climate match was high across much of the United States, except areas of the Gulf Coast and coastal Pacific Northwest. Due to the abundance of information, but lack of impact information from peer-review sources, the certainty of the assessment is medium. The overall risk assessment category is High.

Assessment Elements

- **History of Invasiveness (Sec. 3): High**
- **Climate Match (Sec. 6): High**
- **Certainty of Assessment (Sec. 7): Medium**
- **Remarks/Important additional information:** *Lepidium latifolium* is regulated in multiple States.
- **Overall Risk Assessment Category: High**

10 Literature Cited

Note: The following references were accessed for this ERSS. References cited within quoted text but not accessed are included below in Section 11.

Al-Shehbaz IA. 2010. A synopsis of the South American *Lepidium* (Brassicaceae). Darwiniana 48(2):141–167.

Alibaba. 2019. *Lepidium latifolium* extract/pepperwort extract. Available: https://www.alibaba.com/product-detail/Lepidium-latifolium-extract-pepperwort-Extract_60648902735.html (June 2019).

BISON. 2021. Biodiversity Information Serving Our Nation. U.S. Geological Survey. Available: https://bison.usgs.gov (February 2021).

[CABI] CABI International. 2016. *Lepidium latifolium* (perennial pepperweed) [original text by C. Parker]. CABI Invasive Species Compendium. Wallingford, United Kingdom: CAB International. Available: http://www.cabi.org/isc/datasheet/115209 (June 2019).

California Department of Food and Agriculture. 2015. California Code of Regulations Title 3. Food and Agriculture. Section 4500. Noxious Weed Species.

Darias V, Martín-Herrera D, Abdala S, de la Fuente D. 2001. Plants used in urinary pathologies in the Canary Islands. Pharmaceutical Biology 39(3):170–180.

EDDMapS. 2019. Early Detection and Distribution Mapping System. Tifton, Georgia: University of Georgia, Center for Invasive Species and Ecosystem Health. Available: http://www.eddmaps.org/ (June 2019).

Francis A, Warwick SI. 2007. The biology of invasive alien plants in Canada. 8. *Lepidium latifolium* L. Canadian Journal of Plant Science 87:639–658.

GBIF Secretariat. 2021. GBIF backbone taxonomy: *Lepidium latifolium* L. Copenhagen: Global Biodiversity Information Facility. Available: https://www.gbif.org/species/5376692 (February 2021).

[ITIS] Integrated Taxonomic Information System. 2019. *Lepidium latifolium* L. Reston, Virginia: Integrated Taxonomic Information System. Available: https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=503379#null (June 2019).

New York State Senate. 2014. Prohibited and regulated invasive species. Codes, Rules and Regulations of the State of New York, Title 6, Chapter 5, Subchapter C, Part 575.

Sanders S, Castiglione C, Hoff MH. 2018. Risk assessment mapping program: RAMP, version 3.1. U.S. Fish and Wildlife Service.

U.S. Fish and Wildlife Service. 2010. Chapter II Species accounts. Pages 53–141 in Draft recovery plan for tidal marsh ecosystems of Northern and Central California. U.S. Fish and Wildlife Service. Available: http://ecos.fws.gov/docs/recovery_plan/TMRP/Chapter%20II%20Species%20Accounts.pdf.

World Flora Online. 2021. World Flora Online – a project of the World Flora Online Consortium. Available: www.worldfloraonline.org (February 2021).

Young JA, Turner CE, James LF. 1995a. Perennial pepperweed. Rangelands 17(4):121–123.

Zouhar K. 2004. *Lepidium latifolium*. In Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Available: https://www.fs.fed.us/database/feis/plants/forb/leplat/all.html (November 2019).

11 Literature Cited within Quoted Text

Note: The following references are cited within quoted text within this ERSS, but were not accessed for its preparation. They are included here to provide the reader with more information.

Ahmed MZ, Khan MA. 2010. Tolerance and recovery responses of playa halophytes to light, salinity and temperature stresses during seed germination. Flora (Jena) 205:764–771.

Alberta Government Agriculture, Food and Rural Development. 2006. Alberta certified weed free hay program. Available: http://www.agric.gov.ab.ca/$department/deptdocs.nsf/all/prm1325 (November 2006).

Anonymous. 2004. Invasive species of British Columbia. Available: http://www.geog.ubc.ca/richmond/city/invasivespeciesofbc.html (November 2006).

Anonymous. 2005. Plant Conservation Alliance, Alien Plant Working Group. Perennial pepperweed. Available: http://www.nps.gov/plants/alien/fact/lela1.htm (November 2006).

Baker JL. 1997. Control of broadleaved pepperweed in Wyoming. Pages 28–30 in Management of perennial pepperweed (tall whitetop). Corvallis, Oregon: U.S. Department of Agriculture, Agricultural Research Service and Oregon State University, Agricultural Experiment Station. Special Report 972.

Blank RR. 2002. Amidohydrolase activity, soil N status, and the invasive crucifer *Lepidium latifolium*. Plant and Soil 239:155–163.

Blank RR, Derner JD. 2004. Effects of CO2 enrichment on plant-soil relationships of *Lepidium latifolium*. Plant and Soil 261(1/2):159–167.

Blank RR, Qualls RG, Young JA. 2002. *Lepidium latifolium*: plant nutrient competition-soil interactions. Biology and Fertility of Soils 35:458–464.

Blank RR, Young JA. 1997a. *Lepidium latifolium*: influences on soil properties, rate of spread, and competitive stature. Pages 69–80 in Brock JH, Wade M, Pysek P, Green D, editors. Plant invasions: studies from North America and Europe. Leiden, the Netherlands: Backhuys Publishers.

Blank RR, Young JA. 1997b. Influence of invasion of perennial pepperweed on soil properties. Pages 11–13 in Management of perennial pepperweed (tall whitetop). Corvallis, Oregon: U.S. Department of Agriculture, Agricultural Research Service, and Oregon State University, Agricultural Experiment Station. Special Report 972.

Blank RR, Young JA. 2002. Influence of the exotic invasive crucifer, *Lepidium latifolium*, on soil properties and elemental cycling. Soil Science 167(12):821–829.

Blank RR, Young JA. 2004. Influence of three weed species on soil nutrient dynamics. Soil Science 169(5):385–397.

British Columbia Government Ministry of Agriculture and Food. 2006. Weed alert: perennial pepperweed. Threat to rangeland and riparian areas. Available: http://www.agf.gov.bc.ca/cropprot/pepperweed.htm (November 2006).

Brown K. 2005. Plant assessment form. *Lepidium latifolium*. Detailed risk assessment. Flagstaff, Arizona: Southwest Biological Science Center.

[Cal-IPC] California Invasive Plant Council. 1999. The CalEPPC list: exotic pest plants of greatest ecological concern in California. California Exotic Pest Plant Council. Available: http://groups.ucanr.org/ceppc/1999_Cal-IPC_list (December 2004).

Chaurasia AJ, Ballabh RB. 2008. Potential fodder species of Ladakh Himalaya. Journal of Economic and Taxonomic Botany 32(Supplement):203–209.

Chen HJ, Qualls RG. 2003. Anaerobic metabolism in the roots of seedlings of the invasive exotic *Lepidium latifolium*. Environmental and Experimental Botany 50:29–40.

Chen HJ, Qualls RG, Blank RR. 2005. Effect of soil flooding on photosynthesis, carbohydrate partitioning and nutrient uptake in the invasive exotic *Lepidium latifolium*. Aquatic Botany 82:250–268.

Chen HJ, Qualls RG, Miller GC. 2002. Adaptive responses of *Lepidium latifolium* to soil flooding: biomass allocation, adventitious rooting, aerenchyma formation and ethylene production. Environmental and Experimental Botany 48:119–128.

Cheo T-Y, Lu L-L, Yang G, Al-Shehbaz IA. 2001. Brassicaceae. Pages 1–193 in Wu ZI, Raven PH, editors. Flora of China – Brassicaceae through Saxifragaceae. Beijing: Science Press; St. Louis: Missouri Botanical Garden Press.

Cohen AN, Moyle PB. 2004. Summary of data and analyses indicating that exotic species have impaired the beneficial uses of certain California waters. Available: http://www.sfei.org/bioinvasions/Reports/2004-ImpairedCalWaters382.pdf (November 2006).

D'Antonio CM. 2000. Fire, plant invasions, and global changes. Pages 65–93 in Mooney HA, Hobbs RJ, editors. Invasive species in a changing world. Washington, DC: Island Press.

Donaldson S, Johnson W. 1999. War against tall whitetop. University of Nevada Cooperative Extension Fact Sheet 97– 01. Available: http://www.unce.unr.edu/publications/FS99/FS9995.pdf (November 2006).

Eiswerth ME, Singletary L, Zimmerman JR, Johnson WS. 2005. Dynamic benefit-cost analysis for controlling perennial pepperweed (*Lepidium latifolium*): a case study. Weed Technology 19(2):237–243.

Forman Orth J, Gammon M, Abdul-Basir F, Stevenson RD, Tsirelson D, Ebersole J. 2006. Natural history, distribution, and management of *Lepidium latifolium* (Brassicaceae) in New England. Rhodora 108:103–118.

Gaskin JF, Schwarzländer M, Williams L, III, Gerber E, Hinz HL. 2012. Minimal genetic diversity in the facultatively outcrossing perennial pepperweed (*Lepidium latifolium*) invasion. Biological Invasions 14:1797–1807.

GBIF. 2012. Global Biodiversity Information Facility. Available: http://data.gbif.org.

Grayum MH, Koutnik DL. 1982. New records of vascular plants from the Santa Monica Mountains, California, and adjacent parts of Los Angeles and Ventura counties. Aliso 10:313–320.

Gusev YuD. 1976. Penetration of new adventive plants into Kirov and Perm regions. Botanicheskiĭ Zhurnal SSSR 61:567–570. (In Russian.)

Gusev YuD. 1977. Penetration of new adventive plants into Mari A.S.S.R. by means of the railway. Botanicheskiĭ Zhurnal SSSR 62: 429–431. (In Russian.)

Halvorsen R, Grøstad T. 1998. Is *Lepidium latifolium* L. a ballast plant in Norway? Three new finds of *L. latifolium* in Vestfold and Østfold counties, SE Norway. Blyttia 56:126–131.

Hämet-Ahti L, Suominen J, Ulvinen T, Uotila P, editors. 1998. Field flora of Finland. 4th edition. Helsinki: Finnish Museum of Natural History, Botanical Museum.

Herrero-Cembranos L, Garcia-Gonzalez ME, Peñas A. 1988. De Plantis Legionensibus Notula XI. Acta Botanica Malacitana13:319–323. (In Spanish.)

Hewson HJ. 1981. The genus *Lepidium* L. (Brassicaceae) in Australia. Brumonia 4:217–308.

Howald A. 2000. *Lepidium latifolium* L. Pages 222–227 in Bossard CC, Randall JM, Hoshovsky MC, editors. Invasive plants of California's wildlands. Berkeley: University of California Press.

H.T. Harvey and Associates. 1997. [Source material did not give full citation for this reference.]

Invaders Database System. 2005a. Noxious weeds in the US and Canada. University of Montana. Available: http://invader.dbs.umt.edu/Noxious_Weeds (November 2006).

Invaders Database System. 2005b. *Lepidium latifolium*. Distribution increase line graph. University of Montana. Available: http://invader.dbs.umt.edu/plot_chart.asp (November 2006).

ISSG. 2012. Global Invasive Species Database (GISD). Auckland, New Zealand: University of Auckland. Available: http://www.issg.org/database.

Jalas J, Suominen J, Lampinen R, editors. 1996. Atlas Florae Europaeae - Distribution of vascular plants in Europe. Volume 11 (Cruciferae: *Ricotia* to *Raphanus*). Helsinki, Finland: Helsinki University Printing House.

Kilbride KM, Paveglio FL, Pyke DA, Laws MS, Joel HD. 1997. Use of integrated pest management to restore meadows infested with perennial pepperweed at Malheur National Wildlife Refuge. Pages 31–35 in Management of perennial pepperweed (tall whitetop). Corvallis, Oregon: U.S. Department of Agriculture, Agricultural Research Service, and Oregon State University, Agricultural Experiment Station. Special Report 972.

Kloot PM. 1973. Perennial peppercress - a warning. Journal of Agriculture, South Australia 76:72–73.

Kramer VL, Collins JN, Malamud-Roam K, Beesley C. 1995. Reduction of *Aedes dorsalis* by enhancing tidal action in a northern California marsh. Journal of the American Mosquito Control Association 11:389–395.

Krueger J, Sheley R. 2004. Perennial pepperweed (*Lepidium latifolium*). Montguide: Montana State University Extension Service. Available: http://www.montana.edu/wwwpb/pubs/mt9906.html (November 2006).

Larson L, Kiemnec G. 2005. Germination of two noxious range weeds under water and salt stresses with variable light regimes. Weed Technology 19:197–200.

Leininger SP, Foin TC. 2009. *Lepidium latifolium* reproductive potential and seed dispersal along salinity and moisture gradients. Biological Invasions 11:2351–2365.

Leonard TL, Taylor GE Jr, Gustin MS, Fernandez GCJ. 1998a. Mercury and plants in contaminated soils: 1. Uptake, partitioning, and emission to the atmosphere. Environmental Toxicology and Chemistry 17(10):2063–2071.

Leonard TL, Taylor GE Jr, Gustin MS, Fernandez GCJ. 1998b. Mercury and plants in contaminated soils: 2. Environmental and physiological factors governing mercury flux to the atmosphere. Environmental Toxicology and Chemistry 17(10):2072–2079.

Lundqvist Å. 1979. Weitere Nachträge zur Flora der Insel Öland. Svensk Botanisk Tidskrift 73:281–325. (In German with English abstract.)

Mehrhoff LJ, Silander JA Jr, Leicht SA, Mosher ES, Tabak NM. 2003. *Lepidium latifolium*. IPANE: Invasive Plant Atlas of New England. Storrs: University of Connecticut, Department of Ecology and Evolutionary Biology. Available: http://www.ipane.org (November 2006).

Missouri Botanical Garden. 2012. Tropicos database. St Louis: Missouri Botanical Garden. Available: http://www.tropicos.org/.

Mitchell RS, Tucker GC. 1997. Revised checklist of New York State plants. Albany: The University of the State of New York, The State Education Department.

Mohammad A, Sinha VB, Singh RK, Sivalingam A, Veena P, Zakwan A. 2010. Isolation of cold stress-responsive genes from *Lepidium latifolium* by suppressive subtraction hybridization. Acta Physiologiae Plantarum 32:205–210.

Mohammad A, Sivalingam A, Zakwan A. 2011. Cloning and sequencing of PR5-like gene from high altitude adapted ecotype of *Lepidium latifolium*. Archives of Phytopathology and Plant Protection 44:1025–1032.

Morse AP. 1924. *Lepidium latifolium* in New England. Rhodora 26:197–198.

Pau N, Smith K. 2005. Experimental control of perennial pepperweed (*Lepidium latifolium*) at Parker River National Wildlife Refuge. Pages 39–40 in New England Invasive Plant Summit, September 16–17, 2005, Framingham, Massachusetts. Available: http://nbii-nin.ciesin.columbia.edu/ipane/summit05/Summit_program_05.doc (November 2006).

Pogan E. 1980. Further studies in chromosome numbers of Polish Angiosperms. Acta Biologica Cracovensia Series Botanica 22:129–153.

Pyak AI. 1991. New and rare species of plants for Tomsk Oblast. Sibirskiĭ Biologicheskiĭ Zhurnal 2:26–28. (In Russian.)

Queiros M. 1979. Chromosome numbers for the Portuguese flora 16-37. Boletim da Sociedade Broteriana 53:15–28.

Rana JC, Pradheep K, Chaurasia OP, Sarvesh S, Sharma RM, Archna S, Ranjna N. 2012. Genetic resources of wild edible plants and their uses among tribal communities of cold arid region of India. Genetic Resources and Crop Evolution 59:135–149.

Reid CR, Rasmussen GA, Dewey S. 1997. Managing perennial pepperweed in Uintah County, Utah. Pages 36–42 in Management of perennial pepperweed (tall whitetop). Corvallis, Oregon: U.S. Department of Agriculture, Agricultural Research Service, and Oregon State University, Agricultural Experiment Station. Special Report 972.

Renz MJ. 2000a. *Lepidium latifolium*. In Randall JM, editor. BugwoodWiki. Tifton: University of Georgia, Center for Invasive Species and Ecosystem Health.

Renz MJ. 2000b. Element stewardship abstract: *Lepidium latifolium* L.--perennial pepperweed; tall whitetop. In Invasives on the web: The Nature Conservancy wildland invasive species program. Davis, California: The Nature Conservancy. Available: http://tncweeds.ucdavis.edu/esadocs/documnts/lepilat.html.

Renz MJ, Blank RR. 2004. Influence of perennial pepperweed (*Lepidium latifolium*) biology and plant-soil relationships on management and restoration. Weed Technology 18(Supplement):1359–1364.

Renz MJ, Steinmaus SJ, Gilmer DS, DiTomaso JM. 2012. Spread dynamics of perennial pepperweed (*Lepidium latifolium*) in two seasonal wetland areas. Invasive Plant Science and Management 5:57–68.

Reynolds LK, Boyer KE. 2010. Perennial pepperweed (*Lepidium latifolium*): properties of invaded tidal marshes. Invasive Plant Science and Management 3(2):130–138.

Rice BM, Randall J, compilers. 2003. Weed report: *Lepidium latifolium*--white-top; perennial pepperweed. In Wildland weeds management and research: 1998-99 weed survey. Report of The Nature Conservancy, Wildland Invasive Species Program to U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, Missoula, Montana.

Robbins WW, Bellue MK, Ball WS. 1951. Weeds of California. Sacramento: California State Department of Agriculture Printing Division.

Rollins RC. 1993. The Cruciferae of continental North America. Stanford, California: Stanford University Press.

Schultze-Motel W. 1986. *Lepidium latifolium*. Pages 414–415 in Hegi G, editor. Illustrierte Flora von Mittel-europa, 3rd edition. Berlin: Verlag Paul Parey. (In German.)

Størmer G. 2011. New finding of pepperweed *Lepidium latifolium* near Drøbak - the species is spreading in the Oslofjord area. Blyttia 69:28–31.

Thomas PE, Richards K, Olberding T. 2003. Survival and spread of potato viruses in the Columbia Basin 1: potential for virus survival in overwintering weeds and crops. Potato Progress 3(8):1–4.

Trumbo J. 1994. Perennial pepperweed: a threat to wildland areas. CalEPPC News: Newsletter of the California Exotic Pest Plant Council 2(3):4–5.

USDA-NRCS. 2006. The PLANTS Database, Version 3.5. Baton Rouge, Louisiana: National Plant Data Center. Available: http://plants.usda.gov/ (November 2006).

Vibrans H. 2003. Notes on neophytes 3. Distribution of some Brassicaceae recently introduced in central Mexico. Acta Botanica Mexicana 65:31–44.

Villaseñor Rios JL, Espinosa García FJ. 1998. Catálogo de malezas de México. D.F. México: Universidad Nacional Autónoma de México, Ediciones Cientificas Universitarias.

Wang K-C, Zha X-F, Fan Z-Q, Chen C-Y. 1998. An investigation of *Albugo* in Ningxia. Ningxia Journal of Agricultural Science and Technology 2:4–7. (In Chinese with English abstract.)

Weeds BC. 2006. A guide to weeds in British Columbia. Perennial pepperweed: Identification and management. Victoria: British Columbia Ministry of Agriculture Food and Fisheries. Available: http://www.weedsbc.ca/pdf/perennial_pepperweed.pdf (November 2006).

Wood M. 1998. Toppling tall whitetop. Agricultural Research 46(7):18–19.

Wotring SO, Palmquist DE, Young JA. 1997. Perennial pepperweed (*Lepidium latifolium*) rooting characteristics. Pages 14–15 in Management of perennial pepperweed (tall whitetop). Corvallis, Oregon: U.S. Department of Agriculture, Agricultural Research Service, and Oregon State University, Agricultural Experiment Station. Special Report 972.

Young JA, Blank RR, Clements CD. 2005. Tall whitetop (*Lepidium latifolium*). United States Dept. of the Interior, Bureau of Land Management, National Science and Technology Center. Resource Notes 76. Available: http://www.blm.gov/nstc/resourcenotes/respdf/RN76.pdf (November 2006).

Young JA, Palmquist DE, Blank RR. 1997a. Herbicidal control of perennial pepperweed (*Lepidium latifolium*) in Nevada. Pages 26–27 in Svejcar T, ed. Management of perennial pepperweed (tall whitetop). Corvallis, Oregon: U.S. Department of Agriculture, Agricultural Research Service, and Oregon State University, Agricultural Experiment Station. Special Report 972.

Young JA, Palmquist DE, Blank RR. 1998. The ecology and control of perennial pepperweed (*Lepidium latifolium*). Weed Technology 12(2):402–405.

Young JA, Palmquist DE, Blank RR, Turner CE. 1995b. Ecology and control of perennial pepperweed (*Lepidium latifolium* L.). Pages 29–32 in Lovich JE, Randall J, Kelley MD, editors. Sacramento: Proceedings of the California Exotic Pest Plant Council Symposium.

Young JA, Palmquist DE, Wotring SO. 1997b. The invasive nature of *Lepidium latifolium*: a review. Pages 59–68 in Brock JH, Wade M, Pysek P, Green D, editors. Plant invasions: studies from North America and Europe. Leiden, The Netherlands: Backhuys Publishers.