CIRSIUM PALUSTRE (MARSH THISTLE)

LITERATURE SEARCH AND HABITAT POTENTIAL RISK ANALYSIS

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SUMMARY

Cirsium palustre (marsh thistle)

A world wide literature search was conducted to gather information on *Cirsium palustre*. Other than a plant description in various North American Floras, the bulk of the information came from European sources where *C. palustre* is a native plant. Most of the studies were investigating life history and population dynamics of *C. palustre* in native habitats. Since *C. palustre* is not considered an important weed in Europe (other than in some situations in England) there was no specific information found pertaining to the spread and control of the species.

There was no research or control information of value found from North American sources. *C. palustre* was not a plant of concern in most jurisdictions that were contacted (the exception being Dr. Voss from the University of Michigan Herbarium who was concerned with its spread*). C. palustre* did not appear in any of Canada's text listing invasive species or weeds of concern and the Invasive Plants of Canada Project did not have any information on *C. palustre.*

C. palustre is a facultative biennial of European origin that reproduces by seed. The presence of the species is maintained by: numerous wind dispersed seeds, a persistent seed bank, the ability to germinate during the whole growing season (spring and fall predominantly), the fact that some individuals of a population flower each year, and possible but unconfirmed allelopathic properties.

C. palustre requires a moist habitat. Moisture is the most limiting factor to distribution. Soil texture does not appear limiting with growth reported on a wide range of soil textures, usually with acidic pH.

C. palustre is a shade-avoiding species. Growth, flowering and germination are either slowed or inhibited by shading. *C. palustre* is an early successional species and is inhibited by competition with other species. As succession progresses and canopies close, *C. palustre* decreases in native populations. Increased shade, density and competition limit *C. palustre* by: prolonging its life-cycle (flowering delayed beyond second year of growth), decreasing the fraction of individuals reaching fruiting stage (rosettes die without flowering) and diminishing fecundity and reproduction (rosettes that flower are weak).

Disturbance is not a requirement for germination but it can open up suitable sites and release seed from seed banks. Moist, bare soil that is not shaded is the ideal germination site.

Grazing can limit the distribution of *C. palustre* due to the vulnerability of rosettes to trampling or it can create open sites ideal for germination. Mowing, under hay field management, does not limit *C. palustre* but mowing at flowering does, decreasing plant numbers.

The life cycle, habitat and soils information found in the literature only allows for a discussion of the possible spread of *C. palustre*, not a prediction of its absolute potential distribution within British Columbia. *C. palustre* has the potential to invade moist habitats and riparian areas with acidic soils. Populations are short-lived but the continuous production of wind blown seeds assures distribution into new habitats. It needs open areas to germinate, grow and flower, with limited performance under conditions of competition and shading. There was no literature found indicating that *C. palustre* is found in alpine habitats.

Biological Agents

Of the many insects documented as using *C. palustre* as part of their life cycle, the literature search only turned up useful information on six species. Of these six, only *Terellia ruficauda,* a seedhead fly, shows any promise as a possible biological agent for *C. palustre* in British Columbia. Please refer to the conclusions under ‘Terellia ruficauda’ in the Biological Agent section.

INTRODUCTION

Background

Cirsium palustre (marsh thistle) has become a plant of concern in British Columbia. A native to Europe, *C. palustre* is still considered rare in North America but has established populations in some eastern provinces and states, and in British Columbia.

The species was identified and collected in British Columbia (Prince Rupert) as early as 1954, but has only recently become a potential problem, with rapid spread occurring in the McBride area. Brooke and Grilz (1999) report that *C. palustre* was noted by Ministry of Forests staff in 1991 as a small patch approximately 20 km west of McBride along Highway 16. It has since spread at least 50 km west along the Fraser River and 30 km north along the MacGregor River.

Because of the limited information in British Columbia, a literature search was initiated in the fall of 1999 to gather *C. palustre* information from worldwide sources. Presented in this report are a summary of the information gathered and an analysis of the habitat at risk from invasion by *C. palustre* in British Columbia.

Methodology

A worldwide literature search was conducted using key words searches in BIOSIS, AGRICOLA and TreeCD databases, internet searches on the worldwide web using Netscape, Altavista and Yahoo, and communications with key personnel in North America and Europe. The information gathered consisted of journal articles, theses, text books, email from personnel, government reports and maps.

Citations from all of the accumulated information (with the exception of email communications which are in Appendix IV) are recorded on the 'MASTER LIST' excel spreadsheet (Appendix I) and then subdivided into spreadsheets based on major topics (Appendix II and Appendix III). Websites that were of particular help in locating information are listed in Appendix VI.

Accumulated literature was reviewed for content and relevancy and then compiled and summarized into a report highlighting major topics considered to be of value in formulating a management plan for *C. palustre* in British Columbia. When possible, printed copies (hard copies) of citations were obtained and will form part of the final analysis package. The Master List indicates whether a hard copy was located.

Because of the lack of detailed habitat information found in the literature, an in depth analysis of the potential spread and the habitat at risk from *C. palustre* was not undertaken. Nor were any maps produced visually representing the potential habitat and spread. It was felt that only a general prediction of the habitat types that are considered at risk from invasion by *C. palustre* could be included in this report. The predictions were made by comparing site descriptions in the Biogeoclimatic Ecosystem Site Guides for British Columbia to the habitat descriptions and requirements of *C. palustre*, as documented in European sources. Sites considered at risk from invasion by *C. palustre* are tabulated in the 'Habitat at Risk' section.

CIRSIUM PALUSTRE

Taxonomic Overview

Scientific Name

Cirsium palustre (L.) Scop., Fl. Carn. 2nd ed. II, 128. 1772.

Synonyms:

Carduus palustris L., Sp. Pl. 822. 1753.

Cnicus palustris Willd., Fl. Berol. Prodr. 260. 1787.

Family:

Compositae or Asteraceae

Tribe:

Cardueae

Cirsium Miller, Gard. Dict. Abr. 4th ed. 1754, emend. Scop. Fl. Carn. 355. 1760.

The genus *Cirsium* consists of probably 350 species distributed through the northern hemisphere of both the New and the Old Worlds. Approximately 120 are native to North America, most occurring in the western United States. Fifteen species are found in Canada, three of these being introductions from the Old World (Moore and Frankton 1974).

Common Names

marsh thistle

marsh plume thistle

cirse des marais

European swamp thistle

Table 1. European common names. From Williams (1982).

kaertidsel	Danish
Sumpf-Kratzdistel	German
marsh thistle	English
cardo de pantano	Spanish
suo-ohdake	Finnish
chardon des marais	French
cardo palustre	Italian
kale jonker	Dutch/Flemish
myrtistel	Norwegian
karrtistel	Swedish

Description

Chromosome number: 2*n* = 34 (Czapik 1958, Gadella and Kliphuis 1963, Moore and Frankton 1962a)

The following description was compiled from Douglas et al 1998, Tutin et al 1976, Moore and Frankton 1974, and Clapham et al 1962.

Cirsium palustre is a fibrous rooted, biennial herb growing 0.2 -2.0 m tall. Stems are erect, slender, ribbed, simple or sometimes with ascending branches above and strongly spiny-winged from the winged leaf bases. Basal and lower stem leaves are narrowly elliptic. Middle stem leaves and reduced upper ones are lanceolate, pinnately cut to about ½ the width of the leaf, with narrow, spine-tipped segments and winged bases. Leaves are nearly glabrous to lightly soft-hairy above and lightly to densely long-hairy below.

Flowerheads are discoid with several to many in small, compact purple clusters terminating the stem or at the ends of branches. Involucres are egg-shaped to cylindric and 1-1.5 cm tall. Bracts are sparsely to densely cobwebby, with the outer ones often sticky and usually tapering to a thick, often curved, abruptly sharp pointed spine.

Achenes are 2.5-3.5 mm long, 1mm broad, straw-coloured, almost white with shiny apical collar. The pappus is tawny when mature and 9-10 mm long.

Note: There could be confusion in identifying *Cirsium palustre* from *Cirsium vulgare* (bull thistle). Frankton (1967) states, “Although all thistles have spines on

the leaf edges, bull thistle is the only thistle with a spiny leaf surface. Bull thistle has winged stems with long pointed prickles and this character is also sufficient for differentiation from all other true thistles, *Cirsium* spp, except marsh thistle, *Cirsium palustre* (L.) Scop., a European weed ….” *Cirsium vulgare* is common in southern BC and infrequent in northern BC (Douglas et al 1998) and its habitat can overlap with that of *C. palustre* (van Leeuwen 1987).

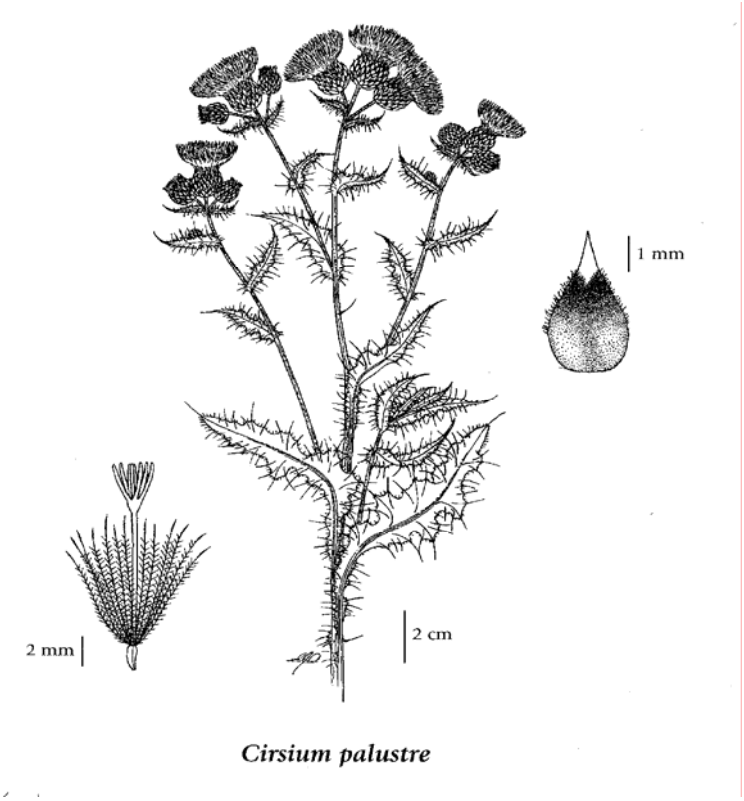


Figure 1. *Cirsium palustre*, from Douglas et al 1998, page 219.

Geographical Distribution

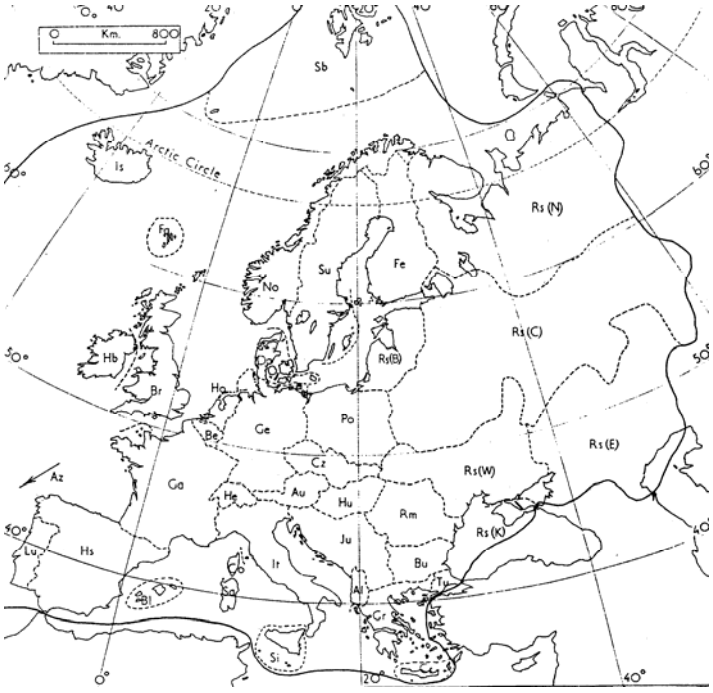
European

C. palustre is native to Europe where it is found in Scandinavia (67^{o} 50’N) (Clapham et al 1962), Atlantic and central Europe, east to western Asia (Lake Baikal), the western Mediterranean region and south to Algeria (Moore and Frankton 1974, Tutin et al 1976).

Williams (1982) lists *C. palustre* as, ‘only of importance in a few situations, although it may be widespread as a minor weed species’ in: (1) northern Europe (Finland, Sweden, Norway, N. Britain, Ireland and Iceland); (2) central Europe (Denmark, N. Germany, Netherlands, Belgium, S. Britain, N. France); and (3)

southern Europe (S. Germany, Austria, Switzerland, Italy, and S. France). It is considered as, ‘of no importance as a weed’ in western Europe (Spain and Portugal).

Holm et al (1979) list *C. palustre* as a ‘common weed’ in England, Finland and Germany. In some parts of the Netherlands it is considered a rare and threatened species (van Leeuwen 1987).



Countries include: Albania, Austria, Belgium, Britain, Czechoslovakia, Denmark, Færöer, Finland, France, Germany, Ireland, Switzerland, Netherlands, Spain, Hungary, Italy, Jugoslavia, Portugal, Norway, Poland, Romania, U.S.S.R, and Sweden

Figure 2 - European Distribution of *Cirsium palustre*. From Tutin et al 1976, page 377.

New Zealand and Australia

According to the ‘Flora of New Zealand’, *C. palustre* was first recorded in the wild in 1911 (Randall 2000, email). It is found in the high rainfall areas of the North Island, occasionally in parts of the east coast of the South Island and is abundant in Westland, in the South Island. It has naturalized but is rarely a major weed and is not of any great economic importance (Lee 2000, email). It is found mainly in damp pasture, roadsides and swampy land (Williams 2000, email).

A reference to *C. palustre* being in Australia was found in Mogford (1974a). He cites Bentham (1863), 'Flora Australiensis'. This lead was not pursued and no papers from Australia turned up during the literature searches.

North American

In Canada, *C. palustre* has been reported from British Columbia, Ontario, Quebec, Nova Scotia, Newfoundland and the French islands of St-Pierre and Miquelon. In the U.S.A., *C. palustre* has been reported from Massachusetts, Michigan, New Hampshire, New York and Wisconsin.

C. palustre has been spreading steadily west since first reported collections on the east coast. It was collected in New Hampshire in 1902 (Holt 1902) and in Newfoundland in 1910 (Fernald 1933). It has been known in Michigan since 1935 and Wisconsin since 1961 (Johnson and Iltis 1962). Dr Edward Voss (1999, email) was horrified to see *C. palustre* along a stream in mixed woods in Pancake Bay Provincial Park about 36 miles northwest of Sault Ste. Marie, Ontario.

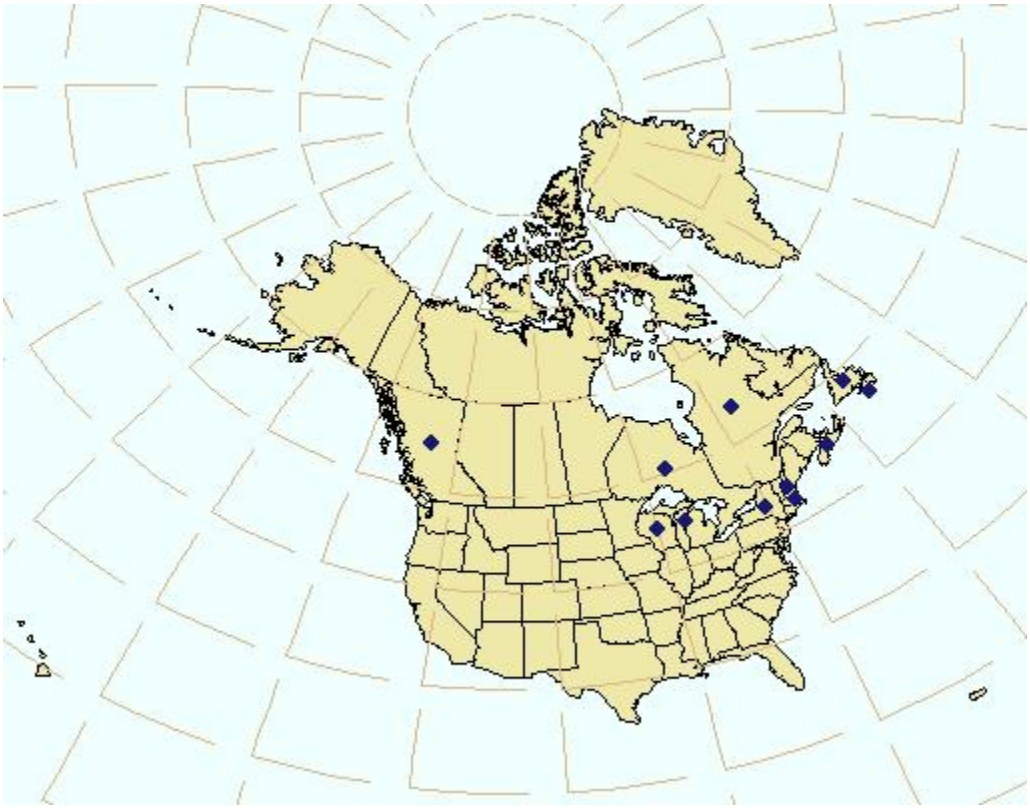


Figure 3 – North American Distribution of *Cirsium palustre*. From BONAP (Biota of North America Program) website, 1999.

British Columbia

Douglas et al (1998) report *C. palustre* as infrequent throughout British Columbia south of 55^{o}N. The following is a map of known populations provided by Dr. George Douglas from the Conservation Data Centre in Victoria. An attempt was made to locate the samples and hence collection dates and exact locations of the dots. Only a few of the specimens were located and the details of the herbarium labels are in Appendix V.

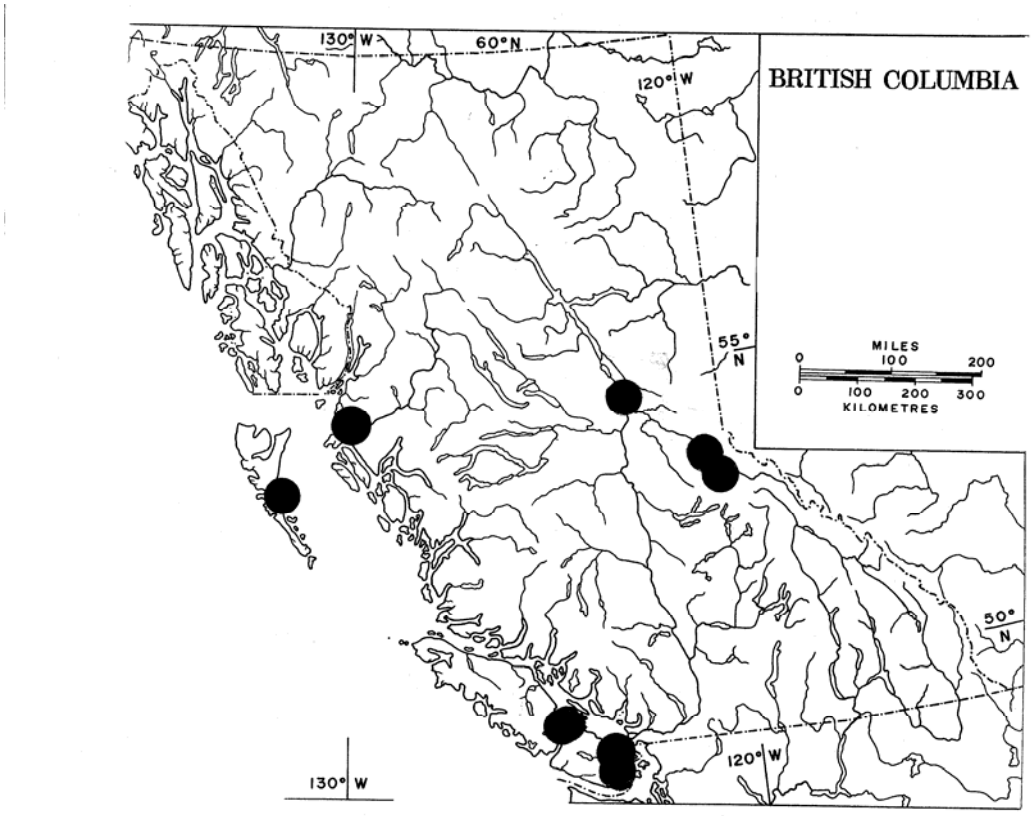


Figure 4 – British Columbia Distribution of *Cirsium palustre*. From Dr. George W. Douglas, Conservation Data Centre, Victoria, 1999, unpublished.

Habitat

European

Habitat types are described as moderately fertile grasslands on moist soils, wet meadows, woods, moist woodland, damp clearings, woodland clearings, marshes and moist grassland hedgerows (van der Meijden et al 1983, Nijland and de Wind 1970, Falinska 1997, Tutin et al 1976, Clapham et al 1962). They also include, fen (water-logged soils, dominated by reeds and sedges), fen litter

(dominated by coarse rushes) and carr (fenland scrub dominated by willows, buckthorns and other shrubs)(Mountford et al 1996).

Mogford (1974a) reports *C. palustre* as very common in Britain and occurring throughout a wide range of habitats from sea level to 800 m, including meadows, moorland, forest clearings and seacliffs.

Van Leeuwen (1987) was the only study to mention slope. *C. palustre* was found only on north slopes.

Soils

Soils information is sketchy in the literature, however, soil texture does not seem to be a limiting factor to establishment. Soils textures are described as clay (Pons 1983), sand, sandy clay, and clay (van Leeuwen 1987), and bare sand (van Leeuwan 1981). Zlinska (1989) describes the soils of a plant association in Czechoslovakia containing *C. palustre* as moisture-wet sand-clay, sandy and clay-sand gravelly and stony soil of the vega type with acid reaction on the siliceous geological grounds at the hilly and submontane belt.

Van Leeuwen, in his 1987 thesis, was the only study to mention peat soils. *C. palustre* was found on peat soils at three times the average compared to sand, sandy clay, clay or peaty soil. (Note: there was no explanation of the difference between peaty soil and peat. It is assumed that peaty soil would have a higher mineral soil content and peat would be only organic matter).

Soil pH, when included in descriptions, is acidic. Pons and During (1987) report a pH of 4.5-6.0. Van Leeuwen (1987) reports a greater occurrence of *C. palustre* on soils of pH <5.05, although it was found on soils up to and above pH 7.0. Zlinska(1989) indicates acid reaction in the soils of the study site.

C. palustre grows on soils of lower nutrient status (van Leeuwen 1987) as measured by nitrogen, phosphorous and potassium values.

Van Leeuwen (1987) is a comparative study of the population biology of *C. palustre, C. arvense and C. vulgare* in the Netherlands. All three species are found in British Columbia and his habitat descriptions for the three species are thought to be relevant to British Columbia. All the species were found together in moist pioneer communities, fertile moist grassland communities, moist woodland, at wood edges and in clearings. *C. arvense* occurred exclusively on heavily disturbed sites (agricultural fields, coastal sites with sand erosion). *C. palustre* occurred exclusively in plant communities characterized by high moisture levels and changing moisture status and was restricted to moist habitats. *C. arvense* and *C. vulgare* were found on sites with comparatively high nutrient status. *C. vulgare* was only found in plant communities in which one of the other species also occurred (both moist and dry habitats). *C. arvense* and *C. palustre* were found in combination in moist gradients near open water and grassland

communities characterized by small-scale disturbances like trampling and mowing.

Associated Species

Associated species are those of moist habitats. Some of the associated species in a study from Czechoslovakia (Zlinska 1989) include, *Alopecurus pratensis*, *Angelica sylvestris*, *Juncus effusus*, *Equisetum palustre*, *Caltha epigejos*, *Deshampsia cespitosa* and *Galium uliginosum*.

Associated vegetation reported in a study from The Netherlands (van Leeuwen 1981), include *Betula* spp. in a dense woodland, *Calamagrostis epigejos* and *Hippophae rhamnoides* in a more open site.

Associated vegetation in a study of abandoned meadows in Poland, (Falinska (1997), include: *Filipendula ulmaria*, *Geum rivale*, *Ranunculus acris*, *Lychnis flos-cuculi* and *Myosotis scorpiodes*; *Lysimachia vulgaris*, *Lythrum salicaria*, *Cirsium rivulare*, *Carex acutiformis*, and willow.

Climate

The only reference found containing climate information was from the Czech Republic. At their study site, Kotorova and Leps (1999) report mean annual temp as 7.8^0C and mean annual precipitation as 620 mm. July was the wettest, warmest month with 102 mm rain and temperatures with mean daily minima and maxima of 11.6^0C and 24.1^0C. Mean daily minima and maxima in January (coldest month) were -6.2^0C and 0.6^0C.

North American

Reported habitat types are similar to those of Europe, namely, moist woodland (Moore and Frankton 1974), moist meadows and forest openings (Douglas et al 1998), damp clearings and thickets (Scoggan 1978). Early collectors thought the species was possibly indigenous in eastern North America, because it was found in habitats where it appeared to be native (Moore and Frankton 1974).

In the U.S.A., Gleason and Cronquist (1991) indicate *C. palustre* as often invading woods and seemingly native. Voss, in Michigan Flora Part III (1996), says, “tall plants form dense ungainly colonies for miles along roadside ditches and adjacent swamps, where it spreads to shores and remoter wetlands. In cedar swamps and somewhat shaded fens it may try to masquerade as the native swamp thistle, *C. muticum*… The tragic spread of this pest into natural wetlands is doubtless aided by logging roads and other human (or inhuman) disturbance.”

Soils

No information was found.

Associated Species

No information was found other than the general descriptions mentioned under habitat above.

British Columbia

C. palustre is found in moist meadows and forest openings in the lowland zone of British Columbia (Douglas et al 1998).

Soils

Field observations from the Prince George and Robson Valley Districts indicate that *C. palustre* is establishing in a variety of habitats and soil textures, provided moisture is not limiting. Paul Sanborn, Research Soil Scientist, Prince George Forest Region, recorded his observations in an email dated September 25, 1999. After looking at infestations in the Interior Cedar Hemlock Zone (ICH), *C. palustre* was thought to be able to establish in all but frequently flooded or permanently ponded areas. It was found growing on:

- fine-textured glaciolacustrine
- coarse gravelly glaciofluvial materials
- bare mineral soil (roadcuts, scalped skidtrails)
- thick (>10 cm) intact forest floors

Associated species

The only information on associated species in British Columbia comes from Paul Sanborn's email of September 25, 1999. *C. palustre* was found to be growing on sites in the ICH zone with the following associated vegetation:

- sparse, low-growing herb cover (*Cornus*)
- tall perennial herbs (*Epilobium*)
- dense sod-forming grasses and sedges (undisturbed Festuca rubra and Carex)
- broadcast-burned and raw-planted plantations
- non-forested wetlands on raised microsites

Population Size

European populations vary greatly in size and discreteness. On seacliffs in Britain, *C. palustre* is commonly found as fairly discrete populations of several hundred individuals, whereas larger and more diffuse populations are characteristic of damp, sheep-grazed meadows, where it frequently becomes established as a difficult weed (Mogford 1974).

In a hay meadow in Poland, Falinska (1989), described a 124m^2 site with 128 randomly located individuals and one big aggregation of 140. Abandoned meadows had a considerable increase in both size and degree of clumping *of C. palustre* populations. Five years after cessation of mowing (which took place at flowering time), four big aggregations (88, 95, 01, 141 individuals) and ten small aggregations (12-48 individuals) were found within 1ha. More over, 138 dispersed individuals grew between the aggregations.

Voss (1996) describes populations in Michigan as “dense ungainly colonies for miles along roadside ditches and adjacent swamps.”

Populations in the McBride area have been noted as being very dense, with a continuous carpet of rosettes being described in some sites (Sanborn 1999). It was also noted that the density of seedheads was not a good visual representation of the density of the population. The number of vegetative rosettes was much greater than the number of plants with flower stalks and seedheads.

Life Span of Individuals

C. palustre is usually classified as a biennial and monocarpic species, producing in the first year a basal rosette of leaves, in the second year an upright flowering stem and then dying after seed set (Mogford 1974a, Pons and During 1987).

Falinska (1997) describes a typical *C. palustre* population exhibiting a biennial life span. Seeds germinate in early spring and rosettes begin growth before other species. Growing vigorously, they fill in surrounding area and by summer, have attained a large size. Their numerous leaves (12-20) form disks that eliminate other species by pressure, shading and by the necromass into which they turn. Plants over winter in the rosette stage. After flowering and fruiting the following year, mature individuals die and are replaced by seedlings. Large rosettes provide ‘safe havens’ and *C. palustre* seedlings emerge under the canopies formed by mature individuals, or on their edges. Since rosettes in a population are uneven-aged, in each season at least one individual attains the reproductive phase, ensuring a supply of several thousand seeds.

Population studies indicate *C. palustre* is not strictly biennial and can behave as a short-lived monocarpic perennial or facultative biennial, depending on habitat

type and conditions (Ballegaard and Warncke 1985a, Falinska 1989, Falinska 1997). Under unfavourable conditions, rosettes fail to attain the size needed to produce a flowering shoot and the plant can remain in a vegetative state for 2 or 3 years before flowering (Falinska 1989). Individuals have been found to extend their life span to 4 or 5 years and sporadically 6 years (Ballegaard and Warncke 1985, Falinska 1997).

C. palustre is a true monocarpic species and all flowering plants die after seed set (Ballegaard and Warncke 1985a).

Reproduction appears to be entirely by seed (Mogford 1974a).

Population Longevity and Succession

C. palustre populations are described as short-lived and sometimes occurring in temporary habitats (van Leeuwen 1981) and the species is considered as part of or dominating early successional stages (Falinska 1989, Falinska 1997, Pons and During 1987).

Falinska (1997) describes the following succession in abandoned meadows in Poland. With the cessation of mowing, *C. palustre* takes advantage of the openings, gaps and patchiness of the vegetation to establish seedlings, presumably from a seed bank. Rosettes grow in size and within 2-3 months, fill the site they occupy. Depending on the amount of vegetative cover of associated species, rosettes can stay vegetative for 4 to 5 years with only a few of the population flowering each season. As 2-4 year old rosettes die (less and less produce seed) they are replaced by other species. *C. palustre* numbers decrease as succession proceeds and tall herbs suppress *C. palustre.* The growth of willows (final successional stage) leads to a further decrease or elimination of the *C. palustre* population.

Pons and During (1987) describe the cycle of *C. palustre* populations in ash coppice in The Netherlands. Emergence of seedlings of *C. palustre* occurs mainly in spring following coppicing in the preceding winter (the tree canopy is removed). Vigourous vegetative growth occurs in the first year after coppicing. This is caused by exposure to full day-light, a fertile soil and reduced competition, particularly in early summer. Mortality is fairly high, but the surviving rosettes generally flower in the second year of growth. Thereafter the population decreases as the tree canopy closes.

In other studies the cause of population decline is not always clear (van Leeuwen 1981). Sometimes vigorous growth of surrounding vegetation can be observed but decline without accompanying closing of the vegetation has also been noted. Post-dispersal predation, poor achene survival and the relationship between cross-pollination, non-cross-pollination and density of plants, has been speculated.

Germination

C. palustre is capable of germinating from April until October (Falinska 1997) but two periods, spring and fall, seem to be when most seedlings emerge (Ballegaard and Warncke1985a, van Leeuwen and van Breemen 1988).

A British study (Roberts and Chancellor 1979) found that a variable and usually small, percentage of achenes collected from field sites germinated in the fall, with the main emergence occurring the following spring. Van Leeuwen (1987) also found that most achenes germinated in the spring (63-79%). Survival of the fall seedling is lower than survival of the spring (van Leeuwen 1987).

Soil temperatures during spring (April) germination in The Netherlands are generally between 10^0C and 16^0C with occasional periods at 20^0C on bright days (Pons 1983). Van Leeuwen (1987) reported that spring germination of achenes began in March when daily maximum temperatures reached 12-17^0C. Minimum temperatures were around zero.

C. palustre germination is inhibited by plant cover. Falinska (1997) found that the largest number of seedlings emerged in early and transition stages of succession (plots dominated by grasses and macroforbs) as opposed to late stages (willow). Also, it was found that at all successional stages, removal of vegetation cover by mowing was followed by a considerable increase in the number of *C. palustre* seedlings and that most seedlings emerged in the first growing season after removal. In subsequent years, once the vegetation cover had regenerated, the number of seedlings was as a rule, lower by half.

C. palustre germination is inhibited by shade (Pons 1983). Seeds will not germinate if they land on the ground under a leaf canopy. Soil temperature was eliminated as the inhibiting factor. Emergence is postponed until the following spring or later, when conditions are more favourable for the survival of the seedlings. Seeds are light-requiring and it is probable that their germination is triggered by exposure to light during the winter.

C. palustre seeds are able to germinate in autumn immediately after dispersal, but if water conditions are limiting and no germination takes place, dormancy can be induced by exposure to light filtered by vegetation and by high (summer) temperatures during burial (Pons 1983). In the following spring, germination depends on favourable temperatures combined with favourable water conditions and, for those seeds with induced dormancy, exposure to light. If no germination takes place in the spring either, the seeds will only leave the seed bank when they are exposed to light.

Kotorova and Leps (1999) found that germinability significantly increased after chilling.

Rosette Growth

Ballegaard and Warncke (1985a) describe the seedling and five life states of *C. palustre* rosettes. Spring seedlings have 2-3 rosette leaves, which are 40-80 mm in length and 7-11 mm in width. The rosette leaves are slightly dentate. The cotyledons have withered or are absent. The root diameters range from 0.8 to 1.2 mm. The taproot is 20-30 mm in length and is fresh-looking and bright cream-coloured. There are about 4 lateral roots. Seedlings that germinated in the fall resemble spring seedlings except for being somewhat bigger. The 2-3 rosette leaves are 90-200 mm in length and have a width of 1.3-2.3 mm. The leaves are still slightly dentate. Root diameters range from1.5 to 2.5 mm. The taproot is 20-30 mm long and is still fresh and bright and has 7-8 lateral roots.

There comes a point in the growing season when spring and fall seedlings can no longer be distinguished (life state 2). At this point the plants have 3-4 rather dentate rosette leaves, 180-400 mm long and 35-73 mm wide. The root diameter is 55-80 mm. The taproot is about 20-50 mm long, dark brown and rather swollen. The plants have 15-30 later roots.

Plants continue growth until flowering (life state 5). In the spring, the flowering plants have a rosette of the same size and type as plants in the 4th life state. As the inflorescence starts growing the rosette disintegrates.

Table 2. Characteristics of the four vegetative life states identified in *Cirsium palustre*. Measurements given in mm. (Ballegaard and Warncke 1985a)

		Life State				
		Spring Seedlings	Fall Seedlings	2nd	3rd	4th
Rosette leaves	Number	2-3	2-3	3-4	3-5	8-18
	Width	7-11	13-23	19-45	35-73	85-123
	Length	40-80	90-200	150-360	180-400	300-600
	Type*	A	A	A-B,B	B-C	C
Tap root	Diameter	0.8-1.2	1.5-2.5	3.1-5.0	5.5-8.0	11.0-22.0
	Length	20-30	20-30	30-50	20-50	30-40
Lateral roots	Number	4	7-8	9-18	15-30	30

*Leaves classified into type based on ontogentic level; type A being least developed and type C the fully developed type.

Ballegaard and Warncke (1985a) found that seedlings were exposed to an extremely high death risk. About 85% of their labeled seedlings died within their first year of growth. In the later stages of rosette growth, mortality was rather low and constant. If a plant was still alive after the first season (the first winter) it had a high probability of survival and of reaching the reproductive state.

The rosette must be around 20 cm in diameter to produce a flowering stem and almost all individuals with rosette diameters 30-40 cm produce flowers (Falinska 1997). Rosette-size limiting factors retard the reproductive phase and extend individual longevity. Size limiting factors include:

- Shading (Pons 1977a, Mitchell and Woodward 1988, van Leeuwen 1987). If seedling are over-shadowed by dense vegetation, they will eventually die.
- Unfavourable hydrology (drought or inundation, van Leeuwen 1987)
- Competition and crowding from other vegetation. Falinska (1997) found that rosette size was most limited by sedges and willows as opposed to grasses. The removal of macroforbs and sedges was followed by a twofold increase in the rosette size of *C. palustre*. The one exception noted involved *C. palustre* individuals growing on the edges of willow patches or in forest-meadow ecotones. They reached a size similar to those under optimum greenhouse conditions in 2 or 3 years. A favourable microenvironment was suspected.
- Density of *C. palustre*. Falinska (1997) reported that 4 individuals in a 0.25m^2 plot had a negative effect on the growth of the rosettes. It was also found that under natural conditions this situation was rare and comprised only 25% of the individuals in a population.)

The density of plants two years or older does not substantially affect the size of the flowering plant in field situations (van Leeuwen 1987). In most populations the majority of plants were found in densities of four or fewer per m^2.

Flowering

Entering the flowering stage is related to rosette size (Pons and During 1987, Falinska 1997). *C. palustre* flowers following vernalization in the winter (Pons 1977b). In the spring, the main axis sprouts and flowers are formed.

C. palustre is typically purple flowered. However, populations occasionally contain white and intermediate flowered forms in high frequency (Mogford 1974).

Shading affects flowering. Falinska (1997) found that individuals growing under the canopy of willows flowered sporadically. Though the rosettes attain a size similar to that necessary to produce the flowering shoot, a close willow canopy and considerable shading reduce the number of individuals attaining the generative phase. Pons (1977b) found that rosettes can grow successfully in shady conditions but plants attempting to flower in shade produce few flowers

and the flowering stems were too weak to support themselves. The plants are unable to increase leaf area sufficiently to offset the lower rate of photosynthesis (Mitchell and Woodward 1988).

All plants reaching the flowering stage, die thereafter (Ballegaard and Warncke 1985a).

Pollination, Seed Production and Dispersal

C. palustre is pollinated by insects (van Leeuwen 1981). The flowers possess colour, fragrance, nectar, an irritability mechanism in the anthers (Small 1917) and are visited by an abundance of insects in European habitats. Muller (1883) recorded the visits of 39 insect species which included Coleoptera, Diptera, Hymenoptera and Lepidoptera.

The ability of self-pollination and/or apomixis has also been recognized (Mogford 1974b, van Leeuwen 1981, Hagerup 1951).

There appears to be two strategies for population survival at work. *C. palustre* produces two types of achenes, one better adapted to survival close to the motherplant and one better adapted to colonizing other sites.

Van Leeuwen (1981) found that achenes produced by self-pollinated flowers were heavier in weight compared with achenes produced by cross-pollinated flowers. Also, self-pollinated achenes were found to be faster to germinate and survival till one-year plants was higher. He concluded that non-cross-pollinated achenes have different germination behaviour compared with cross-pollinated achenes resulting in a better establishment of plants on the site of the motherplant.

On the other hand, cross-pollinated achenes are produced in greater numbers (Mogford 1974b, van Leeuwen 1981). They are lighter in weight than those produced from non-cross-pollinated flowers and have heavier pappi (van Leewen 1981). This increases the chance of long distance wind dispersal (Sheldon and Burrows 1973). The result is a greater number of achenes that are better dispersed and possibly genotypically more suited to colonizing sites different from that of the motherplant. However, they are also slower to germinate and survival till one-year plants is lower (van Leewen 1981).

300-2000 seeds, weighing around 1.5 mg, are produced per plant (van Leeuwen and van Breemen 1988). Grime (1979) reported mean seed weight of 2.00 mg.

C. palustre seeds are dispersed by wind and most fall within 10 metres of the parent plant; a few seeds reach higher air levels, depending on weather conditions, and may come back to the ground anywhere (van Leeuwen 1987).

Seed bank

C. palustre is able to form a persistent seed-bank in the soil (Pons 1984, Grime 1979). The size of a seed bank depends on the input of seeds and on the rate of predation, germination and mortality (van Leeuwen 1987). *C. palustre* produces the type of seed bank in which few of the seeds germinate in the period immediately following dispersal, and seed bank size changes little with season, remaining large in relation to the annual production of seed (Thompson and Grime 1979).

The seed population acquires a light requirement and can therefore remain persistent in the soil after dispersal (Pons 1984). Exposure of the seed to light through soil disturbance or soil mixing, breaks the dormancy.

Falinska (1997) calculated that only 5-10% of seeds in the seed bank developed into seedlings regardless of the successional stage of the surrounding vegetation. Van Leeuwen and van Breemen (1988) found that *C. palustre* achenes buried in pots had a 40% survival rate after one year.

The literature did not contain any estimates of how long *C. palustre* seed remains viable in the seedbank.

Allelopathy

Allelopathy has been documented with Ballegaarde and Warncke (1985b) finding that germination of *C. palustre* achenes was significantly reduced by ethanol extracts of *C. palustre* foliage and that *C. palustre* foliage residue incorporated in soil strongly reduced *C. palustre* seedling growth. It was not determined whether the toxic effect is of significance under natural conditions or whether it is neutralized by microbial, adsorptive, or other physical processes. The possibility of allelopathic effects towards other plant species was not tested in this study.

Falinska (1997) notes the lack of seedlings of other species among *C. palustre* rosettes and states that this permits the assumption that under natural conditions there may be some biochemical changes in the habitat which eliminate seedlings of other species. Further investigations were recommended.

Grazing

Grazing appears to limit the distribution of *C. palustre*. This is attributed to the vulnerability of the rosette to trampling (Nijland and de Wind 1970).

An English grazing study (Fraser 1998) comparing the diet composition of guanacos (*Lama guanicoe*) and sheep (*Ovis aries*), found that *C. palustre* was consistently selected for by guanacos. *C. palustre* seedheads made a substantial contribution to their diet. *C. palustre* was also found in the diet of sheep.

Grazing can also create ideal sites for germination as evidenced in Mogford's (1974) description of large and diffuse populations of *C. palustre* characteristic of damp, sheep-grazed meadows, where it frequently becomes established as a difficult weed.

HABITAT AT RISK

Based on a map provided by Dr. George Douglas of the Conservation Data Centre in Victoria, there are several populations of *C. palustre* in British Columbia. Not all of the locations have been traced back to herbarium samples (only Prince Rupert and McBride area) and hence detailed information on collection date and site conditions are not known for all of the populations.

The biggest infestations seem to be around the McBride area in the Prince George Forest Region. Perry Grilz, Regional Range Planner, Prince George Forest Region, has provided a map constructed from aerial surveys done in the fall of 1999. *C. palustre* is well established and spreading along Highway 16, the Fraser River and the MacGregor River. There are also isolated populations establishing in riparian habitats and plantations.

There is no data or information from the other infestations indicated on the map provided by George Douglas, therefor their spread cannot be reported at present.

Based on the information gathered from the literature search, it is reasonable to assume that *C. palustre* has the potential to continue to spread into moist, open habitats having acidic soils. Spread will be in the direction of the prevailing wind since *C. palustre* reproduces by seed and they are wind dispersed. Any bare ground or disturbed area provides a suitable site for germination and until the canopy closes or *C. palustre* is limited by competition, it will flourish.

No literature was found indicating that *C. palustre* grows in alpine areas. The only reference to elevation was from Scotland where the plant grew to 800 m (Mogford 1974a). The extent of *C. palustre's* northern range is 67^{o} 50'N in Scandinavia (Clapham et al 1962) but climatic differences make it impossible to use this information as a measure of the plant's northern limits in British Columbia. Given the wide geographical range in Europe, the southern extent of its potential range in British Columbia seems to be limited only by the availability of suitable moist habitats with acidic soils.

The following is a table compiled by extrapolating the general information found regarding habitat descriptions and habitat requirements of *C. palustre* in Europe to the site descriptions contained in the Biogeoclimatic Ecosystem Site Guides for British Columbia. It is intended as a general indication of the type of sites that are possibly at risk from invasion by *C. palustre.*

Table 3 - Predicted Sites at Risk.

ZONE	SITES AT RISK	CONDITIONS	RISK
COASTAL			
CDFmm	09	Open canopy	Low
CWH	All sites	Open canopy with bare ground or soil disturbance.	Moderate – high. Populations likely short-lived due to canopy closure.
MH	Riparian	Open canopy with bare ground or soil disturbance.	Moderate – high. Populations likely short-lived due to canopy closure.
INTERIOR			
ESSF	Riparian	Open canopy with bare ground or soil disturbance.	Low. Climatic limitations i.e. short growing season.
ICH	All	Open canopy with bare ground or soil disturbance.	High. Populations documented as spreading. Likely short-lived populations as canopy closes.
IDF	Riparian Zones (sedge)	Opening of sedge canopy by grazing or soil disturbance.	High. Potential to spread and persist if canopy remains open due to grazing.
MS	Riparian Zones (sedge)	Opening of sedge canopy by grazing or soil disturbance.	Low. Climatic limitations.
SBS	Riparian Zones	Opening of sedge canopy by grazing or soil disturbance	Low. Climatic limitations.

Table predictions based on the following information from the literature:

- Persistent seed bank
- Prefers soils of:
- pH 4.5-5.0
- low to moderate nutrients
- variable texture (can be coarse if water table is high and fine if slightly drier sites
- ranges: subhygric to subhydric
- Associated species: Carex, Equisetum, Deschampsia

BIOLOGICAL AGENTS

Review of the literature lead to the names of several insects associated with *C. palustre*. Many just visited the plant during flowering and others used the plant as part of their life cycle.

A database search was conducted for the following species. Papers were found on those highlighted with (*):

Agapanthia villosoviridescens*
Apion onopordi
Autographa gamma*
Cheilosia spp.*
Cheilosia albipila
Cnephasia stephensiana
Epiblema cirsiana
Epiblema obscurana
Epiblema scutulana*
Gortyna flavago
Lixus elongatus
Melanagromyza aeneoventris
Myelois cribrumella
Oedemeridae sp.
Sciaridae sp.
Tephritis spp*
Terellia ruficauda*

Agapanthia villosoviridescens

The following information is taken from Freese (1992):

Host

Agapanthia villosoviridescens DeGeer 1775 (Coleoptera, Cerambycidae) is a palaearctic species in the group of longhorn beetles within the *Lamiinae* subfamily, living in the stems of a broad range of herbaceous plants. It is reported as a polyphagous species (i.e. attacking plants of various families), but thistles are preferred host plants, presumably because of their large size stem. During his investigation in southern Germany, Freese found *A. villosoviridenscens* on *C. palustre*, *C. oleraceum*, *C. vulgare*, *C. arvense* and *Carduus nutans* but he recognized that it can attack almost every thistle species.

Oviposition and Larval Development

Adults appear on host plants in mid to late May, where in the period of maturation feeding, they cause characteristic feeding marks on the stem. The main oviposition period lasts from early June to mid July, though a few eggs can still be found until September. The egg is milky-whitish in colour and 3.4mm X 0.72mm. A pith channel or any other cavity (i.e. a frass-mine or another stem-boring insect) is needed for oviposition. Eggs are seldom found in plant species with almost completely solid pith. The females gnaw a small hole into the stem until the pith channel is reached, then turn around and force their ovipositors into the pith channel. In contrast to Duffy (1953), only one egg at a time was laid but multiple oviposition by one or more females into the same stem was frequently observed. The average number of eggs in an attacked plant was found to be 1.47±0.86 (n=30) in *C. palustre*. The egg was usually attached to the opposite side of the inner wall of the stem. In most cases the hole was closed with a darkish secretion.

On hatching, the first instar larvae are very active, patrolling the pith channel and showing a predacious or even cannibalistic behaviour towards eggs and small conspecific larvae. However, the pith is the main food source. Sometimes the stem will be almost completely hollowed and the larvae will often enter the root. Only one larva per stem was found to survive. There are four larval stages, the last of which overwinters in a self-built chamber and pupates in early to mid May. The mature larva and pupa are described by Duffy (1953). The highly specialized morphology of this species allows the larvae to move quickly in hollow stems.

A. villosoviridescens is parasitized by the egg-ectoparasitoid *Chlorocytus* sp. The parasitiod occurred in every *A. villosoviridenscens* population sampled and was the most important mortality factor in the immature stages.

Attack Rates

In the study area, the average amount of attack was 39% in *C. palustre*, reaching a maximum of 88% in at one site. (The average values for *C. vulgare and C. arvense* were significantly lower with less than 10% of the plant population being attacked). Plant size did not seem to affect attack rate.

Though *A. villosoviridescens* is one of the few stem feeders of thistles consuming a considerable amount of plant material no apparent effect on the host plants was detected in this study.

Conclusion

The literature indicates that *A. villosoviridenscens* does attack *C. palustre* (sometimes at high attack rates) but with little affect to the host. There was insufficient information found on *Cheilosia* spp to draw any conclusions as to the relevance of the species for biological control of *C. palustre* in British Columbia.

Autographa gamma

Autographa gamma (Linnaeus) is a common migratory moth species that is distributed throughout the Haloarctic Region (Balachowsky 1972). It is a member of Noctuidae, the largest family of Lepidoptera, most of which are worldwide pests of various economically important crops (Etman 1989). *A. gamma* was recorded as a pest in France as early as 1735 (Balachowsky 1972) and is considered a pest in most countries where it occurs.

The larvae are highly polyphagous and have been recorded feeding on at least 224 plant species, including 100 weeds, from 51 families (Maceljski and Balarin 1972). They have also been recorded damaging many crops, especially Brassica spp. (Balachowsky 1972).

Adult *A. gamma* make seasonal northward migrations into areas where they are unable to breed continuously (Hill and Gatehouse 1992). For example, individuals migrate into Britain each spring, and after, one, two or three generations, descendants of the spring migrants return to over-wintering sites in North Africa and the Middle East (Hill and Gatehouse 1992).

Adults feed on nectar from weed flowers before reproduction or migration (Maceljski and Balarin 1972).

Conclusion

The literature search did indicate that *A. gamma* was associated with *C. palustre* (Internet information supplied by S. Turner). Although it was never found referenced, adults most likely use *C. palustre* flowers as a nectar source. The articles that were found through database searches, concerned themselves with *A. gamma* as a pest of crops and hence its control. There was no information found indicating *A. gamma* as a potential biological control agent for *C. palustre.*

Cheilosia spp.

Species of *Cheilosia* (Diptera: Syrphidae) are common and widespread in many regions of the world, but are biologically poorly known (Rotheray 1988). Smith (1979) stated that descriptions were available for fewer than 7% of the 130 or so Palearctic species. The number of species has since been revised to 286 (Rotheray 1988).

The larvae are phytophagous, feeding on fungi or in stems of angiosperm plants, often Compositae (Rizza et al 1988). There is a large community associated with *Carduus* and *Cirsium* thistles, but few are plant-specific species (Stubbs and Falk 1983, Rotheray 1988).

Cheilosia larvae were found to be common in the stems and roots of *Cirsium palustre* in Dunbartonshire, Scotland in 1984 and from these in the spring of 1985, adults of *Cheilosia albipila* Meigen, *Cheilosia. fraterna* (Miegen), *Cheilosia.*

grossa (Fallen) and *Cheilosia proxima* (Zetterstedt) were obtained (Rotheray 1988). *Cheilosia cyanocephala* Loew and *Cheilosia vulpina* (Meigen) have also been reared from *Cirsium palustre,* in Italy (Rotheray 1988).

Rotheray (1988) describes in detail the appearance of the four species of third-stage larvae found in his study and draws the following conclusions:

- All were very similar but could be distinguished by the form of the posterior respiratory process.
- All four species tunneled towards the roots and third-stage larvae spent most time there, close to pupation sites in the soil.
- It was thought that stems away from the base were too narrow for tunneling by these relatively large larvae.

Predation of *C. palustre* by *Cheilosa grossa* was noted by van Leeuwen (1983). Due to the predation of larvae or puparia in the basal part of the flowering stem, growth of the main tip was stopped at about a quarter of its potential, causing loss of apical dominance, and resulting in a degenerated tip and altered growth form. Rotheray (1988) found that *Cheilosa grossa* eggs appear in batches in early May on the tips of young stems. On hatching, larvae enter the growing point of the stem and tunnel downwards. The growing tip is killed and the plant produces a mass of basal stems increasing the food supply in which the larvae subsequently fed. The stimulation of dormant side-branches and increased potential for flowering was speculated to reduce the effect of this type of predation (van Leeuwen 1983).

References were found indicating that the syrphid fly, *Cheilosia corydon* Harris (= *grossa* Fallen) was considered a candidate for biological control of musk thistle (*Carduus nutans* L.) in the United States. Because there was no mention of *Cirsium* species, the papers were not pursued in great detail.

Conclusion

There was insufficient information found on *Cheilosia* spp to draw any conclusions as to the relevance of the species for biological control of *C. palustre* in British Columbia.

Epiblema scutulana

Epiblema scutulana (Den. & Schiff.)(Microlepidoptera) was reported as a predator of *C. palustre* by van Leeuwen (1983). It was also recorded by Freese (1995) as one of the insects associated with thistle species. A literature search did not find any more relevant papers.

A study discussing predation of *C. palustre,* (van Leeuwen 1983), puts forth the following tentative outline for the life-cycle of *E. scutulana:* adults lay their eggs in

the flowers of *Cirsium* plants and the larvae feed on the achenes and receptaculum. At the end of the season the larvae migrate to rosettes of *Cirsium* (and possibly to plants of other species as well) to feed and overwinter. During the next summer flowering stems are attacked and the life-cycle is completed in the stems. This outline was based on finding, in summer, small larvae (usually shorter than 5 mm) in flowerheads, and as well larger larvae (11-15 mm) and pupae in the stems, empty pupae from August onwards. In late summer, large larvae were also found in rosettes. As a result of predation by the larvae of *E. scutulana*, damaged achenes became detached from the pappi and often stuck to the receptaculum, causing reduced dispersal capacity.

The predation of *E. scutulana* on the rosettes of *C. palustre* is also documented by van Leeuwen (1983). The level of attack was found to be higher in larger rosettes. The growth point was damaged by the larvae and often fungi were found in the centre of the rosettes, probably stimulated by faeces and/or deteriorated plant material. The survival of attacked rosettes was not significantly different from that of non-attacked rosettes. The percentage of rosettes attaining the flowering stage two years after attack, was higher for the non-attacked rosettes, but the differences were not statistically significant. Also, the flowerhead production of the rosettes that did flower, was not affected by the presence *of E. scutulana* in the rosette. In conclusion, van Leeuwen (1983) felt that predation by *E. scutulana* did have an affect on *C. palustre* but the sample size was too small show it.

Conclusion

There was insufficient information found on *E. scutulana* to draw any conclusions as to the relevance of the species for biological control of *C. palustre* in British Columbia.

Tephritis spp.

The literature search found references to *Tephritis conura* and *Tephritis cometa* in association with *C. palustre.*

Tephritis conura Loew (Dipt.: Tephritidae) larvae are endophytic to the flowerheads of thistles (Romstock and Arnold 1987). Several species in the host-plant genus *Cirsium* are attacked by *T. conura* and *C. palustre* has been documented as a host plant (Romstock-Volkl 1990, Romstock and Arnold 1987).

In a 1990 study of *T. conura* and *Cirsium heterophyllum*, Romstock-Volkl described the following biology of the insect. *T. conura* is a univoltine tephritid fly whose larvae develop in flowerheads. Mating occurs exclusively on the host-plant at the start of flower bud development in mid-May. Eggs are laid randomly in batches into small buds of a limited development stage. Females avoide overcrowding of buds by discriminating against buds with extremely high egg

loads. Females die soon after completing oviposition. First instar larvae feed on developing florets; second and third instar larvae consume the flowerhead's receptacle where they induce additional callus growth. Pupation takes place within the flowerheads and adults start to emerge in late July. Flies over winter in the adult stage. *T. conura* lives at least 9 months as an adult, in contrast to many other flowerhead tephritids.

Romstock-Volkl (1990) found that between 1% and 92% of the flowerheads in a population of *C. heterophyllum* were attacked.

T. cometa (Loew, 1840) is found throughout Europe and western Asia (Scheirs et al 1993). It has been reared from *C. arvense*, *C. vulgare* (White 1988) and recently from *C. palustre* (Scheirs et al 1993). No other information was found on the relationship between this species and *C. palustre*.

Conclusion

There was insufficient information found on *Tephritis* spp .to draw any conclusions as to the relevance of the species for biological control of *C. palustre* in British Columbia.

Terellia ruficauda

Terellia ruficauda, previously *Orellia ruficauda* (Fabricius) (Deptera: Tephritidae) (Gassman 1997), is a tephritid seedhead fly of European origin. It is found throughout the Palearctic region except the South (White 1988). An oligophagous species, it is found only on plants belonging to the subtribe Carduinae of the family Compositae (Rivero-Lynch and Jones 1993). Members of the genus *Terellia* are rather large yellow flies bearing characteristic black markings on the body and spots or transverse bands on the wing (McFadden and Foote 1960).

T. ruficauda was accidentally introduced into North America and has been collected here since 1885 (McFadden and Foote 1960). Its North American range is from Newfoundland to British Columbia in Canada, the northern U.S.A. and California (Maw 1976). McFadden and Foote (1960) list *T. ruficauda* as having been collected in British Columbia, Manitoba, Ontario, New Brunswick and Newfoundland in Canada, and California, Idaho, Massachusetts, Michigan, Minnesota, Montana, New York, North Dakota, Oregon, Pennsylvania, Virginia, Vermont and Washington in the U.S.A. It is considered an adventive agent in Canada (Gassman 1997).

In Europe, it is one of a complex of species that use thistle flowerheads for part of their life-cycle (as referenced in Lalonde 1991). It is thought to be a fugitive species in Europe because of its poor ability to compete with other thistle head feeders and may have been reduced to a fugitive species in British Columbia with the introduction of *Larinus planus* (Lalonde 1991).

Europe

In England, female *T. ruficauda* flies oviposit into *C. palustre* flowerheads between mid-June and mid-August (Jones et al 1996). The fly inserts its eggs only among the florets of a recently opened flowerbud. The florets are still closed and level with the outstanding bracts of the involucre (Rivero-Lynch and Jones 1993). This strong pattern of selection suggests the synchronization of oviposition with flowerhead development to ensure that growth of early larval instars coincides with achene maturation (Rivero-Lynch and Jones 1993). The young larvae hatch almost immediately and develop among the achenes, entering them through the pericarp. (Rivero-Lynch and Jones 1993). After completely consuming the seed, the larvae crawl out and weave a cocoon of pappus hairs glued together with a substance secreted by the larvae. The larvae overwinter in the final instar within the flowerhead, which may remain attached to the dead thistle stem or fall onto the ground, and pupation occurs the following spring with the adult fly emerging the following June (Jones et al 1996).

Typically, only one tephritid fly completes development within an individual flowerhead and there is generally one generation of *T. ruficauda* each year (Rivero-Lynch and Jones 1993). If climatic conditions are optimal (e.g. late, warm summer) a second generation may occur (Rivero-Lynch and Jones 1993).

Jones et al (1996) found that *T. ruficauda* was largely parasitized by two species of pteromalid wasp, *Pteromalus elevatus* (Walker) and *P. albipennis* Walker, and two species of torymid wasp *Torymus* sp*. A and* sp*. B*. In each case, the female wasp probes the thistle captula with her ovipositor and lays an egg externally on the third-instar fly larva. Parasitoids are active from the end of June, with a peak in early and mid-August, except for *Torymus sp. B*, which was found to be most active in late August. Only one larva develops in each fly larva and the wasps pupate in the remains of the host, overwintering like the tephritid within the thistle flowerhead.

T. ruficauda has also been recorded from the flowerheads of *C. arvense* in England (White 1988).

North America

Canada thistle *(Cirsium. arvense)* is the host plant in all of the North American papers that were found containing information on *T. ruficauda*.

In a survey of phytophagous insects associated with Canada thistle in southern Montana, Story et al (1985) found that *T. ruficauda* was one of the most common insects collected. Adults were frequently observed on the flower buds through June and July, while the larvae were readily dissected from seedheads collected during the following months. Up to 38% of the seedheads collected at four sites were attacked with an average of 1.5 larvae per head.

In a survey of the insects associated with Canada thistle in Canada, Maw (1976) reported that *T. ruficauda* has been collected and reared from seedheads of

Cirsium arvense and *Taraxacum officinale* and swept from alfalfa and wheat (Maw 1976). He also reported that *T. ruficauda* may destroy up to 70% of the thistle seed in the heads of Canada thistle.

Forsyth and Watson (1985) summarize Canadian data collected over a period of 3 decades from sample sites across Canada. *T. ruficauda* was found to occur in about 20-85% of the seedheads of *C. arvense* and the proportion of damaged seeds per attacked head averaged 20-80% depending on geographical location and sampling date. Damaged seeds were easily distinguished by the entrance/exit holes in the pericarp and by the presence of fragmented seed coats. The location of the holes in the seeds varied, with 45% near the base, 27% in middle, and 28% near the apex of the seed. Attacked seedheads sometimes appeared blighted and twisted, however, insects were also found in heads that were not visibly disfigured so no association between seedhead appearance and insect presence could be drawn.

Lalonde (1991) is a Phd dissertation studying *T. ruficauda* oviposition behaviour on *C. arvense* in the lower mainland area of British Columbia. Findings are also published in Lalonde and Roitberg (1992). The following is a summary from the two sources. Female flies preferentially oviposit into seedheads that are a single day from opening. Eggs are placed individually between the florets, about 0.5 cm above the developing ovary. After laying a clutch of eggs, flies circumscribe the rim of the flowerhead with their extended ovipositor and deposit a clear fluid that is believed to be a marking pheromone. Single-egg clutches were found to be the rule in the field but clutches of 3 eggs were frequently found and larger clutch sizes were thought to occur. Larvae move to a still-soft ovary and feed internally during the entire 1st instar. This feeding causes a hypertrophic growth of the ovary, which becomes gall-like in appearance. The larvae leave the ‘galled’ ovary and feed on ripe achenes during the 2nd and 3rd instar. A single circular hole is bored through the pericarp and the soft embryo is eaten. The number of achenes consumed by a single larva (4-12 achenes), depends on achene size. The 3rd instar larvae form cocoons of pappus hairs when fully-grown. The larvae overwinter inside the cocoon, and pupate and emerge in the spring.

Lalonde (1991) found that 3rd instar larvae were parasitized by two species of eulophid endoparasites causing death, *Crataepus marbis* and *Tetrastichus venustus*. Third instar larvae were also prone to disease mortality from an unknown pathogen. Infected larvae became translucent and died prior to pupating. Forsyth and Watson (1985) indicate that several parasites of *T. ruficauda* occur in Canada.

Conclusion

For the following reasons, as concluded from the information found in the literature, *T. ruficauda* could be a promising biocontrol agent for *C. palustre* in British Columbia:

- *T. ruficauda* is an adventive species present in British Columbia (Lalonde 1991).
- *T. ruficauda* uses *C. palustre* as a host. It has been documented in European studies (Rivero-Lynch and Jones 1993) and it has been identified as attacking *C. palustre* in British Columbia (Dwaine Brooke, personal communication).
- *C. palustre* reproduces entirely by seed. An agent such as *T. ruficauda* that causes damage to seeds and seedheads could have a significant effect on the reproductive success of *C. palustre*.
- Although there were no numbers found indicating the extent of damage *T. ruficauda* causes to *C. palustre*, physical damage done to *C. arvense* seedheads and seeds is extensive (Forsyth and Watson 1985).
- There was no information found indicating that *T. ruficauda* is a pest. Story et al (1985) states that the host range of *T. ruficauda* in Montana was not considered to include any economic crops.

APPENDIX I – MASTER LIST OF CITATIONS

APPENDIX II – CIRSIUM PALUSTRE CITATIONS

APPENDIX III – BIOLOGICAL CONTROL CITATIONS

APPENDIX IV – EMAIL COMMUNICATIONS

Erich Haber

From: ehaber@magi.com[SMTP:ehaber@magi.com]

Sent: Friday, November 05, 1999 7:20 AM

To: Nancy E. Fraser

Subject: Re: Cirsium palustre

Hi Nancy,

C. palustre also occurs as a rare exotic in Ontario as listed in the new Ontario Plant List compiled by the Ontario Forest Research Institute.

In the maritimes you should consult Marian Zinck at the NS Museum of Naturial History (zinckmc@gov.ns.ca). She's a curatorial assistant or curator of the collections. Apparently, according to Scoggan's Flora of Canada, there is a record from NFLD as well and from St.Pierre and Miquelon as well as NS.

For distributional information in Europe, use the following address and search the database using the scientific name. (http://www.bgbm.fu-berlin.de/IOPI/GPC/query.htm)

If you need specific info on the habitat, biology and range in Europe you likley will have to go to a large university library and look up some standard floras for Europe to see what has been written. Hegi's Flora of Middle Europe likely has some information but in German.

If you search the BONAP database and have a general North America range map printed out you can see what provinces and states it has been reported from.

(http://www.mip.berkeley.edu/query_forms/browse_checklist.html)

Without doing a lot more searching on the web this is about all I can provide right now. I would be interested in knowing the extent of the problem in BC and how much concern there is for the spread of this species. I could put an information notice on the Invasive Plants of Canada web site on this species as an alert to the spread of this species, at least in BC. Could you write several sentences that describe the extent of the problem and impact on natural areas and send it to me for posting?

Good luck. Hope to hear more about this.

Erich

Rick Hoeg

From: Rick Hoeg[SMTP:RHoeg@nsdam.gov.ns.ca]
Sent: Monday, November 08, 1999 8:18 AM
To: nefraser@pacificcoast.net
Subject: marsh plume thistle

Nancy,

Sorry to take soo long to get back. I don't have any particular information myself, but you may try contacting the NS Museum of Natural History. It is listed as occurring in several locations around the province in the Flora of Nova Scotia.

You can direct your question to educnsm.webmaster@gov.ns.ca

Good-luck, I hope this will be of some help.
Rick Hoeg
Acting Supervisor for Weed Control Act, Production Technology
Nova Scotia Department of Agriculture and Marketing
P.O. Box 550
Truro, NS
B2N 5E3

Phone: (902)893-6549
Fax: (902)893-0244
E-mail: rhoeg@gov.ns.ca

Hefin Jones

From: Hefin Jones[SMTP:t.h.jones@ic.ac.uk]

Sent: Saturday, November 06, 1999 8:48 AM

To: nefraser@pacificcoast.net

>Date: Sat, 06 Nov 1999 16:47:45 +0000

>To: nefraser@pacificccoast.net

>From: Hefin Jones <t.h.jones@ic.ac.uk>

>

Dear Nancy

Charles Godfray has asked me to reply to your e-mail regarding Cirsium palustre. Most European work on thistles has been carried out on either Cirsium arvense or Cirsium vulgare - if you do a literature search on either of these plants you'll find numerous studies by Cameron, Harris, Redfern and Zwolfer, to name but a few. As well as the paper you mention on tephritid and parasitoid dispersal you should also look at the Rivero-Lynch and Jones paper cited in that study - this reports on the window of attack of the tephritid fly and some fecundity aspects.

I currently hold a research grant investigating the tephritids attacking C. plaustre - you may wish to contact Iain Williams, the post-doc working on that grant (i.s.williams@ic.ac.uk) for an update of what he is doing.

As far as I am aware there has never been a major biological control attempt on C.palustre. You will very likely be familiar with the attempts made in Canada to control the creeping thistle, C. arvense. For more information in this area I would direct your attention to Zwolfer's (1969) paper on aspects of biological weed control in Europe and North America and Claridge et.al's (1970) paper on using Haltica carduorum as a potential thistle biological control agent in Britain.

>>

>>Hope this is of some help

>>Best wishes

>>Hefin

Bill Lee

From: Bill Lee[SMTP:LeeW@landcare.cri.nz]
Sent: Sunday, January 23, 2000 9:02 PM
To: nefraser@pacificcoast.net
Subject: Cirsium palustre information -Reply

Dear Nancy

Cirsium palustre is naturalised and widespread in NZ but it is generally local and is rarely considered a major weed. Apart from this there is little info about. Did you want to know about anything in particular?
Bill

Dr William G. Lee

John Randall

From: John Randall[SMTP:randallj@maf.govt.nz]

Sent: Sunday, January 09, 2000 2:25 PM

To: nefraser@pacificcoast.net

Subject: Re: Cirsium palustre info

Dear Nancy

According to the "Flora of New Zealand", Cirsium palustre was first recorded in the wild in New Zealand in 1911.

It's distribution in New Zealand is the high rainfall areas of the North Island, occasional in parts of the east coast of the South Island and abundant in Westland in the South Island.

I am not aware of any specific work currently being undertaken on this species but the following are possible research contacts involved in invasive weed programmes:

William (Bill) Lee - LeeW@landcare.cri.nz

Peter Williams - WilliamsP@landcare.cri.nz

While they may not be involved in research on this species they may be able to direct you to appropriate references or other contacts.

for Herbarium Information:

Kerry Ford - FordK@landcare.cri.nz

or their general plant enquiry e-mail - PlantInfo@landcare.cri.nz

Regards

John

John Randall

National Adviser

Pest Management Strategies (Plants)

Plants Biosecurity

MAF Biosecurity Authority

PO Box 2526

WELLINGTON

Glen Sampson

From: Glen Sampson[SMTP:gsampson@cadmin.nsac.ns.ca]
Sent: Tuesday, November 09, 1999 7:16 PM
To: Nancy E. Fraser
Subject: Re: Cirsium palustre

Hello Nancy:

Marsh thistle is not a common species in this region. We have reports from it in Halifax county and Cape Breton. I am aware of one infestation near our location here in Truro. Because it is not a problem in the area, we have not collected much information on the weed other than what you mentioned. For the one site near truro, the infestation follows a very wet area in the field as the water drains from the field. Other than that I can't be much more help.

Glen

Forwarded by: gsampson@cox.nsac.ns.ca
Forwarded to: Glen.Sampson@nsac.ns.ca
Date forwarded: Mon, 1 Nov 1999 13:34:29 -0400
From: "Nancy E. Fraser" <nefraser@pacificcoast.net>
To: "'gsampson@cox.nsac.ns.ca'" <gsampson@cox.nsac.ns.ca>
Subject: Cirsium palustre
Date sent: Mon, 1 Nov 1999 09:33:10 -0800

Alan Tasker

From: Alan V Tasker[SMTP:Alan.V.Tasker@usda.gov]

Sent: Monday, January 10, 2000 2:14 PM

To: IPM Return Requested

Cc: Polly.P.Lehtonen@usda.gov; Larry.Fowler@usda.gov; rwestbrooks@weblnk.net%i

Subject: Re: Info on Cirsium palustre

I am not aware of work on this weed at this time, but will ask colleagues who might know of relevant work.

Marisa Tohver

From: Ingrid Marisa Tohver[SMTP:itohver@umich.edu]

Sent: Monday, January 17, 2000 12:14 PM

To: Nancy E. Fraser

Subject: Re: Cirsium palustre

ms. fraser,

From what i can glean from your message, I am under the impression that you surely have more information about C. palustre than I. My research at the u of m biological station focused on comparing morphological differences between C. palustre and C. muticum, the native swamp thistle. Of course, when they are flowering, the differences are striking in the flowers and the flowering stalks. However, being biennial in life cycles, these two species appear quite similar when they are in their basal rosette stage. The difference in the rosettes lies in the prickles of the leaves. C. muticum, as implied by the name, has a purple pigment at the base of the prickles of the basal rosette leaves. i believe this is caused by a higher level of anthocyanins in this species. However, I was never able to test this. C. palustre has no purple in the prickles of these leaves. so, my research was primarily taxonomic, but may be helpful in identifying the weed from the native when implementing biological control. I have not seen C. palustre this far south, (Ann Arbor), but I don't doubt its invasiveness. My report, which is more detailed and is enhanced with photographs, is on file at the biological station and is available for use. I also performed an experiment using a lepidopterous insect that i found eating the seeds in the flower heads of C. palustre and C. muticum. I thought this insect might be a candidate for biological control, but the larvae did not seem to choose one thiste over another. It might actually devastate native populations. This report is also on file at the bio. station and you are welcome to look through it. I am afraid that perhaps my information might not be what you need, but I am interested in the results of your research. Please let me know if anything was unclear and send me a message about your conclusions. I am curious about the fate of this thistle.

Marisa

Dr. Edward Voss

From: Edward G. Voss[SMTP:egvoss@umich.edu]

Sent: Tuesday, December 07, 1999 7:41 PM

To: Nancy E. Fraser

Cc: itohver@umich.edu

Subject: Re: Cirsium palustre

Dear Ms. Fraser:

It is not clear to me just what you have already discovered about C. palustre, so forgive me if I am repetitious. The sole thing that you quote is one sentence from my Michigan Flora (hardly a "paper," but a 622-page book, the third volume (published in 1996) of my 3-volume flora of the state). Have you seen the rest of my treatment of this species there? (The Flora should be in the UBC library and elsewhere, perhaps cataloged as Bull. 61 of the Cranbrook Institute of Science or perhaps by author.) If you cannot find it, please send me a mailing address and I'll xerox the page (519) for you along with the distribution map (on p. p. 517) for this state. I might add that we have no additional county records in our herbarium.

Have you looked at the other references I cite there? Of particular importance to you (and surely available in B.C.) is "The Thistles of Canada" by R. J. Moore and C. Frankton (Canada Dept. Agric. Monogr. 10. 1974). C. palustre is the first species treated in that genus (pp. 21-22), with full description, references to chromosome work, and a brief history of its distribution to that date. That work and my own both cite Johnson and Iltis (actually published 1964--cf. my p. 342) for the early Wisconsin records. I gave early Michigan records in 1957 (Brittonia 9: 97).

I'm not familiar with recent data for neighboring areas, including Ontario, but I'm sure there would be specimens in Ottawa (National Herbarium and Department of Agriculture Herbarium) and Toronto (University of Toronto, now I believe housed in the Royal Ontario Museum). Last July I was horrified to find this pest along a stream in mixed woods in Pancake Bay Provincial Park, ca. 36 miles northwest of Sault Ste. Marie. So I doubtless violated Park rules and collected a specimen for documentation; it is in our herbarium (my no. 16679).

I do not happen to know of anyone working on this species, for control or otherwise. Apparently you do not have Cirsium muticum in your part of the continent. That is our native swamp thistle here, and its foliage is very similar to that of C. palustre, although the smooth

stem will distinguish it when it bolts. But control efforts would have to distinguish between the two species if they grow together. In 1998 I had a student in my summer course at our Biological Station working on the problem of distinguishing the species in sterile condition, and maybe she found out something else about C. palustre of interest to you. Her project report is on file at the Biological Station (about 300 miles north of Ann Arbor) so I cannot consult it until May. But you may want to contact her by e-mail: <itohver@umich.edu> [that may be obsolete, but it is all I have and is in this year's University directory]. Her full name is Ingrid Marisa Tohver, but she goes by her middle name. The last I heard she was planning to pursue her work further, but I have not seen her since I returned to Ann Arbor in September; she was a senior last year and would presumably now be graduated.

This is about all I can offer. Let me know if you want specific data from specimen labels for our Michigan collections.

Sincerely,

Edward G. Voss
Curator & Professor Emeritus
University of Michigan Herbarium
North University Bldg.
Ann Arbor, Michigan 48109-1057
U.S.A.

Peter Williams

From: Peter Williams[SMTP:WilliamsP@landcare.cri.nz]

Sent: Tuesday, January 18, 2000 1:25 PM

To: nefraser@pacificcoast.net

Subject: Cirsium palustre information -Reply

Kia ora Nancy

Yes, this species is present in NZ, but it is not of any great economic importance. In the index of our weed society proceedings, there are only two mentions since 1947, cf dozens for other spp. One is to the effect that it is eaten by goats, the other is a mention in a paper on biocontrol of nodding thistle (I have not got this paper). There are no papers on it being a problem, or how specifically how to control it. Even so, it is widespread in NZ., mainly in damp pasture, roadsides, swampy land. I think this is why it is not of economic importance...most places it grows are of no great importance to farming. Also, it is only a biennial, cf C.arvense which is by far and away the more serious weed on this class of "rough country'.

Cheers

Peter

Dr. Peter A.Williams

Landcare Research

Private bag 6

Nelson, New Zealand.

Ph. + 64 3 545 7715 Fax + 64 3 546 8590

Email WilliamsP@Landcare.cri.nz

APPENDIX V – HERBARIUM SPECIMENS

Dr George Douglas, of the Conservation Data Centre in Victoria, provided an unpublished map of known populations of *C. palustre* in British Columbia. Dr Douglas indicated the map was constructed from specimens housed in major herbariums in Canada.

In an attempt to pinpoint the exact location and collection dates of the dots on the map the following herbariums were contacted:

1. University of Victoria – no specimens
2. Agriculture Canada (Kamloops) – no specimens
3. Museum of Nature (Ottawa) – no BC specimens

4. Agriculture Canada (Ottawa) – 1 specimen from BC

Date: August 25, 1954
Collector: J. A. Calder, B. Saville, J.M. Ferguson
Location: Prince Rupert, along roadside on outskirts of town.

5. University of British Columbia – 2 specimens from BC

Date: August 13, 1995
Location: Cariboo, north of Prince George, 8.4 km north of Bear Lake.

Date: August 5, 1992
Location: Prince George, along Highway 16 to Mount Boson, Goat River rest stop

6. Royal British Columbia Museum – 2 specimens

Date: September 1, 1993

Collector: Denise McLean

Location: McBride, along Highway 16 near McBride between Dome Creek and Goat River, 93H 8. Common on roadsides and cutblocks
Lat: 53018'N Long: 120010'W

161890

Date: September 10, 1997

Location: QC1, South Moresby, 0.5 km west of Alliford Bay ferry along logging road to Moresby Camp. On road side with alder.
Lat: 53012'N Long:131059'W Elev: 0m

171227

APPENDIX VI – WEBSITES

BONAP (Biota of North America Program)

www.mip.berkeley.edu/query_forms/browse_checklist.html

Federal Interagency Committee for the Management of Noxious and Exotic Weeds (FICMNEW)

http://bluegoose.arw.r9.fws.gov/FICMNEWfiles/FICMNEWHomePage.html

Invasive Plants of Canada

http://infoweb.magi.com/~ehaber/ipcan.html

IOPI (International Organization for Plant Information)

http://www.bgbm.fu-berlin.de/IOPI/GPC/query.htm

ITIS*ca (Taxonomic Information Systems)

http://res.agr.ca:8800/itisca/owa/taxastep?hierarchy=no&king=Plantae&p_action=exactly+for&taxa=Cirsium+palustre

PLANTS database (USDA/NRCS)

http://plants.usda.gov/plants

US Forest Service

http://www.fs.fed.us/r9/weed

APPENDIX VII – PHOTOGRAPHS