Garry Oak Ecosystems Recovery Team

Annotated Bibliography on the Ecology and Management of Invasive Species:

Oxeye daisy (*Leucanthemum vulgare* Lam.)

(synonym *Chrysanthemum leucanthemum* L.)

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(synonym *Chrysanthemum leucanthemum* L.)

Peer-reviewed Journal Articles

Belair, G., and D. L. Benoit. 1996. Host suitability of 32 common weeds to *Meloidogyne hapla* in organic soils of southwestern Quebec. Journal of Nematology 28 (4): 643-647, Suppl. S.

Authors' abstract: Thirty-two weeds commonly found in the organic soils of southwestern Quebec were evaluated for host suitability to a local isolate of the northern root-knot nematode *Meloidogyne hapla* under greenhouse conditions. Galls were observed on the roots of 21 species. Sixteen of the 21 had a reproduction factor (Pf/Pi = final number of *M. hapla* eggs and juveniles per initial number of *M. hapla* juveniles per pot) higher than carrot (Pf/Pi = 0.37), the major host crop in this agricultural area. Tomato cv. Rutgers was also included as a susceptible host and had the highest Pf/Pi value of 13.7. *Bidens cernua, B. frondosa, B. vulgata, Erysimum cheiranthoides, Eupatorium maculatum, Matricaria matricariodes, Polygonum scabrum, Thalictrum pubescens, Veronica agrestis,* and *Sium suave* are new host records for *M. hapla*. *Bidens cernua, B. frondosa, B. vulgata, D. carota, M. matricarioides, Pastinaca sativa, P. scabrum, S. suave,* and *Thlaspi arvense* sustained moderate to high galling by *M. hapla* and supported high *M. hapla* production (12.4 less than or equal to Pf/Pi greater than or equal to 2.9). *Capsella bursa-pastoris, Chrysanthemum leucanthemum, Gnaphalium uliginosum, Stellaria media,* and *Veronica agrestis* sustained moderate galling and supported moderate *M. hapla* reproduction (2.8 less than or equal to Pf/Pi greater than or equal to 0.5). *Chenopodium album, C. glaucum, E. cheiranthoides, P. convolvulus, Portulaca oleracea,* and *Rorippa islandica* supported low reproduction (0.25 less than or equal to Pf/Pi greater than or equal to 0.02) and sustained low galling.

Galling was observed on *Senecio vulgaris* but no eggs or juveniles; thus, *S. vulgaris* may be useful as a trap plant. *Eupatorium maculatum* and *T. pubescens* harbored no distinct galling but supported low to moderate *M. hapla* reproduction, respectively. *Amaranthus retroflexus, Ambrosia artemisiifolia*, *Echinochloa crusgalli, Erigeron canadensis, Oenothera parviflora, Panicum capillare, Setaria glauca, S. viridis,* and *Solidago canadensis* were nonhosts. Our results demonstrate the importance of adequate weed control in an integrated program for the management of *M. hapla* in organic soil.

Clements, D. R., D. E. Cole, S. Darbyshire, J. King, and A. McClay. 2004. The biology of Canadian weeds—128: *Leucanthemum vulgare* Lam. Canadian Journal of Plant Science 84: 343-363.

Authors' abstract: *Leucanthemum vulgare* Lam. (Asteraceae), known as ox-eye daisy, is a familiar perennial herb with white ray florets and yellow disc florets. It commonly inhabits roadside verges, pastures and old fields from Newfoundland to British Columbia, and also as far north as the Yukon Territory. Introduced from Europe, *L. vulgare* was well established in North America by 1800. The Canadian distribution of *L. vulgare* has expanded in many areas recently, particularly in western Canada. It can form dense populations that may

reduce diversity of natural vegetation or pasture quality, and also serves as a host and reservoir for several species of polyphagous gall-forming *Meloidogyne* nematodes that feed on crops. It is considered a noxious weed under provincial legislation in Quebec, Manitoba, Alberta and British Columbia, as well as under the Canada Seeds Act. Control efforts are sometimes complicated by difficulties in distinguishing ox-eye daisy from some forms of the commercially available Shasta daisy (*L*. X *superbum*).

Coulson, S. J., J. M. Bullock, M. J. Stevenson, and R. F. Pywell. 2001. Colonization of grassland by sown species: dispersal versus microsite limitation in responses to management. Journal of Applied Ecology 38 (1): 204-216.

Authors' abstract: 1. Diversification of species-poor grassland often requires the introduction of desirable species by sowing seed. Little is known about the factors controlling the spread of introduced species, or how these interact with management. We determined whether management affected spread rates of two grassland species by modifying seed dispersal or seedling establishment.

2. An experiment was set up in 1995 on a species-poor grassland. It comprised five blocks, each with four treatments: (1) autumn grazed only; (2) cut July; (3) cut July and September; (4) cut July and aftermath grazed. Twenty-two plant species were separately slot-seeded into each treatment plot, providing discrete linear colonization foci.

3. The mechanisms controlling spread were studied in two species: *Rhinanthus minor*, an annual with large seeds adapted for wind dispersal; and *Leucanthemum vulgare*, a perennial with small seeds with no obvious dispersal adaptations.

4. Perpendicular spread of each species by 1998 was described well by a simple inverse power model. *Rhinanthus* had spread further in the hay-cut treatments (2-4) than in the grazed treatment (1). *Leucanthemum* spread poorly in all plots, with no treatment effects.

5. Seed dispersal from source slots was also described well by the inverse power model. Dispersal curves for *Rhinanthus* were much longer in the hay-cut treatment (3) than in the grazed treatment (1), because more seed dispersed during hay cutting than before, and cutting dispersed seed longer distances. There was no dispersal by grazing animals. Dispersal showed directional effects: seeds travelled farther in the prevailing wind direction before the hay-cut and in the grazed treatment; dispersal by hay cutting was farther in the cut direction than in the opposite direction.

6. *Leucanthemum* showed poor dispersal, with no treatment effects, except that more seeds were dispersed in the grazed (1) than the hay-cut (3) treatment.

7. The establishment and survival of sown seeds showed no treatment effects for either species.

8. Management effects on the spread of *Rhinanthus* reflected effects on dispersal, rather than establishment. *Leucanthemum* showed poor dispersal but good establishment in all treatments, suggesting its spread may also have been dispersal-limited. *Rhinanthus* was positively affected by hay cutting because it set seed at the time of cutting, whereas *Leucanthemum* set seed later and cutting reduced its seed production.

9. The results indicate that management of grassland to enhance the colonization of sown species might be best targeted at enhancing seed-dispersal distances. Hay cutting can do this, but must coincide with seed set.

Derr, J. F. 1993. Wildflower tolerance to metolachlor and metolachlor conbined with other broadleaf herbicides. Hortscience 28 (10): 1023-1026.

Author's abstract: The tolerance of transplanted lanceleaf coreopsis (*Coreopsis lanceolata* L.), ox-eye daisy (*Chrysanthemum leucantheum* L.), purple coneflower (*Echinacea purpurea* L. Moench.), and blanket flower (*Gaillardia aristata* Pursh) to metolachlor was determined in field trials. Metolachlor at 4.5 kg.ha-1 (maximum use rate) and 9.0 kg.ha-1 (twice the maximum use rate) did not reduce stand or flowering of any wildflower species after one or two applications, although plants developed transient visible injury. Combining metolachlor with the broadleaf herbicides simazine or isoxaben resulted in unacceptable injury and stand reduction, especially in ox-eye daisy. Metolachlor plus oxadiazon was less injurious to the wildflowers than metolachlor plus either simazine or isoxaben. Treatments containing metolachlor controlled yellow nutsedge (*Cyperus esculentus* L.) by at least 89% in both experiments. Treatments containing isoxaben controlled eclipta (*Eclipta alba* L.) 100% in both studies.

Guillet, G., M. E. Lavigne, B. J. R. Philogene, and J. T. Arnason. 1995. Behavioral adaptations of two phytophagous insects feeding on two species of phototoxic Asteraceae. Journal of Insect Behavior 8 (4): 533-546.

Authors' abstract: Two phototoxic plants of the Asteraceae family were studied in relation to species of phytophagous insects for which they are hosts: *Argyrotaenia velutinana* Wlk. feeding on *Chrysanthemum leucanthemum* L. and *Chlorochlamys chloroleucaria* (Guenee) colonizing *Rudbeckia hirta* L. The toxicity of these two plants is related to the presence of acetylenes and thiophenes that induce a light-mediated production of deleterious singlet oxygen and other free radicals (phototoxicity). Results showed that females of *A. velutinana* laid their eggs preferentially in the shade and the larvae adopted hiding behaviors, such as bending of ligulate corollas and silk spinning to build opaque shelters. By avoiding direct exposure to the sun, both behaviors may reduce phototoxicity associated with ingested plant materials. Furthermore, larvae of *C. chloroleucaria* demonstrated a preference in the field for pollen, which constitutes a nonphototoxic tissue of their host plant. Experimental alterations of these specific behaviors induced important biological consequences for larvae of both insects such as mortality or reduction of larval growth rate. These results reinforce the idea that behavior may constitute an efficient adaptation to avoid phototoxicity.

Hopkins, A., R. F. Pywell, S. Peel, R. H. Johnson, and P. J. Bowling. 1999. Enhancement of botanical diversity of permanent grassland and impact on hay production in Environmentally Sensitive Areas in the UK. Grass and Forage Science 54 (2): 163-173.

Authors' abstract: Five methods for increasing the botanical diversity of permanent grassland, either by sowing site-specific species-rich grass/forb seed mixtures (strip-seeding; or over-sowing after sward disturbance by light harrowing, partial rotary cultivation or turf removal), or by introducing transplanted plug plants, were compared with a control treatment in replicated field experiments on six farm sites in Environmentally Sensitive Areas (ESAs) in England and Wales. Effects on herbage production under hay cutting in July and on botanical composition were recorded in the two subsequent years. Turf removal before sowing was the only treatment that significantly reduced herbage production; this treatment also had the greatest effect on increasing botanical diversity (to a mean of twenty-eight plant species per site compared with fifteen species for the control two years after sowing).

The least successful establishment of sown species resulted from light harrowing before sowing; the rotary-cultivated and strip-seeded treatments increased species diversity, although by less than turf removal. Successful establishment of introduced species was greatest on sites having a low soil nutrient status. Species that established successfully from seed on most

sites and treatments included the grasses *Alopecurus pratensis, Cynosurus cristatus, Festuca rubra* and *Phleum pratense,* and the forbs *Achillea millefolium, Leucanthemum vulgare, Plantago lanceolata* and *Prunella vulgaris*; in addition, *Centaurea nigra, Hypochoeris radicata* and *Lotus corniculatus* were also established by one or more methods on most sites, *Lychnis flos-cuculi* established successfully on mesotrophic sites, and *Medicago lupulina* on calcareous sites. Several species failed to establish at all or most sites where they were sown, e.g. *Helianthemum nummularium*, *Pimpinella saxifraga* and *Rhinanthus minor*. Most transplanted plug-plant species established successfully in the short term, but many failed to persist or their frequency in the sward remained low; exceptions included *A. millefolium* and *P. lanceolata*. The results are discussed in relation to the requirements for management to further the objectives of ESAs and agri-environmental schemes.

Howarth, S. E., and J. T. Williams. 1968. *Chrysanthemum leucanthemum* L. Journal of Ecology 56 (2): 585-586.

This article provides a comprehensive botanical description of *Leucanthemum vulgare*.

Kuhn, K. D., H. C. Weber, H. W. Dehne, and N. A. Gworgwor. 1991. Distribution of vesicular-arbuscular mycorrhizal fungi on a fallow agriculture site: 1. Dry habitat. Angewandte Botanik 65 (3-4): 169-185.

Authors' abstract: The assessment of VA-mycorrhizal infection in the vegetation of a fallow agricultural soil in Germany was investigated. The habitat is characterized by sufficient nutrient content, low pH as well as soil moisture. From 43 examined species of flowering plants 40 were heavily infected by VA-mycorrhizal fungi. They belong to the Apiaceae, Fabaceae, Ranunculacae, and Asteraceae, whereas the other three species, *Calluna vulgaris*, *Cardamine pratense* and *Anthoxanthum odoratum,* showed no VA-mycorrhizal structures within their roots. Some plants which very seldom occur, such as *Tragopogon pratensis, Agrimonia eupatoria*, *Chrysanthemum leucanthemum*, *Heracleum spondylium* and *Lathyrus pratensis,* are very heavily infected by VAM. The extension of typical mycorrhizal structures as well as the important role of unstained mycorrhizal root segments for the isolation of efficient VAM-fungi is pointed out.

Lass, L. W., and R. H. Callihan. 1997. The effect of phenological stage on detectability of yellow hawkweed (*Hieracium pratense*) and oxeye daisy (*Chrysanthemum leucanthemum*) with remote multispectral digital imagery. Weed Technology 11 (2): 248-256.

Authors' abstract: Many upland pastures and forest meadows in the western United States contain significant infestations of yellow hawkweed and oxeye daisy. Documentation of infestations is necessary in order to plan and assess control tactics. Previous work with an airborne charge coupled device (CCD) with spectral filters indicated that flowering yellow hawkweed with at least 30% cover was detectable at 1 m resolution. A single image of a large area may not capture all plants in the flowering phase and multiple images are costly. The objective of this paper was to assess the accuracy of images recorded at different phenological stages. We compared three methods of classification: unsupervised classification of a three principal component analysis image, supervised classification of a three principal component analysis image, and supervised classification of a composited image consisting of four bands and normalized difference near infrared (NIR)/red band. Regardless of the classification method, images of yellow hawkweed and oxeye daisy in full bloom had lower classification error than at early bloom or post bloom. The percent error for yellow hawkweed classification was about twice as high at post bloom as at full bloom, but varied slightly depending on the method of classification and cover class. The ability to detect discrete colonies of yellow hawkweed was not affected by phenological stage, but the

ability to measure the area of each cluster differed among stages. Less than one-third of the pixels classified as yellow hawkweed or oxeye daisy in the early bloom image remained in the same class in the full bloom image. About half the pixels in the full bloom image remained in the 90 to 100% cover class at the post bloom image. Seasonal growth of the grasses masked some yellow hawkweed and oxeye daisy plants, and accounted for differences in classification among phenological stages.

Mitich, L. W. 2000. Oxeye daisy (*Chrysanthemum leucanthemum* L.), the white-flowered gold flower. Weed Technology 14 (3): 659-662.

Abstract not available.

Olliff, T., R. Renkin, C. McClure, P. Miller, D. Price, D. Reinhart, and J. Whipple. 2001. Managing a complex exotic vegetation program in Yellowstone National Park. Western North American Naturalist 61 (3): 347-358.

Authors' abstract: The number of documented exotic plants in Yellowstone National Park has increased from 85 known in 1986 to over 185 today. Exotic plants are having a substantial impact on the park's natural and cultural resources and are a high management priority. We have adopted an integrated weed management approach with regard to exotic vegetation, emphasizing prevention, education, early detection and eradication, control and, to a lesser degree, monitoring. The program involves over 140 staff with program expenditures averaging approximately $190,000 annually. Prevention actions include: using only approved gravel on construction projects; banning hay in the backcountry; transport of only certified weed-seed-free hay through Yellowstone; requiring construction equipment to be pressure-cleaned prior to entering the park; and re-vegetation with native species after road, housing, and other construction projects have disturbed ground.

Over 4500 acres, primarily along roadsides and in developed areas, are surveyed annually in early detection efforts with emphasis placed on eradicating small new infestations of highly invasive species, such as sulfur cinquefoil (*Potentilla recta* L.) and leafy spurge (*Euphorbia esula* L.). Control efforts focus on about 30 priority species, such as spotted knapweed (*Centaurea maculosa* Lam.), oxeye daisy (*Chrysanthemum leucanthemum* L.), and hoary cress (*Cardaria draba* [L.] Desv.) using chemical, mechanical, and cultural techniques. A total of 2027 acres were treated during 1998, whereas control efforts for 12 species occurred on 2596 acres during the previous 3-year period 1995-1997. Strong and expanding partnerships with other federal, state, and local agencies and private companies contribute to management efforts within the park. Future program goals emphasize increases in base funding to ensure continued weed management efforts as well as expanding survey, monitoring, and reclamation efforts. Ultimately, a more rigorous assessment of program effectiveness is desired.

Olson, B. E., R. T. Wallander, and P. K. Fay. 1997. Intensive cattle grazing of oxeye daisy (*Chrysanthemum leucanthemum*). Weed Technology 11 (1): 176-181.

Authors' abstract: Oxeye daisy has invaded seeded pastures, roadsides, and mountain rangelands in western Montana. In 1990, we began a study to: (1) determine use of oxeye daisy and introduced perennial grasses by cattle; (2) determine effects of intensive cattle grazing on the number of oxeye daisy seeds in the soil; and (3) assess effects of intensive grazing on year-to-year changes in oxeye daisy and associated perennial grasses. Cattle grazed oxeye daisy but much of their impact was from trampling or removing stems. The number of oxeye daisy seeds in the soil seed bank was lower in 1992 than in 1990 in grazed areas, whereas the number was higher in ungrazed areas. Two years of intensive grazing

reduced densities of oxeye daisy seedlings and rosettes, but did not change densities of mature stems. Intensive grazing had minimal impact on the introduced grasses.

Suttle, K. B. 2003. Pollinators as mediators of top-down effects on plants. Ecology Letters 6 (8): 688-694.

Author's abstract: This paper explores the idea that predators may disrupt plant-pollinator relationships and consequently inhibit reproduction in flowering plants. Amidst growing evidence that predators influence plant-pollinator interactions, I suggest that such pollinator-mediated indirect effects may be a common feature of terrestrial communities, with implications for research into top-down effects and pollination ecology. Experimental evidence of such an effect from a riparian system in northern California is provided, where crab spiders decreased seed production in inflorescences of the invasive plant *Leucanthemum vulgare* by reducing the frequency and duration of floral visits by pollinating insects.

Thomas, A. G., D. J. Doohan, and K. V. McCully. 1994. Weed survey of spring cereals in New Brunswick. Phytoprotection 75 (3): 113-124.

Authors' abstract: During 1986 and 1987, a weed survey of 187 New Brunswick cereal fields was conducted. A total of 76 species were identified of which 40 were considered agronomically important. About 50% of the species were perennial. Hemp-nettle (*Galeopsis tetrahit)*, quack grass (*Agropyron repens*), sheep sorrel (*Rumex acetosella*), ox-eye daisy (*Chrysanthemum leucanthemum*), corn spurry (*Spergula arvensis*), and chickweed (*Stellaria media*) had the highest relative abundance values. Quack grass and hemp-nettle had the highest densities at 8.0 and 7.1 plants m-2, respectively. The highest weed density (103 plants m-2) was found in oats (*Avena sativa*) grown after a forage crop. The lowest density (24 plants m-2) was found in wheat (*Triticum aestivum*) grown after potatoes (*Solanum tuberosum*). Most of the abundant species were tolerant to MCPA, the most commonly used herbicide. Farmers could make major improvements in cereal weed control by choosing a herbicide that would control species tolerant to MCPA or 2,4-D, and using pre-plant or post-harvest weed control to minimize the impact of perennial weeds.

van Ruijven, J., G. B. De Deyn, and F. Berendse. 2003. Diversity reduces invasibility in experimental plant communities: the role of plant species. Ecology Letters 6 (10): 910-918.

Authors' abstract: Several studies have presented experimental evidence that diversity reduces invasibility in grassland communities. The interpretation of these results has been disputed recently and it was proposed that sampling effects were responsible for the observed decrease of invasibility with diversity. The experiments performed to date were not designed to adequately separate sampling from diversity effects. Using the establishment of native plant species in experimental plant communities as a model of invasibility, we show that the number of invaders decreased with increasing diversity. When the presence of particular species is included, their effects are dominant. *Centaurea jacea* showed a strong effect at low diversity, whereas *Leucanthemum vulgare* showed a very strong negative impact at each diversity level. The negative effect of the latter might be related to root-feeding nematodes that showed far higher abundance in plots with *Leucanthemum*. However, diversity remained a significant factor in determining the number of invading species and the numbers of an abundant invader.

Vécrin, M. P., R. van Diggelen, F. Grévilliot, and S. Muller. 2002. Restoration of species-rich flood-plain meadows from abandoned arable fields in NE France. Applied Vegetation Science 5 (2): 263–270.

Authors' abstract: Attempts to restore species-rich flood-plain meadows from abandoned arable fields in the valley of the river Meuse, northeast France, were studied. The study area was sown with a commercial seed mixture, composed of *Phleum pratense, Festuca pratensis, Lolium perenne* and *Trifolium repens*. The above-ground vegetation in the study area 1, 2 and 3 yr after restoration was compared to (1) the vegetation present during the previous 5-yr fallow stage and (2) target flood-plain meadows. Before restoration, the above-ground fallow vegetation was dominated by ruderal and annual species, while only very few meadow species were present. Sowing led to tall, dense vegetation, mainly dominated by the sown species. Ruderal and annual species had decreased 3 yr after restoration, but target species were still poorly represented. Species richness was significantly lower in the sown site than in the semi-natural target meadows and the vegetation had a different composition. Analysis of the soil seed bank of the restored meadow showed that only a few meadow species were present and that it was dominated by a few ruderal species. Three years after sowing, the vegetation of our experimental site is moving slowly towards the target communities but impoverished seed sources seem to limit the success of this restoration operation and will lead to under-saturated communities.

Wahlman, H., and P. Milberg. 2002. Management of semi-natural grassland vegetation: evaluation of a long-term experiment in southern Sweden. Annales Botanici Fennici 39 (2): 159-166.

Authors' abstract: Vascular plants were recorded in a long-term (28-year) experiment on semi-natural grassland vegetation comparing six treatments: continued grazing, mowing every year, mowing every third year, annual spring burning, removal of woody plants, and untreated control. The treatments had created very different vegetation types: the annually mown and grazed plots had the highest species number while the untreated plots had the lowest. The species' ordination scores correlated with Ellenberg indicator values for nutrient status and light: species indicating poor nutrient conditions were mainly in grazed and mown plots, and shade-tolerant species were mainly in untreated and grazed plots. The original aim of this experiment was to evaluate alternative ways of maintaining semi-natural grassland vegetation, but there were no satisfactory long-term alternatives to annual mowing or grazing. An ordination contrasted annual mowing and grazing, ranking species from those associated with mowed plots (e.g. *Leucanthemum vulgare, Luzula pilosa, Campanula persicifolia, Ajuga pyramidalis*) to those associated with grazed plots (e.g. *Ranunculus* spp., *Geum* spp., *Vicia sepium*).

Other Published Sources

Douglas, G. W., G. B. Straley, D. V. Meidinger, and J. Pojar (eds.). 1998. Illustrated Flora of British Columbia, Volume 1: Gymnosperms and Dicotyledons (Aceraceae through Asteraceae). BC Ministry of Environment, Lands and Parks and BC Ministry of Forests, Victoria, BC. 436 pp.

This comprehensive reference has excellent identification keys and detailed technical descriptions of vegetative and sexual morphology. This flora is the taxonomic authority for the invasive species fact sheets (unless otherwise indicated). Douglas et al. describe the habitat of *Leucanthemum vulgare* Lam., as mesic to dry roadsides, pastures and waste places in the lowland, steppe and montane zones; common throughout BC south of 56^{o} north. Introduced from Eurasia.

Gilkey, H. M. 1957. Weeds of the Pacific Northwest. Oregon State College, Corvallis, OR. 441 pp.

This book includes a descriptive paragraph, line drawings and brief discussion about how readily *Leucanthemum vulgare* spreads. No information on control measures.

Olson, B. E., and R. T. Wallander. 1999. Oxeye daisy. Section 11 *in* Sheley, R. L., and J. K. Petroff (eds.). Biology and Management of Noxious Rangeland Weeds. Oregon State University Press, Corvallis, OR. 464 pp.

This book provides a comprehensive overview of the biology and management of rangeland weeds. The chapter devoted to *Leucanthemum vulgare* contains excellent information on biology, ecology and management.

Olson, B. E., and R. T. Wallander. 1994. Oxeye daisy. Chapter 13 *in* Sheley, R. L. (ed.). Identification, Distribution, Impacts, Biology and Management of Noxious Rangeland Weeds. US Department of Agriculture, Eastside Ecosystem Management Project, Walla Walla, WA. 454 pp. Also online: http://www.icbemp.gov/science/sheley.pdf

This document provides a discussion of the biology and management of rangeland weeds. The chapter devoted to *Leucanthemum vulgare* contains excellent (though somewhat dated) information on biology, ecology and management.

Province of British Columbia. 2002a. A Guide to Weeds in BC. Crown Publications, Victoria, BC. 195 pp.
Also online: http://www.weedsbc.ca/pdf/oxeye_daisy.pdf

This book provides a good overview of weeds in BC, including *Leucanthemum vulgare*. The information includes identification, distribution in BC, impacts and management strategies and is available as a pdf from the website.

Province of British Columbia. 2002b. Field Guide to Noxious and Other Selected Weeds of British Columbia. 4th edition. Prepared by R. Cranston, D. Ralph, and B. Wikeem. British Columbia Ministry of Agriculture, Fisheries and Food, Victoria, BC.
Also online: http://www.agf.gov.bc.ca/cropprot/weedguid/weedguid.htm

Pywell, R. F., M. Nowakowski, K. J. Walker, D. Barratt, and T. H. Sparks. 1998. Preliminary studies on the effects of pre-emergence herbicides on the establishment of injurious weed and wildflower species. Pages 173-178 *in* Champion, G. T., A. C. Grundy, N. E. Jones, E. J. P. Marshall, and R. J. Froud-Williams (eds.). Weed Seedbanks: Determination, Dynamics and Manipulation. St. Catherine's College, Oxford.

Abstract not available.

Royer, F., and R. Dickinson. 1999. Weeds of Canada and the Northern United States. Lone Pine Publishing and University of Alberta Press, Edmonton, AB. 434 pp.

This book includes a two-page botanical description of *Leucanthemum vulgare*, reasons why the species is of concern and photos. It does not include information on control measures.

Rutledge, C. R., and T. McLendon. 1998. An Assessment of Exotic Plant Species of Rocky Mountain National Park: *Chrysanthemem leucanthemem* L. [*sic*] (*Leucanthemem vulgare* Lam.),

[*sic*] Oxe-eye daisy, white daisy (Asteraceae). Department of Rangeland Ecosystem Science, Colorado State University, Fort Collins, CO. 97 pp.
Also online: http://www.npwrc.usgs.gov/resource/plants/explant/chryleuc.htm

Abstract: If given the opportunity, this plant can become noxious and is capable of taking over pasture. *Chrysanthemum leucanthemum* has potential to invade and modify existing communities. Little information has been published on mechanical, cultural, or biological control of this species. One important consideration is that seeds remain viable in soil for at least 2-3 years. An option for small scale control is to dig out the plant before the heads are produced, being sure to get the underground parts. Herbicides active on ox-eye daisy are 2,4-D, Banvel (dicamba), Tordon (picloram), Arsenal (imazapyr), and Oust (sulfometuron methyl). These herbicides are not, however, specific to ox-eye daisy, which is moderately resistant to MCPA, 2,4-D, and dicamba.

Taylor, R. J. 1990. Northwest Weeds: The Ugly and Beautiful Villains of Fields, Gardens and Roadsides. Mountain Press Publishing, Missoula, MT. 177 pp.

This book includes a descriptive paragraph and photos. No information on control measures.

Wallander, R. T., B. E. Olson, P. K. Fay, and K. Olson-Rutz. 1991. The effects of intensive grazing on oxeye daisy. Western Society of Weed Science Proceedings 44: 91-94.

Abstract not available.

Unpublished Sources and Websites

Baskauf, S. J. 2004. *Leucanthemum vulgare*. Bioimages, Department of Biological Sciences, Vanderbilt University, Nashville, TN.
http://www.cas.vanderbilt.edu/perl/bioview.pl?genspec=levu&action=View

Excellent photos for identification of leaves, seed head, stem and plant.

California Invasive Plant Council. No date. *Leucanthemum vulgare*. Berkeley, CA.
http://ucce.ucdavis.edu/datastore/detailreport.cfm?usernumber=59&surveynumber=182

A fairly comprehensive overview of *Leucanthemum vulgare* including identification, habitat, vectors of spread, impacts and management techniques.

Center for Invasive Plant Management. 2004. Problem Weeds in the West. Bozeman, MT.
http://www.weedcenter.org/management/weed_mgmt_profiles.htm

This website provides information on prevention and management of many invasive plants. For *Leucanthemum vulgare*, a list of key links is provided.

Hawaiian Ecosystems at Risk Project. 2001. *Chrysanthemum leucanthemum* L. A Global Compendium of Weeds.
http://www.hear.org/gcw/html/index.html

Very basic information on *Leucanthemum vulgare*, and crosslinks to related references from around the world.

Karl, M. G., S. G. Leonard, P. M. Rice, and J. Rider. 1996. Noxious Weeds in the Interior Columbia Basin and Portions of the Klamath and Great Basin: Science Assessment of Selected Species: Review Draft. Interior Columbia Basin Ecosystem Management Project, Walla Walla, WA. 119 pp.
Also online: http://www.icbemp.gov/science/karl1.pdf

This document discusses the noxious weed problem in Washington, Montana, Oregon, Idaho and Wyoming, including numerous problem species, giving distribution information and management and control suggestions. For *Leucanthemum vulgare*, the paper outlines susceptibility to invasion (e.g. of riparian areas, true grassland types, Mountain Shrub, and Sepen). The paper reports that *L. vulgare* "typically responds negatively to excessive livestock grazing pressure. Horses, cattle, sheep, and goats will consume it and cattle and sheep grazing can result in reduced seed production. Its response to fire is typically neutral. The rhizomatous root system readily resprouts post-fire, and oxeye daisy exists on mesic to relatively mesic sites where fire has little deleterious effect in the subterranean environment."

Klinkenberg, B. 2004. E-Flora BC: Atlas of the Plants of British Columbia. Lab for Advanced Spatial Analysis, Department of Geography, University of British Columbia, Vancouver, BC.
http://www.eflora.bc.ca/

This site provides information on the distribution of *Leucanthemum vulgare* in BC as well as information on identification, ecology, habitat and nomenclature, with links to other relevant websites.

Krueger, J. M., and R. L. Sheley. 2002. Oxeye Daisy (*Chrysanthemum leucanthemum*) MontGuide Fact Sheet. Montana State University Extension Service, Bozeman, MT.
http://www.montana.edu/wwwpb/pubs/mt200002.html
http://www.mtweed.org/Identification/oxeye_daisy/oxeye_daisy.html
http://www.co.yellowstone.mt.us/extension/ag/pubs/mt200002.html

This fact sheet, available as a pdf or html from these websites, provides information on the identification and biology, history, US distribution and management of *Leucanthemum vulgare*.

Missoula County Weed District. No date. Integrated Weed Management for Oxeye Daisy Control. Missoula County Weed District, Missoula, MT.
http://www.mslacountyweed.org/pages/IWMCHLE.html

This website briefly outlines various methods of managing *Leucanthemum vulgare*, including hand-pulling, chemical treatment, fertilization and mowing.

Natural Resources Conservation Service. No date. Plants Profile: *Leucanthemum vulgare* Lam. Oxeye Daisy. United States Department of Agriculture Plants Database, Washington, DC.
http://plants.usda.gov/index.html

This website provides excellent information including an illustrated description of *Leucanthemum vulgare*, alternative nomenclature, distribution by state, the classification system for this species and the invasiveness and noxious status for each state. The site also provides links to other US websites. Photos and line drawings on this page are not copyrighted, and may be used by acknowledging the author.

NatureServe. 2005. Invasive Species Impact Ranks for the United States. Arlington, VA.
http://www.natureserve.org/getData/plantData.jsp

NatureServe is assessing all of the estimated 3500 non-native plant species that have escaped from cultivation in the US using a new methodology called “Invasive Species Assessment Protocol.” This system, developed by NatureServe, the Nature Conservancy and the National Park Service, creates a prioritized list of non-native plants and their impact on biodiversity. The site also includes citations and references used in assessing the species. According to this matrix (January 10, 2005), *Leucanthemum vulgare* has a national impact rank of medium/low.

NatureServe Explorer. 2005. Comprehensive Report *Leucanthemum vulgare*. NatureServe, Arlington, VA.
http://www.natureserve.org/explorer/servlet/NatureServe?init=Species

This website provides a distribution map for *Leucanthemum vulgare* in Canada and the US and provides information on the species’ status (exotic). This species is found throughout the continent.

Noxious and Nuisance Plant Information System. No date. *Leucanthemum vulgare* Lam. (Oxeye Daisy) Mechanical Control Information. US Army Corps of Engineers, Vicksburg, MS.
http://el.erdc.usace.army.mil/pmis/mechanical/html/leucanth.html
http://el.erdc.usace.army.mil/pmis/herbicides/html/herbi103.htm

Detailed information on mechanical control, including hand removal and hand-pulling, which includes description, operational considerations, timing and expected results. The second link outlines herbicides used to control *Leucanthemum vulgare*.

Plants for a Future Database. No date. *Leucanthemum vulgare*. Plants for a Future, Chapel Hill, NC.
http://www.ibiblio.org/pfaf/cgi-bin/arr_html?Leucanthemum+vulgare

This database provides information on physical characteristics, habitats and locations, edible and medicinal uses, cultivation and propagation. There are also links to numerous other sites.

Sirota, J. 2003. Best Management Practices for the Noxious Weeds of Mesa County. Colorado State University Cooperative Extension, Grand Junction, CO.
http://www.coopext.colostate.edu/TRA/Weeds/weedmgmt.html

This website outlines the management of several species, and provides a calendar of flowering, seed set and germination for each weed. According to this information, *Leucanthemum vulgare* should be treated at early flowering (late May or early June in Colorado).

Washington State Noxious Weed Control Board. 2000. Oxeye Daisy *Leucanthemum vulgare* Lam. Olympia, WA.
http://www.nwcb.wa.gov/weed_info/Written_findings/Leucanthemum_vulgare.html

A well-referenced overview of *Leucanthemum vulgare*, including description, economic importance, geographic distribution, habitat, growth and development, reproduction and response to treatment.

General summaries of basic information, or fact sheets:

- http://www.agf.gov.bc.ca/cropprot/weedguid/oxeyed.htm
- http://www.wildflowers-and-weeds.com/weedsinfo/Chrysanthemum_leucanthemum.htm
- http://www.tcweed.org/oxeye.htm
- http://montana.plant-life.org/species/leucant_vulga.htm
- http://ohioline.osu.edu/b866/b866_4.html
- http://www.co.stevens.wa.us/weedboard/other%20weeds/o_daisy.htm
- http://www.coopext.colostate.edu/gilpin/oxeyedaisy.shtml
- http://www.co.stevens.wa.us/weedboard/msdoc_weed/ox.doc
- http://www.oardc.ohio-state.edu/weedguide/singlerecord.asp?id=940
- http://www.co.whatcom.wa.us/publicworks/pdf/weeds/oxeye_daisy2.pdf
- http://www.spokanecounty.org/weedboard/pdf/2004OxeyeDaisy.pdf
- http://www.weeds.org.au/cgi-bin/weedident.cgi?tpl=plant.tpl&state=&s=0&ibra=all&card=H50
- http://www.weeds.asn.au/weeds/txts/oxeye_daisy.htm
- http://www.weedalert.com/weed_pages/wa_oxeye_daisy.htm
- http://www.npwrc.usgs.gov/resource/plants/explant/chryleuc.htm

Personal Communications

Banman, Irvan. 2005. *Personal communication*. Site Manager and Restoration Technician, Cowichan Garry Oak Preserve, The Nature Conservancy of Canada, Duncan, BC. March 3, 2005.

> Banman notes that oxeye daisy is widespread on southern Vancouver Island. He has seen it dominating fields, and particularly infesting disturbed sites such as roadsides, ditches and logging roads. He has seen this species commonly in the Garry oak preserves in BC, particularly at Cowichan, Sominos and Mt. Tzouhalem. He has not seen a natural site invaded by this species, however, since oxeye daisy prefers disturbed areas. Banman has tried to control this species by hand-pulling and by using a whipper-snipper. He reports that hand-pulling is reasonably effective since where you pull it, it is gone. However, this can only be done at sites where disturbing the soil is not a problem. He has used a whipper-snipper to control oxeye daisy on a road that used to be a logging road. He diligently mowed and whipper-snipped the area for two years, cutting the plants down to bare ground. He has found the plants to be tenacious. He suggests preventative measures such as limiting soil disturbance and being careful not to distribute seeds.

Beckwith, Brenda. 2005. *Personal communication*. Ethnoecologist, University of Victoria, Victoria, BC. March 18, 2005.

> Beckwith has not observed oxeye daisy species in Garry oak ecosystems, but has seen it commonly in lawns and other manicured areas. It can be found along trails, especially near trailheads, and on the edges between residential zones and natural areas.

Betts, Michael. 2005. *Personal communication*. Weed Specialist, Ministry of Agriculture, Food and Fisheries, Victoria, BC. March 22, 2005.

> Betts has observed oxeye daisy on Vancouver Island, particularly in dry sites. It is mostly in agricultural situations where good practices have not been followed and it does extremely well in poorly managed “waste” areas. He notes that it is very difficult to control.

Boyer, Lynda. 2005. *Personal communication*. Restoration Biologist and Native Materials Manager, Heritage Seedlings Inc., Salem, Oregon. March 21, 2005.

Boyer notes that in the prairie and oak habitats that she has been restoring, oxeye daisy is present but not dominant. If the desire is to selectively remove invasive species from a prairie remnant and oxeye daisy is one of the problem species, she has found that the most effective herbicide for composites and legumes is one containing clopyralid (e.g. Confront). The best time to spot-spray this chemical is in the rosette stage. The effects can be seen in only a day so plants that were missed can be easily spotted. A chemical dye can also be added to the herbicide to ensure all plants are sprayed. However, clopyralid has a long life in the soil so it should be very carefully spot-sprayed. Spot-spraying is preferable to broadcast-spraying, which requires that native composites or legumes not be reintroduced until after one to two years, when the chemical degrades. She and others in the restoration community feel the largest threats to native species persistence on Garry oak prairies are perennial pasture grasses such as tall oatgrass, tall fescue, bentgrass and velvet grass. However, in some sites, invasive forbs such as oxeye daisy can also have a devastating impact due to their highly competitive nature and lack of natural predators.

Ceska, Adolf. 2005. *Personal communication*. Botanist, Victoria, BC. March 16, 2005.

Ceska has observed oxeye daisy on the margin of Garry oak ecosystems, since it requires open soil and more moisture. He has seen this species in the zone of contact of Garry oak and Douglas-fir, but not in Garry oak ecosystems per se.

Costanzo, Brenda. 2005. *Personal communication*. Plant Species at Risk Biologist, Ministry of Water, Land and Air Protection, Victoria, BC. February 28, 2005.

Costanzo has observed oxeye daisy in disturbed areas and old fields and pastures. This species, in conjunction with non-native grasses, can dominate sites that were once used for agricultural purposes. Costanzo suggests that the spread of this species could be reduced by preventing people from dumping compost and garden waste in Garry oak meadows.

Cranston, Roy. 2005. *Personal communication*. Professional Agrologist (retired), Tsawwasen, BC. April 8, 2005

While working for the Ministry of Agriculture, Food and Fisheries, Cranston did trials on oxeye daisy with herbicide, fertilizers and combinations of the two. He identified an association of oxeye daisy with soils low in sulphur. In trials, Cranston fertilized areas that were solid with oxeye daisy using ammonium sulphate fertilizer, and found it to substantially reduce populations.

Delvin, Eric. 2005. *Personal communication.* Thurston County Project Manager, The Nature Conservancy, Olympia, WA. March 14, 2005.

Delvin has observed oxeye daisy growing extensively throughout Olympia, Washington, especially in disturbed sites, but he considers it to be a low priority species. He has found that oxeye daisy is not as competitive as other non-native species, although it can form dense, monoculture patches that prevent recruitment of native species to those sites. Oxeye daisy does not tolerate fire particularly well. Delvin has noticed a strong correlation between oxeye daisy and Scotch broom that he attributes to nitrogen enrichment and soil disturbance. Delvin has observed that a shift toward more nitrogen-rich soils favours oxeye daisy and other non-native species, and he is aware of research on the addition of carbon or sugar to

soil to tie up nitrogen and switch soil back to its native profile. Delvin notes that oxeye daisy is a nectar source that butterflies utilize.

Ennis, Tim. 2005. *Personal communication.* Director of Land Stewardship for BC Region, The Nature Conservancy of Canada, Victoria, BC. March 1, 2005.

Ennis is familiar with oxeye daisy in the Garry oak ecosystems at Cowichan Garry Oak Preserve in the Maple Bay area and Somenos. He has observed that in oak sites it is restricted to roadside and trail habitats, although he has seen a couple of oxeye daisy plants growing in more "wild" situations. Ennis has noticed that oxeye daisy can become a dominant element of the ecosystem in terms of percent foliar cover in places like Corvallis. The Nature Conservancy has been actively managing oxeye daisy for a couple of years in these sites. He has tried mowing using a whipper-snipper, but the plants seem to come back. He has also tried using selective flaming on other species and suggests that it might work for oxeye daisy, although he hasn't tried it. Hand-pulling in the wet season is another method that he recommends. Ennis has tried "Waipuna" on oxeye daisy, which is a hot water treatment (steam) combined with an organic coconut foam for insulating the plants. He has found it effective, but notes that the machine is restricted to 150 m of hose. Ennis suggests that access management is an important element in managing oxeye daisy.

Fairbarns, Matt. 2005. *Personal communication*. Plant Ecologist, Aruncus Consulting, Victoria, BC. February 22, 2005.

Fairbarns has observed oxeye daisy typically occurring on sub-hygric to mesic soils with moderate to high nutrient levels. This species is not shade tolerant, and prefers soil disturbance. Most sites in which he has observed oxeye daisy have been tilled, plowed or disturbed in one way or another. He has noticed this species growing in a phalanx growth style—a wave growing across the vegetation. It will outcompete most plants that grow in its immediate vicinity but since it is rare in undisturbed sites, this invasiveness is probably not an issue in Garry oak ecosystems. As with all invasive species, Fairbarns suggests minimizing soil disturbance.

Gayton, Don. 2005. *Personal communication*. Ecosystems Management Specialist, FORREX, Nelson, BC. March 1, 2005.

In the interior of BC, Gayton notes that classic oxeye daisy habitat is pasture that has been cut out of a forest, as well as roadsides and landings. It is a very invasive species.

Hebda, Richard. 2005. *Personal communication*. Curator of Botany and Earth History, Royal BC Museum, Victoria, BC. March 16, 2005.

Hebda has seen oxeye daisy primarily in pastures and roadsides, and does not usually encounter it in Garry oak ecosystems. This species became well established years ago, and he speculates that it has already reached the maximum extent of its impact. In pastures and on roadsides it can be quite dense and abundant, but it does not invade really dry sites.

One potential control method that he suggests is leaf mulching (using oak leaves). By placing the leaves over oxeye daisy plants, it may hinder the growth of this invasive species while permitting native species to establish (although this method would not be appropriate for rocky outcrops). Annual short mowing of this species reduces it in pasture areas, especially if mowing is carried out during flowering. As with other weed species, Hebda cautions against disturbing the soil, which provides a new seed bed for invasive species.

Lomer, Frank. 2005. *Personal communication*. Naturalist, New Westminster, BC. March 8, 2005.

Lomer has observed oxeye daisy in Garry oak meadows, but doesn't think it is a Garry oak meadow problem. He has seen it more frequently in pastures.

Polster, Dave. 2005. *Personal communication*. Plant Ecologist, Polster Environmental Services Ltd., Victoria, BC. February 21, 2005.

Polster has observed oxeye daisy throughout southern BC. He has not seen this species in Garry oak ecosystems, but in coastal bluff ecosystems, which are related. It can form dense stands and moves into areas that are disturbed and lacking species. Oxeye daisy has not been considered a problem in Garry oak ecosystems.

Ralph, Dave. 2005. *Personal communication*. Provincial Weed Technologist, Ministry of Agriculture, Food and Fisheries, Kamloops, BC. March 22, 2005.

Ralph has observed oxeye daisy throughout BC. He notes that it is fairly aggressive in pasture areas as well as fringe areas of forest canopy. When he was involved in soil sampling for orange hawkweed where oxeye daisy was also found, results indicated that these species prefer soils low in sulphur. Fertilization with nitrogen and sulphur helps reduce oxeye daisy and Ralph has seen good results with that fertilizer mix. In wild situations oxeye daisy is difficult to control with herbicides because it is often found in fringe conifer and deciduous forests. The herbicide 2,4-D can be used to suppress it, and the ester type is more effective than an amine. Since oxeye daisy reproduces by both seeds and stolons, care should be taken not to discard pulled plants on moist soil or they may root on the surface. As with all invasive species, maintaining natural ecosystems helps resist invasion.

Roemer, Hans. 2005. *Personal communication*. Botanist, Victoria, BC. March 17, 2005.

Roemer has not observed oxeye daisy directly in Garry oak communities but in ecosystems that are nearby. As a European species it needs some moisture in summer. He has seen this species grow on highway embankments, roadsides and fields but not in classical Garry oak communities. He has seen oxeye daisy on grassy bluffs near the periphery of the Garry oak distribution, but not in dry communities, and he predicts that the plant would not survive in a very dry environment.

Turner, Nancy. 2005. *Personal communication*. Ethnobotanist, University of Victoria, Victoria, BC. February 18, 2005.

Turner notes that the leaves of oxeye daisy are edible and delicious in salads.