Annotated Bibliography on the Ecology and Management of Invasive Species:

Common Velvet-grass (*Holcus lanatus*)

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AgWest and Hawaiian Ecosystems at Risk Project. 2001. The global compendium of weeds. Website: www.hear.org/gcw/index.html Accessed: November 7, 2002.

The information on this website is still being compiled and updated. It currently gives details on nomenclature (including an extensive list of alternate common names), the origin of the species (Eurasia) and a list of data sources that refer to this species.

Alien plants of Hawaii. 1998. *Holcus lanatus* L. common velvet-grass. Website: www.botany.hawaii.edu/faculty/cw_smith/hol_lan.htm. Accessed: November 7, 2002.

The website provides limited information on the impacts of common velvet-grass on Hawaiian biota and the ecology of the species in relation to control options. Velvet-grass readily invades disturbed sites in Hawaii and will remain stable in native grasslands. Velvet-grass seedlings grow very rapidly and once established, the plants can prevent native seedlings from establishing. Velvet-grass can tolerate fire and will resprout after a burn. There are no known biological control agents.

Bardgett, R. D., J. L. Mawdsley, S. Edwards, P. J. Hobbs, J. S. Rodwell, and W. J. Davies. 1999. Plant species and nitrogen effects on soil biological properties of temperate upland grasslands. Functional Ecology 13 (5): 650-660.

Authors' abstract: The aim was to assess the extent to which the microbial biomass and activity, and community structure of fertilized upland grasslands are directly related to changes in soil N availability or indirectly related to individual plant species effects caused by changes in plant species composition and dominance. We investigated the

short-term interactive effects of dominant plant species (*Lolium perenne, Agrostis capillaris, Holcus lanatus* and *Festuca rubra*) and nitrogen (N) amendment using an N-limited upland grassland soil. 2. In soils planted with different grass species, soil microbial biomass, and to some extent microbial activity, were determined by temporal changes in plant productivity. Variations in the way that individual plants influenced soil microbial biomass and activity were highly inconsistent over time, and largely independent of N-additions and differences in plant productivity. At the final sample date, those grass species which co-dominate the total plant biomass of intermediate fertility (*H. lanatus*) and semi-improved grasslands (*A. capillaris* and *F. rubra*) had a beneficial effect on the soil microbial biomass. In contrast, the dominant plant species of improved grasslands, *L. perenne*, had zero or a negative effect on soil microbial biomass. Two plant species (*A. capillaris* and *H. lanatus*) increased the proportion of fungi relative to bacteria in the soil microbial community, relative to the unplanted control soil and the other plant species. *Lolium perenne* and *A. capillaris* reduced the evenness of microbial PLFAs, suggesting negative effects of these plant species on the diversity of the soil microbial community. 3. The addition of N had no consistent effect on measures of soil microbial biomass or activity, but significantly altered the structure of the microbial community in favour of fungi. The lack of effects of N-addition on microbial biomass and activity were despite the finding that nitrogen addition reduced root biomass in all plant species and increased rhizosphere acidity. 4. The results suggest that in the short term, the abundance and activity of soil microorganisms in upland grasslands are regulated more by plant species traits than by a direct effect of nitrogen. These effects are likely to be related to variations amongst plant species in root exudation patterns and/or efficiency of nutrient acquisition. 5. Our study provides evidence that the functional characteristics of dominant plant species are important determinants of soil biological properties, and hence ecosystem functioning in temperate upland grasslands.

Barthram, G. T., D. A. Elston, C. P. D. Birch, and G. R. Bolton. 2002. Defoliation and site differences influence vegetative spread in grassland. New Phytologist 155 (2): 257-264.

Authors' Abstract: Plants spread vegetatively at rates that depend on both their own and their neighbours' traits. We tested hypotheses that such rates also interact with defoliation intensity and differ between sites, Well-established monoculture patches (20X20 cm) of five grass species were arranged in plots so that every species patch had all the remaining species as neighbours. Sites were in central Scotland, UK, and at a drier location in eastern Scotland. Plots were cut at 3 cm ('short') or 6 cm ('tall'), either uniformly or in a chessboard pattern, Invasiveness and resistance to invasion followed the transitive hierarchy, *Agrostis capillaris>Festuca rubra>Lolium perenne=Holcus lanatus>Poa trivialis*, except that *P. trivialis* strongly invaded *H. lanatus* at the damper, more fertile site. 'Tall' patches spread and intermixed most, independent of species. The effects of cutting neighbouring patches depended on both invading and invaded species' traits, Thus, defoliation altered the relationships between species, as did differences between sites, influencing both the speed and direction of species replacement.

Beckwith, B. 2002. *Personal communication*. PhD. Candidate, University of Victoria,

Victoria, BC. November 1, 2002.

Common velvet-grass is in Beckwith's research plots only at Devonian Park, Victoria, British Columbia. This species is not common in the other Garry oak ecosystems she has studied. Beckwith suspects that velvet-grass first came to Devonian Park after a big fire in 1998 since the species is known to follow fires and that it has subsequently spread.

Beddows, A. R. 1961. Biological flora of the British Isles: *Holcus lanatus* L. Journal of Ecology 49 (2): 421-430.

This reference serves as a foundation for ecological information on velvet-grass and is a comprehensive overview of early research on this species in its native habitat. The ecological background provided in this paper is essential for determining key management techniques for velvet-grass in Garry oak ecosystems. Detailed technical description and distribution information are as described in other references. The habitat is described as being north of the 26.7 °C July isotherm where annual rainfall is above 12.7 cm. In Europe, velvet-grass grows in most soils except undisturbed podsoils and very thin, droughty soils. It is most abundant in wetter sites with poor drainage. Velvet-grass is tolerant of salt spray. Velvet-grass produces large amounts of seed and rapidly invades disturbed soils. For these reasons, it has been sown to prevent erosion and for restoration; using velvet-grass for restoration is not recommended in Garry oak ecosystems. The seed germinates readily without treatment and can be carried large distances by wind. Buried seeds remain viable for many years. Velvet-grass also reproduces vegetatively and can form dense swards. Velvet-grass can live at least 3 years. Velvet-grass generally becomes less frequent with intense grazing although the response depends on which associated species are present, in part because of differences in palatability. Late mowing after the seeds set favours velvet-grass. Velvet grass is associated with mycorrhiza. The paper also lists an extensive list of grazers and parasites that feed on velvet-grass although none are listed as potential biological controls.

Bekker, R. M., G. L. Verweij, R. E. N. Smith, R. Reine, J. P. Bakker, and S. Schneider. 1997. Soil seed banks in European grasslands: Does land use affect regeneration perspectives? Journal of Applied Ecology 34 (5): 1293-1310.

Authors' abstract: Soil seed banks of 38 grassland sites in western Europe were sampled and species composition was determined. All sites differed in geographical region, soil type and intensity of management. 2. Relationships between the composition of the seed bank, the established vegetation, and soil and management parameters were analysed using different ordination techniques. 3. Common species in the seed bank of extensively managed grasslands were *Juncus* without septa, *Plantago lanceolata, Holcus lanatus* and *Cerastium fontanum*. General differences in the species composition reflected the country of origin of the sites. 4. Differences between sites within a chronosequence were used to interpret the impact of management on the proportion of species in the seed bank representing different functional groups. Seed banks were generally dominated by species of mid-range nutrient conditions. Species associated with poor nutrient conditions were relatively scarce at most sites. 5. Intensive agricultural management had a negative effect

on the soil seed bank of grassland species, whereas lack of management or abandonment resulted in the loss of grassland species from both the vegetation and the soil seed bank owing to the invasion of woodland species. Restoration management, following long periods of intensive use, took more than 20 years to establish a significant increase in species of poor nutrient conditions. 6. A regeneration index was calculated for each chronosequence to estimate the relative 'distance' between a degraded site and a species-rich target site in the same series. These regeneration indices provide an indication of the timescales required for the restoration of sites towards the species-rich target grassland community types. However, for most agriculturally improved grassland sites, the study indicated that restoration of unimproved or semi-natural types of grassland cannot depend on a high level of recruitment from the seed bank of species which have disappeared from the established vegetation. This implies that maintenance of existing species-rich grassland resources should be given high priority. 7. The results of this seed bank study show that grassland sites with a short history of agricultural improvement or biodiversity degradation are likely to be the most worthwhile for restoration purposes.

Belesky, D. P., C. M. Feldhake, and D. G. Boyer. 2002. Herbage productivity and botanical composition of hill pasture as a function of clipping and site features. Agronomy Journal 94(2): 351-358.

Authors' abstract: Complex topography and varied soil of hill-land pastures create microsite conditions that support an array of floristic associations and herbage production patterns. This complicates management for forage and livestock production because the seasonal distribution and quantity of forage vary. Our objective was to determine herbage production and floristic composition of a hill pasture as a function of site characteristics and canopy management. An existing 3-ha hill pasture watershed was oversown with white clover (*Trifolium repens* L.) and orchardgrass (*Dactylis glomerata* L.) and fertilized with reactive phosphate (PO4) rock (PR). Replicated plots on each of four sites were clipped once (stockpiled), twice (hay harvest), or three times (long rotation) annually. Site had a significant impact on cumulative herbage production, whereas the influence of clipping was mixed. The least (1.9 Mg ha-1) amount of herbage production in a given season occurred on a northeast (NE)-facing site and the greatest (4.6 Mg ha-1) in a natural drainage area (ND) traversing the pasture. Herbage production increased by about 80% with overseeding and PR, but the relative ranking of production among sites stayed the same. Botanical composition was also strongly influenced by site, with velvetgrass (*Holcus lanatus* L.) predominating in ND and red fescue (*Festuca rubra* L.) occurring primarily on the NE site. The stockpiled treatments became dominated by grasses and weeds 4 yr after treatments were imposed, regardless of site, and were similar to the least productive site (NE-facing) in the pasture. Our results suggest that application of amendments to the more productive portions of a site are likely to have greater return.

Belnap, J. and S. L. Phillips. 2001. Soil biota in an ungrazed grassland: Response to annual grass (*Bromus tectorum*) invasion. Ecological Applications 11 (5): 1261-1275.

Authors' abstract: *Bromus tectorum* is an exotic annual grass that currently dominates many western U.S. semi-arid ecosystems, and the effects of this grass on ecosystems in

general, and soil biota specifically, are unknown. *Bromus* recently invaded two ungrazed and unburned perennial bunchgrass communities in southeastern Utah. This study compared the soil food-web structure of the two native grassland associations (*Stipa* (S) and *Hilaria* (H)), with and without and presence of *Bromus*. Perennial grass and total vascular-plant cover were higher in S than in H plots, while quantities of ground litter were similar. Distribution of live and dead plant material was highly clumped in S and fairly homogenous in H. Soil food-web structure was different between H and S, with lower trophic levels more abundant in H and higher trophic levels more abundant in S. In *Bromus*-invaded plots, the quantity of ground litter was 2.2 times higher in *Hilaria-Bromus* (HB) than in H plots, and 2.8 times higher in *Stipa-Bromus* (SB) than in S plots. Soil biota in HB generally responded to the *Bromus* invasion in an opposite manner than in SB, e.g., if a given component of the food web increased in one community, it generally decreased in the other. Active bacteria decreased in H vs. HB, while increasing in S vs. SB. Soil and live plant-infecting fungi were the exception, as they increased in both types of invaded plots relative to uninvaded plots. Dead-plant-infecting fungi decreased in H vs. HB and increased in S vs. SB. Most higher-trophic-level organisms increased in HB relative to H, while decreasing in SB relative to S. Given the mixed response to invasion, the structure of these soil food webs appears to be controlled by both plant inputs and internal dynamics between trophic levels. When compared to non-invaded sites, soil and soil food-web characteristics of the newly invaded sites included: (1) lower species richness and lower absolute numbers of fungi and invertebrates; (2) greater abundance of active bacteria; (3) similar species of bacterial and fungi as those found in soils invaded over 50 yr ago; (4) higher levels of silt (thus greater fertility and soil water-holding capacity); and (5) a more continuous cover of living and dead plant material (thus facilitating germination of the large-seeded *Bromus*). These results illustrate that (1) soil food-web structure can vary widely within what would generally be considered one vegetation type (semi-arid grassland), depending on plant species composition within that type, and (2) addition of a common resource can evoke disparate responses from individual food-web compartments, depending on their original structure.

Booker, N. 2002. *Personal communication.* Aliens-L listserve, Berkeley, CA.

Booker states that common velvet-grass is a noxious weed in central and northern California, especially in moist grasslands near the coast. Velvet-grass is a serious problem in remnant coastal prairies in coastal California and is very difficult to deal with. Booker has been involved with control measures such as selective mowing (weed whacking) to reduce seed set and some hand weeding but I was unable to determine the results of these control measures.

Brown, C. S. and K. J. Rice. 2000. The mark of zorro: Effects of the exotic annual grass *Vulpia myuros* on California native perennial grasses. Restoration Ecology 8 (1): 10-17.

Authors' abstract: Native perennial grasses were once common in California prairies that are now dominated by annual grasses introduced from Europe. Competition from exotics may be a principal impediment to reestablishment of native perennial grasses. Introduced

annual grasses, such as *Vulpia myuros* (zorro fescue), are often included with native perennial species in revegetation seed mixtures used in California. To examine the potential suppressive effect of this graminoid, we evaluated the growth and performance of a mixture of California native perennial grasses and resident weeds when grown with varying densities of *V. myuros*. The annual fescue exhibited a strongly plastic growth response to plant density, producing similar amounts of above-ground biomass at all seeding densities. Perennial grass seedling survival and above-ground biomass decreased and individuals became thinner (i.e., reduced weight-to-height ratio) with increasing *V. myuros* seeding density. *V. myuros* also significantly suppressed above-ground biomass and densities of weeds and had a more negative effect on weed densities than on native perennial grass densities. Biomass of native grasses and weeds was not differentially affected by increasing densities of *V. myuros*. Overall, because *V. myuros* significantly reduced the survival and performance of the mixture of native perennial grasses and this effect increased with increasing *V. myuros* density, we conclude that including this exotic annual in native seed mixtures is counterproductive to restoration efforts.

Buckland, S. M., K. Thompson, J. G. Hodgson, and J. P. Grime. 2001. Grassland invasions: Effects of manipulations of climate and management. Journal of Applied Ecology 38 (2):301-309.

Authors' abstract: 1. Climate change, in combination with the impacts of land use, will give rise to new opportunities for grassland invasion. This paper reports on the repercussions of a field experiment. 2. Plant species, sown into experimental plots as part of a 6-year study investigating factors limiting the success of seedling invasions, were resurveyed in 1999, 3 years after terminating experimental manipulations of climate, soil fertility and disturbance. 3. The most dramatic observation was the protracted expansion in populations of *Brachypodium pinnatum*, despite being at the northern limit of its distribution in Britain. In contrast, all other sown species, including those of both southern and widespread distribution in Britain, had become extinct, declined or remained unchanged in abundance. 4. Patterns of establishment were strongly deterministic. Populations of the southern grass, *B. pinnatum*, were highest in areas of the experimental plots unamended by fertilizer and physical disturbance, but expansion was apparently promoted by cessation of management. Among invaders of widespread distribution, two were dependent upon fertilizer addition (*Arrhenatherum elatius* and *Dactylis glomerata*), one significantly increased its cover with a combination of fertilizer and disturbance (*Holcus lanatus*), and one benefited from disturbance (*Plantago lanceolata*). 5. Two southern perennials, *Origanum vulgare* and *Senecio erucifolius*, both remained present in 1999 in plots that were formerly heated and subject to drought (1991-96), whereas they had become extinct in control plots. 6. Although the most successful invader was a rhizomatous perennial grass, an alternative strategy for survival and expansion was revealed after the severe drought in 1995: gap recolonization by annuals with a persistent seed bank. 7. Most notably, this study revealed the hidden potential of a native species to establish beyond its current range of distribution and, contrary to many recognized weeds, the capacity to achieve dominance in the absence of eutrophication or disturbance. This highlights the potent effects of climate change when plant traits effective for establishment coincide with the removal of current barriers to dispersal.

Bull, I. D., C. J. Nott, P. F. van Bergen, P. R. Poulton, and R. P. Evershed. 2000. Organic geochemical studies of soils from the Rothamsted classical experiments: VI. The occurrence and source of organic acids in an experimental grassland soil. Soil Biology & Biochemistry 32 (10):1367-1376.

Authors' abstract: To tal lipid extracts (TLEs) of grass (aerial and sub-aerial, *Holcus lanatus*) from a plot on a long-term grassland experiment, and associated soil, along with the organic fraction of the TLE hydrolysates and the hydrolysates of the solvent extracted vegetation have been separated into fractions containing specific compound classes and analysed using gas chromatography (GC) and gas chromatography/mass spectrometry (GC/MS). The distributions of n-alkylcarboxylic acids, omega- hydroxycarboxylic acids and dicarboxylic acids in the grass and the underlying soil have been determined. Short-chain (< C20) n-alkylcarboxylic acids were designated as having derived from both aerial and sub-aerial vegetation. However, longer-chain n- alkylcarboxylic acids were ascribed to suberin as a predominant source. Moreover, omega-hydroxycarboxylic acids and dicarboxylic acids observed in the soil were designated as having predominantly derived from inputs of free, extractable polyesters and suberin intimately associated with plant roots. This study indicates the importance of root material as a predominant source of aliphatic, organic acids in the soil of temperate grassland biomes.

Bullock, J. M., A. M. Mortimer and M. Begon. 1995. Carryover effects on interclonal competition in the grass *Holcus lanatus*: A response surface analysis. Oikos 72 (3):411-421.

Authors' abstract: The effects of past (carryover) and present (direct) clipping environment on the competitive interaction between two clones of the grass *Holcus lanatus* were investigated in a glasshouse experiment using response surface analysis. Two carryover treatments, previous clipping or no clipping, were applied to plants for eight weeks. Tillers from these plants were planted in mixtures of the two clones over a range of frequencies and tiller densities, between 44-40 000 tillers m- 2. During the competition experiment two direct treatments, clipping or no clipping, were applied. Carryover and direct treatments were applied factorially in two replicate blocks. After ten weeks of growth plant mortality and yield of biomass and tiller number by each clone were measured in each treatment. Plant mortality was very low. The biomass and tiller yield data sets for each clone in each clipping treatment combination were analysed us ing a non-linear competition model. Every data set gave an r-2 gt 0.99. Statistical comparison of response surfaces showed significant clonal differences within each combination of carryover and direct treatments in the model parameters for both biomass and tiller numbers. The short-term outcome of competition was determined by calculating the growth rates of clones, in terms of biomass accumulation and tiller production, using the model parameter estimates. In most clipping treatments the planting densities of the competitors affected the outcome of competition. Both carryover treatment and direct treatment significantly affected the model parameter estimates of both clones and changed the equivalence coefficients of the competitive interaction. The responses to the carryover treatment were affected by the direct treatment and vice versa. Therefore, the

short-term outcome of competition and the effects of the competitor densities on the outcome were different in each of the four treatment combinations. These results may explain the high genotypic diversity previously observed in the study population of *H. lanatus*. Spatial and temporal environmental heterogeneity, e.g. in grazing levels, may cause intra-population variation in the outcome of interclonal competition and thus promote genotypic coexistence. Carryover effects from past environmental conditions will magnify this process, effectively increasing the environmental heterogeneity experienced by the population.

Bullock, J. M., A. M. Mortimer and M. Begon. 1994. Physiological integration among tillers of *Holcus lanatus*: Age-dependence and responses to clipping and competition. New Phytologist 128 (4): 737-747.

Authors' abstract: The ecological consequences of physiological integration among tillers were examined in a glasshouse experiment on the clonal grass *Holcus lanatus* L. We measured the effects of severing the internode connection between a tiller and its parent on the growth and survival of this marked tiller. The effects of three factors on the response to severing were determined using this procedure: competition with the parent plant, by comparing tillers repotted in isolation with tillers remaining in the neighbourhood of the parent; clipping treatment, comprising no clipping, clipping only the marked tiller and its daughter tillers or clipping the whole parent plant, including the marked tiller; and the change in the response with tiller age at severing, using four tiller ages (1, 2, 4 and 8 wk). These age, clipping and severing treatments were applied factorially. After 8 wk of growth the responses to severing of the marked tillers were dependent on the age and clipping treatments. Severing always decreased survival and growth (tiller production, biomass and tiller extension) of the youngest tillers (ages 1 and 2 wk), indicating that they were dependent on the parent to support their early growth. Age 4 tillers were able to support their own growth and grew best in isolation; but when grown in the parent's neighbourhood competition with the parent reduced growth, although parental support ameliorated these effects. Some of the oldest tillers (age 8 wk) showed decreased growth when unsevered. This indicated an outflow of resources to the parent and suggested that integration allowed the control and coordination of tiller growth. The pattern of the severing effects was similar in all clipping treatments, varying only in degree. There was little evidence of increased support for clipped tillers or for a change in the pattern of integration when the whole plant was clipped, except that age 8 tillers showed a continued benefit of the connection, in contrast to the positive effect of severing in the other two clipping treatments. The extension rate of the marked tiller showed complex responses to clipping and severing treatments, including effects of integration on regrowth after clipping. This experiment has shown that the growth of tillers in *H. lanatus* is highly integrated but that this integration is extremely plastic in response to tiller age and, to a lesser extent, clipping treatment.

Ceska, A. 2002. *Personal communication*. Botanist, Victoria, BC.

Ceska has observed common velvet-grass in wetter depressions and moist sites such as Uplands Park, Victoria, British Columbia. He notes this species is pervasive, prolific and

has an abundant seed bank and management will be very difficult, if not hopeless. Ceska observes that it is difficult to gauge the effect of this species because the original understory composition of Garry oak ecosystems is not known.

Clark, D. L. and M. V. Wilson. 2001. Fire, mowing, and hand-removal of woody species in restoring a native wetland prairie in the Willamette Valley of Oregon. Wetlands 21 (1):135-144.

Authors' abstract: The invasion of prairies by woody species is a worldwide conservation concern. Fire is frequently used to inhibit this invasion. However, there is little documentation of the effect of fire in wetland prairies, which are also threatened with encroachment of woody species. The present study investigated wetland species responses to experimental burning, hand-removal of woody species, and mowing with removal of cut material. The possible ecological mechanisms responsible for individualistic responses of species, including direct mortality, ability to resprout, and release from competition are considered. We also evaluated these treatments as tools for meeting restoration objectives of reducing the abundance of woody species, reducing or preventing spread of non-native pest species, and increasing or at least maintaining native species' abundance. After two years of treatments (1994 and 1996) three patterns emerged. 1) Woody species: Burning and hand-removal caused the greatest reductions in cover of woody species. Mowing with removal of cut material, however, did not reduce the cover of woody species compared to controls. As woody plant cover decreased, plant mortality increased, indicating that treatments influenced woody plant cover at least partially through mortality. 2) Native herbaceous species: Burning significantly decreased inflorescence production of *Deschampsia cespitosa*, the dominant wetland prairie grass. In contrast, burning, along with mowing, significantly increased flowering of *Juncus tenuis*. Flowering and cover of all native graminoids combined, however, showed no significant responses to treatments. Burning and hand-removal significantly promoted the cover of native forbs as a group, with *Lotus purshiana* and *Veronica scutellata* showing the greatest increases. 3) Non-native herbaceous species: Burning and hand-removal significantly reduced the cover of non-native forbs as a group and particularly reduced the cover of *Hypericum perforatum.* The number of inflorescences of non-native grasses (*Holcus lanatus* and *Anthoxanthum odoratum*) increased with hand-removal and mowing. Overall, no treatment was clearly superior in fulfilling the restoration objectives. Burning was effective in reducing woody cover and did not promote abundance of non-native herbaceous species. Burning, however, reduced the flowering of the key native grass, *Deschampsia cespitosa*. Hand-removal of woody species was also effective at reducing woody cover and promoted the abundance of some native species, but it sometimes increased the cover of non-native herbaceous species. Because mowing with removal of cut material was ineffective in reducing woody cover and tended to promote non-native herbaceous species, this treatment is not recommended as a management tool.

Clark, H., P. C. D. Newton and D. J. Barker. 1999. Physiological and morphological responses to elevated CO2 and a soil moisture deficit of temperate pasture species growing in an established plant community. Journal of Experimental Botany 50 (331): 233-242.

Authors' abstract: Periods of limited soil water availability are a feature of many temperate pasture systems and these have the potential to modify pasture plant and community responses to elevated atmospheric CO2. Using large pasture turves, previously exposed to elevated CO2 concentrations of 350 or 700 mumol mol-1 for 324 d under well-watered conditions, the morphological and physiological responses of pasture species growing at these CO2 concentrations were compared when subjected to a soil moisture deficit - and to recovery from the deficit - with those that continued to be well watered. Net leaf photosynthesis of *Trifolium repens* (C3 legume), *Plantago lanceolata* (C3) and *Paspalum dilatatum* (C4) was increased by exposure to elevated CO2, but there was no consistent effect of CO2 on stomatal conductance. At low soil moistures, net photosynthesis declined and stomatal conductance increased in these three species. There was a strong CO2 X water interaction in respect of net photosynthesis; in *Trifolium repens*, for example, elevated CO2 increased net photosynthesis by approximately 50% under well- watered conditions and this increased to over 300% when soil moisture levels reached their minimum values. Similar values were recorded for both *Paspalum dilatatum* and *Plantago lanceolata.* Potential water use efficiency (net photosynthesis/stomatal conductance) was increased by both exposure to elevated CO2 and drought. Leaf water status was measured in three species: *Trifolium repens*, *Paspalum dilatatum* and *Holcus lanatus* (C3). Total leaf water potential (psitau) and osmotic potential (psipi) were decreased by drought, but CO2 concentration had no consistent effect. psit and psipi were highest in the C4 species *Paspalum dilatatum* and lowest in the legume *Trifolium repens*. In the wet turves, rates of leaf extension of the C3 grasses *Holcus lanatus* and *Lolium perenne* at elevated CO2 were frequently higher than those at ambient CO2, but there was no effect of CO2 concentration on the rate recorded in the C4 grass *Paspalum dilatatum* or the rate of leaf appearance in the legume *Trifolium repens*. Drought reduced leaf extension rate irrespective of CO2 in all species, but in *Holcus lanatus* the reduction was less severe at elevated CO2. Immediately after the dry turves were rewatered the leaf extension rates on tillers of *Holcus lanatus* and *Lolium perenne* were higher than on tillers in the wet turves, but only at ambient CO2. Consequently, despite the greater leaf extension rate during the soil moisture deficit at elevated CO2, because of the overcompensation after rewatering at ambient CO2, total leaf extension over both the drying and rewetting period did not differ between CO2 concentrations for these C3 grass species. Further investigation of this difference in response between CO2 treatments is warranted given the frequent drying and wetting cycles experienced by many temperate grasslands.

Clay, K and V.K. Brown. 1997. Infection of *Holcus lanatus* and *H. mollis* by *Epichloe* in experimental grasslands. Oikos 79 (2): 363-370.

Authors' abstract: The infection of grasses by systemic fungal parasites in the genus *Epichhloe* was documented in six experimental grassland sites at Silwood Park, Berkshire, UK. The potential of insect herbivory acting as a selective agent favouring infection was investigated by comparing insecticide-treated and control plots within sites. The sites were established at different times from the colonization of bare ground and represented a range of grassland types occurring in close proximity. Five of 11 common

grasses were occasionally infected by *Epichloe*. *Holcus lanatus* and *H. mollis* were the most frequent hosts and infection occurred primarily in the three oldest sites. Disease levels and host density were quantified by counting all healthy and diseased inflorescences in replicated one-m-2 plots at each site. In two of the sites where *H. lanatus* was the primary host disease levels were three times higher in insecticide-treated vs control plots. *Holcus mollis* was the primary host in the other site although visible manifestations of disease were rare. However, microscopic examinations revealed that 69% of all samples were asymptomatically infected and that infections were significantly less frequent in insecticide-treated plots. While insect herbivory appears to favour infected *H. mollis*, disease incidence in *H. lanatus* was highest in insecticide- treated plots.

Cullington and Associates. 2001. Invasive species in Garry oak and associated ecosystems in British Columbia. Fact sheets: *Anthoxanthum odoratum* and *Dactylis glomerata*. Garry oak ecosystems recovery team, Victoria, BC.

These fact sheets state "Non-native grasses such as sweet vernalgrass [orchard grass] are present in most Garry oak ecosystems and may comprise over 30 percent of the vegetation". This inoformation was included in the current fact sheets but the original source of the information is not known.

De Bruyn, L., J. Scheirs and R. Verhagen. 2002. Nutrient stress, host plant quality and herbivore performance of a leaf-mining fly on grass. Oecologia 130 (4):594-599.

Authors' abstract: Environmental stresses affect plant growth and performance in nature. Host plant quality in turn affects herbivore performance and population dynamics. In view of these interactions, two major hypotheses were formulated. The plant stress hypothesis proposes that physiologically stressed plants become more susceptible to herbivores. The plant vigour hypothesis proposes that plants that grow vigorously are favourable to herbivores. Here we test the plant stress/plant vigour hypotheses for a leaf miner, *Agromyza nigripes* (Diptera; Agromyzidae), on the grass *Holcus lanatus*. We assessed larval performance (survival, developmental time, pupal mass) on grasses growing under different levels of nutrients (Hoagland solution) and drought stress, under controlled field and greenhouse conditions. Plant vigour and nutrient content were high on soils with an intermediate nutrient concentration and lower under drought stress and soil nutrient shortage and overdose. Larval performance was also highest on wet soils with intermediate nutrient supply. The results of the mining flies support the plant vigour hypothesis (density, survival and development better on vigorous plants). Herbivore performance is higher on leaves with a higher protein content.

Douglas, G.W., D. Meidinger, and J. Pojar (eds.). 2001. Illustrated Flora of British Columbia, Volume 7: Monocotyledons (Orchidaceae through Zosteraceae). Ministry of Sustainable Resource Management, British Columbia Ministry of Forests, Victoria, BC.

This comprehensive reference has excellent identification keys and detailed descriptions of vegetative and sexual morphology. This flora is the taxonomic authority for the

invasive species fact sheets (unless otherwise indicated). Douglas *et al.* describes the habitat of common velvet-grass as "mesic to dry lawns, fields, roadsides, railways and waste areas". This species has been introduced from Eurasia and is common in southwest BC and rare in other locations in BC.

Dunn, P. 1998. Prairie habitat restoration and maintenance on Fort Lewis and within the South Puget Sound prairie landscape: Final report and summary of findings. Report for the Nature Conservancy of Washington. February 1, 1998.

The report summarizes ongoing restoration efforts in prairie grasslands at Fort Lewis, Washington. This site is one of few active restoration sites in ecosystems similar to Garry oak ecosystems in Canada and provides a valuable resource for effective control methods. Invasive species management used at Fort Lewis includes prescribed burning, mechanical control and herbicides. Native species have also been replanted to this site. Common velvet-grass is a problem species at Fort Lewis. It is highly invasive and forms dense swards that exclude native plants, especially forbs. Fire is not an effective tool for controlling velvet-grass because it increases in abundance after burns even after short (2 year) burn intervals. Non-selective herbicides such as glysophate have been effective against pasture grasses but will also kill native grasses and forbs. Selective herbicides such as sethoxydim and fluazifop will kill broad-leaved invasive grasses including velvet-grass but do not harm fine-leaved grasses (e. g. *Festuca idahoensis*), sedges and dicotyledonous plants. Applications of sethoxydim on colonial bentgrass at Fort Lewis indicate that the herbicide will control but not eradicate invasive grasses. Sethoxdim and/or smothering mulch application increases the survivability of transplanted native grasses. Application of fertilizer favoured invasive grasses and should not be used for restoration in Garry oak ecosystems.

Dunwiddie, P. W. 1997. Yellow Island vegetation studies: 1997 data and analysis. The Nature Conservancy, Seattle, WA.

The report summarizes ongoing restoration efforts in prairie grasslands on Yellow Island in the San Juan Islands, Washington. This site is one of few active restoration sites in ecosystems similar to Garry oak ecosystems in Canada and provides a valuable resource for effective control methods. Invasive species management used on Yellow Island includes prescribed burning, mechanical control and herbicides. Common velvet-grass is a problem species on Yellow Island. It rapidly invades disturbed sites and becomes a dominant species before native species can establish. Prescribed fires are not an effective management tool for velvet-grass because velvet-grass increased in cover after burns. In conjunction with replanting native species, Dunwiddie recommends the use of herbicides to control invasive species.

Dunwiddie, P. W. 2002. *Personal communication*. Restoration ecologist, The Nature Conservancy, Seattle, WA. November 13, 2002.

Dunwiddie has been involved with restoration on Yellow Island, Washington. Common velvet-grass is a pest species on the island. It is easily hand pulled although this is usually

done in restoration areas where there are few remaining native species. In areas with high densities of native species, a selective herbicide, Poast, is used. Poast kills broad-leaved grasses including native species such as *Elymus glaucus* and native *Bromus spp.* However, Poast will not harm lilies unless it is applied during a drought and will not harm dicots or native thin-leaved grasses such as *Festuca idahoensis.* Poast is most effective when applied when the target grasses are at least 6" tall.

Duwensee, H. A. 1995. *Holcus lanatus* L. var. *soboliferus*, var. *nova* (Poaceae-Aveneae). Phyton 35 (2): 291-293

Author's abstract: *Holcus lanatus* var. *soboliferus* DUWENSEE, var. *nova*, includes plants with subterraneous creeping shoots (stolons). This variety occurs sporadically through the area of the species and is easily to distinguish from the stolons bearing *H. mollis* by characters of the indument and the awns.

Edge, C. P., S. A. Bell and T. W. Ashenden. 1994. Contrasting growth responses of herbaceous species to acidic fogs. Agriculture Ecosystems & Environment 51 (3): 293-299.

Authors' abstract: Plants of *Lolium perenne* L., *Holcus lanatus* L., *Lotus corniculatus* L. and *Anthoxanthum odoratum* L. were exposed to fog treatments at pH values of 2.5, 3.5, 4.5 and 5.6. There were three 4-h exposures per week providing a total of 6 mm deposition. Supplementary watering with pH 4.5 simulated acid rain provided a further 24 mm deposition per week. Plants of *Lotus corniculatus* showed reduced growth at pH 2.5 and 3.5 compared with the less acidic fog treatments and greatest dry matter accumulation at pH 4.5. In contrast, plants of the other three species showed greater dry weights in the most acidic pH 2.5 treatment in comparison with other treatments. For *H. lanatus* and *A. odoratum*, the increased dry matter production at pH 2.5 was associated with a reduced root/shoot ratio. There was a promotion of flowering stem production in the pH 2.5 treatment for *Lolium perenne* and increased numbers of flowers and buds in the pH 5.6 treatment for *Lotus corniculatus*. It is suggested that leguminous species are more susceptible to acid deposition than other plant families.

Edwards, G. R. and M. J. Crawley. 1999. Herbivores, seed banks and seedling recruitment in mesic grassland. Journal of Ecology 87 (3):423-435.

Authors' abstract: An experiment was carried out in a species-poor acid grassland to determine the effect of insect, mollusc and rabbit herbivory on the size and composition of the seed bank and on seedling recruitment from the seed bank and seed rain. From 1991 to 1997, insects and molluscs were excluded with pesticides, and rabbits with fences. Seedling recruitment was monitored over 22 months in gaps established in the vegetation in summer 1995. 2 The most common species recorded from the seed bank in early summer 1995 were dicots (17 species), but perennial grasses (five species) were numerically the most abundant (65% of total). There was no relationship between the species composition of the seed bank and the established vegetation. 3 The size of the seed bank of eight species was greater on fenced plots, a result that reflected increased

seed rain where rabbits were excluded. Insects and molluscs had no effect on the size of the seed bank of any species. The number of species in the seed bank was not affected by any of the herbivore exclusions. 4 A comparison of seedling emergence in gaps formed over the original soil with gaps where the soil had been sterilized indicated that only *Galium saxatile* and *Cytisus scoparius* recruited from the seed bank. Seedling recruitment was almost entirely derived from the recent seed rain, was dominated by the most abundant perennial grasses in the vegetation (*Festuca rubra* and *Holcus lanatus*), and had a species composition that resembled the established vegetation. Results highlight that the potential for seedling establishment in gaps to bring about vegetation change in this grassland is low. 5 Six species had higher seedling densities on rabbit-fenced plots, but the significant effect of fencing disappeared by plant maturity for most species. Survival of seedlings was lower on fenced plots where non-grazed biomass accumulated, so that after 22 months *Agrostis capillaris* was the only species with more plants present where rabbits were excluded. *Rumex acetosa* and *Stellaria graminea* showed higher seedling emergence where molluscs were excluded. More seedlings of *Rumex acetosa* were also found where insects were excluded. These invertebrate effects were still evident at plant maturity.

Eliason, S. A. and E. B. Allen. 1997. Exotic grass competition in suppressing native shrubland re-establishment. Restoration Ecology 5 (3): 245-255.

Authors' abstract: Disturbance of coastal sage scrub in southern California has led to extensive displacement of native shrubs by exotic annual grasses. The initial conversion from shrubland to exotic grassland is typically associated with disturbance caused by intense grazing, high fire frequency, or mechanical vegetation removal. While native shrubs have been shown to recolonize annual grasslands under some conditions, other annual grasslands are persistent and show no evidence of shrub recolonization. This study examined the mechanisms by which annual grasses may exclude native shrubs and persist after release from disturbance. Grass density was manipulated in experimental plots to achieve a series of prescribed densities. *Artemisia californica*, a dominant native shrub, was seeded or planted into the plots and responses to the grass density treatments were measured over two growing seasons. *A. californica* germination, first season growth, and survival were all negatively related to the density of neighboring annual grasses. The most probable mechanism underlying the reduction of first season growth and survival was depletion of soil water by the grasses. The effects of the grasses on *A. californica* were no longer significant in the second season. The results of this study indicate that Mediterranean annual grasses reduce recruitment and can persist by inhibiting postdisturbance establishment of *A. californica* from seed. Although succession alone may not return disturbed annual grasslands to their former shrubland composition, the results suggest that restoration can be achieved by using container plantings or grass removal followed by seeding.

Erickson, W. 2002. *Personal communication*. Botanist, Ministry of Forests, Victoria, BC.

Erickson has observed common velvet-grass in the northern portion of the Garry oak

range but notes the species if found primarily in wetter sites, deeper soils and pasture land. It also occurs in small seeps in bedrock-dominated landscapes and has been recorded at Government House, Victoria, British Columbia. Velvet-grass impacts rare and common native species by occupying space, commanding resources and acting as a physical barrier to distribution. Velvet-grass was found infrequently in Erickson's research plots, in association with *Rhacomitrium canescens, Mimulus guttatus* or *Trifolium wormskjoldii*.

Eurobodalla Shire Council. 2002. Yorkshire fog grass (*Holcus lanatus*) Website: www.esc.nsw.gov.au/Weeds/index.asp Accessed: November 7, 2002.

The website provides information on the ecology and control of noxious weeds in New South Wales, Australia. The site provides an excellent lay description of the grass that highlights key identification features (purplish seed head, velvety leaves) and similar species (*Anthoxanthum odoratum*). The habitat of common velvet-grass is described as wet soil with a range of light conditions from sun to semi-shade conditions. Seeds are readily spread in mud, by adhering to animals or in manure. The best control method is to remove isolated plants before they set seed. The seed bank is abundant and well established populations are very difficult to control.

Evans, R. D., R. Rimer, L. Sperry and J. Belnap. 2001. Exotic plant invasion alters nitrogen dynamics in an arid grassland. Ecological Applications 11 (5): 1301-1310.

Authors' abstract: The introduction of nonnative plant species may decrease ecosystem stability by altering the availability of nitrogen (N) for plant growth. Invasive species can impact N availability by changing litter quantity and quality, rates of N2-fixation, or rates of N loss. We quantified the effects of invasion by the annual grass *Bromus tectorum* on N cycling in an arid grassland on the Colorado Plateau (USA). The invasion occurred in 1994 in two community types in an undisturbed grassland. This natural experiment allowed us to measure the immediate responses following invasion without the confounding effects of previous disturbance. Litter biomass and the C:N and lignin:N ratios were measured to determine the effects on litter dynamics. Long-term soil incubations (415 d) were used to measure potential microbial respiration and net N mineralization. Plant-available N was quantified for two years in situ with ion-exchange resin bags, and potential changes in rates of gaseous N loss were estimated by measuring denitrification enzyme activity. *Bromus* invasion significantly increased litter biomass, the *Bromus* litter had significantly greater C:N and lignin:N ratios than did native species. The change in litter quantity and chemistry decreased potential rates of net N mineralization in sites with *Bromus* by decreasing nitrogen available for microbial activity. Inorganic N was 50% lower on *Hilaria* sites with *Bromus* during the spring of 1997, but no differences were observed during 1998. The contrasting differences between years are likely due to moisture availability; spring precipitation was 15% greater than average during 1997, but 52% below average during spring of 1998. *Bromus* may cause a short-term decrease in N loss by decreasing substrate availability and denitrification enzyme activity, but N loss is likely to be greater in invaded sites in the long term because of increased fire frequency and greater N volatilization during fire. We

hypothesize that the introduction of *Bromus* in conjunction with land-use change has established a series of positive feedbacks that will decrease N availability and alter species composition.

Fitzsimmons , J. P. and L. C. Burrill. 1993. Weeds: Common velvetgrass & German velvetgrass. PNW 441. March 1993. Website: eesc.orst.edu/agcomwebfile/edmat/PNW441.pdf Accessed: October 24, 2002.

The document was originally published by the universities of Oregon State, Washington State and Idaho, and the United States Department of Agriculture. It provides excellent, detailed species descriptions that can be understood by lay botanists including characteristics that distinguish common and German velvet-grass (the latter does not occur in Garry oak ecosystems). Common velvet-grass was introduced as an agronomic species from Europe and it is now found in lawns and pastures. Common velvet-grass seed may be introduced in contaminated turf seed, contaminated soil and/or spread by animals, machinery or wind. Once at a site, it can spread by rhizomes. Control methods that may be applicable in Garry oak ecosystems are also discussed. The best management options are to prevent the introduction of common velvet-grass, to identify invasion early and to eliminate plants before they spread. Seedlings and isolated plants are effectively controlled by herbicides or hand removal. In established swards, regular mowing, grazing or repeated plowing prevents seeding and limits the spread of common velvet-grass. Common velvet-grass is less palatable than other agronomics so grazing must be intensive in order to be effective. The best time to identify velvet-grass is in the early morning when the velvety leaves are wet with dew.

Fleming, Tracy. 2002. *Personal communication*. CRD Parks, Victoria, BC. October 25, 2002.

Fleming notes that common velvet-grass is not common in CRD Parks, Victoria, British Columbia. CRD Parks has manually removed orchard grass (*Dactylis glomerata*) around rare species in Garry oak ecosystems and this may be an option for velvet-grass.

Fransen, B. and H. De Kroon. 2001. Long-term disadvantages of selective root placement: Root proliferation and shoot biomass of two perennial grass species in a 2-year experiment. Journal of Ecology 89 (5): 711-722.

Authors' abstract: 1 The long-term benefits of root foraging in heterogeneous environments are unclear. The short duration of many previous studies may have overlooked the effects of patch depletion and root turnover, which may limit the long-term rewards of root foraging for perennial plants. 2 The benefits of root foraging were investigated for *Holcus lanatus* and *Nardus stricta* over two growing seasons. Shoot biomass of each species was measured in homogeneous nutrient-rich and nutrient-poor treatments and in a heterogeneous treatment consisting of a nutrient-rich and a nutrient-poor side, at a high and a low overall level of nutrient availability at the same patch contrast. Large initial differences in nitrate concentrations in the soil solution between the soil types disappeared so that, after several months, nitrate levels were low in all soil

types. 3 In heterogeneous treatments, *Holcus* was able to proliferate roots in the nutrient-rich side compared with the nutrient-poor side, but only at the high overall level of nutrient availability. *Nardus* did not selectively place roots in the nutrient-rich side of the heterogeneous treatment at either nutrient level. 4 Root longevity, as determined by minirhizotron observations, revealed that roots of *Holcus* tended to be shorter lived than those of *Nardus*, and to live longer in nutrient-poor soils. 5 Initially, *Holcus* produced more shoot biomass in the heterogeneous treatments, at both overall levels of nutrient availability, than expected from values in the homogeneous treatments, but this advantage disappeared by the end of the first growing season and, after 2 years, shoot biomass in the heterogeneous treatments was much less than expected. At the high overall level of nutrient availability, *Holcus* shoot biomass was not significantly greater than that produced in the homogeneous nutrient-poor treatment. In contrast, shoot biomass of *Nardus* in the heterogeneous treatment was similar to the expected value, both after the first and second growing seasons. 6 For *Holcus*, fast root proliferation and presumably a high nutrient uptake resulted in increased shoot biomass in the short term, but this was then curtailed by rapid patch depletion and high losses due to a limited root life span. We discuss the implications for the long-term rewards of root proliferation in perennial species of heterogeneous environments.

Fransen, B., J. Blijjenberg and H. de Kroon. 1999. Root morphological and physiological plasticity of perennial grass species and the exploitation of spatial and temporal heterogeneous nutrient patches. Plant and Soil 211 (2): 179-189.

Authors' abstract: Root morphological and physiological characteristics of four perennial grass species were investigated in response to spatial and temporal heterogeneous nutrient patches. Two species from nutrient-rich habitats (i.e. *Holcus lanatus* and *Lolium perenne*) and two species from nutrient-poor habitats (i.e. *Festuca rubra* and *Anthoxanthum odoratum*) were included in the study. Patches were created by injecting equal amounts of nutrient solution into the soil either on one location (i.e. spatial heterogeneity) or on several, alternating locations (i.e. temporal heterogeneity) within the pot. The consequences of changes in root morphology and the implications for the exploitation of the nutrient patches by individual plants were quantified by the amount of 15N captured from the enriched patches. The effects of nutrient heterogeneity on the acquisition of nutrients by species were determined by comparing the total nitrogen and phosphorus acquisition of the species in the two heterogeneous habitats with the total nitrogen and phosphorus acquisition in a homogeneous treatment. In this homogeneous treatment the same amount of nutrient solution was supplied homogeneously over the soil surface. The experiment lasted for 27 days and comprised one harvest. In response to the spatial enrichment treatment, all species produced significantly more root biomass within the enriched patch. The magnitude of the response was similar for species from nutrient-rich and nutrient-poor habitats. In contrast to this response of root biomass, root morphology, including specific root length, branching frequency and mean lateral root length was not affected by the treatments. In response to the temporal enrichment treatment, all species were able to increase the nitrogen uptake rate per unit of root biomass. The species from nutrient-poor habitats had, on average, higher uptake rates per unit root biomass than the species from nutrient-rich habitats, but the magnitude of the

response did not differ between the species. These results question the general validity of the assumptions that root foraging characteristics differ among species from nutrient-rich and nutrient-poor habitats. As a result of these root responses, all species captured an equal amount of 15N from the spatial and temporal enriched nutrient patches and all species acquired significantly more nitrogen in the heterogeneous treatments than in homogeneous treatment. Hence, the ability to exploit local and temporal nutrient heterogeneity does not appear to differ between species from nutrient-rich and nutrient-poor habitats, but is achieved by these species in different ways. The ecological implications of these differences are discussed.

Garden, D. L., G. M. Lodge, D. A. Friend, P. M. Dowling and B. A. Orchard. 2000. Effects of grazing management on botanical composition of native grass-based pastures in temperate south-east Australia. Australian Journal of Experimental Agriculture 40 (2): 225-245.

Authors' abstract: Grazing management strategies to alter botanical composition of native pastures were investigated at 4 locations in the high rainfall zone of south-east Australia, including Tasmania. These studies were conducted as part of the Temperate Pasture Sustainability Key Program, which evaluated the effects of grazing management on a wide range of pasture types between 1993 and 1996. Pastures in this study were based on *Aristida ramosa-Bothriochloa macra, Microlaena stipoides-Austrodanthonia* spp. or *Themeda triandra-Austrodanthonia* spp. Seasonal rests, increased grazing pressure in spring, mob stocking and cutting for hay were compared to continuous grazing at all sites. In addition, specific local treatments were tested at individual sites. Changes in composition resulting from the treatments were minimal at most sites. This may have been due to a combination of the inherent stability of the pastures, the relatively short duration of the experiments, and the drought conditions experienced, which minimized differences between treatments. Some strategies to alter composition of natural pastures are suggested. In the *Aristida-Bothriochloa* pasture there was a general decrease in *Aristida* and an increase in *Bothriochloa*, which was largely unaffected by the type of grazing management applied. The combination of drought conditions and increasing grazing pressure was sufficient to alter composition without specific management strategies being necessary. In the *Themeda-Austrodanthonia* pasture, resting in spring, 12-month rests or cutting for hay (which involved a spring rest) allowed *Themeda* to increase in the pasture. The *Microlaena-Austrodanthonia* pastures were very stable, especially where annual grass content was low. However, certain treatments allowed *Microlaena* to increase, a result which is regarded as being favourable. The major effects in these latter pastures were on undesirable species. *Vulpia* spp. were reduced by resting in autumn and increased spring grazing pressure, while *Holcus lanatus* was increased dramatically by resting in spring and was also increased by resting in autumn or winter, but only when conditions were suitable for growth of this species. In many cases, treatment differences were only expressed following recovery from drought, showing that timing of grazing management to achieve change is critical.

Gayton, Don. 2002. *Personal communication*. Grasslands Ecologist, Ministry of Forests, Nelson, BC. October 10, 2002.

Gayton was only vaguely familiar with common velvet-grass from various casual trips to Garry oak ecosystems, and had no direct knowledge of autecology or control. He suggests minimising soil disturbance would help prevent invasion and spread of the species.

Goodwin, M. J., R. J. Parkinson, E. N. D. Williams and J. R. B. Tallowin. 1998. Soil phosphorus extractability and uptake in a *Cirsio- Molinietum* fen-meadow and an adjacent *Holcus lanatus* pasture on the culm measures, north Devon, UK. Agriculture Ecosystems & Environment 70 (2-3):169-179

Authors' abstract: The seasonal pattern of extractable soil P and soil solution P was determined for topsoil samples taken from a *Cirsio- Molinietum* fen-meadow community, and also for an adjacent agriculturally improved pasture in Devon, UK. Phosphorus concentration was investigated using three methods during 1993; Olsen's reagent (sodium bicarbonate) for soil P, centrifuging and polymeric suction cups for soil solution P. Solutions were extracted at two-weekly intervals during the spring and at monthly intervals during the summer. Phosphorus removed from both sites by centrifuging was in the range 5-30 mug dm-3 soil, in comparison with 1-6 mg kg-1 for Olsen P. Olsen P on the *Cirsio-Molinietum* was significantly lower than on the improved pasture in mid-March and mid-June. The concentration of P in soil solution removed by suction cups was below the level of detection (<2 mug dm-3) on the *Cirsio-Molinietum*. Suction cup P on the improved pasture peaked in April and May at 16-19 mug dm-3 soil. Herbage yield and P concentration were measured throughout the growing season. Above-ground standing crop was greater on the *Cirsio-Molinietum* than the improved pasture at the beginning of the grazing season, because of the large litter component on the former. Total P content of this material was only 1.81 kg P ha-1 on the *Cirsio-Molinietum*, in comparison with 5.58 kg P ha-1 on the improved pasture. Phosphorus concentration of plant material obtained by repeated defoliation was approximately 1.0 mg P g-1 DM on the *Cirsio-Molinietum*, whereas a clear seasonal trend, peaking at 3.5 mg P g-1 DM, was observed on the improved pasture. Phosphorus concentration of litter, grass and sedge from ungrazed plots on the *Cirsio-Molinietum* indicated distinct seasonal variations for the grass, with no seasonal pattern for the sedge component.

Gordon, D. R. and K. J. Rice. 1993. Competitive effects of grassland annuals on soil water and blue oak (*Quercus douglasii*) seedlings. Ecology 74(1): 68-82.

Gordon and Rice experimentally tested the impact of four nonnative annual plants on soil water availability and the growth of adjacent blue oak seedlings. Two forbs (*Erodium botrys* and *Hemizonia luzulaefolia*) and two grasses (*Bromus diandrus* and *B. mollis*) were sown at different densities around one acorn. Gordon and Rice found that survivorship of oak seedlings was negatively impacted by soil water depletion. The nonnative annuals had varying degrees of impact on oak seedlings depending on the phenology and root length of the annual.

Hamilton, J. G., C. Holzapfel and B. E. Mahall. 1999. Coexistence and interference

between a native perennial grass and non-native annual grasses in California. Oecologia 121 (4): 518-526.

Authors' abstract: Little is known about the potential for coexistence between native and non-native plants after large-scale biological invasions. Using the example of native perennial bunchgrasses and non-native annual grasses in California grasslands, we sought to determine the effects of interference from non-native grasses on the different life stages of the native perennial bunchgrass *Nassella pulchra*. Further, we asked whether *N. pulchra* interferes with non-native annual grasses, and whether competition for water is an important component of these interspecific interactions in this water-limited system. In a series of field and greenhouse experiments employing neighbor removals and additions of water, we found that seedling recruitment of *N. pulchra* was strongly seed-limited. In both field and greenhouse, natural recruitment of *N. pulchra* seedlings from grassland soil was extremely low. In field plots where we added seeds, addition of water to field plots increased density of *N. pulchra* seedlings by 88% and increased total aboveground *N. pulchra* seedling biomass by almost 90%, suggesting that water was the primary limiting resource. In the greenhouse, simulated drought early in the growing season had a greater negative effect on the biomass of annual seedlings than on the seedlings of *N. pulchra*. In the field, presence of annuals reduced growth and seed production of all sizes of *N. pulchra*, and these effects did not decrease as *N. pulchra* individuals increased in size. These negative effects appeared to be due to competition for water, because *N. pulchra* plants showed less negative pre-dawn leaf water potentials when annual neighbors were removed. Also, simply adding water caused the same increases in aboveground biomass and seed production of *N. pulchra* plants as removing all annual neighbors. We found no evidence that established *N. pulchra* plants were able to suppress non-native annual grasses. Removing large *N. pulchra* individuals did not affect peak biomass per unit area of annuals. We conclude that effects of interference from non native annuals are important through all life stages of the native perennial *N. pulchra.* Our results suggest that persistence of native bunchgrasses may be enhanced by greater mortality of annual than perennial seedlings during drought, and possibly by reduced competition for water in wet years because of increased resource availability.

Hanley, M. E., M. Fenner and P. J. Edwards. 1996. The effect of mollusc grazing on seedling recruitment in artificially created grassland gaps. Oecologia 106 (2): 240-246

Authors' abstract: Two experiments conducted in spring and autumn 1992 examined the effect of mollusc grazing on seedling regeneration from natural grassland seedbanks by creating artificial gaps in plots in a grassland sward. Molluscs were excluded from half the gaps by application of molluscicide. Mollusc grazing in both the spring and autumn experiment significantly reduced seedling recruitment, though the intensity of grazing was greatest in autumn. Recruitment of five species was markedly influenced by molluscicide application. In spring, plots from which molluscs were excluded contained significantly more seedlings of *Chenopodium polyspermum* and *Ranunculus acris.* In the autumn, exclusion of molluscs resulted in increased populations of *R. acris, Stellaria graminea* and *Rumex acetosa. Cerastium holosteoides* populations were greatest in autumn grazed plots. Other species, notably the grasses *Holcus lanatus* and *Agrostis*

capillaris and the legume *Trifolium repens* were unaffected by molluscicide application. Species diversity was significantly decreased by molluscicide application in the autumn. Gap size significantly affected the recruitment of two species. *Ranunculus acris* populations were significantly higher in small gaps in both spring and summer, while *Chenopodium* recruitment in the spring was greater in small gaps. Gap size also significantly influenced the risk of mollusc attack on *Ranunculus* as molluscs appeared to show an aggregative feeding response in the high seedling density small gaps. Selective grazing of vulnerable seedlings by molluscs may influence the eventual relative proportions of the species present and so provide a potent mechanism in shaping community composition in grasslands.

Hitchcock, C. L. and A. Cronquist. 1973. Flora of the Pacific Northwest: an illustrated manual. University of Washington Press, Seattle, WA.

This comprehensive reference provides keys for identification and detailed, technical descriptions of vegetative and sexual morphology. Taxonomy is given including the Latin origin of the nomenclature. Common velvet-grass is widely established in North America especially west of the Cascade Mountains. It was probably introduced as a meadow grass although it is less palatable than other range species.

Hubert, J. 2001. The influence of *Scheloribates laevigatus* (Acari: Oribatida) on decomposition of *Holcus lanatus* litter. Acta Societatis Zoologicae Bohemicae 65 (2):77-80.

Author's abstract: The influence of the panphytophagous oribatid mite *Scheloribates laevigatus* (C. L. Koch, 1835) on the decomposition of grass litter (*Holcus lanatus*) was tested in microcosms under laboratory conditions. *Scheloribates* is known to be a fungivorous grazer. The mites fed on fungi growing in the microcosm in soil and on litter. The weight loss of litter was significantly higher in microcosms with 50 mites than without mites (0.035 g and 0.031 g, respectively) after 20 days of experiment. Pieces of fungal mycelium were ingested, the fungal cell contents were digested, while the fungal cell walls were not. The mechanisms of the interaction mites - fungi - litter decomposition and possible interpretation of this interaction to outdoor conditions are discussed.

Hubert, J., A. Kubatova and J. Sarova. 2000. Feeding of *Scheloribates laevigatus* (Acari: Oribatida) on different stadia of decomposing grass litter (*Holcus lanatus*). Pedobiologia 44 (5):627-639.

Authors' abstract: The feeding of the panphytophagous mite *Scheloribates laevigatus* on litter of the abundant meadow grass *Holcus lanatus* was studied in laboratory experiments. The micro-anatomy of the digestive tract and the isolation of fungi from the microcosms, the mite surface and the digestive tract were used to compare the feeding on dried-remoistened leaves, representing the initial stadium of decomposition, and partly decomposed litter. Additionally, food preference tests between sterilised litter and dried-remoistened leaves and exposition of litter and dried-remoistened leaves on soil surface

were used. *Scheloribates laevigatus* fed on the fungi growing on the dried and remoistened grass leaves in the initial stadium of grass litter decomposition. The crashed and partly destroyed fungal hyphae formed a food bolus in the mesenteron. No leave pieces were observed in the food boli. The *Scheloribates laevigatus* individuals feeding on grass litter in a later decomposition stadium consumed plant debris, spores and fungal mycelium. Litter was less preferred by *Scheloribates laevigatus* than the dried-remoistened leaves in the food preference tests. The *Scheloribates laevigatus* choice between the litter and the dried-remoistened leaves was influenced by fungal communities. The sterilisation of leaves influenced the mite choice. The sterilised leaves were not preferred in comparison to the non- sterilised ones in the preference tests. The exposition of leaves and litter on soil surface before the experiment had no influence on the mite choice.

Hutchings, M. J. and K. D. Booth. 1996. Studies on the feasibility or re-creating chalk grassland vegetation on ex-arable land. I. The potential roles of the seed bank and the seed rain. Journal of Applied Ecology 33 (5): 1171-1181.

Authors' abstract: 1. This study is an investigation of the potential of the seed bank and the seed rain to promote the re-establishment of chalk grassland vegetation on an ex-arable site which had not been cultivated for 10 years. Comparisons are drawn with the composition of the seed bank as recorded in a study undertaken close to the current site 6 years after cultivation ceased. 2. The seed bank had the following composition: 46-6% grass seeds, 38-6% perennial forbs, 8.4% biennial forbs and 6.3% annual forbs. In comparison, annual forbs had accounted for 49.5% of the seed bank 6 years after cultivation ceased. The seed bank was concentrated near the top of the soil profile and grass seeds showed a more marked decline in abundance with depth than forb species. However, common annual forb species mostly germinated from the lower soil strata. The common grasses and perennial forbs were species with wide ecological amplitudes, characteristic of fertilized, neutral grassland. 3. Only 20 of the 68 forb species recorded in the seed bank were characteristic components of adjacent ancient chalk grassland. These species accounted for less than 20% of the total forb seed bank. Only two out of 11 recorded grass species were characteristic of the ancient chalk grassland, and these accounted for only 0.3% of all grass seedlings. The grass component of the seed bank was dominated by *Agrostis stolonifera*. 4. The species richness of the seed bank has increased in recent years due mainly to acquisition of seeds of non-annuals. However, species characteristic of the ancient chalk grassland have made little contribution either to the seed bank or to the vegetation growing on the site. Those chalk grassland species which were most abundant in the seed bank tended to be short-lived species and they occurred mainly at the margins of the ex-arable site, close to the adjacent chalk grassland. Even here they rarely accounted for more than 20% of the germinable seed bank. They were strongly concentrated at the soil surface, indicating their deposition since cultivation ceased. 5. *Agrostis* spp., *Phleum pratense* and *Holcus lanatus* accounted for over 50% of the recorded seed rain. Of the commonly trapped species, analyses of mean dispersal breadths indicated that forb species characteristic of the adjacent chalk grassland would be comparatively slow invaders of ex-arable habitats. 6. The vegetation on transects across the ex-arable site contained few of the species which occurred in the adjacent old

chalk grassland. Chalk grassland species were more abundant in vegetation at the margins of the ex-arable site, but even here similarity indices between the ex-arable vegetation and the chalk grassland vegetation were normally below 25%. 7. The slow invasion of species from the adjacent chalk grassland into this ex-arable site, which is ideally placed for their colonization, suggests that seeds of such species will often need to be artificially introduced to prevent ex-arable sites becoming dominated by fast-growing more weedy species. Further management would also be necessary to prevent more weedy species subsequently invading and eliminating the chalk grassland species.

Iqbal, M. Z. 1994. Yield responses of some field-grown plants subjected to low degree of atmospheric pollution during different growing periods. Ekologia Polska 40 (4): 511-525.

Author's abstract: All the species (*Festuca rubra* L., *Agrostis tenuis* Sibth., *Bromus mollis* L., and *Holcus lanatus* L.) showed noticeably higher yield at the polluted as compared to clean site, particularly during prolonged periods in the summer. The chemical analysis of *Festuca* plants showed higher levels of anions and cations at the polluted site, particularly in the aerial parts.

Isselstein, J., J. R. B. Tallowin and R. E. N. Smith. 2002. Factors affecting seed germination and seedling establishment of fen-meadow species. Restoration Ecology 10 (2): 173-184.

Authors' abstract: Availability of seeds and provision of "safe sites" for seedling recruitment are essential for successful restoration of seminatural grassland communities. Inability to provide species-specific conditions for seedling recruitment appears to be a major factor limiting establishment of fen-meadow species on restoration sites. This contention was tested in the field for both germination and establishment conditions for a selection of fen-meadow species. A *Cirsio-Molinietum* fen meadow and an agriculturally semi-improved species-poor grass dominated rush pasture were used. Seeds of *Carex ovalis, Cirsium dissectum, Molinia caerulea, Succisa pratensis,* and *Holcus lanatus* were sown onto treatments comprising either irrigation or no irrigation, presence or absence of existing vegetation canopy, and presence or absence of soil disturbance. Germination of all except *H. lanatus* was higher in the fen meadow than in the rush pasture. The fen-meadow site was less susceptible to drought, provided more light to the seed environment, and showed a stronger day-night variation in relative humidity compared with the rush pasture. All the fen- meadow species responded strongly to the experimental treatments, whereas *H. lanatus* showed only a small response. Soil disturbance was the major factor that increased germination. Removal of the vegetation canopy improved germination only in *S. pratensis.* Conditions affecting survival of seedlings were different from those affecting seed germination. Seedling survival was greater on the fen-meadow site than on the rush pasture. Canopy presence was the major factor that reduced seedling survival. Few seedlings survived in the presence of the rush pasture canopy. Irrigation and soil disturbance were of minor importance for seedling survival on both sites. Safe sites for seed germination and seedling establishment of fen-meadow species existed on the fen meadow even without soil disturbance and gap

creation. Safe sites for seedling recruitment were not present in the rush pasture. The need for species-specific definition of safe site characteristics at the two stages of seedling recruitment (i.e., for seed germination and for seedling survival) was demonstrated. The implications of these findings for restoration of seminatural grasslands are discussed.

Jesson, L., D. Kelly and A. Sparrow. 2000. The importance of dispersal, disturbance, and competition for exotic plant invasions in Arthur's Pass National Park, New Zealand. New Zealand Journal of Botany 38 (3): 451-468.

Authors' abstract: This study investigated the effects of disturbance, dispersal, and plant competition on exotic plant invasion. An assessment of the change in species distributions in the Mingha Valley, Arthur's Pass National Park, over five years showed that many species had increased in range, suggesting that dispersal had limited the distribution of these species. The dispersal barrier was removed experimentally by transplanting plants and seeds of *Anthoxanthum odoratum, Holcus lanatus, Cerastium fontanum,* and *Hieracium pilosella* into undisturbed areas. Although transplants of *A. odoratum, H. lanatus,* and *H. pilosella* could survive without disturbance, it was essential for the establishment from seed in all four species. These species were therefore limited by the absence of disturbance. A survey of the plant distribution in the Mingha and Edwards Valleys found many exotic species associated with hut, track, and river disturbance regimes. The association of exotic plants with disturbances may be due to the role of disturbance as a window through the barriers of competition, dispersal, and abiotic barriers. The success of these exotic plants in New Zealand seems largely due to success of seedlings of exotic species establishing in areas disturbed by human activity.

Kidd, P. S. and J. Proctor. 2000. The growth response of ecotypes of *Holcus lanatus* L. from different soil types in northwestern Europe to phenolic acids. Plant Biology 2 (3): 335-343.

Authors' abstract: Phenolics are often discussed in relation to either allelopathy or to herbivory. This work, however, was undertaken to determine if phenolic acids benefit the growth of plants in very acid soils. We here report racial differences in the phenolic acid concentrations of the important plant species found in five sites within Central Scotland which covered a wide range in soil acidity from very acid (organic peats) to mildly acid (calcareous), and describe the racial differences in the growth response of *Holcus lanatus* L. to phenolic acids with increasing acidity. The total concentrations of phenolic acids in the ecotypes of important species were correlated with the total concentrations found in their respective soils. In general, the most phenolic-rich ecotypes of the five came from the organic acid soils (Flanders Moss (FM) and Sheriffmuir (SMB)). However, with the exception of ferulic acid which was a major component of both acid soils and their associated vegetation, individual simple phenolic acids extracted from either plants or soils were not consistently correlated. The addition of dry plant material collected from the five sites (0.5 g plant material 100 g-1 soil) to the acid-organic Flanders Moss (FM) soil stimulated the growth of two ecotypes of *Holcus* (acid-mineral Sheriffmuir (SMM), calcareous Kinloch Rannoch (KR)) but the same litter addition in non-organic, less acidic

or calcareous soil inhibited growth of these ecotypes. In hydroponic solutions, growth response of Flanders Moss (FM) and Kinloch Rannoch (KR) to pH and phenolic acid mixtures was interdependent: in acid solutions (pH 4.0) but not at pH 6.5 root elongation rates (RER) of both ecotypes, and shoot elongation rates (SER) of Flanders Moss (FM), increased after treatment with a mixture of seven commonly occurring phenolic acids.

Kirkham, F. W., J. O. Mountford and R. J. Wilkins. 1996. The effects of nitrogen, potassium and phosphorus addition on the vegetation of a Somerset peat moor under cutting management. Journal of Applied Ecology 33 (5): 1013-1029.

Authors' abstract: 1. A range of nitrogen (N), phosphorus (P) and potassium (K) fertilizer treatments was applied for 4 years in a randomized block experiment to a species-rich hay meadow on peat soil, within the Somerset Moors and Levels Environmentally Sensitive Area. 2. The percentage composition of each species present was recorded in May and October each year on plots cut for hay, followed by further cuts of aftermath growth. The effects on species richness, diversity and dominance were analysed, and ordination techniques were used to investigate the effects of fertilizers on plant community composition. Data for mean annual biomass production are also presented. 3. Botanical results were compared with those of a concurrent experiment where aftermath growth was grazed. 4. P was more important than N in determining both biomass production and botanical change. In both cases, the effects were small when substantial amounts of N and K were applied without P, but when high rates of P were included biomass increased very significantly and species diversity was severely reduced, with *Holcus lanatus, Rumex acetosa* and *Lolium perenne* dominating. 5. *Lolium perenne* was not increased by N and modest rates of P in the absence of aftermath grazing, but dominated all fertilized plots when aftermath grazing was maintained. *Agrostis canina* came to dominate plots receiving 200 kg ha-1 of N with modest rates of P and K in the absence of aftermath grazing, but was negatively associated with N where the aftermath was grazed. 6. *Trifolium pratense* became very abundant where P and K were applied with nil or 25 kg ha-1 of N each year, both with and without aftermath grazing, but all legumes were suppressed at high rates of N, particularly in conjunction with high P. 7. Substantial botanical change occurred on unfertilized plots as a result of the cessation of aftermath grazing. These plots became dominated by *Plantago lanceolata*, with significant increases in *Leontodon hispidus* and *L. autumnalis*.

Kirkham, F. W. and J. R. B. Tallowin. 1995. The influence of cutting date and previous fertilizer treatment on the productivity and botanical composition of species-rich hay meadows on the Somerset levels. Grass and Forage Science 50 (4): 365-377.

Authors' abstract: The effects on productivity, botanical and chemical composition of cutting species-rich hay meadows in Somerset on four different dates between late May and early September in two consecutive years, were measured. Plots that had received 200 kg N ha-1 year-1 with low levels of P and K for the previous 5 years were compared with plots that had previously received no fertilizer. Previous fertilizer treatment increased metabolizable energy (ME) production only with cutting in May. Dry-matter (DM) yield increased significantly with date of cutting until August, whereas ME value

declined correspondingly. There was no difference in either yield or quality of herbage cut between August and September. ME output per hectare increased very significantly between May and July, but showed no further change between cutting dates. Botanical diversity was reduced by cutting in May after 1 year and by cutting in either May or September after 2 years, and was greatest with cutting in August. The dominance of *Holcus lanatus* on previously fertilized plots increased after cutting in either May or September. The contribution to vegetation cover of species that regenerate primarily by seed, including annuals, was greatly influenced by cutting date in preceding years, whereas species that regenerate vegetatively were not affected.

Krahulec, F., H. Skalova, T. Herben, V. Hadincova, R. Wildova and S. Pechackova. 2001. Vegetation changes following sheep grazing in abandoned mountain meadows. Applied Vegetation Science 4 (1): 97-102.

Authors' abstract: Sheep grazing was investigated as an alternative to traditional management of meadows in the Krkonose Mts. Until the second World War these meadows were mown in mid-summer and grazed by cattle for the rest of the season. Subsequent abandonment of the meadows has resulted in decreasing species richness. Degradation phases of the former communities have been replacing the original species-rich vegetation. Significant changes were apparent six years after the introduction of sheep grazing. In grazed plots the proportion of dominant herbs (*Polygonum bistorta* and *Hypericum maculatum*) decreased and grasses (*Deschampsia cespitosa, Festuca rubra, Agrostis capillaris, Anthoxanthum alpinum*) increased. The increase in grasses was positively correlated with an increase in several herbs. The proportion of some herbs increased despite being selectively grazed (*Adenostyles alliariae, Melandrium rubrum, Veratrum lobelianum*). Any losses caused by grazing of mature plants were probably compensated by successful seedling establishment. Cessation of grazing resulted in significant changes in vegetation within three years. The cover of nitrophilous tall herbs and grasses (e.g. *Rumex alpestris, Holcus mollis, Deschampsia cespitosa, Geranium sylvaticum*) increased in the abandoned plots. In the plots grazed for nine years cover of species-rich mountain meadow species increased (e.g. fine-leaved grasses, *Campanula bohemica, Potentilla aurea, Viola lutea, Silene vulgaris*). The main conservation risk is the expansion of a competitive species with low palatability, *Deschampsia cespitosa*. This species can be suppressed by a combination of grazing and mowing. In order for grazing to be effective, the number of sheep should be proportional to meadow production. This may be difficult to maintain as production is variable and is impossible to predict at the beginning of a growing season. A large part of the biomass may thus remain intact in some years. Negative effects of grazing may be, at least partly, eliminated by a combination of cutting and grazing.

Kuske, C. R., L. O. Ticknor, M. E. Miller, J. M. Dunbar, J. A. Davis, S. M. Barns and J. Belnap. 2002. Comparison of soil bacterial communities in rhizospheres of three plant species and the interspaces in an arid grassland. Applied and Environmental Microbiology 68 (4): 1854-1863.

Authors' abstract: Soil bacteria are important contributors to primary productivity and

nutrient cycling in arid land ecosystems, and their populations may be greatly affected by changes in environmental conditions. In parallel studies, the composition of the total bacterial community and of members of the Acidobacterium division were assessed in arid grassland soils using terminal restriction fragment length polymorphism (TRF, also known as T-RFLP) analysis of 16S rRNA genes amplified from soil DNA. Bacterial communities associated with the rhizospheres of the native bunchgrasses *Stipa hymenoides* and *Hilaria jamesii*, the invading annual grass *Bromus tectorum*, and the interspaces colonized by cyanobacterial soil crusts were compared at three depths. When used in a replicated field-scale study, TRF analysis was useful for identifying broad-scale, consistent differences in the bacterial communities in different soil locations, over the natural microscale heterogeneity of the soil. The compositions of the total bacterial community and Acidobacterium division in the soil crust interspaces were significantly different from those of the plant rhizospheres. Major differences were also observed in the rhizospheres of the three plant species and were most apparent with analysis of the Acidobacterium division. The total bacterial community and the Acidobacterium division bacteria were affected by soil depth in both the interspaces and plant rhizospheres. This study provides a baseline for monitoring bacterial community structure and dynamics with changes in plant cover and environmental conditions in the arid grasslands.

Marcuvitz, S. and R. Turkington. 2000. Differential effects of light quality, provided by different grass neighbours, on the growth and morphology of *Trifolium repens* L. (white clover). Oecologia 125 (2): 293-300.

Authors' abstract: The ability to respond in a specific manner to different light conditions imposed by different species of grass is a major factor contributing to white clover persistence in pastures. Gaps in a pasture provide light with a higher red:far-red ratio (R:FR) and higher photosynthetic photon flux density (PPFD) than the light filtered through neighbours. White clover (*Trifolium repens* L.) was grown under different light conditions in ways that tried to simulate as closely as possible some of the light conditions experienced in a natural field situation, being partially shaded and receiving light reflected from neighbouring grasses. The objective was to determine specifically if the mere presence of neighbouring grasses could influence the growth and morphology of white clover individuals without physically contacting them, and thereby send a signal of impending competition. In the first experiment, white clover was subjected to shading cast from three different grass species. There were differences in both the quantity and quality of light received under the various grass canopies. The canopies reduced overall growth and branching of clones, while increasing the length of and biomass allocation to petioles. *Lolium perenne* L. canopy shade had different effects compared to *Holcus lanatus* L. or *Dactylis glomerata* L., but between the latter two species, no differences were detected. In the second experiment, light reflected from grass neighbours was provided simultaneously with direct light. There was a strong increase in FR and a resulting decrease in the R:FR due to neighbouring *D. glomerata*, but few consistent effects on white clover growth and morphology; there was evidence of phototropic movement by the leaves. We show that plants must experience partial shading, and not just reflected light, in order to alter their morphology in response to the presence of different species of grass neighbours.

Mehrhoff, L. A. and R. Turkington. 1996. Growth and survival of white clover (*Trifolium repens*) transplanted into patches of different grass species. Canadian Journal of Botany 74 (8): 1243-1247.

Authors' abstract: Previous studies on *Trifolium repens* L. showed differentiation with respect to neighbouring plant species and local environmental conditions. In this study, we conducted a series of reciprocal transplants among and within different pastures and among neighbouring grass species (*Lolium perenne* L., *Dactylis glomerata* L., and *Holcus lanatus* L.). While the presence of a grass neighbour decreased survival and growth of *T. repens*, no evidence of differentiation by *T. repens* to either local environmental conditions or to neighbouring grass species was found. We suggest that *T. repens*, in systems like our study pastures that have small, transient grass patches, may show inconsistent and ephemeral responses to the presence of neighbouring plants, whereas in other systems with larger grass patch size and a longer period of exposure to selection processes, *T. repens* show fine-scale biotic differentiation to neighbouring grass species.

Pakeman, R. J., J. P. Attwood and J. Engelen. 1998. Sources of plants colonizing experimentally disturbed patches in an acidic grassland, in eastern England. Journal of Ecology 86 (6): 1032-1041.

Authors' abstract: 1. The sources of propagules for regeneration in an acidic grassland were identified from analysis of differences in colonization between plots subject to surface (0-5 cm) soil disturbance and plots where surface soil had been replaced by 'seed-free' soil from deeper soil horizons (30-35 cm), and between plots with and without the removal of rabbit pellets. 2. After 1 year, 10 species had a significantly higher cover on plots where the seed bank had been left intact. These included *Agrostis capillaris* (the dominant species prior to disturbance), *Myosotis arvensis* and *Veronica arvensis*. 3. Five species, including *Sagina apetala*, *Senecio jacobaea* and *Veronica arvensis*, showed significantly higher cover on plots where rabbit pellets were left in situ. 4. From calculations it appeared that rabbit-dispersed seeds accounted for 15% of the developing higher plant cover, other means of dispersal from outside the plot accounted for 40%, and regeneration from the seed bank accounted for 45%. 5. Similar calculations suggested that three higher plant species, *Geranium molle*, *Myosotis arvensis* and *Senecio jacobaea*, appeared to depend most on non-rabbit dispersed seed for colonization of bare ground. 6. High concentrations of *Urtica dioica* in pellets contrasted with its poor establishment in the experiment. However, the other common species in the pellets, *Sagina apetala*, *Senecio jacobaea* and *Veronica arvensis*, all established in greater numbers on the plots where the pellets were not removed. 7. Seed bank content correlated well with the pattern of regeneration for *Agrostis capillaris*, *Holcus lanatus*, *Myosotis arvensis* and *Veronica arvensis*. However, removal of the seed bank did not have a significant effect on the regeneration of either of the most common species in the seed bank, *Rumex acetosella* and *Sagina apetala*. 8. No species appeared to be reliant on only one mechanism for regeneration from seed in disturbed areas in this community.

Pedrol, N., P. Ramos and M.J. Reigosa. 2000. Phenotypic plasticity and acclimation to water deficits in velvet-grass: A long-term greenhouse experiment. Changes in leaf morphology, photosynthesis and stress-induced metabolites. Journal of Plant Physiology 157 (4): 383-393.

Authors' abstract: Wild velvet-grass (*Holcus lanatus*) collected from a natural population along a drought gradient, previously demonstrated as genetically homogeneous, was studied for phenotypic plasticity and acclimation mechanisms to water deficits. A three months greenhouse experiment was designed with plants submitted to nine levels of water availability, three months being the usual length of summer drought in field conditions. Aboveground biomass, total soluble proteins, free proline, free polyamines, leaf morphology, stomatal and hair characteristics, and net photosynthetic rates were analysed, and their significance discussed. Moderate drought did not damage the velvet-grass, and the plants grew better than without water limitation. Water stress-typical responses were shown as time and severity dependent in all the measured parameters. Lowest water availability treatments induced significative increase in free proline and soluble protein contents, as well as reductions in leaf size and aboveground biomass. Spermidine contents rose significatively in the most severe water stress. Furthermore, velvet-grass acclimated progressively to long-term water limitation.

Pickart, A. J., L. M. Miller and T. E. Duebendorfer. 1998. Yellow bush lupine invasion in northern California coastal dunes I. Ecological impacts and manual restoration techniques. Restoration Ecology 6 (1): 59-68.

Authors' abstract: We studied the ecological effects of the invasion of coastal dunes by *Lupinus arboreus* (yellow bush lupine), an introduced species, and used the results to develop manual restoration techniques on the North Spit of Humboldt Bay. Vegetation and soil data were collected in five vegetation types representing points along a continuum of bush lupine's invasive influence. We collected data on the number and size of shrubs, vegetation cover, and soil nutrients. One set of plots was subjected to two restoration treatments: removal of lupine shrubs only, or removal of all nonnative vegetation and removal of litter and duff. Treatments were repeated annually for four years, and emerging lupine seedlings were monitored for three years. Prior to treatment, ammonium and nitrate were found to increase along the lupine continuum, but organic matter decreased at the extreme lupine end. Yellow bush lupine was not the most significant variable affecting variation in soil nutrients. After four years, nonnative grasses, including *Vulpia bromoides, Holcus lanatus* (velvet grass), *Bromus* spp. (brome), and *Aira* spp. (European hairgrass), were significantly reduced in those restoration plots from which litter and duff was removed. Native species increased significantly in vegetation types that were less influenced by lupine. By the third year, soil variables differed among vegetation types but not by treatment. Bush lupine seedling emergence was higher, however, in plots receiving the litter and duff removal treatment. Based on these results, we conclude that bush lupine invasion results in both direct soil enrichment and indirect enrichment as a result of the associated encroachment of other nonnative species, particularly grasses. Although treatment did not affect soil nutrients during the period of this study, it did reduce establishment of normative grasses and recruitment of

new bush lupine seedlings. Restoration should therefore include litter and duff removal. In areas that are heavily influenced by lupine and contain few native propagules, revegetation is also required.

Pitcairn, C. E. R., I. D. Leith, L. J. Sheppard, M. A. Sutton, D. Fowler, R. C. Munro, S. Tang and D. Wilson. 1998. The relationship between nitrogen deposition, species composition and foliar nitrogen concentrations in woodland flora in the vicinity of livestock farms. Environmental Pollution 102 (1): 41-48.

Authors' abstract: Measurements of atmospheric ammonia concentration along a gradient of decreasing concentration, species composition and tissue nitrogen content of a range of plant species were made in woodland in the vicinity of four intensive animal units in Scotland. Ammonia concentrations were large at woodland edges close to the livestock buildings (annual means 20-60 mug m-3) and exceed critical levels for NH3 (8 mug m-3 annual mean). Surveys of species composition of ground flora along an 0.5 km transect from livestock buildings show marked changes within 300 m downwind of the buildings. Species such as *Deschampsia flexuosa, Holcus lanatus, Rubus idaeus* and *Urtica dioica* were abundant close to livestock units and their percentage cover decreased rapidly with distance from source, while the more N- sensitive species such as *Oxalis acetosella, Galium odoratum*, mosses and ferns which are found upwind and outside the influence of the NH3 source, were scarce at all sites receiving >25 kg ha-1 N year-1. Visible injury to pine and spruce needles was observed immediately downwind of the buildings. Foliar nitrogen concentration of a number of species was large close to the buildings and declined with distance. Total nitrogen deposition at the woodland boundaries is estimated to range from 40 to 80 kg N ha-1 year-1 at the 4 sites and exceeds critical loads for acidic coniferous forest, i.e., 15-20 kg N ha-1 year-1 to protect ground flora, and is also often in excess of that (11-50 kg N ha-1 year-1) proposed to protect tree health. Foliar nitrogen content of mosses, (LN, % dry weight) is related to nitrogen deposition (FN, kg N ha-1 year- 1) according to LN = 3.81(1-e-0.04FN).

Pitcher, D. and M. J. Russo. 1988. Element Stewardship Abstract for *Holcus lanatus* common velvet grass. The Nature Conservancy, Arlington, VA. Website: tncweeds.ucdavis.edu/esadocs/holclana.html Accessed: November 3, 2002.

The paper compiles existing information on the ecology of common-velvet grass, its impact on natural ecosystems and potential control options. This paper is especially useful for managers of Garry oak ecosystems because of the focus on management and the comprehensive ecological information presented. However, Pitcher and Russo state contradictory results in some cases without evaluating the primary references. Distinguishing features of the species are described as: purplish colour, lack of rhizomes and velvety hairs covering the entire plant. Velvet-grass was introduced to North America as a range grass and has since escaped throughout Canada and the United States. Velvet-grass can tolerate nutrient poor sites at altitudes from 0-1500 m. It prefers wet to mesic sites and is favoured by slightly acidic conditions and increased nutrient levels. Velvet-grass produces abundant seeds that germinate readily but also remain in the seedbank. Velvet-grass can also reproduce vegetatively by tillers which may be favoured

with mowing or grazing. Velvet-grass is highly aggressive and if not controlled can decrease species diversity. Mechanical control methods that are applicable in Garry oak ecosystems include hoeing and handpulling. The paper also states that mowing and grazing in combination with burning may cause velvet-grass to decrease in abundance. This recommendation appears to be based on only one primary reference which is not sufficient given the complexity of management responses of this species. For example, numerous other authors state that velvet-grass increases after fire and this paper suggests that mowing and grazing may increase tiller production. If mowing is considered as a management option, it must be done before seeds set; late mowing can favour velvet-grass. The site lists natural predators and diseases but none have been used as effective biological controls. Herbicides are also effective against velvet-grass, especially when applied as the seed heads first appear.

Pojar, J. and A. MacKinnon. 1994. Plants of coastal British Columbia including Washington, Oregon and Alaska. Ministry of Forests, Lone Pine Publishing. Vancouver, BC.

This field guide is designed for the lay botanist and provides basic identification characteristics of common velvet-grass. Key diagnostic features listed include soft hairiness of the plants, wide leaves (3-10 mm), pale grayish or purplish panicles, smooth shiny lemmas and hooked awns on the upper spikelets. General habitat is described as "fields, lawns roadsides, railroad embankments [and] open waste ground".

Rew, L. J., R. J. Froud-Williams and N. D. Boatman. 1995. The effect of nitrogen, plant density and competition between *Bromus sterilis* and three perennial grasses: The implications for boundary strip management. Weed Research 35 (5): 363-368.

Authors' abstract: The competitive ability of *Festuca rubra* L., *Holcus lanatus* L. and *Poa trivialis* L. when grown from seed, in monoculture and in 1:1 additive mixtures with *Bromus sterilis* L. was studied. *B. sterilis* was more aggressive when grown in additive mixtures with *F. rubra* than *P. trivialis* or *H. lanatus*. *H. lanatus* was less dominated by *B. sterilis* at the second harvest; visual observations suggested that this dichotomy was due to its slower initial growth rate and its subsequent dense vegetative growth habit. There was no statistically significant difference between the Relative Yield Total (RYT) of *B. sterilis* in additive mixtures with *F. rubra, H. lanatus* or *P. trivialis*, indicating that they were competing for the same resources. *B. sterilis* produced significantly more reproductive tillers and seeds as a result of nitrogen application, and such production was accentuated in the absence of interspecific competition. The implications of sown grass strips for field margin management are discussed.

Reynolds, S. A., J. D. Corbin and C. M. D'Antonio. 2001. The effects of litter and temperature on the germination of native and exotic grasses in a coastal California grassland. Madrono 48 (4): 230-235.

Authors' abstract: Through their effects on seed germination, accumulation of plant litter and temperature may play a role in the invasion of coastal California grasslands by exotic

annual and perennial grasses. Germination of native and exotic grasses was examined as a function of both litter cover and temperature. When species were grouped by life form (native perennial grass vs. exotic perennial grass), exotic species germinated at consistently higher rates than native species. Individual species, however, varied in their response to litter addition. While one exotic perennial species, *Festuca arundinacea*, maintained germination rates significantly higher than native species' across three levels of litter cover, the other exotic perennial species, *Holcus lanatus*, showed no advantage over native species in the presence of a heavy litter layer. Exotic annual grasses had significantly higher germination rates than native perennial or exotic perennial grasses in laboratory growth chambers. Decreasing the average fall temperature in laboratory growth chambers by 5degreeC significantly reduced the germination percentages of *Bromus diandrus* and *F. arundinacea* relative to other species. The remaining two exotic annual grasses, *Avena barbata* and *Vulpia myuros*, were consistently the first seeds to germinate. Grouping species according to life form masked germination responses of individual species that otherwise provide insight into the potential role of germination conditions in community composition of coastal grasslands in California.

Ryan, M. and G. Douglas. 1996. Status report on the seaside birds-foot lotus, *Lotus formosissimus,* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON

Ryan and Douglas report that *Lotus formosissimus* should be considered an endangered species. *L. formosissimus* has been extirpated from much of its historical range. The species occurs in Garry oak ecosystems and grows in a range of sites from open grass-dominated meadows to exposed rock to shaded oak forest. In the remaining sites where *L. formosissimus* is found, it is associated with exotic grasses including common velvet-grass. Ryan and Douglas suggest that the largest threats facing *L. formosissimus* are habitat destruction followed by competition from invasive species.

Schippers, P. and H. Olff. 2000. Biomass partitioning, architecture and turnover of six herbaceous species from habitats with different nutrient supply. Plant Ecology 149 (2): 219-231.

Authors' abstract: Three grasses (*Holcus lanatus, Anthoxanthum odoratum* and *Festuca ovina*) and three herbs (*Rumex obtusifolius, Plantago lanceolata* and *Hieracium pilosella*) were grown in a greenhouse at 3 nutrient levels in order to evaluate plant allocation, architecture and biomass turnover in relation to fertility level of their habitats. Four harvests were done at intervals of 4 weeks. Various plant traits related to biomass partitioning, plant architecture, biomass turnover and performance were determined. Differences in nutrient supply induced a strong functional response in the species shoot:root allocation, but architecture and turnover showed little or no response. Architectural parameters like specific leaf area and specific root length, however, in general decreased during plant development. Species from more nutrient-rich successional stages were characterized by a larger specific leaf area and longer specific shoot height (height/shoot biomass), resulting in a higher RGR and total biomass in all nutrient conditions. There was no evidence that species from nutrient-poor environments

had a longer specific root length or any other superior growth characteristic. The only advantage displayed by these species was a lower leaf turnover when expressed as the fraction of dead leaves and a shorter specific shoot height (SSH) which might prevent herbivory and mowing losses. The dead leaf fraction, which is a good indicator for biomass and nutrient loss, appeared to be not only determined by the leaf longevity, but was also found to be directly related to the RGR of the species. This new fact might explain the slow relative growth rates in species from a nutrient-poor habitat and should be considered in future discussions about turnover.

Schippers, P., I. Snoeijing and M. J. Kropff. 1999. Competition under high and low nutrient levels among three grassland species occupying different positions in a successional sequence. New Phytologist 143 (3): 547-559.

Authors' abstract: To clarify the role of seasonal change, competitive response and nutrient availability in the competitive asymmetry of grassland species a competition experiment was conducted on *Holcus lanatus, Anthoxanthum odoratum* and *Festuca ovina*, which represent a successional sequence of decreasing nutrient availability. Seven harvests were taken over two growing seasons. At each harvest the dry weight of plant parts, dead leaves, leaf area and plant height were measured. Three key traits that determine the successional status of the species were studied: specific leaf area, specific shoot height, and dead leaf fraction. The response of these traits to competition appeared to be limited and insufficient to change the competitive relations in the experiment. However, all three traits showed marked seasonal changes which resulted in superior growth and survival in winter of the species adapted to nutrient-poor environments. The findings support the theory that competitive asymmetry increases at higher nutrient levels. It is postulated that the directionality of light makes it possible for the dominant species to monopolize this resource more easily than nutrients.

Semiadi, G., T. N. Barry, P. D. Muir and J. Hodgson. 1995. Dietary preferences of sambar (*Cervus unicolor*) and red deer (*Cervus elaphus*) offered browse, forage legume and grass species. Journal of Agricultural Science 125 (1): 99-107.

Authors' abstract: Grazing sambar and red deer in New Zealand were offered a free choice of seven different plant species (forage legumes, browse and grasses) in 1992 and 1993 and dietary preference rankings were determined. Nutritive value of plants on offer and diet selected, plant height, plant species purity and stem diameter selected (browse only) were also determined. Total nitrogen (N) and organic matter digestibility (OMD) were highest for red clover, lowest for grasses and intermediate for browse species (willow, poplar and lupin). Top dietary preference ranking was willow for sambar and red clover for red deer in both years, with Yorkshire fog and prairie grass being lowly preference ranked with both deer species. Sambar selected willow stems up to 38 mm in diameter and poplar stems up to 54 mm in diameter. When the plants were grouped into browse, grass and forage legume categories, both deer species showed a similar preference ranking for grasses. Relative to grasses, sambar showed a strong preference for browse and a low preference for forage legumes, whilst red deer showed a strong preference for forage legumes of high nutritive value and a very low preference for

browse. It was calculated that sambar selected a total diet higher in condensed tannins and lignin but lower in nitrogen than that selected by red deer, with similar values for total fibre and OMD. Differences in dietary preference between the two deer species may be linked with the greater ability of sambar deer to neutralize some plant secondary compounds and their more efficient rumination pattern compared with red deer. Both sambar and red deer can be classified as intermediate feeders, having a similar preference for grasses, but differing preferences for forage legumes and browse.

Smith, R. S. H. Buckingham, M. J. Bullard, R. S. Shiel and A.Younger. 1996. The conservation management of mesotrophic (meadow) grassland in northern England: 1. Effects of grazing, cutting date and fertilizer on the vegetation of a traditionally managed sward. Grass and Forage Science 51 (3): 278-291.

Authors' abstract: The results are reported from an experiment on the effects of cutting date (14 June, 21 July and 1 September), fertilizer application (none or 80 kg ha-1 N plus 40 kg ha-1 P and K) and grazing treatments (none, autumn or autumn plus spring) on the vegetation of an upland mesotrophic grassland in Upper Teesdale, northern England, UK. Effects on plant species number and cover are reported for 4 years (1989-93) of treatment. Effects on 'species-attributes' are given for the fourth year. The cessation of grazing combined with the use of fertilizer progressively reduced species number by about 25%. Under traditional management (no fertilizer, cutting date on 21 July, autumn and spring grazing) the species number and cover remained relatively static over the 4 years. Comparison between treatments in the fourth year showed a reduction in species number under the fertilizer application, cutting date on 1 September and no-grazing treatments. Fertilizer use together with cutting date on 1 September particularly lowered species number and cover. Analysis of variance was used to assess the effect of treatment on species that occurred frequently in the sward. A cutting date of 1 September favoured *Agrostis capillaris, Alopecurus pratensis, Poa trivialis, Phleum pratense* and *Trisetum flavescens*. The absence of grazing favoured *Dactylis glomerata* and *Holcus lanatus*. The use of fertilizer particularly favoured *A. pratensis* and *H. lanatus*. Ordination methods were used to assess the effect of treatment on the less frequent species. These were primarily associated with the treatment combination that matched 'traditional' management. Deviations from this 'traditional' regime acted separately, rather than in combination, and favoured different grass species. Traditional management was associated with ruderal, stress-tolerant ruderal and competitive ruderal strategists and with longer seed germination times, heavier seeds, some of which needed scarifying or chilling to break dormancy, and transient seed banks that germinated in the autumn. The original sward was an *Anthoxanthum odoratum-Geranium sylvaticum* grassland, *Briza media* subcommunity (MG3b). After 4 years, *Festuca ovina-Agrostis capillaris-Galium saxatile* grassland, *Holcus lanatus-Trifolium repens* subcommunity (U4b) and *Lolium perenne-Alopecurus pratensis-Festuca pratensis* grassland (MG7c) were found in many of the fertilized and late-cutting treatments.

Solangaarachchi, S. M. 1996. The influence of neighbouring grasses on the growth of white clover (*Trifolium repens* L.). Journal of the National Science Council of Sri Lanka 24 (2): 95-110.

Author's abstract: Plants of white clover (*Trifolium repens*) were allowed to grow across a boundary between bare ground and a grass sward of *Lolium perenne, Cynosurus cristatus, Holcus lanatus* or *Agrostis tenuis* which was defoliated to 4 cm height at ten day intervals. Growth of the clover was strongly suppressed within the grass canopies. Canopies of *H. lanatus* and *A. tenuis* produced the greatest reduction in photosynthetically active radiation beneath them and most reduced the growth of *T. repens*. The canopy of *H. lanatus* reduced the ratio of red to far red radiation more than the canopy of the other grass species. Clones of clover differed in their response to the grass species. Clover was allowed to grow into swards of *L. perenne* that had been repeatedly defoliated to different heights. Clover invasion was reduced by increasing height of the sward and branching was largely inhibited in the taller swards. In the shortest swards the plants branched as freely as in bare ground.

Strykstra, R. J., G. L. Verweij and J. P. Bakker. 1997. Seed dispersal by mowing machinery in a Dutch brook valley system. Acta Botanica Neerlandica 46 (4): 387-401.

Authors' abstract: Seed dispersal by mowing machinery was investigated within a grassland reserve. Transported seed numbers amounted to hundreds of thousands. Seeds of 26 species were found on the machinery, including species that play an important role in succession during vegetation restoration (*Holcus lanatus, Rhinanthus angustifolius, Anthoxanthum odoratum*). Species occurrence was related to field abundance, but not to plant size, seed size or month of first flowering. Species seed amounts were also positively correlated only to their abundance within fields. Several abundant species were not found because they carried no seeds at the cutting date (*Caltha palustris, Juncus acutiflorus*). There was a difference in species composition within material accumulating in two machinery parts, which was related to their height above ground level. It was concluded that dispersal by mowing machinery is moderately selective towards and against certain species. Seeds were transported from species-rich fields into species-poor fields and vice versa. The seeds transported after mowing a field were partially deposited in the next field. Dispersal by machinery may have a larger impact on the speed of succession in the hay- fields of the Drentse A reserve than any other form of dispersal and establishment from the seed bank. Therefore, it is important for vegetation restoration in practice. However, machinery does not always connect seed sources with restoration areas. Large-scale machinery movement also creates a new form of vegetation dynamics compared to the days of former, more primitive, agricultural use. Both factors have to be considered when attempts are made to restore species-rich vegetation types. It is probable that new methods will not produce the vegetation that once existed.

Tallowin, J. R. B. and S. K. E. Brookman. 1996. The impact of differences in nitrogen content, nitrogen utilization and loss from laminae on competition between four grass species in an old pasture. Journal of Agricultural Science 126 (1): 25-35.

Authors' abstract: The concentration of nitrogen (N) within the emerging, youngest fully expanded and the youngest dead leaf laminae were examined in the grasses *Lolium perenne, Agrostis stolonifera, Holcus lanatus* and *Poa trivialis* in Devon, UK, in 1986

and 1987. Lamina growth, appearance interval and lamina utilization were also examined in each species. Marked tillers were measured in situ over 14-21 day periods in a continuously grazed permanent pasture under steady state management on plots receiving either zero (0N) or 400 kg nitrogen (400N) fertilizer/ha per annum. The concentration of N tended to be greatest in the distal half and least in the basal part of each lamina in each species. Total mass showed an opposite trend due in part to the shape of the lamina. Less than 40 % of the lamina N was lost through grazing either in the 0N or 400N plots in the four species, except once in *H. lanatus* when more was lost. In absolute terms, because *L. perenne* and *H. lanatus* maintained larger and longer laminae than either *A. stolonifera* or *P. trivialis*, they lost more N through grazing. The four grass species recycled N from the senescing lamina with the same apparent efficiency; this meant that differences in lamina N concentration and carbon: nitrogen ratios were present in the dead laminae of the four species. *L. perenne* achieved the highest tissue growth rate per unit of N in the lamina in the 0N plot, not only in comparison with the three other grasses but also compared with the 400N plot. This high N-use efficiency in *L. perenne* was not translated into an ability to either expand or maintain its population in the 0N plot. *L. perenne* had a lower leaf appearance rate than the other species in both the 400N and 0N plots, but this inherent characteristic of the species was particularly pronounced in the 0N plot. A slower leaf appearance rate would limit the potential tillering capacity of *L. perenne* compared with the other species. A reduced tillering capacity, exacerbated by N deficiency, was probably the principal factor limiting the ability of *L. perenne* to exploit available niches in the 0N pasture.

Thompson, J. D. and R. Turkington. 1988. The biology of Canadian weeds. 82. *Holcus lanatus* L. Canadian Journal of Plant Science 68 (1): 131-148.

This paper is a comprehensive summary of peer reviewed literature on the ecology, distribution and management of common velvet-grass. The authors relate the information to Canadian populations of the species and evaluate the primary literature when there are contradictory results. The comprehensive, technical species description is as referenced elsewhere although the authors provide further details about the morphological variation of the species. The global distribution is as described in other sources. Velvet-grass is listed as common in British Columbia. Velvet-grass has invaded road margins, fields and lawns in the province. It prefers moist sites over a wide range of ph. In Britain, velvet-grass is found on a range of soil types although there are few references for soils in Canada. Velvet-grass produces abundant seeds that require no special treatment for germination. Velvet grass forms dense swards by outcompeting other species. Velvet-grass reproduces vegetatively by tillers that spread laterally and create dense litter layers on the soil surface. It also grows quickly and the broad leaves are aggressive competitors for light. It is less palatable to livestock than other plants and is tolerant of heavy metals. Velvet-grass flowers from June to September in British Columbia. There are no studies on mycorrhizae in Canada. There are also no studies on the effectiveness of herbicides as a control of velvet-grass in Canada but research elsewhere indicates that velvet-grass is susceptible to herbicides. Intensive mowing or grazing controls but does not eradicate velvet-grass but the effects may also depend on the other species present. Moderate grazing does not control the species. Most studies indicate that fertilizer application

increases the competitive ability of velvet-grass. A wide range of parasites and grazers are listed but none are recommended as biological controls.

Titus, J. H. and J. Leps. 2000. The response of arbuscular mycorrhizae to fertilization, mowing, and removal of dominant species in a diverse oligotrophic wet meadow. American Journal of Botany 87 (3): 392-401.

Authors' abstract: In a wet oligotrophic meadow located in the Czech Republic, a factorial experiment with treatments consisting of fertilization, mowing, and removal of the dominant species (*Molinia caerulea*) was established in 1994. In 1997 *Holcus lanatus, Molinia caerulea, Potentilla erecta, Prunella vulgaris,* and *Ranunculus auricomus* were examined for arbuscular mycorrhizal (AM) hyphae, arbuscles, and vesicles three times over the season. Time had a significant effect on AM in all five species. Except for *Molinia* arbuscles, a modal effect occurred, with the second sampling having a greater level of AM structures than the first and the third. Fertilization had the greatest effect on AM levels by decreasing the level of *Holcus* hyphae and vesicles, *Potentilla* vesicles, *Prunella* hyphae, and *Ranunculus* hyphae and vesicles. Mowing significantly increased the number of *Potentilla* vesicles, and the removal of dominant species had no significant effects. Interactions between time and treatments were common. Significant effects to the arbuscle:vesicle ratio were infrequent, and those that occurred were related to changes over the season. Seasonal effects appear to have a more powerful effect on AM structures and the arbuscle:vesicle ratio than do treatment effects. In a second experiment, *Ranunculus auricomus, R. acris,* and *R. nemorosus,* sampled four times over the season, showed significant changes in AM colonization. Overall, AM structures either declined over the season or increased from April to May and then declined. There was no AM colonization response to a spring fertilization in the three species. It is postulated that the patterns observed are due to phosphorus availability and seasonal changes in soil moisture and rates of root growth and turnover.

USDA Natural Resources Conservation Service. 2002. Conservation Plant Characteristics for: *Holcus lanatus*. Website: http://plants.usda.gov Accessed: October 23, 2002.

The website shows a detailed range map of velvet-grass for the United States, provides classification information and lists extensive references and links to other websites for further information. Plant characteristics are provided in a point form format which has not been specifically designed for grasses. The information is not referenced and the information tends to be general in nature. The section describing growth requirements including soil characteristics and temperature is especially useful. The active growth period is listed as the spring. Velvet-grass growth rate is listed as moderate but slow after harvest. The lifespan is listed as short but no time duration is given. The site lists no resprout ability but this is contradicted by other references. Velvet-grass grows in coarse to medium textured soils with a ph ranging from 4-7. Velvet-grass has a medium drought tolerance and intermediate shade tolerance. Velvet-grass can tolerate infertile sites. The site states that velvet-grass blooms in the summer and also begins to set seed in the summer but no months are given. The seed spread rate is listed as slow which seems in

contradiction to the highly invasive nature of this species. It produces abundant seed and does not require cold stratification to germinate. Velvet-grass has a low palatability for grazing animals.

van der Krift, T. A. J., P. Gioacchini, P. J. Kuikman and F. Berendse. 2001. Effects of high and low fertility plant species on dead root decomposition and nitrogen mineralisation. Soil Biology & Biochemistry 33 (15): 2115-2124.

Authors' abstract: The influence of growing grass species *Holcus lanatus* and *Festuca ovina* on the decomposition of dead roots of *H. lanatus, F. rubra* and *F. ovina* and on the nitrogen (N) mineralisation from these residues was studied in a greenhouse experiment. *H. lanatus, F. rubra* and *F. ovina* are typical of soils with high, intermediate and low fertility, respectively. Dead roots of high fertility species were expected to decompose faster compared to those of low fertility species and living roots of high fertility species were expected to accelerate the rate of decomposition of dead roots more than low fertility species. To test this hypothesis, decomposition of 15N-labelled roots of these three species was measured after a 6-week incubation period in soil planted with either *H. lanatus* or *F. ovina* plants. After this period, the remaining dead root mass, living plant biomass, and the N and 15N distribution among plant, soil and dead roots was measured. The decomposition rate of dead roots from the three plant species was not significantly different. However, *H. lanatus* dead roots caused a lower N uptake by the growing plants (18.3 mg N) compared to *F. ovina* (21.5 mg N) and *F. rubra* (21.9 mg N) dead roots, as a result of a higher N immobilisation by *H. lanatus* dead roots. The presence of growing plants stimulated dead root decomposition and N mineralisation, the effect of *Holcus* plants being larger than that of *Festuca*. *H. lanatus* plants took up more N and 15N (26.3 mg N and 0.30 mg 15N) than *F. ovina* plants (14.1 mg N and 0.17 mg 15N). Our results provide evidence that living plant roots stimulate the nitrogen release from plant residues and thereby facilitate their own growth. This effect was stronger for high fertility species than for the low fertility species, because the high fertility species produced more root biomass. On the other hand, dead roots of high fertility species immobilised more N, due to their lower N concentration, resulting in a lower N availability to the growing plants.

Verschoor, B. C., T. E. Pronk, R. G. M. de Goede and L. Brussaard. 2002. Could plant-feeding nematodes affect the competition between grass species during succession in grasslands under restoration management? Journal of Ecology 90 (5): 753-761.

Authors' abstract: 1 We examined the effects of plant-feeding nematodes on competition between *Holcus lanatus* and *Anthoxanthum odoratum*. In the Drentse A nature reserve, the Netherlands, a relatively productive grassland, represented by *H. lanatus*, has gradually been replaced by a less-productive community, represented by *A. odoratum*, after the application of fertiliser was stopped. Stressed plants are generally considered to be more sensitive to herbivory. 2 We hypothesized that plant-feeding nematodes would exacerbate the competitive disadvantage of *H. lanatus* resulting from nutrient limitation. We compared performance in an adjusted De Wit replacement series with monocultures, grown in soil that was either treated or untreated with nematicides at both low and high nutrient supply. 3 The biomass production of both plant species was negatively affected

by intra- and interspecific competition. Although *H. lanatus* was a stronger competitor than *A. odoratum* in mixed cultures, it was more sensitive to plant-feeding nematodes and nutrient limitation. Nematodes and nutrient stress therefore reduced the competitive suppression of *A. odoratum* by *H. lanatus*. Low nutrient availability did not enhance the effect of plant-feeding nematodes on plant growth and competition, indicating additive rather than synergistic effects on plant performance. 4 We conclude that plant-feeding nematodes may contribute to species replacements in grasslands after fertilization has been stopped, albeit to a lesser extent than reduced nutrient availability. Plant species-specific differences in tolerance to plant-feeding nematodes in general, rather than host specificity of nematodes, are responsible for any effects.

Welch, D. 1995. Trends in the botanical composition of set-aside fields in North-East Scotland uncultivated for five years. Botanical Journal of Scotland 47 (2): 141-150.

Author's abstract: Species composition was monitored in 13 set-aside fields from 1989 to 1993 and in six others from 1989 to 1991. Grasses contributed more cover than dicotyledonous species throughout, but weedy species, e.g. *Agrostis gigantea* and *Poa annua*, were steadily replaced by grasses of permanent grassland, e.g. *Agrostis capillaris*, *Dactylis glomerata* and *Holcus lanatus. Ranunculus repens* (creeping buttercup) and *Trifolium repens* (white clover) became the main dicotyledonous species, and weeds characteristic of arable land had negligible cover after the first year of set-aside. As a result species richness declined, herbs of semi-natural grasslands being slow to colonize; many entrant species were recorded only in edge quadrats which extended 5 m into the fields from the headland. Noxious weeds (docks, ragwort and thistles) remained at low cover levels.

West, H. M. 1996. Influence of arbuscular mycorrhizal infection on competition between *Holcus lanatus* and *Dactylis glomerata.* Journal of Ecology 84 (3): 429-438.

Author's abstract: 1. *Holcus lanatus* and *Dactylis glomerata* were grown in monocultures and mixtures to determine the influence of mycorrhizal fungi on intra- and interspecific competition. 2. In monoculture, shoot biomass per plant of both species was increased over all densities by mycorrhizal infection. Increased tiller and leaf numbers per plant for *H. lanatus*, but not for *D. glomerata*, suggested that enhanced biomass was a result of greater tiller and leaf production in *Holcus*, but to increased tiller weight in *Dactylis*. Increased competition reduced shoot biomass, tiller number and leaf number in both species. 3. Although the response was variable, mycorrhizal infection generally enhanced shoot biomass of both species in mixed cultures. Tiller production in *D. glomerata* was generally unaffected by infection but reductions in leaf number were observed in mycorrhizal stands. In contrast to its effects on monocultures, infection had no effect on tiller production when *H. lanatus* was in mixture. 4. Relative yield totals (RYT) calculated for grasses grown in mixture suggest that, overall, mycorrhizal infection resulted in a reduction of resource complementarity, i.e. it increased the level of competition for the same resources. This was reflected in the relative yields which showed that the shoot biomass for each species in mixture was lower than that expected from growth in monoculture. 5. Aggressivity indices suggested that *H. lanatus* was more

aggressive than *D. glomerata* when present in equal or greater numbers. Mycorrhizal infection altered the degree of aggressivity in favour of the already more aggressive plant within the combination, although, at very low densities, *D. glomerata* was more aggressive than *H. lanatus* when mycorrhizal.