Garry oak ecosystems recovery team

Annotated Bibliography on the Ecology and Management of Invasive Species:

Canada Bluegrass (*Poa compressa*) and Kentucky Bluegrass (*Poa pratensis*)

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For the Garry Oak Ecosystems Recovery Team

February 2009

Funding supplied by the Habitat Stewardship Program for Species at Risk of Environment Canada

Environment Canada Environnement Canada

Peer-Reviewed Journal Articles

Bhowmik, P. C. and S. W. Bingham. 1990. Preemergence activity of dinitroaniline herbicides used for weed control in cool-season turfgrasses. Weed Technology 4 (2): 387-393.

Abstract: Dinitroaniline herbicides are major herbicides used to control annual grass weeds in cool-season turgrasses. At least three herbicides, benefin, pendimethalin, and trifluralin are labeled preemergence to control weeds in established turfgrass. Prodiamine could be a competitive product. Benefin at 2.2 to 3.4 kg/ha, pendimethalin at 1.7 to 3.4 kg ai/ha, prodiamine at 0.6 to 1.7 kg ai/ha, and benefin plus trifluralin at 1.1 plus 0.6 to 2.3 plus 1.1 kg ai/ha effectively control many annual grass weeds, including large and smooth crabgrass, yellow and green foxtail, barnyardgrass, goosegrass, fall panicum, and annual bluegrass Most dinitroaniline herbiceids provide residual preemergence weed control for the entire growing season. In general, Kentucky bluegrass, perennial ryegrass, tall fescue, red fescue, and other cool-season turfgrasses tolerate most of these herbicides, although higher-than-normal rates of any dinitroaniline herbicide could restrict root growth and cause stand thinning in turfgrass species.

Bookman, P. A. and R. N. Mack. 1983. Competition between *Bromus tectorum* L. and *Poa pratensis L.:* the role of light. Oecologia 57 (3): 406-411.

Abstract: *Bromus tectorum* L. dominates sites of large-scale disturbance, while *Poa pratensis* L. dominates the sites of small-scale disturbance in the *Festuca/Symphoricarpos* habitat type in eastern Washington (USA). The role of incident irradiation in influencing these distributions was examined using field and glasshouse experiments. Glasshouse grown swards of *B. tectorum* growing beneath an established canopy of *P. pratensis* displayed larger biomass and higher survival when exposed to supplemental light versus controls. Neither mean plant height nor the skewness in the individual biomass distribution were significantly different between the supplemental light and control plots. Maximum net photosynthesis for *P. pratensis* and *B. tectorum* was 11.5 and 14.87 mg CO2.dm-Z-h 1, respectively. For *Poa,* light utilization efficiency was greater, although light compensation point was lower than that exhibited by *Bromus.* These photosynthetic characteristics along with the seasonal pattern of light transmission through the meadow steppe canopy may largely account for the successful establishment of *P. pratensis* in small sites of disturbance with little light, while restricting the establishment of *B. tectorum* to patches with more irradiance.

Bosy, J. L. and R. J. Reader. 1995. Mechanisms underlying the suppression of forb seedling emergence by grass (*Poa pratensis*) litter. Functional Ecology 9 (4): 635-639.

Abstract: 1. We investigated the mechanism by which grass litter (dead *Poa pratensis* L. shoots) suppressed the emergence of seedlings of four old-field forbs by determining the effect of litter on their seed germination and shoot extension. 2. When seeds were placed beneath litter that had been collected from an old-field, the germination of all species except *Verbascum* was reduced significantly by 26% to 41% compared to a no-litter control. 3. When seeds were placed in plastic dishes containing a leachate solutions made from litter, the germination of two species (i.e. *Centaurea* and *Dipsacus*) was reduced significantly by 10% to 34% compared to the distilled water control. 4. When germinated seeds were placed beneath litter, the emergence of seedlings of all species was reduced significantly by 95% to 100% compared to a no-litter control. 5. These results indicate that grass litter may suppress forb seedling emergence by reducing seed germination and (or) by preventing shoot extension and that these effects are species dependent.

D'Antonio, C. M. and P. M. Vitousek. 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. Annual Review of Ecology and Systematics 23: 63-87.

Abstract: This paper discusses biological invasions by exotic grasses in response to human-caused globalization. It describes the processes for invasions and the effects on invaded ecosystems and fire regimes along with examples. It also discusses the effects of changes in land use on the grass-fire cycle and the regional and global effects.

Didham, R. K., J. M. Tylianakis, M. A. Hutchison, R. M. Ewers, and N. J. Gemmell. 2005. Are invasive species the drivers of ecological change? Trends in ecology and evolution 20 (9): 470-474.

Abstract: Invasive species are widely accepted as one of the leading direct causes of biodiversity loss. However, much of the evidence for this contention is based on simple correlations between exotic dominance and native species decline in degraded systems. Although appealing, direct causality is not the only possible interpretation. A plausible alternative hypothesis is that exotic dominance could be the indirect consequence of habitat modification driving native species loss. In a new paper, MacDougall and Turkington now provide the first direct test of whether invasive species are the drivers of community change, or merely 'passengers' along for the environmental ride.

DiTomasio, J. M., M. L. Brooks, E. B. Allen, R. Minnich, P. M. Rice, and G. B. Kyser. 2006. Control of invasive weeds with prescribed burning. Weed Technology 20: 535-548.

Abstract: Prescribed burning has primarily been used as a tool for the control of invasive late-season annual broadleaf and grass species, particularly yellow starthistle, medusahead, barb goatgrass, and several bromes. However, timely burning of a few invasive biennial broadleaves (e.g., sweetclover and garlic mustard), perennial grasses (e.g., bluegrasses and smooth brome), and woody species (e.g., brooms and Chinese tallow tree) also has been successful. In many cases, the effectiveness of prescribed burning can be enhanced when incorporated into an integrated vegetation management program. Although there are some excellent examples of successful use of prescribed burning for the control of invasive species, a limited number of species have been evaluated. In addition, few studies have measured the impact of prescribed burning on the long-term changes in plant communities, impacts to endangered plant species, effects on wildlife and insect populations, and alterations in soil biology, including nutrition, mycorrhizae, and hydrology. In this review, we evaluate the current state of knowledge on prescribed burning as a tool for invasive weed management.

Edwards, G. R., H. Clark, and P. C. D. Newton. 2001. The effects of elevated CO_2 on seed production and seedling recruitment in a sheep-grazed pasture. Oecologia 127 (3): 383-394.

Abstract: Seed production and seedling recruitment were measured over 2 years under ambient (360 ppm) and elevated (475 ppm) atmospheric CO_2 in a free air carbon dioxide enrichment (FACE) experiment, carried out in a sheep-grazed pasture on dry, sandy soil in New Zealand. In both years elevated CO2 led to more dispersed seeds of the grasses *Anthoxanthum odoratum*, *Lolium perenne* and *Poa pratensis*, the legumes *Trifolium repens* and *T. subterraneum* and the herbs *Hypochaeris radicata* and *Leontodon saxatilis*. The increased seed dispersal in *A. odoratum*, *H. radicata*, *Leontodon saxatilis* and *T. repens* reflected both more inflorescences per unit area and more seeds per inflorescence under elevated CO_2. The increased seed dispersal in *Lolium perenne*, *P. pratensis* and *T. subterraneum* was due solely to more inflorescences per unit area. The number of seedlings that emerged and survived to at least 7 months of age was increased by elevated CO_2 for *H. radicata*, *Leontodon saxatilis*, *T. repens* and *T. subterraneum* in both years and for *A. odoratum* and *Lolium perenne* in the first year. For species where increased

seedling recruitment was noted, there was a significant positive correlation between seed production in summer and seedling emergence in the following autumn and winter, and sowing 200 extra seeds per species m^{-2} resulted in more seedlings compared to unsown controls. Elevated CO_2 did not affect seedling survival in any species. There was no measurable effect of elevated CO_2 on canopy and soil surface conditions or soil moisture at the time of seedling emergence. The results suggest the dominant effect of elevated CO_2 on seedling recruitment in this pasture was an indirect one, reflecting effects on the 5 number of seeds produced. The biomass of *H. radicata*, *Leontodon saxatilis*, *T. repens* and *T. subterraneum* in the aboveground vegetation was greater under elevated than ambient CO_2. However, the size of individual seedlings and mature plants of these four species was unaffected by elevated CO_2. The results indicate an important way elevated CO_2 influenced plant species composition in this pasture was through changes in the pattern of seedling recruitment.

Heide, O. M., M. G. Bush, and L. T. Evans. 1986. Inhibitory and promotive effects of gibberellic acid on floral initiation and development in *Poa pratensis* and *Bromus inermis*. Physiologia Plantarum 69 (2): 342-350.

Abstract: Flowering in *Poa pratensis* L. cv. Holt and *Bromus inermis* Leyss. cv. Manchar requires exposure to short days (SD) for primary induction to occur, followed by long days (LD) to allow the inflorescence to develop. Weekly sprays with gibberellic acid (GA3) during primary induction inhibited flower initiation in both *P. pratensis* and *B. inermis*. With 10-4M GA3 flowering of *P. pratensis* was suppressed even after an induction period of 10 weeks. Since both GA3 and non-inductive LD conditions greatly stimulate leaf elongation, the degree of primary induction was closely negatively correlated with plant height (leaf sheath and blade length) at the end of the induction period. GA3 application or the interpolation of LD during SD induction were most inhibitory during the later middle part of the SD period, whereas they were stimulatory near the beginning or immediately before the SD period. We suggest that changes in the portfolio or levels of endogenous gibberellins mediate photoperiodic control of growth and floral initiation in these plants. However, GA3 sprays could not substitute for LD in causing heading and culm elongation in SD induced plants of the two species. The results are discussed in the light of results with other plants with dual floral induction requirements.

Hewett, D. G. 1985. Grazing and mowing as management tools on dunes. Vegetatio 62: 441-447.

Abstract: A brief review of mowing and grazing of sand dune vegetation introduces the first results of the use of these management techniques at Newborough Warren National Nature Reserve, Anglesey, north Wales. In the mowing experiments, plots are mown one (May), twice (May and July), three times (May, July and September) and five times (May, June, July, August and September). The grazing experiment has the equivalent of one or two animals to three-quarter acre paddocks (0.3 ha) which are grazed for one third, two thirds or for the whole year. Mean numbers of species per plot, and *Lotus corniculatus* have increased in both sets of experiments whereas *Arrhenatherum elatius* has declined. Other species do not show clear-cut changes. Both methods provide practical means of maintaining a short turf, but the long-term effects of mowing may not be beneficial to the vascular plant flora. Grazing can however provide a crop as well as a desirable flora although manpower and capital costs may limit its use by conservationists.

Keeley, J. E., M. Baer-Keeley, and C. J. Fotheringham. 2005. Alien plant dynamics following fire in Mediterranean-climate California shrublands. Ecological Applications 15 (6): 2109-2125.

Abstract: Over 75 species of alien plants were recorded during the first five years after fire in southern California shrublands, most of which were European annuals. Both cover and

richness of aliens varied between years and plant association. Alien cover was lowest in the first postfire year in all plant associations and remained low during succession in chaparral but increased in sage scrub. Alien cover and richness were significantly correlated with year (time since disturbance) and with precipitation in both coastal and interior sage scrub associations. Hypothesized factors determining alien dominance were tested with structural equation modeling. Models that included nitrogen deposition and distance from the coast were not significant, but with those variables removed we obtained a significant model that gave an $R^2 = 0.60$ for the response variable of fifth year alien dominance. Factors directly affecting alien dominance were (1) woody canopy closure and (2) alien seed banks. Significant indirect effects were (3) fire intensity, (4) fire history, (5) prefire stand structure, (6) aridity, and (7) community type. According to this model the most critical factor influencing aliens is the rapid return of the shrub and subshrub canopy. Thus, in these communities a single functional type (woody plants) appears to the most critical element controlling alien invasion and persistence. Fire history is an important indirect factor because it affects both prefire stand structure and postfire alien seed banks. Despite being fire-prone ecosystems, these shrublands are not adapted to fire per se, but rather to a particular fire regime. Alterations in the fire regime produce a very different selective environment, and high fire frequency changes the selective regime to favor aliens. This study does not support the widely held belief that prescription burning is a viable management practice for controlling alien species on semiarid landscapes.

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.

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.

Kramberger, B. and M. Kaligaric. 2008. Semi-natural grasslands: The effects of cutting frequency on long-term changes of floristic composition. Polish Journal of Ecology 56 (1): 33-43.

Abstract: The objective of the experiment was to study the effects of different frequencies of cutting on long-term changes in the floristic composition of grassland, with an emphasis on the effects of very late cutting. Cutting at 2, 4, 6, 8 10 and 12-weekly intervals was applied from 1995

to 2006 in a randomized block experiment on semi-natural grassland fertilized with 170 kg N, 40 kg P and 150 kg K ha^{-1}. The floristic composition of treatments was determined in May 1995, 1999, 2002 and 2006. In the final year (2006) the proportion of grasses in the dry matter of harvest was highest (77%) in the treatment with the least frequent cuts, and it was the highest obtained during the whole experiment. Under very frequent cuts, the proportion of grasses ranged only from 45 to 57%. Among legumes, only *Trifolium repens* L. was represented in high proportions in the dry matter of the harvest (from 19 to 25%) in 2006, but only in the treatments involving high cutting frequencies. The proportion of non-legume forbs in treatments involving low cutting frequency did not exceed other treatments; moreover, their proportion in the dry matter of the harvest in the treatment with the lowest cutting frequency decreased significantly to the lowest value (19%). The increased proportion of grasses in treatments with low cutting frequency indicates that a very late cut does not necessarily mean that forbs increase in the floristic composition, but can help grasses to retain their dominant and stable proportion in the semi-natural sward. Consequently, when farmers are being provided with financial incentives with the aim of protecting diversity and the natural environment, it is worth recommending also a very late cutting, which includes natural reseeding to a greater extent. This can help to find a compromise between farmers' expectations of stable yield and quality forage, and the public interest in having grasslands of high biodiversity.

MacDougall, A. S. 2005. Responses of diversity and invasibility to burning in a northern oak savanna. Ecology 86 (12): 3354-3363.

Abstract: The role of diversity in buffering environmental change remains poorly tested in natural systems. Diversity might enhance stability if different species have different disturbance susceptibilities (i.e., functional complementarity). Alternatively, diversity might decrease stability because, at high diversity, populations are predicted to be more temporally variable and therefore more vulnerable to extinction following perturbation. There is theoretical support for both hypotheses but limited empirical evidence. I examine these issues with experimental burning along a natural diversity gradient in a savanna where fire has been suppressed for 150 years. I examined how two components of stability, resistance (invasion by added and naturally recruiting species) and resilience (recovery of the predisturbance light levels, the primary limiting resource in this system), varied with diversity. I also examined how the abundance of dominant species and soil depth affected stability, as both are negatively correlated with diversity and could have hidden impacts (e.g., invasion resistance on shallow soils correlated with diversity but caused by moisture stress). Species rich communities were stable because they contained fire-tolerant species that, despite their rarity, significantly increased in cover after fire, reduced light availability, and limited seedling survival. Species-poor communities were rapidly invaded, apparently due to the combined effects of (1) trade-offs between competitive ability and disturbance tolerance (dominants in species-poor areas were competitive but fire sensitive), and (2) low functional complementarity. Colonization by woody plants was also significantly higher in low-diversity plots; these species are known to form a new stable state that excludes all savanna taxa. The abundance of dominants and soil depth were negatively correlated with diversity because they appear to determine its spatial variation in the absence of fire, but diversity alone accounted for variation in stability. Without burning, most subordinates are confined to shallower soils where they play a minor role in controlling resource flows and production. Diversity, therefore, was more important for buffering the effects of change than controlling ecosystem function under undisturbed conditions. If applicable to other systems, the results indicate that species loss will compound the negative effects of environmental change on ecosystem function by limiting the ability of ecosystems to respond.

MacDougall, A. S. and R. Turkington. 2004. Relative importance of suppression-based and tolerance-based competition in an invaded oak savanna. Journal of Ecology 92: 422-434.

Abstract: 1 Invasive species dominate many ecosystems but the competitive strategies

underlying this dominance are unclear. Are invasive species generalist competitors, or do they only thrive in certain environments? Do they occur mainly post-disturbance or can they persist throughout succession? 2 We tested the relative importance of resource acquisition (competitive suppression ability) and the ability to tolerate reduced resource levels (competitive tolerance ability) among four C3 perennial grass species in an invaded oak savanna. Two species (*Poa pratensis* and *Dactylis glomerata*) are exotic invaders and are thought to have replaced the two native species (*Bromus carinatus* and *Elymus glaucus*) as dominants. 3 Using glasshouse and field experiments we tested whether the two strategies were maintained with changing resource levels and successional conditions, and their relative roles in explaining exotic dominance. 4 The relative importance of suppression- and tolerance-based competition shifted with neighbour density, burning and planting order. Further, the relative importance of particular plant traits changed depending on the imposed conditions, and the exotic dominants were only competitively superior under certain circumstances. 5 Competitive suppression ability was maintained with changing resource levels but was confined to post-disturbance conditions. When planting of neighbours was delayed, the early establishing targets were dominant regardless of species, fertility and neighbour density. 6 Competitive tolerance ability determined long-term patterns of relative abundance and coexistence, but only under the current field conditions of low fertility and limited disturbance. Alteration of these conditions changed the relative abundance of the four grasses, and would probably reconfigure species patterns in the oak savanna community generally. 7 Exotic dominance is presently determined by tolerance-based competitive traits interacting with the long-term absence of disturbance. Dominance is therefore contingent on the interaction of competitive strategies, resource availability and disturbance history rather than any one factor alone. 8 Exotic flora dominate all stages of succession in this savanna because there exists both early (suppression) and late (tolerance) successional specialists. The identity of the dominant changes with succession based on the competitive strategy it employs. This result highlights the importance of examining the historical context of invaded communities and tracking their successional status over time.

MacDougall, A. S. and R. Turkington. 2007. Does the type of disturbance matter when restoring disturbance-dependent grasslands? Restoration Ecology 15 (2): 263-272.

Abstract: The reintroduction of burning is usually viewed as critical for grassland restoration; but its ecological necessity is often untested. On the one hand, fire may be irreplaceable because it suppresses dominant competitors, eliminates litter, and modifies resource availability. On the other hand, its impacts could be mimicked by other disturbances such as mowing or weeding that suppress dominants but without the risks sometimes associated with burning. Using a 5-year field experiment in a degraded oak savanna, we tested the impacts of fire, cutting and raking, and weeding on two factors critical for restoration: controlling dominant invasive grasses and increasing subordinate native flora. We manipulated the season of treatment application and used sites with different soil depths because both factors influence fire behavior. We found no significant difference among the treatments-all were similarly effective at suppressing exotics and increasing native plant growth. This occurred because light is the primary limiting resource for many native species and each treatment increased its availability. The effectiveness of disturbance for restoration depended more on the timing of application and site factors than on the type of treatment used. Summer disturbances occurred near their reproductive peak of the exotics, so their mortality approached 100%. Positive responses by native species were significantly greater on shallow soils because these areas had higher native diversity prior to treatment. Although likely not applicable to all disturbance-dependent ecosystems, these results emphasize the importance of testing the effectiveness of alternative restoration treatments prior to their application.

Sheffer, K. M., J. H. Dunn, and D. D. Minner. 1987. Summer drought response and rooting depth of three cool-season turfgrasses. Hortscience 22 (2): 296-297.

Abstract: This study was conducted to determine root distribution, soil moisture depletion, and 32P uptake, as an indicator of water absorption, by Kentucky bluegrass (*Poa pratensis* L. 'Fylking'), perennial ryegrass (*Lolium perenne* L. 'Manhattan'), and tall fescue (*Festuca arundinacea* Schreb. 'Kentucky 31'). 32P was injected at 6, 18, 30, 42, and 54 cm from the soil surface under each turfgrass plot on 18 July 1978. Leaf blade radioactivity revealed differences in uptake among species, but was inconsistent with rooting patterns. Root mass measurements below 36 cm in late August showed tall fescue > perennial ryegrass > Kentucky bluegrass. Root mass above 12 cm showed Kentucky bluegrass > tall fescue = perennial ryegrass. Soil water content (SWC) at three depths in August reflected root distribution for the three species. SWC was lowest under Kentucky bluegrass and highest under tall fescue at 6 cm. At 54 and 78 cm, SWC was highest under Kentucky bluegrass and lowest under tall fescue. SWC was better than 32P injection for detecting species differences in water uptake.

Symstad, A. J. 2000. A test of the effects of functional group richness and composition on grassland invasibility. Ecology 81 (1): 99-109.

Abstract: Although many theoretical and observational studies suggest that diverse systems are more resistant to invasion by novel species than are less diverse systems, experimental data are uncommon. In this experiment, I manipulated the functional group richness and composition of a grassland community to test two related hypotheses: (1) Diversity and invasion resistance are positively related through diversity's effects on the resources necessary for invading plants' growth. (2) Plant communities resist invasion by species in functional groups already present in the community. To test these hypotheses, I removed plant functional groups (forbs, C3 graminoids, and C4 graminoids) from existing grassland vegetation to create communities that contained all possible combinations of one, two, or three functional groups. After three years of growth, I added seeds of 16 different native prairie species (legumes, nonleguminous forbs, C3 graminoids, and C4 graminoids) to a 1 x 1 m portion of each 4 x 8 m plot. Overall invasion success was negatively related to resident functional group richness, but there was only weak evidence that resident species repelled functionally similar invaders. A weak effect of functional group richness on some resources did not explain the significant diversity-invasibility relationship. Other factors, particularly the different responses of resident functional groups to the initial disturbance of the experimental manipulation, seem to have been more important to community invasibility.

Tveten, R. K. and R. W. Fonda. 1999. Fire effects in prairies and Oak woodlands on Fort Lewis, Washington. Northwest Science 73 (3): 145-158.

Abstract: Before 1800, frequent fires maintained Idaho fescue prairies and Garry oak woodlands on Fort Lewis. Fire exclusion in the 1900s, however, has allowed Scot's broom, Douglas-fir, and numerous herbaceous aliens to invade native prairies and oak woodlands. Since 1978, a management program using prescribed fires on 3-5 yr rotations has been used in an effort to maintain the open communities. We evaluated the role of fire on fescue prairies, oak woodlands, and broom thickets using prescribed fires in fall 1994 and spring 1995, and compared preburn/postburn species frequency to identify fire maintainers, increasers, and decreasers. Fall fires were more effective than spring fires, and best promoted native species and communities. Prescribed fires had no effect on Idaho fescue frequency, which maintained dominance in the postfire prairie. Other native prairie graminoids and forbs, and hairy cats-ear, a prominent alien, were maintained by fire. Prescribed fires also maintained open Garry oak woodlands, reduced Scot's broom cover in broom thickets, and killed small Douglas-firs. These fires, however, tended to favor alien species instead of native species. A large prairie subjected to >50 yr of broadcast burns ignited annually by artillery fire has been converted from fescue prairie to an open meadow dominated by hairy cats-ear and alien grasses, such as sweet vernal grass. Of the three regimes we investigated, fire intervals shorter or longer than the 3-5 yr fire rotation now employed on Fort

Lewis are detrimental to fescue prairie and oak woodland. Excessive burning or fire exclusion causes loss of prairie and oak woodland.

Welch, D. and D. Scott. 1995. Studies in the grazing of heather moorland in north-east Scotland. VI. 20-Year trends in botanical composition. Journal of Applied Ecology 32 (3): 596-611.

Abstract: 1. Botanical composition and herbivore usage were monitored over a 20-year period at 15 moorland sites; point quadrats were recorded in fixed positions. Although composition reflected soil type and altitude, *Calluna vulgaris* was initially the main species at all sites, with cover averaging 61%. 2. Grazing pressures varied from light to heavy, causing wide variation in the utilization of *Calluna* shoots. Hence, *Calluna* declined at four sites, stayed in balance or showed negligible trend at four sites, and increased at seven sites. 3. At sites with *Calluna* decline, graminoids and forbs showed a general rise in cover, and ericoids and lichens decreased. Species increasing significantly included *Agrostis capillaris*, *Anthoxanthum odoratum*, *Festuca ovina*, *Galium saxatile, Luzula multiflora*, *Nardus stricta* and *Rhytidiadelphus squarrosus*; *Deschampsia flexuosa* was reduced in cover. At one site with agricultural reseeding nearby, *Cynosurus cristatus*, *Dactylis glomerata* and *Lolium perenne* became established. 4. At sites with *Calluna* steady, changes in the main plant groups were small. Bryophytes increased modestly, the chief contributor being *Pleurozium schreberi* which replaced *Hypnum cupressiforme*. 5. At sites with Calluna increase, chances were greater when the *Calluna* sward was continuous rather than patchy. At the former sites graminoids and forbs declined sharply, and bryophytes increased, particularly the pleurocarpous mosses *Hylocomium splendens*, *Hypnum cupressiforme* and *Pleurozium schreberi*. 6. Species richness, as measured by the number of contacts with vascular plant species per point-quadrat pin, was much more affected by soil type than by *Calluna* trend. Species number declined somewhat at sites with *Calluna* static and increasing; at sites with *Calluna* decline, an increase in the number of herbs was offset by reduced numbers of bryophytes and lichens.

Other Published Sources

Alaska Natural Heritage Program. 2005. Non-Native Plant Species of Alaska: Canada bluegrass (*Poa compressa* L.). Alaska Natural Heritage Program.

Abstract: The Non-Native Plant Species of Alaska is a series of fact sheets about invasive flora in Alaska. They discuss the plant identification, ecological impacts, invasive potential, distribution and abundance, and management of each species.

Alaska Natural Heritage Program. 2005. Non-Native Plant Species of Alaska: Kentucky bluegrass (*Poa pratensis* ssp. *pratensis* L.), Spreading bluegrass (*Poa pratensis* ssp. *irrigata* (Lindm.) Lindb. f.), Rough bluegrass *(Poa trivialis* L.). Alaska Natural Heritage Program.

Abstract: The Non-Native Plant Species of Alaska is a series of fact sheets about invasive flora in Alaska. They discuss the plant identification, ecological impacts, invasive potential, distribution and abundance, and management of each species.

Dunwiddie, P. W. 2005. Management and Restoration of Grasslands on Yellow Island, San Juan Islands, Washington, USA. The Nature Conservancy. 217 Pine St., Suite 1100, Seattle, WA 98101.

Abstract: A native grassland dominated by Roemer's fescue (*Festuca idahoensis* var. *roemeri*), great camas (*Camassia leichtlinii*), and a diversity of other forbs has been the focus of a variety of experiments on restoration techniques, as well as studies tracking ecological changes since 1981. Investigations in existing grasslands have primarily focused on responses of native and non-native species to prescribed burns. Following each of 3 burns, responses of different species are complex, varying in direction, magnitude, and duration. A second series of studies has focused on developing effective means for controlling and removing invading trees and shrubs, and on limiting non-native grasses and forbs. Methods have included a variety of manual, mechanical, and chemical techniques. We have also tested several approaches for restoring native grassland species in areas where they had been excluded by competing woody plant growth. Even when abundant native seed sources exist in close proximity, non-native species usually establish more quickly following removal of trees and shrubs, and continue to dominate for many years. Out-planting of propagated plants has proven most effective in rapidly re-establishing native species. Greatest success has been achieved in establishing a dense fescue matrix that excludes invasive species.

Hartz-Rubin, J. S., T. Weaver, C. S. Rubin, and J. Plaggenmeyer. 2003. Effect of fire and grazing on invasive species in northern mixed grass prairie.

Abstract: Invasive plants pose a threat to pristine and natural mixed grass prairie so managers seek to control them. On the basis of experience in the tall grass prairie, some hypothesize that they may be controlled with fire and grazing. The fact that the invaders are cool season species in a cool season prairie, rather than cool season species in a warm season matrix, reduces the possibility of selectively treating them- - and casts doubt on the applicability of these tools in mixed grass prairie. Long-term management experiments at Lostwood and Des Lacs National Wildlife Refuges (NWR) provide a near ideal opportunity to test these hypotheses. The replicated factorial experiment includes six burning treatments (0-6 burns) crossed with two grazing (grazed and ungrazed) treatments. By subsampling each unit, one can estimate the local (bottom, N-slope, S-slope, and hilltop) and regional (North Dakota vs. Montana) effects of water availability. We field-sampled units to compare the spread of nine species - - i.e., the long distance dispersal (frequency) and clonal spread (cover) - - among these treatments. Responses to various aspects of fire and grazing were measured with multiple regression. The species studied included two perennial grasses (*Bromus inermis* and *Poa pratensis*), three woody plants (*Symphoricarpos occidentalis*, *Populus tremuloides*, and *Elaeagnus commutata*), two perennial forbs (*Cirsium arvense* and *Euphorbia esula*) and two biennial forbs (*Melilotus officinalis* and *Tragopogon dubius*). The growth (+) of invaders with very different ecological strategies were highly correlated (p=0.0001-0.01) with aspects of environment, grazing, and fire. The responses were, however, not strong, that is, slopes of the regression lines were low and little of the variance was accounted for (low r^2). In addition, the responses were inconsistent between the two nearby refuges. Thus, while managers use fire and grazing for other reasons (e.g., management of woody biomass, litter, and wildlife habitat), we see no evidence that either is useful for weed control.

MacDougall, A. 2002. Invasive perennial grasses in *Quercus garryana* meadows of southwestern British Columbia: Prospects for restoration. In Proceedings of the Fifth Symposium on Oak Woodlands: Oaks in California's changing landscape. Gen. Tech. Rep. PSW-GTR-184. Standiford, R. B., D. D. McCreary, and K. L. Purcell (eds.). U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. Albany, CA. pp. 159-168.

Abstract: Garry oak (*Quercus garryana*) meadows of the Pacific Northwest are heavily invaded but the dynamics surrounding this ecosystem transformation are poorly understood. Of particular uncertainty is the role of the invasive species in structuring the community, and the potential stability of this invasive-dominated system when disturbed. Clarifying such issues is central to restoration success for Garry oak meadows, one of Canada's most endangered

terrestrial ecosystems. This paper examines the competitive inter-relationships among exotic and native flora, and how these inter-relationships are modified by a series of disturbance treatments (burning, mowing, and selective removal of invasives). Recruitment dynamics are also described. Pre-treatment surveys of vascular plant taxa identified 80 species within the study area located near Duncan, British Columbia, Canada. Thirty-nine of the species were non-native. Two of the invasives—Kentucky blue grass and orchard grass—were dominant, averaging a combined 80 percent of total cover in all plots. Disturbance treatments, regardless of type or intensity, caused significant decreases in total percent cover of the exotic dominant grasses, and significant increases in ground level light, total species richness, and total percent cover of native flora. A combination of disturbance and native seed additions revealed that native plant recruitment is limited by primarily by dispersal, though the dense invasive sward probably restricts recruitment success also. These results indicate that the invasive sward could be de-stabilized by disturbance treatments, though supplemental recruitment measures are also needed to restore native species dominance to these meadows.

Parminter, J. and D. Bedford. 2006. Fire effects on selected bryophytes, lichens and herbs in Garry oak and associated ecosystems. The Garry Oak Ecosystems Recovery Team and the Nature Conservancy of Canada. Victoria, BC.

Abstract: This paper summarizes the effects of fire on plant species in the Garry oak and associated ecosystems. Discusses the fire ecology of each species, the effects of fire on the plant, the response of the plant to fire and considerations for fire management.

Rice, P. M. 2005. Fire as a tool for controlling nonnative invasive plants. Centre for Invasive Plant Management. Bozeman, Montana.

Abstract: This paper is a review of 235 available published papers about controlling invasive species with intentional burning. It is specified that knowledge of a plant's life history, plant morphology, and phenology is required to effectively prescribe management by burning, as is the promoting of desirable species in conjuction with burning. *Bromus hordeaceus* was found to increase after burning aimed at controlling medusahead, as it seeds much earlier. However, the removal of the mulch layer by burning or other method, reduced seed germination of *B. hordeaceus* and other exotic grass species.

Sather, N. 1996. Element stewardship abstract for *Poa pratensis*, *Poa compressa*. The Nature Conservancy. Arlington, VA.

Abstract: Element Stewardship Abstracts (ESAs) are prepared to provide The Nature Conservancy's Stewardship staff and other land managers with current management-related information on those species and communities that are most important to protect, or most important to control. The abstracts organize and summarize data from numerous sources including literature and researchers and managers actively working with the species or community. We hope, by providing this abstract free of charge, to encourage users to contribute their information to the abstract. This sharing of information will benefit all land managers by ensuring the availability of an abstract that contains up-to- date information on management techniques and knowledgeable contacts. Contributors of information will be acknowledged within the abstract and receive updated editions. To contribute information, contact the editor whose address is listed at the end of the document. For ease of update and retrievability, the abstracts are stored on computer at the national office of The Nature Conservancy. This abstract is a compilation of available information and is not an endorsement of particular practices or products.

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