Garry oak ecosystems recovery team

Annotated Bibliography on the Ecology and Management of Invasive Species:

Sheep Sorrel (*Rumex acetosella*)

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For the Garry Oak Ecosystems Recovery Team

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Peer-Reviewed Journal Articles

Crawley, M. J. 1990. Rabbit grazing, plant competition and seedling recruitment in acid grassland. Journal of Applied Ecology 27 (3): 803-820.

Abstract: 1. Two experiments were done to determine the effects of grazing by rabbits on plant recruitment in mature grassland and on cultivated soil. The first was a factorial experiment, with and without rabbit fencing, and with and without soil cultivation, carried out between 1986 and 1989 in acid grassland with a long history of rabbit grazing. In the second, carried out between 1982 and 1985 in two contrasting arable fields, rabbits grazed crops of winter wheat, with fencing exclosures erected at different times and for different durations. 2. Rabbit grazing affected the stature and composition of the grassland throughout the year. Species that increased in cover in rabbit-grazed grassland included the grass *Anthoxanthum odoratum* and the forb *Rumex acetosella*. Species that decreased included the grasses *Festuca rubra* and *Agrostis capillaris* and the forbs *Vicia sativa* and *Trifolium repens*. There was negligible change in the total number of plant species with grazing. 3. The cultivated treatments showed that the seed bank under the acid grassland was extremely heterogeneous. 4. Eight of the twenty-three commonest ruderal species beneath acid grassland decreased in cover significantly (e.g. *Capsella bursa-pastoris* and *Papaver dubium*), and none increased significantly. In contrast, most of the ruderal species in the seed bank of nearby arable soils increased under grazing. 5. Most plants species on cultivated grassland soils regenerated from vegetative fragments (e.g. *Holcus mollis*, *Stellaria graminea*, *Rumex acetosa* and *R. acetosella*), rather than by germination of seed. Regrowth shoots outnumbered seedlings by a factor of between 1.3 and 23.3. 6. The extent of spatial heterogeneity within and between plots in both the composition of the buried seed bank, and in recruitment by vegetative regrowth, highlights the need for large sample size in this kind of study. 7. The mechanisms that determine whether a plant species increases or decreases under grazing are discussed.

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

Abstract: 1. 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.

Fan, J. and W. Harris. 1996. Effects of soil fertility level and cutting frequency on interference among *Hieracium pilosella, H. praealtum, Rumex acetosella,* and *Festuca novae-zelandiae.* New Zealand Journal of Agricultural Research 39: 1-32.

Abstract: The role of ecological factors in the invasion of fescue tussock grassland by *Hieracium* species was investigated in a box experiment. Soil fertility and cutting frequency effects on interference between the introduced flat weeds *Hieracium pilosella, H. praealtum,* and *Rumex acetosella* and the native bunch grass *Festuca novae-zelandiae* established on a denuded soil were examined using a model and technique involving stress and disturbance gradients. The weed species showed marked biomass and phenological responses to increased availability of mineral nutrients compared to *F. novae-zelandiae,* which had reduced yield at the highest level of soil fertility. At high soil fertility, *R. acetosella* suppressed both *Hieracium* species and *F. novae-zelandiae,* probably because it competed more effectively for light. Cutting frequency also influenced the pattern of interference between the species by effects on competition for light, vegetative spread, and partitioning of biomass to parts of the plants above and near or below ground. Characteristics that have enabled *Hieracium* species to be successful invaders of tussock grasslands include markedly phasic growth coincident with the time of year when temperature, water, and nutrients are least limiting, ability to respond rapidly in vegetative and reproductive growth to pulses of mineral nutrient availability, and growth habits that enable them to invade and then hold on to sites they have occupied. Once they have occupied inter-tussock spaces it appears that hawkweeds can competitively exclude tussocks. The pattern *of Hieracium* root distribution and seasonal periodicity of the activity of their root systems may be important in the process of competitive exclusion of tussock grasses.

Jentsch, A., S. Leipzig, W. Friedrich, B. Beyschlag, and E. W. Nezadal. 2002. Significance of ant and rabbit disturbances for seedling establishment in dry acidic grasslands dominated by *Corynephorus canescens*. Phytocoenologia 32 (4): 553-580.

Abstract: Seedling establishment is a crucial bottleneck for vegetation dynamics. However, little is known about the spatio-temporal patterns of small-scale disturbances offering bare substrate for germination, nor about the establishment rates of key pioneer species. This paper presents (i) temporal patterns of ant and rabbit disturbances in dry acidic grasslands dominated by *Corynephorus canescens* on inland sand dunes, and (ii) establishment rates of *Corynephorus canescens*, *Spergula morisonii*, *Teesdalia nudicaulis* and *Rumex acetosella* on disturbance patches versus undisturbed controls. Spatially explicit disturbance patterns of five sites – characterized by the associations *Sperguło morisonii-Corynephoretum typicum* and *Spergulo morisonii-Corynephoretum cladoniatosum* – are recorded throughout 17 months at two scales (1 m ×1 m; 0.1 m ×0.1 m) in addition to plant establishment rates and cryptogam cover. A total of 1050 data records from 75 permanent plots is statistically analysed. Between 1% and 15% of the grasslands are covered by disturbance patches with a distinct seasonal pattern and limited longevity. For *Corynephorus canescens*, *Spergula morisonii* and *Teesdalia nudicaulis*, successful seedling establishment is significantly higher on small disturbed plots than on control plots, which are covered by cryptogams. Hence, these results provide evidence of the importance of small-scale disturbances as a window of opportunity for seedling establishment in dry acidic grassland. The findings are discussed with regard to the contribution of disturbance to the balance of grassland dynamics.

MacDougall, A. S., B. R. Beckwith, and C. Y. Maslovat. 2004. Defining conservation strategies with historical perspectives: a case study from a degraded oak grassland ecosystem.

Conservation Biology 18 (2): 455-465.

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.

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.

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 'seedfree' 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.

Pakeman, R. J., J. Engelen, and J. P. Attwood. 1999. Rabbit endozoochroy and seedbank build-up in an acidic grassland. Plant Ecology 145 (1): 83-90.

Abstract: The sources of seed for seedbank build-up in an acidic grassland were identified from analysis of differences in seedbank build-up over one year between plots where the input of rabbit pellets to 'seed-free' soil had either been left or removed. In parallel, the flux of seed arriving in rabbit pellets was monitored. Pellet seed content and total seed input were highest in late summer/early autumn and again in the spring. The seed content of the pellets was dominated by a small number of species: *Sagina apetala*, *Senecio jacobaea*, *Urtica dioica* and *Veronica arvensis*. Smaller seeded species were more likely to be present as germinable seed in the pellets. Seedbank build-up as a result of wind, splash or adhesive dispersal totalled 547 seeds/m^2. The additional effect of allowing seed input in pellets was 267 seeds/m^2, though this increase was not significant. The total increase in seedbank over one year was equivalent to 15-20% of the seedbank present in undisturbed soil. Eight species showed a significant build-up of seed in the seedbank over one year as a result of all means of dispersal, but only *Myosotis discolor* showed a significantly higher soil germinable seed content in the plots where pellets had been allowed to remain in situ. The build-up of seed in the seedbank is contrasted with the build-up of vegetation on disturbed areas within the same system.

Roberts, H. A. and J. E. Boddrell. 1985. Seed survival and seasonal emergence in some species of Geranium, Ranunculus and Rumex. Annals of Applied Biology 107 (2): 231-238.

Abstract: Seeds of 14 species were collected, usually in each of 2 or 3 yr, and mixed with the top 7.5 cm of sterilised soil confined in cylinders sunk in the ground outdoors and cultivated three times yearly. Seedling emergence was recorded for at least 3 and usually 5 yr. Most seedlings of Ranunculus bulbosus and *Rumex acetosa* appeared during the autumn of sowing, while the main emergence of *Geranium pratense*. *Ranunculus acris*, *Rumex conglomeratus* and *R. maritimus* was in the following spring. Emergence of *G. pyrenaicum* and *G. robertianum* took place throughout much of the year after sowing. Seeds of all these species were relatively short-lived in cultivated soil, and few seedlings appeared after the second year. Seed survival was greater in *G. dissectum*. *G. molle*, *Rumex acetosella*. *Ranunculus sceleratus* and especially *R. repens*, of which emergence in the fifth year after sowing amounted to 4% of the seeds sown. Emergence from the persistent seed bank was mainly from May to September for *G. dissectum* and *G. molle* and during autumn for *Ranunculus flammula* and *R. sceleratus*, while seedlings of *Ranunculus repens* and *Rumex acetosella* appeared sporadically over most of the year.

Other Published Sources

Alaska Natural Heritage Program. 2006. Non-native plant species of Alaska: Sheep sorrel (*Rumex acetosella*). 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.

BC Ministry of Agriculture, Food and Fisheries and Open Learning Agency. 2002. Guide to weeds in British Columbia. Province of British Columbia. Victoria, BC.

Abstract: This document is a comprehensive resource on weed management in British Columbia. For each weed species, information is provided on identification, impacts, habitat and ecology, and management.

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.

Juska, F. V. 1960. Sheep sorrel: Its control. The Golf Course Reporter June: 44-46.

Abstract: This article summarizes the results of a study that tested the combined effects of liming together with the application of various herbicides on sheep sorrel.

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.

Tveten, R. K. 1997. Fire effects on prairie vegetation, Fort Lewis, Washington. The Nature Conservancy of Washington. Seattle, WA.

Abstract: STUDY OBJECTIVES: 1) What prairie plant communities have developed as a result of the prescribed burning program and annual burning in the Artillery impact area on Fort Lewis? 2) What fire regime best promotes native prairie vegetation? 3) Do fall prescribed fires affect prairie vegetation differently from spring fires? LOCATION: Fort Lewis, Washington. RESULTS: Fire suppression is gradually allowing Western Washington's prairies to be lost to invading Douglas-fir forest of *Cytisus* shrublands. Too much burning destroys native prairie communities. The study shows that native prairie species are adapted to withstand and thrive in the presence of fires (every 3 to 5 years). This study also showed that prairie vegetation response is essentially the same for both spring and fall prescribed fires.

Online Resources

E-Flora. 2008. E-Flora BC: Electronic Atlas of the Plants of British Columbia. http://www.eflora.bc.ca/. Klinkenberg, Brian. (ed.) Lab for Advanced Spatial Analysis, Department of Geography, University of British Columbia. Vancouver, BC.

Esser, L. L. 1995. *Rumex acetosella*. In: Fire Effects Information System. http://www.fs.fed.us/database/feis/. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory.

Graham, G. L. and M. J. Melanson. 2007. Evaluation of spring applied, crop-year herbicides for sheep sorrel control in wild blueberries. http://www.gnb.ca/0389/2007/03892007009-e.asp. New Brunswick Department of Agriculture and Aquaculture.

Metlen, K. L., E. K. Dodson, and C. E. Friedler. 2006. Vegetation response to restoration treatments in ponderosa pine-Douglas-fir forests of western Montana. In: Fire Effects Information System. http://www.fs.fed.us/database/feis/. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory.

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Virginia Tech College of Agriculture and Life Sciences. 2008. Virginia Tech Weed Identification Guide. www.ppws.vt.edu/weedindex.htm. Virginia Tech College of Agriculture and Life Sciences.

WeedAlert.com. 2005. The turf professional's online source for weed control options. http://weedalert.com/index.html. PBI/Gordon Corporation.