Garry oak ecosystems recovery team

Annotated Bibliography on the Ecology and Management of Invasive Species:

Perennial Ryegrass (*Lolium perenne*)

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For the Garry Oak Ecosystems Recovery Team

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Peer-Reviewed Journal Articles

Bardgett, R. D., J. L. Mawddsley, 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: 650-660.

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: 257-264.

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.

Clark, H., P. C. D. Newton, and D. J. Barker. 1999. Physiological and morphological responses to elevated CO_2 and a soil moisture deficit of temperate pasture species growing in an established plant community. Journal of Experimental Botany 50 (331): 233-242.

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 CO_2. Using large pasture turves, previously exposed to elevated CO_2 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 CO_2 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 CO_2, but there was no consistent effect of CO_2 on stomatal conductance. At low soil moistures, net photosynthesis declined and stomatal conductance increased in these three species. There was a strong CO_2 X water interaction in respect of net photosynthesis; in *Trifolium repens*, for example, elevated CO_2 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 CO_2 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 CO_2 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 CO_2 were frequently higher than those at ambient CO_2, but there was no effect of CO_2 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 CO_2 in all species, but in *Holcus lanatus* the reduction was less severe at elevated CO_2. 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 CO_2. Consequently, despite the greater leaf extension rate during the soil moisture deficit at elevated CO_2, because of the overcompensation after rewatering at ambient CO_2, total leaf extension over both the drying and rewetting period did not differ between CO_2 concentrations for these C3 grass species. Further investigation of this difference in response between CO_2 treatments is warranted given the frequent drying and wetting cycles experienced by many temperate grasslands.

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

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., H. Clark, and P. C. D. Newton. 2001. The effects of elevated CO2 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 CO_2 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.

Elberse, W. T. and F. Berendse. 2008. A comparative study of the growth and morphology of eight grass species from habitats with different nutrient availabilities. Functional Ecology 7 (2): 223-229.

Abstract: To find out which properties enable plant species to dominant in nutrient-poor habitats and which properties benefit species in nutrient-rich habitats, we studied the growth and morphology of eight perennial grass species from habitats with contrasting soil fertilities in a pot experiment under controlled conditions in a glasshouse. The species were grown under nutrient-poor and nutrient-rich conditions. Ranked from the least responsive to the most responsive to the supply of nutrients they were: *Festuca ovina*, *F. rubra*, *Anthoxanthum odoratum*, *F. arundinacea*, *Alopecurus pratensis*, *F. pratensis*, *Arrhenatherum elatius*, *Lolium perenne*. The response correlated positively with the Ellenberg nitrogen number of the species. No differences in initial relative growth rate was found between the species, but after 4 weeks the plant dry weight increased with increasing nitrogen number as a result of variation in embryo plus endosperm weight. Species characteristic of nutrient-rich hayfields are taller and show a more homogeneous vertical distribution of photosynthetic area than the species from nutrient-poor habitats, which have most of their leaf area below 15 cm. Species from the nutrient-poor habitats allocated less dry matter to the roots and consequently more to the shoot, than species from nutrient-rich conditions. However, leaf and root morphology seem to be most clearly adapted to the habitat. Species from nutrient-rich habitats have a higher specific leaf area (SLA) than species from nutrient-poor habitats, while species from nutrient-poor habitats had more root length per unit root weight (SRL) than species from nutrient-rich habitats.

Fransen, B., J. Blijjenberg, and H. de Kroon. 2008. 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.

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.

Keith, C., S. Marks, and G. Cheplick. 1993. Effects of insect herbivory and fungal endophyte infection on competitive interactions among grasses. Ecology 74 (6): 1767-1777.

Abstract: Interactions among plants may be influenced by pests or parasites that differentially affect one competitor. The purpose of this study was to determine the effects of fungal parasitism and insect herbivory, alone and in concert, on plant competitive interactions. The effects of fungal endophyte (*Acremonium* spp.) infection and fall armyworm (*Spodoptera frugiperda*) herbivory on competitive interactions in one- and two-species mixtures of the grasses tall fescue (*Festuca arundinacea*), red fescue (*F. rubra*), and perennial ryegrass (*Lolium perenne*) were examined in greenhouse experiments. In general, herbivory reduced plant biomass whereas endophyte infection increased plant biomass. Endophyte-infected (E+) plants were less damaged by herbivory than uninfected (E-) plants of the same species. Studies on fall armyworm larval feeding and choice tests with the five grass species were generally consistent with the outcome of the competition experiments; E+ plants were less nutritious and less preferred than E- plants of the same species. There were significant interactions among factors so that the outcome of competition depended on the species identities and the presence or absence of endophytes and herbivores. In competition with Kentucky bluegrass (*Poa pratensis*), E+ and E- perennial ryegrass produced similar biomass in the absence of herbivory, but E+ perennial ryegrass had nearly twice the biomass of E- plants when herbivores were present. E+ and E- tall fescue were poor competitors with orchard grass (*Dactylis glomerata*) when herbivores were absent, but E+ tall fescue was a better competitor than E- plants and orchard grass when herbivores were present. This study indicates that competitive hierarchies among grasses are altered by interactions with insect herbivores and fungal endophytes, which have typically been ignored in past studies.

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.

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.

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*.

Kon, K. F., G. B. Follas, and D. E. James. 2007. Seed dormancy and germination phenology of grass weeds and implications for their control in cereals. New Zealand Plant Protection 60: 174-

82.

Abstract: Seeds of Italian ryegrass, perennial ryegrass, wild oat, winter wild oat, phalaris and barnyard grass, collected during the 2005/06 season, were tested for dormancy and germination phenology between April and December 2006. In laboratory and outdoor environments, dormancy was widespread in grass weed but not in ryegrass seeds. The seeds of grass weeds had better germination in the outdoor environment than the laboratory. In the outdoor environment, only 15% of wild oat and winter wild oat, 19-63% of phalaris and 39% of barnyard grass seed germinated. Protracted germination varied between species in two to seven flushes. The earliest timing for effective post-emergence grass control under the experimental conditions appeared to be about 6 weeks after sowing for wild oats and ryegrasses, 12 weeks for phalaris and 14 weeks for barnyard grass. The extended germination periods of phalaris and barnyard grass are a challenge to growers in designing a cost-effective herbicide programme.

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). Speciesrich 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. 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.

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.

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.

Roberts, H. A. 1986. Persistence of seeds of some grass species in cultivated soil. Grass and Forage Science 41: 273-276.

Abstract: Freshly collected ripe caryopses of twenty-five indigenous grasses were mixed with the top 7-5 cm of sterilized soil confined in cylinders sunk in the ground and cultivated three times yearly. There was a flush of seedlings of most species shortly after sowing, but species differed in the persistence of viable seeds. About one third, including *Bromus sterilis, B. hordeaceus, Lolium perenne ssp. perenne, Arrhenatherum elatius a.nd Alopecurus pratensis,* produced few seedlings after the initial flush. Others such as *Deschampsia cespitosa, Holcus lanatus* and *Poa trivialis,* recognized as forming persistent seed banks in grassland soils, produced appreciable numbers of seedlings in the second year after sowing. Most persistent were species that occur as arable weeds *{Avena fatua, Poa annua)* or in wetlands *{Glyceria plicata, G. maxima, Alopecurus geniculatus).* Emergence from the seed bank generally followed

soil disturbance but some species *{Aira praecox, Avena fatua, A. sterilis* ssp. *ludoviciana, Danthonia decumbens)* exhibited consistent seasonal patterns which may be associated with cyclic changes in germination requirements of the buried seeds.

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

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.

Pollak, O. and T. Kan. 1998. The Use of Prescribed Fire to Control Invasive Exotic Weeds at Jepson Prairie Preserve. In Ecology, Conservation, and Management of Vernal Pool Ecosystems – Proceedings from a 1996 Conference. Witham, C. W., E. T. Bauder, D. Belk, W. R. Ferren, Jr., and R. Ornduff (eds.). California Native Plant Society. Sacramento, California. pp. 241-249.

Abstract: Jepson Prairie in Solano County, an outstanding example of remnant California Central Valley vernal pool and grassland habitats, is threatened by invasive exotic species. This paper describes the results of a 200-acre late-spring prescribed fire conducted at Jepson Prairie in June of 1995 and aimed at reducing the cover of an extensive infestation of Medusahead (*Taeniatherum caput-medusae*). Burned and unburned control plots are compared with respect to changes in community composition within three habitat types. The habitat types - mound, intermound, and swale - correspond to three topographic/hydrologic regimes within vernal pool

complexes. Ocular estimates of percent cover (using Daubenmire cover classes) were recorded for six species guilds: native grasses, exotic grasses, native early forbs, exotic early forbs, native late forbs, and exotic late forbs. Cover of thatch, bare ground and residual dry matter was also measured. Results show significant decreases in the cover of exotic annual grasses (including Medusahead) and thatch in burned mound and intermound habitats. Cover of native grasses and native early forbs increased on burned mound and intermound habitats. However, exotic early forbs also increased on burned mounds and intermounds, due mainly to an increase in cover of *Erodium* spp. The results provide strong evidence that late-spring burning reduces the cover of non-native annual grasses, such as Medusahead, while increasing the dominance of native species and the cover of native grasses and forbs. Prescriptions for management of vernal pool and grassland habitats in California should include late-spring prescribed fire in areas that have heavy infestations of Medusahead or an accumulated thatch layer.

Online Resources

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