Garry oak ecosystems recovery team

Annotated Bibliography on the Ecology and Management of Invasive Species:

Colonial Bentgrass (*Agrostis capillaris*)

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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.

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.

Hester, A. J., J. Miles, and C. H. Gimingham. 1991. Succession from heather moorland to birch woodland i. experimental alteration of specific environmental conditions in the field. Journal of Ecology 79: 303-315.

Abstract: 1. The effects of experimental alteration of light intensity, nutrient availability and simulated grazing on plant communities beneath different ages of birch are examined. Plant responses are discussed in relation to their role in the succession from heather moorland to mature birch woodland. 2. A generalized sequence of changes in species dominance as the birch (*Betula pendula* and *B. pubescens*) ages is identified. *Calluna vulgaris* gradually declines and is replaced by *Deschampsia flexuosa* and then *Agrostis capillaris* as the woodland matures and the canopy opens out. 3. The growth of *Calluna* was greatly reduced in shaded plots and nutrient addition had no significant compensatory effect. *Empetrum nigrum* showed similar growth responses. *Vaccinium myrtillus* and *Deschampsia flexuosa* also grew less well in reduced light but *D. flexuosa* responded positively to nutrient addition. 4. Clipping reduced the growth of *Calluna*, *Empetrum nigrum*, *Vaccinium myrtillus* and *Deschampsia flexuosa* in most plots. Only Galium saxatile showed increased growth after clipping at one site. 5. Competitive interactions between the main species were apparent and are further examined by the second paper in this series.

Hester, A. J., C. H. Gimingham, and J. Miles. 2008. Succession from heather moorland to birch woodland iii. seed availability, germination and early growth (abstract). Journal of Ecology 79 (2): 329-344.

Abstract: 1. This paper examines seed input, germination and early growth of species found during the succession from heather moorland to mature birch woodland. 2. Numbers of seeds of *Calluna vulgaris* in the seed rain decreased rapidly with increasing age of birch stands. Large numbers of *Calluna* seeds were found, however, in soil beneath all ages of birch as well as the open moor, illustrating the longevity of seeds of this species. 3. Large numbers of *Deschampsia flexuosa* seeds arrived in the seed rain but very few germinated from the soil, indicating dependence on immediate seed regeneration, unlike *Agrostis capillaris* which had large, persistent soil seed stores. 4.The presence of seeds of *Anthoxanthum odoratum*, *Agrostis capillaris* and *Rumex acetosella* in seed rain and soil seed stores showed that the absence of these species from open moorland and young birch was not due to unavailability of propagules. 5. Germination of the species studied was apparently not affected by stand age, with the exception of *Agrostis capillaris* and *Cerastium holosteoides* which showed reduced germination on the open moor. Early growth of most species was faster, however, beneath the birch than on the open moor and improved beneath increasing ages of birch. 6. The natural regrowth of vegetation in the cleared plots was faster beneath the older birch than the young birch or the open moor. 7. The implications of differences in seed availability, germination and early growth are discussed in relation to observations and experiments on species changes beneath developing birch reported in the first two papers of this series.

Hulme, P. E. 1996. Herbivores and the performance of grassland plants: A comparison of arthropod, mollusc and rodent herbivory. Journal of Ecology 84 (1): 43-51.

Abstract: 1. A field experiment involving exclosure techniques was used to assess the relative roles of arthropods, molluscs and rodent herbivores in the survival and growth of temperate grassland plants. The study focused on the impact of herbivores on plant survival, above-ground biomass and root weight ratios of 21 plant species which were sown experimentally in a grassland and meadow. 2. Of the three herbivore groups studied, rodents exerted the greatest influence on plant performance, reducing plant biomass by as much as 50% and substantially increasing plant mortality. Molluscs significantly decreased plant numbers but plants appeared more able to compensate for biomass lost through grazing. By comparison, arthropods played only a minor role in determining either plant biomass or survival. 3. Positive

correlations in the responses of plant species to herbivory by molluscs and rodents indicate that the major difference in the impact of these two guilds of herbivores on plant performance (survival, biomass and root weight ratio) is in the magnitude rather than the direction of the plant response. Legumes were more susceptible to herbivory than grasses, exhibiting both lower survival and greater loss of biomass. 4. Results indicate that where resources are limiting, as in the meadow, the direct influence of herbivores on plant numbers is minimal since herbivore induced mortality is only one component of naturally low plant survival. In contrast, the influence of herbivores on plant growth can be considerable since plants are often unable to compensate for tissue loss via regrowth. Thus, in the grassland, the overall influence of herbivores was on plant numbers whereas in the meadow their main impact was on mean plant biomass. 5. Although the majority of the variation in both plant survival and biomass occurred independently of the experimental treatments, with almost 50% attributable to intrinsic species effects, indirect evidence reveals herbivores to have an impact on plant community composition. Plants which suffer both high mortality and poor growth as a result of herbivory (e.g. *Trifolium repens*, *T. pratense*) are rare while those plants whose performance is little influenced by herbivores (e.g. *Agrostis capillaris*, *Dactylis glomerata*, *Plantago lanceolata*) are abundant in the grassland communities studied.

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.

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.

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 lsquoseed-freersquo 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/m2. The additional effect of allowing seed input in pellets was 267 seeds/m2, 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.

Pollock, K. M. and D. Scott. 1993. Introduction, production, and persistence of five grass species in dry hill country: 3. High country, Tekapo, New Zealand (abstract). New Zealand Journal of Agricultural Research 36 (1): 19-24.

Abstract: Grass species were rotary-hoe-drilled into heiracium-dominated fescue tussock. Late autumn and early spring herbage accumulation and composition were determined after three summer grazing treatments (0, 6, and 10 weeks freedom from grazing), and two pre-winter grazing managements. Subplots compared species production and persistence of two superphosphate (P) and three nitrogen (N) fertilizer levels. Over the 7 years, sown grasses only occasionally made significant contribution to the sward. 'Grasslands Apanui' cocksfoot (*Dactylis glomerata* L.) was the best introduced species, reaching dominance in 66% of subplots receiving P and N in the third year. Ryegrass (*Lolium perenne* L.) and tall fescue (*Festuca arundinacea* Schreb.) made some contribution to sward production, and there were only occasional plants of prairie grass (*Bromus willdenowii* Kunth) and tall oat grass (*Arrenatherum elatius* (L.) Beauv. ex J & C. Presl). The principal response was to fertilizer, with alsike cover (*Trifolium hybridum* L.) responding to P in the early years, and resident fescue tussock (*Festuca novae-zealandiae*) (Hack.) Ckn, sweet vernal (*Anthoxanthum odoratum* L.), and browntop (*Agrostis capillaris* L.) to N in later years. Summer spelling increased March herbage mass but decreased late -autumn growth. Pre-winter lax grazing only slightly increased spring growth.

Session, L. and D. Kelly. 2002. Predator-mediated apparent competition between an introduced grass, *Agrostis capillaris*, and a native fern, *Botrychium australe* (*Ophioglossaceae*), in New Zealand. Oikos 96 (1): 102-109.

Abstract: This study provides an example of how invasive plant species may indirectly affect native species through apparent competition by altering the local invertebrate community. The native New Zealand fern *Botrychium australe* (Ophioglossaceae) is thought to benefit from disturbances such as fire, because this species is generally found in disturbed habitats with low shade and increasing competition. However, in this study we show that a mapped population of *B. australe* experienced a marked decrease in survival and reproduction after an accidental fire in May 1995. Mortality was not due to the direct effects of fire; in the year following the fire, survival was normal and reproduction was higher than in previous years. However, after 1996 an introduced grass (*Agrostis capillaris*) spread across the area and *B. australe* survival in the second to fourth years after the fire (1996-1999, 59.63%) was significantly lower than survival before the fire, and plants did not produce spores at all during this 3-yr period. *B. australe* survival was not lower in plots with dense *A. capillaris* growth. From 1997 onwards, *B. australe* plants suffered very extensive defoliation by a herbivore, and insecticide and molluscicide experiments in 1999 and 2000 showed that the introduced slug *Deroceras reticulatum* was responsible for the damage. The slug increased after the fire in association with the spread of *Agrostis capillaris*, probably because this plant created a suitable habitat for slugs.

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

Abstract: The results are reported from an experiment on the effects of cutting date (14

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

Stampfli, A. and M. ZEiter. 2008. Mechanisms of structural change derived from patterns of seedling emergence and mortality in a semi-natural meadow. Journal of Vegetation Science 19: 563-574.

Abstract: Questions: Is seedling emergence limited by the set of viable seeds, by incompatibility between the phenology of seed shedding and timing of mowing, or by dry weather in germination periods? Does seedling mortality fluctuate with season and weather? Location: Negrentino, southern Alps, Switzerland. Methods: Fecundity estimates of the dominant grass *Bromus erectus*; highly frequent counts of spontaneous seedlings by species and calculation of a community-level average mortality rate across 5 years; species-level records of seed shedding date and measurements of seed mass; measurement of soil moisture. Results: *B. erectus* produced 143.9 viable seeds/m^2/year while the density of its seedlings was a 55 times smaller fraction. Grasses had fewer seedlings than forbs and their phenology of seed shedding was less compatible with mowing date. Soil moisture was a strong determinant of seedling emergence in spring and less so in autumn. Average seedling mortality declined with age of the populations and reached a maximum in an extremely dry summer. In relatively wet summers establishment success was positively related to seed mass. Conclusion: Community structure is susceptible to drought through mechanisms that selectively reduce recruits of coexisting plant functional groups. We propose that (1) more frequent intense droughts tend to reduce species that depend on frequent recruitment from seed, hence favour long-lived clonally spreading species, (2) drought timing selects between species with different germination phenology and drought resistance, and (3) drought impacts can be mitigated by changing management regimes that affect seed shedding.

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.

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

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

Zhao, H., S. S. Bughrara, and J. A. Oliveira. 2006. Genetic diversity in colonial bentgrass (*Agrostis capillaris* L.) revealed by *Eco*RI–*Mse*I and *Pst*I–*Mse*I AFLP markers. Genome 49: 328-335.

Abstract: Colonial bentgrass (*Agrostis capillaris* L.) is a potential source for genetic improvement of resistance to environmental stress and disease for other bentgrass species (*Agrostis* spp.). To conserve and study the existing genetic resources of colonial bentgrass for use in breeding, genetic diversity was investigated using amplified fragment length polymorphism (AFLP) markers. Included in this study were 22 accessions from US Department of Agriculture germplasm collected from 11 countries, in conjunction with 14 accessions from northern Spain and 3 commercial cultivars. Ten *Eco*RI–*Mse*I and 6 *Pst*I–*Mse*I AFLP primer combinations produced 181 and 128 informative polymorphic bands, respectively. Cluster analysis of genetic similarity estimates revealed a high level of diversity in colonial bentgrass species with averages of 0.51 (*Eco*RI–*Mse*I) and 0.63 (*Pst*I–*Mse*I). Greater genetic diversity was detected by the *Eco*RI–*Mse*I AFLP primer combinations. A low but significant positive correlation ($r = 0.44$, $p = 0.0099$) between the 2 Jaccard similarity matrices was obtained by the Mantel test. Commercial cultivars of bentgrass showed a narrow genetic background. The assessment of genetic diversity

among colonial bentgrass accessions suggested the potential value of the colonial bentgrass germplasm in turfgrass cultivar improvement.

Other Published Sources

Holgate, G. L. 1986. A role for goats in range utilization and shrubweed control on New Zealand's pastoral lands (abstract). Rangelands: a resource under siege.Proceedings of the 2nd International Rangeland Congress, Adelaide, Australia May 13-18 1984: 296-297.

Abstract: Merino sheep, feral goats and Angora goats were set-stocked at equivalent liveweight 0.73 in 0.5-ha paddocks of *Agrostis capillaris*/*Anthoxanthum odoratum* infested with *Rosa rubiginosa*. Goats rapidly reduced the size of *R. rubiginosa* plants whereas sheep had little effect. After 2 years, *Trifolium repens* cover was significantly greater where Angoras grazed than in the other 2 treatments.

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