Collaboration for Environmental Evidence

Systematic Review No. 83

WORKING TITLE: ***Does fertilisation decrease biodiversity in temperate montane grasslands?***

Review Protocol

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Cover Sheet

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1. Background

Semi-natural montane grasslands in Europe were traditionally established below the tree line and maintained as treeless grasslands through extensive grazing and / or mowing for hay production. Traditionally (i.e. extensively) managed montane grasslands support impressive biodiversity at multiple scales (Baur et al. 1996). However over the last 50 years patterns of land-use have changed in two ways: (1) the abandonment of less accessible areas and (2) the intensification of practices in more favourable areas. Abandonment, and hence cessation of traditional disturbance regimes, usually results in encroachment by lower-diversity forests (e.g. Albert et al. 2008). Intensification on the other hand involves the application of liquid manure (manuring) and and / or mineral fertilisers. Montane plant growth is characteristically nutrient limited (Bowman et al. 1993, Kohler et al. 2001), so fertilisation can increase productivity, but usually by means of increasing the dominance a few productive plant species (usually graminoids) at the expense of forb and legume species (Marini et al. 2007, Niu et al. 2008). Such alterations of plant community composition and structure are likely to impact grassland biodiversity more broadly. Declines in diversity associated with intensification have already been reported for a range of taxonomic groups (Boschi and Baur 2008, Marini et al. 2008).

In addition to direct nutrient additions associated with intensification, deposition of atmospheric nitrogen is also increasing in many terrestrial ecosystems (Galloway et al. 2003) and concern has been raised over the effects of N deposition on species rich alpine grasslands in Europe (Bassin et al. 2007) and North America (Burns 2004). While alpine grasslands occur above the tree line and are less frequently utilised by farmers, many are N-limited ecosystems and insights from experiments exploring nitrogen enrichment effects on diversity are relevant to management of montane grasslands more generally.

Experimental studies that investigate the direct effects of nutrient addition on ecosystem properties are undertaken at small spatial scales within an ecosystem. While these studies yield important information, the generality of results is often limited. Observational studies on the other hand explore effects at larger scales and aim to determine the relative influence of intensification after accounting for other sources of variation. The results are applicable at broader scales but the uncertainty surrounding fertiliser effects is larger than in experimental studies and it may not be possible to completely isolate these from the effects of covariates. The drawbacks of both of these approaches highlight the value of synthesising research in a systematic way.

This systematic review aims to evaluate all relevant and available evidence on the effects of fertilisation on the diversity of montane grasslands in temperate regions.

2. Objective of the Review

2.1 Primary question

Does fertilisation decrease biodiversity in temperate montane grasslands?

Table 1. Elements of the systematic review question

Subject	Intervention	Comparators	Outcomes
Natural and semi-natural montane grasslands (including montane, subalpine and alpine zones) in temperate regions	Fertilisation	Control plots or reference sites that have not been fertilised	Species diversity or richness

2.2 Secondary question *(if applicable)*

Does the absolute abundance of particular functional groups consistently increase or decrease in response to fertilisation in temperate montane grasslands?

Do different taxonomic groups respond differently to fertilisation in temperate montane grasslands?

3. Methods

3.1 Search strategy

The following databases will be searched for relevant documents (title, abstract and keywords): ISI Web of Knowledge, Science Direct, Scirus, Directory of open access journals, Scopus, Scientific Electronic Library Online, JSTOR, Agricola, CAB Abstracts and Index to Theses Online. The first 100 pdf or word documents from a Google Scholar search will also be included and the first 50 hits of a more general Google search will be checked for relevant documents. Hits from each search will form the first cut of the overall search, in addition to relevant citations no more than one step away from original hits to capture relevant grey literature. Titles and abstracts from each search will be stored in a single Endnote database and duplicates removed. At present the lab only has the capacity to assess studies in English, German and French.

The following search string will be used in English:

Subject:
(oligotrophic OR mesotrophic OR “nutrient limited” OR “nutrient poor” OR seminatural OR semi-natural OR "semi natural" OR "traditionally managed" OR unimproved OR "extensively managed" OR alpine OR subalpine OR montane OR submontane OR sub-montane OR mountain* OR upland OR highland)
AND
(grassland OR meadow OR fen OR tundra OR moor*)

AND

Intervention:
(fertilis* OR fertiliz* OR nitrogen OR ammonium OR nitrate OR manur* OR intensifi* OR eutrophi* OR "land use change" OR "nutrient addition")
AND

Outcome:
(diversity OR richness OR assemblag* OR "functional type" OR "functional group" or guild or "growth form" or "species number" or "species density" OR "botanical composition" OR "species composition" OR "number of species" OR "floristic composition" OR "community composition")

This search string was developed through a scoping exercise using ISI Web of Knowledge, following CEBC recommendations (CEBC 2009). It returned 1,267 records and is considered a conservative (i.e. sensitive) starting point, but is small enough list refine given available time and resources. In relation to the subject search terms, montane meadows and pastures are often referred to as "semi-natural", "extensively managed" or "traditionally managed" grasslands without mention of the climatic zone. We recognise that such grasslands occur in lowland regions as well but included the term in this general sense as a conservative measure. All studies from lowland regions will be discarded.

The intervention terms are also quite general. "Nitrogen", "ammonium" and "nitrate" captured many irrelevant ecosystem studies, but were included to ensure adequate sensitivity. The outcome terms should refine the search somewhat. They were developed to capture all studies that report changes in diversity or species composition of any taxonomic group. "Functional group", "functional type", "guild" and "life form" were also included to capture studies relevant to a secondary question.

3.2 Study inclusion criteria

Firstly, titles from the first cut database will be assessed for obviously spurious results. Then, the remaining titles and abstracts will be manually scanned to assess relevance. References will be retained if they refer to the following in the title or abstract:

1. montane, upland, highland, sub-alpine or alpine grasslands;
OR
semi-natural, traditionally managed or extensively managed grasslands;

AND
2. Fertilization (or other acceptable terms from the search string);
OR
land use intensification or land use change;
OR
Nitrogen deposition

AND
3. Some mention of ecosystem or community properties (e.g. not just a selection of species from an montane habitat)

No specific mention of species richness or diversity is required at this stage. Studies that compare relevant interventions (e.g. fertilization) across multiple ecosystems should also be retained even if no mention is made of montane grasslands in the title or abstract. A conservative approach will be taken so that references are retained if doubt remains after applying the above selection criteria. The criteria will allow for the inclusion of both experimental and observational studies.

A random subset of the database will be scanned by a second reviewer using the same inclusion criteria. Inclusion consistency will be assessed using kappa statistics. If $\kappa > 0.6$, the selection criteria will be redefined to increase agreement.

Finally, the refined list of studies will be inspected in more detail to ensure they include the following:

- **Relevant subject(s):**
  Natural or semi-natural grasslands in temperate montane zones. We define grasslands as generally treeless, dominated by graminoid and forb species (>50% graminoid and herbaceous cover prior to interventions). Natural and semi-natural grasslands are characteristically nutrient limited and traditionally receive little or no fertilisation (traditional manure application permitted). We define montane grasslands as those occurring on mountain ranges within temperate regions that experience winter snow cover. We define temperate regions as those (1) within with temperate latitudes and (2) classified in the Köppen Climate Classification System as: Et, Cfb, Cwb, Cfc, Cwc, Cfd, Cwd, Dfb, Dwb, Dfc, Dwc, Dfd and Dwd. The use of these 13 categories successfully excludes Mediterranean, subtropical and arid climates that occur within the temperate latitudes.

- **Types of intervention:**
  Addition of nitrogen fertilizer (alone or in combination with other nutrients).

- **Types of comparator:**
  Control plots that did not receive treatment (experimental studies) or suitable reference areas that have not been fertilised (observational studies). Control plots should be managed in the same way as treatment plots with the exception of fertiliser addition. Any changes in management (in control or treatment plots) from pre-experimental conditions must be documented.

- **Types of outcome:**
  Richness or diversity of at least one taxonomic group. Also changes in absolute abundance of functional groups.

- **Types of study:**
  Scientific journal articles, book chapters, PhD theses, MSc theses, technical reports and any other types of document that fulfil the study quality requirements (see below).

3.3 Potential effect modifiers and reasons for heterogeneity:

Fertilization of montane grasslands has been studied to assess the direct effects of agricultural intensification on various ecosystem characteristics (e.g. vascular plant richness) or functions (e.g. soil microbial activity, biomass production). Experimental application of fertilizers has also been used to explore the potential effects of increased atmospheric nitrogen deposition. Therefore effect modifiers will include the type, rate, frequency and duration of fertilizer application.

Additional sources of heterogeneity will include baseline phytosociological differences and variation in geological parent material, soil characteristics, latitude, altitude, topography and other important environmental factors. Additional management factors (in addition to the interventions) may also be important, e.g. grazing and mowing history. Changes in management from pre-experimental conditions may have confounding effects and we will attempt to account for such changes.

3.4 Study quality assessment

Studies will be assessed using the classification system of Pullin and Knight (2003). Only studies in category II-2 and above will be considered for inclusion. This will allow for both experimental and observational studies to be included, but will exclude studies that provide only qualitative evidence.

3.5 Data extraction strategy

Richness ignores the relative abundance of species, but is often quoted in combination with other diversity measures such as Simpson and Shannon indices. All richness and diversity responses will be extracted where multiple measures are provided. Data from each reference will be entered into spreadsheets including all potentially relevant information for comparisons (see sources of heterogeneity). Where insufficient data are provided for extraction, an attempt will be made to contact the corresponding author to obtain the required data. We have already contacted multiple authors during the pilot selection strategy and received a largely positive response. So far we have received additional data (mostly mean responses and associated standard errors) from four relevant experimental studies.

3.6 Data synthesis and presentation

Both qualitative and quantitative syntheses will be undertaken. The qualitative part will be a simple vote counting exercise reporting the number of studies reporting increases, decreases or no change. This qualitative assessment will incorporate findings from observational as well as experimental studies. Only experimental studies will be included in the quantitative analysis because reported effects sizes from observational studies are often conditional on the effects of covariates included to explain intersite variation. The type of diversity responses and the manner in which results are presented will determine the approach to a large extent. Results presented in relevant publications obtained during the pilot selection process indicate that richness is likely to be the most commonly presented response. If a common measure can be extracted for control and treatment plots with associated sample sizes and standard errors (or variances or standard deviations), then a response ratio approach will be used (Hedges et al. 1999). Because most experimental studies include multiple fertiliser treatments (e.g. control and four increasing rates of fertiliser application), we will treat each treatment effect as a separate data point. To do this we also need to

account for variation (i.e. heterogeneity) between studies. Thus, we will need to estimate two levels of variance: (1) between study variance and (2) between effect variance (nested within the relevant study). The hierarchical Bayesian framework is suitable for this task. Firstly, we will estimate 'raw' variance components in a model without moderators. Then we will add moderators in a meta-regression analysis. This will allow suitable covariates to be incorporated while accounting for the nested structure in the data. The 'left over' unexplained variance at each level can then be compared to the 'raw' variance components to estimate how much variance is explained by the moderators. Significance of each moderator will be assessed by consulting 95% credible intervals generated from the posterior distribution of each coefficient. Suitable non-informative prior distributions will be used for all variance components and coefficients to be estimated in the model.

The completed review will be submitted for peer-review to the CEE website. Once accepted as a final review, a succinct and clearly communicated summary of findings will be distributed to public administrators and Agricultural unions. We plan to submit the review for publication in a peer-reviewed ecological journal.

4. Potential Conflicts of Interest and Sources of Support

None declared.

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