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Effects of Plant Functional Groups on Vegetation Dynamics and Ecosystem Properties

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LOSS OF BIODIVERSITY has likely been the most dramatic change humans have imposed on ecosystems in the past century (Chapin et al., 2000); the global extinction rate is currently between 100 and 1000 times faster than pre-human extinction levels (Pimm et al., 1995). There is growing concern that this species loss will have important effects on ecosystem functioning: that species-poor ecosystems may perform differently, or less efficiently than the species-rich systems from which they are derived (Zedler et al., 2001). This concern has prompted much research to focus on how biodiversity loss affects ecosystem functioning (e.g., Hector et al., 2000; Pfisterer and Schmid, 2002) and the response of ecosystems to global change (Reich et al., 2001).

The resulting studies have created a decade-long debate on the relationship between biodiversity and ecosystem function. An emerging conclusion is that the composition of the community, as well as diversity, plays a major role in controlling ecosystem function (see Hooper and Vitousek, 1998; Scherer-Lorenzen et al., 2003): in fact, the types of species in the community may play an even larger role than the number of species. Despite this realization, virtually no studies have specifically examined the independent effects of species composition on the functioning of ecosystems.

Species composition is likely to play an important role in determining ecosystem function because species differ in their traits. The effect of the loss of a species on an ecosystem is the result of both (1) the loss of the direct effects of the organism on ecosystem functioning and (2) the response of other organisms to that loss. These effects and responses occur through numerous mechanisms. For example, species can directly affect soil nutrient and water content through varying root mass. In addition, specific species can alter plant community composition through varying competitive abilities and facilitative effects, which in turn may affect ecosystem function.

To date, most experimental biodiversity work has used random assembly experiments, which contain artificially assembled communities of local plants (e.g., Hooper and Vitousek, 1997; Tilman et al., 1997; Hector et al., 1999; Fridley, 2003). Recently, however, removal experiments in natural communities are being promoted as a more realistic way to examine the consequences of biodiversity loss (Diaz et al., 2003). The major difference between random assembly experiments and removal experiments is that the manipulated communities have gone through different assembly processes: removal experiments are based on naturally assembled communities and therefore may include important natural processes that might be underestimated by random assembly experiments.

My PhD research uses a removal experiment to examine the roles of different plant functional groups (groups of plants that have similar roles in a community, e.g., grasses, legumes) both in influencing plant community dynamics (responses of other functional groups to the loss of a particular group) and in determining ecosystem function (properties and processes of an ecosystem affected by the biota). Specifically, my questions are:

1. Do different functional groups have different effects on community dynamics and ecosystem processes?

2. Does the role of a functional group change when the environment changes?

STUDY AREA

The study area is a relatively dry grassland near Kluane Lake in the southwestern Yukon in northern Canada. The area is in the rain shadow of the St. Elias Mountains and receives a mean annual precipitation of ca. 230 mm. About half of this total falls as rain during the summer months, but it also includes an average annual snowfall of about 100 cm. The grassland is surrounded by a spruce forest community dominated by *Picea glauca*. I recognized three functional groups of grassland plants: graminoids, non-leguminous forbs (hereafter called forbs), and legumes. The grassland is dominated by the graminoids *Poa glauca* and *Carex stenophylla* and also contains many non-leguminous forbs (dominated by *Erigeron caespitosus* and

Artemisia frigida) and legumes (dominated by *Oxytropis campestris*).

EXPERIMENTAL DESIGN

The experiment was established in May 2003 and has been carried out over four field seasons between 2003 and 2006. The experiment is a 4 (removal) × 2 (fertilizer) fully crossed design and consists of 80 1 × 1 m plots. The four removal treatments are independent removal of each of the three functional groups (graminoids, forbs, and legumes) and a no-removal control. Plants in the functional group to be eliminated were painted with Roundup™ nonselective herbicide and removed once visible yellowing had occurred. Removals were first completed in 2003 and have been maintained since.

As species loss occurs as a result of and in concert with global change, it is also important to understand how these losses will affect ecosystem responses to environmental changes. Thus, the second factor in the design is a fertilization treatment to examine if the role a species plays depends on the environment in which it is found. Fertilizer (21:7:7 N:P:K) was added each spring in pellet form at the rate of 17.5 g N, 5.8 g P, and 5.8 g K per square metre to be consistent with other experiments being done in the area.

RESPONSE MEASUREMENTS

Over the past four growing seasons (2003–06), I have monitored (1) responses of the remaining functional groups (community response variables) and (2) response variables that are integrative across the entire ecosystem (ecosystem function response variables). Community response variables measured include species frequency as a measure of species abundance and a community leaf area index, which gives a three-dimensional measure of species cover.

I have also monitored numerous ecosystem functions. Ecosystem productivity, the function most commonly measured in biodiversity-ecosystem functioning studies, is usually estimated indirectly through the surrogate measurement of aboveground biomass. The measurement of aboveground biomass is a destructive process. However, the community leaf area index described above correlates very well with biomass, making nondestructive measurement of this ecosystem function possible.

Nutrient supply rates were measured using ion exchange membranes (Plant Root Simulator (PRS™ probes; Western Ag Innovations Inc., Saskatoon, SK). The PRS probes were placed in the soil each growing season to measure in situ nutrient supply rates. Ions measured include NO_3, NH_4, P, K, S, Ca, Mg, Mn, Fe, Cu, Zn, B, Al, and Pb. In addition, soil moisture (using a water content sensor; Hydrosense Water content measurement system, Campbell Scientific, Australia) and percent light transmittance (using a quantum meter; Apogee Instruments Inc., Utah) were both measured multiple times per growing season.

FIG. 1. Grassland site (hillside opposite lake) for functional group removal experiment.

Above- and belowground litter decomposition rates were measured using the litter-bag technique (mesh bags containing plant material are left in situ through the growing season to examine loss of mass over time). Litter decomposition is an important ecosystem function; the availability of nutrients to vegetation is dependent on these nutrients being recycled from organic matter through decomposition and mineralization. Removals may affect the decomposition rate either by changing the environmental conditions that control decomposition processes or by changing the leaf material available to decompose. To examine the effects of changes in environmental conditions, I placed litter bags containing dried leaves or roots from a single source on the soil surface (leaves) or buried them just below the soil surface (roots). To examine the direct effects of species composition on decomposition rate, I used different litter bags containing each of the seven possible combinations of the dominant species from the three functional groups (3 monocultures, 3 two-species mixtures, and 1 three-species mixture) to determine decomposition rate of mixtures during a single growing season.

PRELIMINARY RESULTS

Samples and data for this experiment are still under analysis. However, preliminary results indicate significant effects of removals on many of the ecosystem functions measured. For example, significant effects of removal were found for soil nutrients including total N, NO_{3-}, P, and S. For N and NO_{3-}, control treatments generally had lower nutrient supply rates than the removal treatments, whereas the opposite trend was found for P and S. NH_{4+} and P were the only nutrients significantly affected by the removal-fertilizer interaction, indicating that for these

FIG. 2. Functional groups used in removal treatments: a) legumes, b) graminoids (grasses and sedges) c) non-leguminous forbs, and d) no-removal (control).

nutrients the role of a functional group is partially determined by the environment in which it is found.

Litter decomposition results indicate that grasses play an important role in this ecosystem in controlling nutrient recycling. The presence of grasses in a community creates conditions that promote decomposition both through changes in the environment and also through changes in the species composition of the litter material; species mixtures containing grasses decompose more rapidly than those without grass. Further exploration of these mixtures indicates that while the grasses themselves do not generally have different decomposition rates in mixture vs. monoculture, their presence promotes decomposition of other species present. This indicates that loss of grass species from this ecosystem may have interactive effects on decomposition greater than those predicted by either common source decomposition experiments or litter mixing experiments independently.

FIG. 3. Jennie McLaren measuring species cover in grassland plots.

SIGNIFICANCE

My research examines the role that different functional groups play in determining ecosystem processes within a natural grassland in the southwest Yukon. In addition, I am examining whether these roles are consistent between environments or whether environmental change may also lead to changes in the relationship between plant functional groups and their environment. These types of experiments are particularly important in Arctic ecosystems because of their sensitivity to climate change. Since climate warming may be amplified through positive feedbacks in these systems (Grogan and Chapin, 2000), the effects of warming could become evident in the Arctic before they are noticed elsewhere. Additionally, community ecology is particularly understudied in northern ecosystems. In particular, biodiversity research has commonly focused on temperate grassland ecosystems, despite the possible severe impacts of species changes (both losses and additions) in depauperate alpine and Arctic ecosystems.

This research project is an important contribution to both biodiversity research and northern research in general, but it is also a new combination of the two fields. Knowing the roles of different functional groups in an intact community provides predictive power regarding the effects of their loss. Additionally, the way these roles change when environments change is important, as species loss will likely occur in concert with global changes we are observing today. Finally, as the impacts of changes in species and changes in climate are both likely to show earlier and more extreme consequences in Arctic ecosystems, the field location of this research is particularly important.

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