Testing multiple nutrient limitation of plant species and ecosystem productivity in Southern California grasslands

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Presentation Outline

- Research questions
- Experimental design & methods
- Results
- Future directions

Background

- Plants require many resources in order to grow and maintain tissues. In particular, individual plants and ecosystem productivity as a whole may be limited by multiple macronutrients simultaneously.

- Species vary in their ecological strategies; the species best able to draw down a limiting soil resource to the lowest level is predicted to be the best competitor for that resource (Tilman 1982).

Focal Research Questions:

- Are different species limited by different resources?
  - If so, growth of species planted alone will be limited by a single resource, but when planted together community biomass should be limited by multiple resources.

- Does variation in nutrient drawdown predict plant competitiveness in mixture?
  - If so, we predicted the species that could draw down a soil resource (particularly nitrogen = N) to the lowest level in monoculture would be the best competitor under control conditions.
  - Conversely, we predicted that strong competitors under control conditions would be the most disadvantaged under conditions of nutrient enrichment (N fertilization). This reflects the expectation of an ecological trade-off between competitive ability under low resource levels, and fast-growth under high resource levels.

Focal species

Exotic annual grasses:
Bromus hordeaceus (BRHO)
Vulpia myuros (VUMY)
Lolium multiflorum (LOMU)

Exotic annual forb:
Erodium cicutarium (ERCI)

Native perennial forb:
Sisyrinchium bellum (SIBE)

Native perennial grass:
Nassella pulchra (NAPU)


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Experimental design

- We planted seeds of 6 focal species both alone (monocultures) and together (polyculture) in 1.7 L treepots near the UCSD greenhouses.
- We applied N (10 gN/m^2 as urea), P (20 gP/m^2 as triple super phosphate) & K (10 gK/m^2 as potash) in a factorial design.
- 7 species treatments x 8 nutrient treatments x 5 replicates = 280 pots, plus 3 additional unfertilized controls for each of the 7 species treatments = 301 total pots.
- Experiment began in January 2009, plants and soils were harvested in May 2009.

Soil nutrient analysis

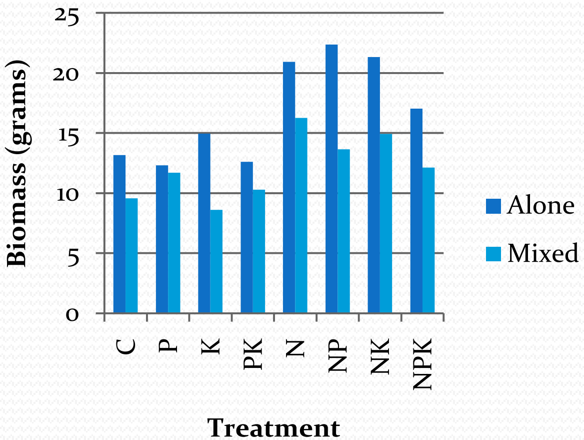
- Fresh soil samples were extracted with salt solutions to calculate extractable concentrations of:
  - nitrate and ammonium (using KCl)
  - phosphate (using sodium bicarbonate, Olsen P method)
- Soils were stored at -20 C until photometric analysis on a microplate reader

Statistics

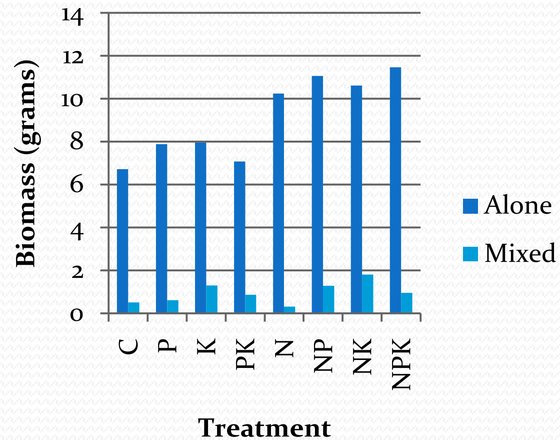
- Data were analyzed with a three factor (N,P,K) linear mixed model in the SAS statistical software package, version 9.2. The mixed model uses a maximum-liklihood method for estimating the significance of the factors, which deals better with missing data than traditional sums of squares methods (missing data are common in ecological experiments).
- Data were analyzed separately for the biomass of each species grown alone and grown in mixture. Data for each soil nutrient were additionally analyzed with a 4 factor linear mixed model (including species), to evaluate whether species different from one another in the degree to which they could draw down resources.

Aboveground biomass results

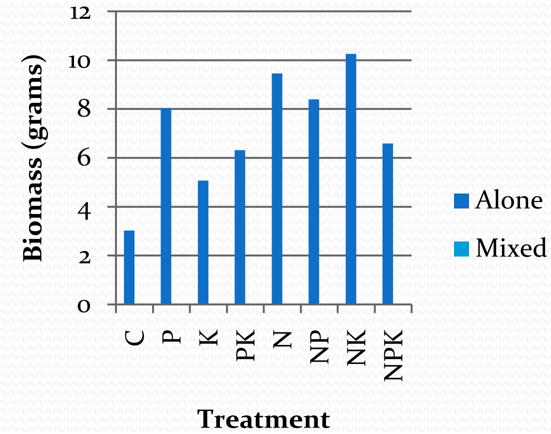
Lolium multiflorum



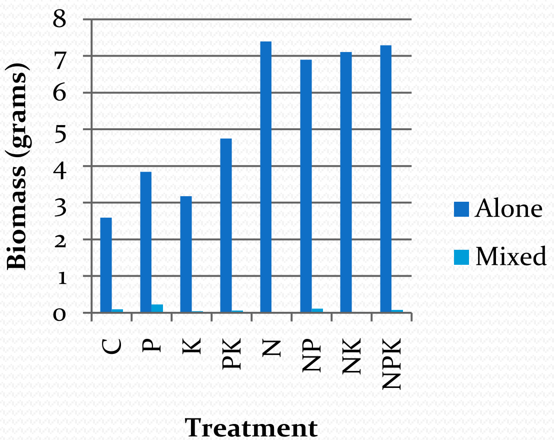
Bromus hordeaceus



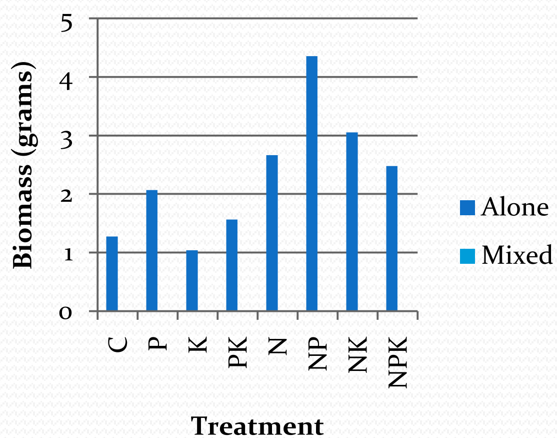
Erodium cicutarium



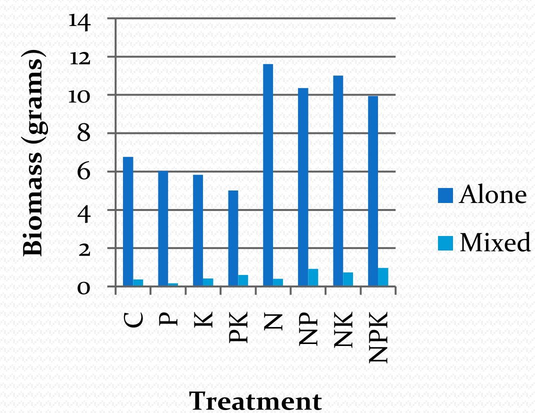
Nassella pulchra



Sisyrinchium bellum



Vulpia myuros



Results: species grown in monoculture

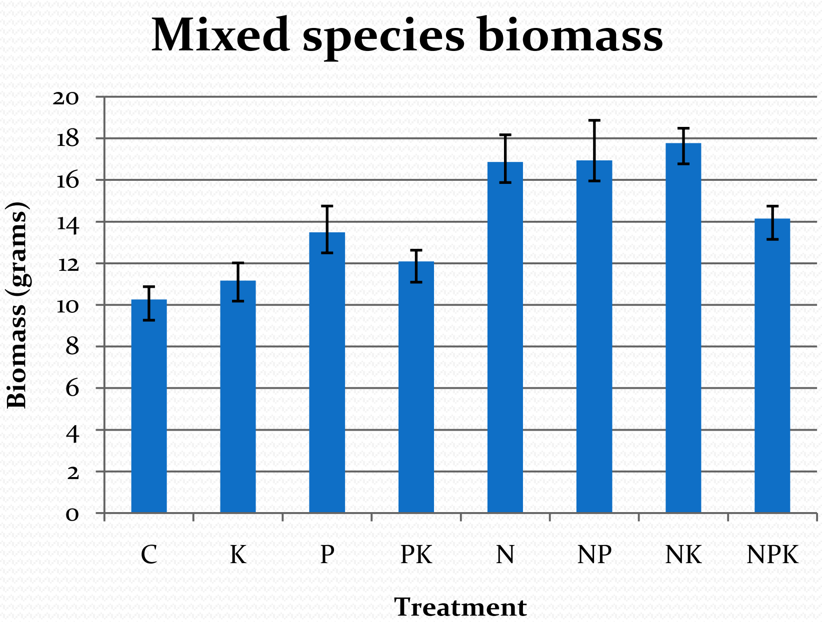
- Growth of all species was enhanced most by N addition ($p<0.01$ for all species, F value always largest)

- *L. multiflorum* produced the most aboveground biomass in monoculture and in mixtures

- *L. multiflorum* growth was also stimulated by P addition, but this effect was suppressed by K addition (P*K $p=0.02$)

- No evidence that species were limited by different resources (at least N vs P vs K, just N limitation)

Results: mixed community



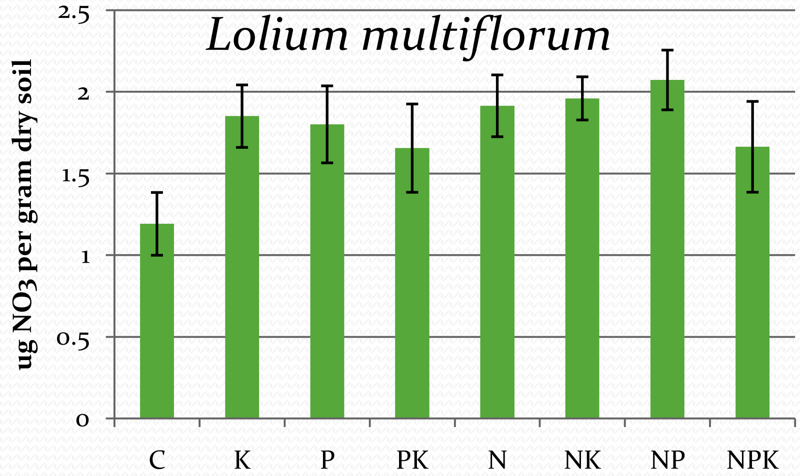
Aboveground community biomass was primarily N limited ($p < 0.0001$)

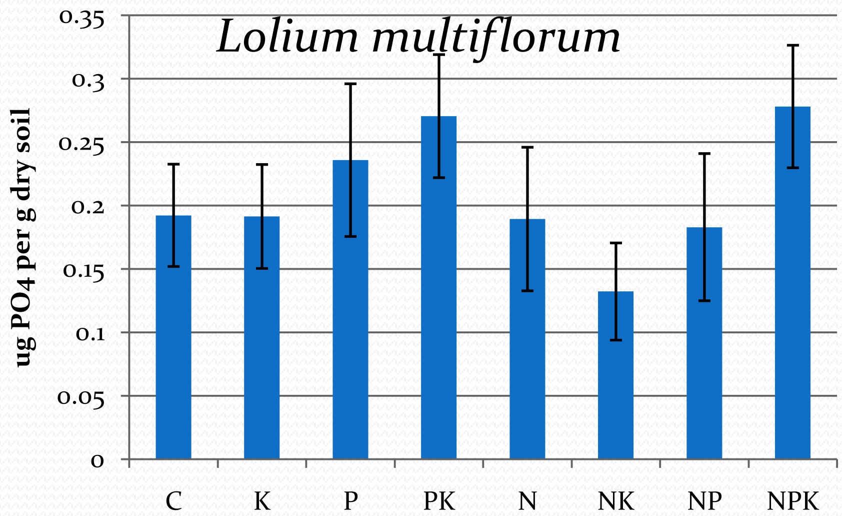
NP additions increased biomass less than expected based on the response to N or P alone (**N*P** $p=0.01$)

K addition tended to suppress the stimulatory effect of P addition (**P*K** $p=0.04$)

Results: soil nutrient concentrations

- There was no significant variation among treatments or species in their effects on ending soil nitrate concentrations
- Soil phosphate increased with P additions ($p<0.01$), but no significant variation among species observed





Conclusions

- There was no evidence to support our hypothesis that species vary in their nutrient limitation (N limitation predominated)
- At the community level we saw only single nutrient limitation, not multiple nutrient limitation

- These findings question classical ecological theories regarding trade-offs among species in strategies for resource capture, competitive abilities, and growth rates.

- There was little variation among species in nutrient drawdown
- Nitrate levels in soil were remarkably non-responsive to treatments, indicating that this resource was efficiently captured by plants or leached from the soil
- In general, phosphate additions increased soil phosphate levels, reflecting that P was not limiting to growth, or was less mobile in soil than nitrate

Future directions

- These experiments ran for a short time with a small number of species
- Ideally, we would like to repeat these experiments under field conditions and with a greater diversity of species
- The Nutrient Network Research Cooperative has begun such an effort, and we look forward to participating
- http://nutnet.science.oregonstate.edu/

A Nutrient Network experimental plot at the UC Elliott Chaparral Reserve, near UCSD

Acknowledgements

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