LINKING MICROBIAL EXTRACELLULAR ENZYME ACTIVITIES WITH RATES OF PLANT LITTER DECAY

Stephanie Castle & Eliška Rejmánková
Dept. of Environmental Science & Policy, University of California, Davis

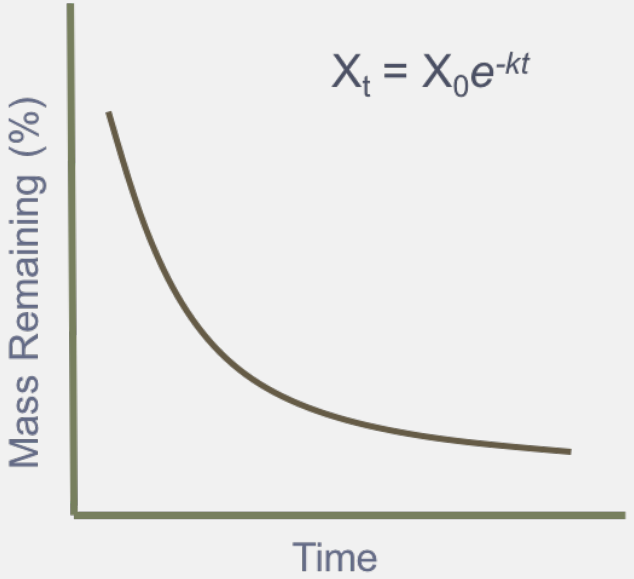
LITTER DECOMPOSITION

Complex process controlled by a variety of factors

Decomposition is an important ecological process

- Soil organic matter development
- Nutrient turnover
- C sequestration and C loss

Can impact systems from local to global scales



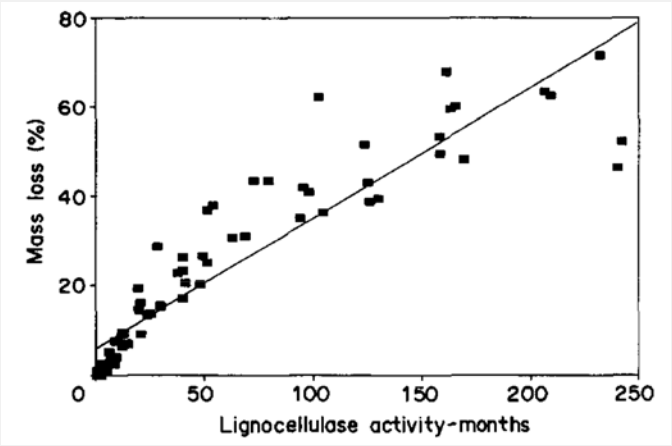
IMPORTANCE OF ENZYME SYSTEMS IN DECOMPOSITION

Directly mediate breakdown of organic matter

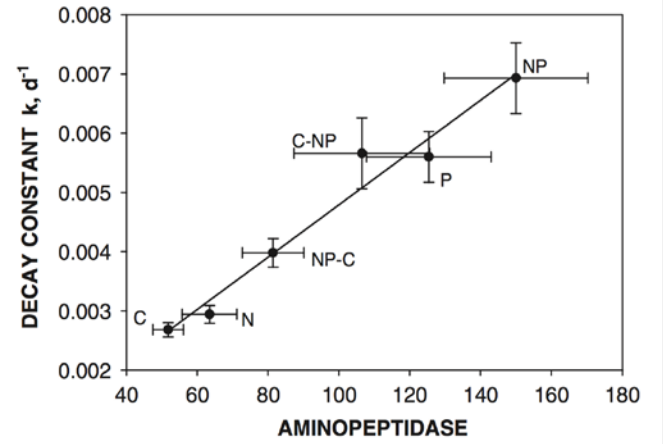
Link microbial organization, litter composition and environmental conditions

Nutrient limitations of OM turnover in heterogeneous systems

Enzyme activity as a proxy for decay



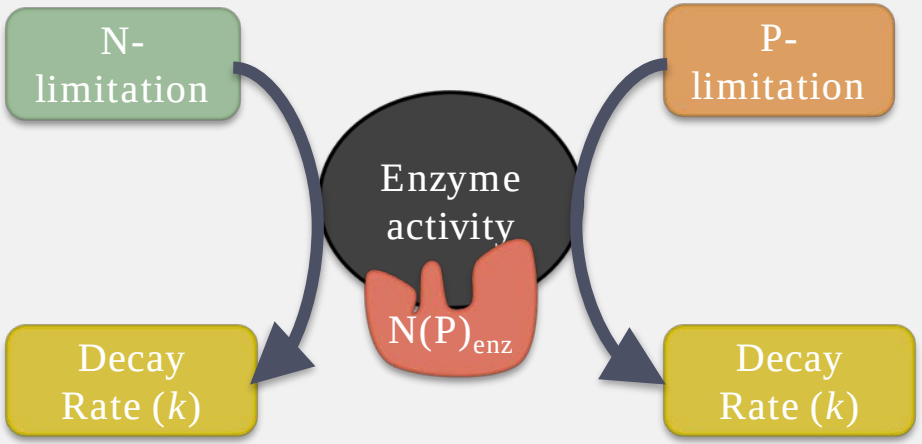
Sinsabaugh 1992



Rejmánková and Sirová 2007

Factors influencing rate of enzyme production and activity

- Nutrient investment into enzymes
- Economic theory of enzyme production
- Microbial biomass



STUDY AIMS

- Determine whether rates of plant litter decay can be correlated to extracellular enzyme activities

- Understand how relationships between microbial enzyme production and decay rates change under differing nutrient limitations

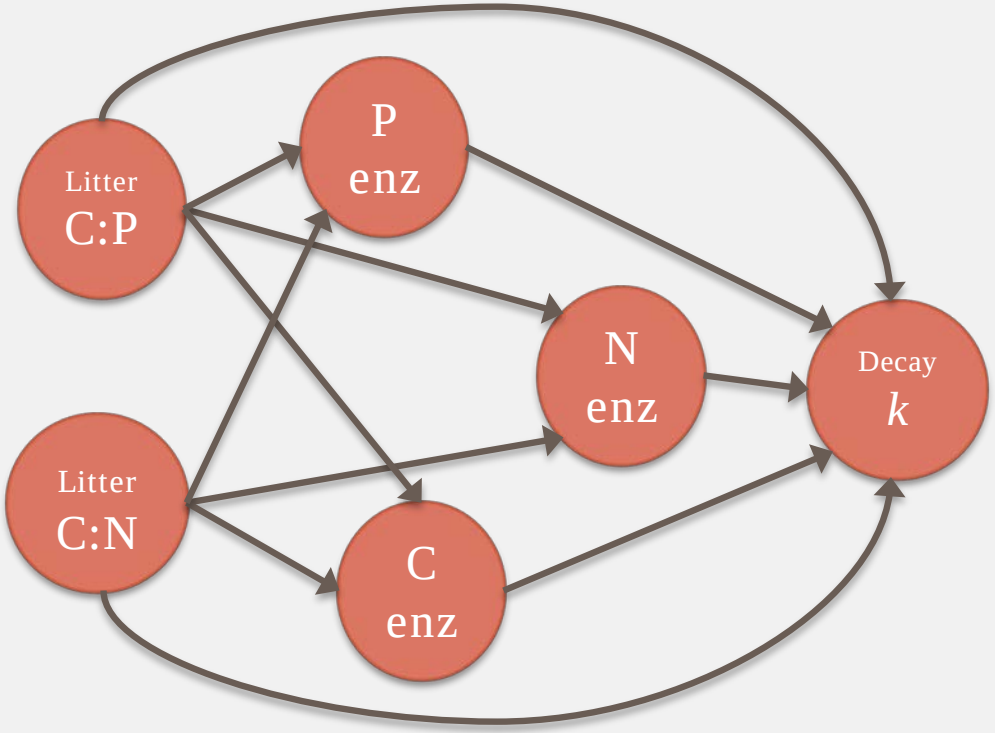
HYPOTHESES

- Decay rate will ↑ with enzyme activity
- Nutrient limitation will influence the pattern and strength of relationships

  P limited: P → enzyme → decay

  N limited: N → enzyme → decay

- Enzyme activity and decay may be limited overall by N



Methods: Data Search and Selection Criteria

- ISI Web of Knowledge
- Keywords: litter decay, litter decomposition, enzyme activity extracellular enzymes, ecoenzymes, exoenzymes
- Inclusion Criteria
  - Litterbag technique
  - Field collected, senescent litter
  - Mass loss (%) or decay constant (*k*) reported
  - At least one index of litter quality reported (C:N, C:P, N:P)
  - Enzyme activity reported

Methods: Analysis

- Calculation of decay constant,

$$X_t = X_0 e^{-kt}$$

- Calculation of enzyme activity as cumulative activity (mol g^{-1})

- Finally, ratios of relative enzyme activity were used (Sinsabaugh et al. 2002)

$$N_{enz} : C_{enz}$$

$$P_{enz} : C_{enz}$$

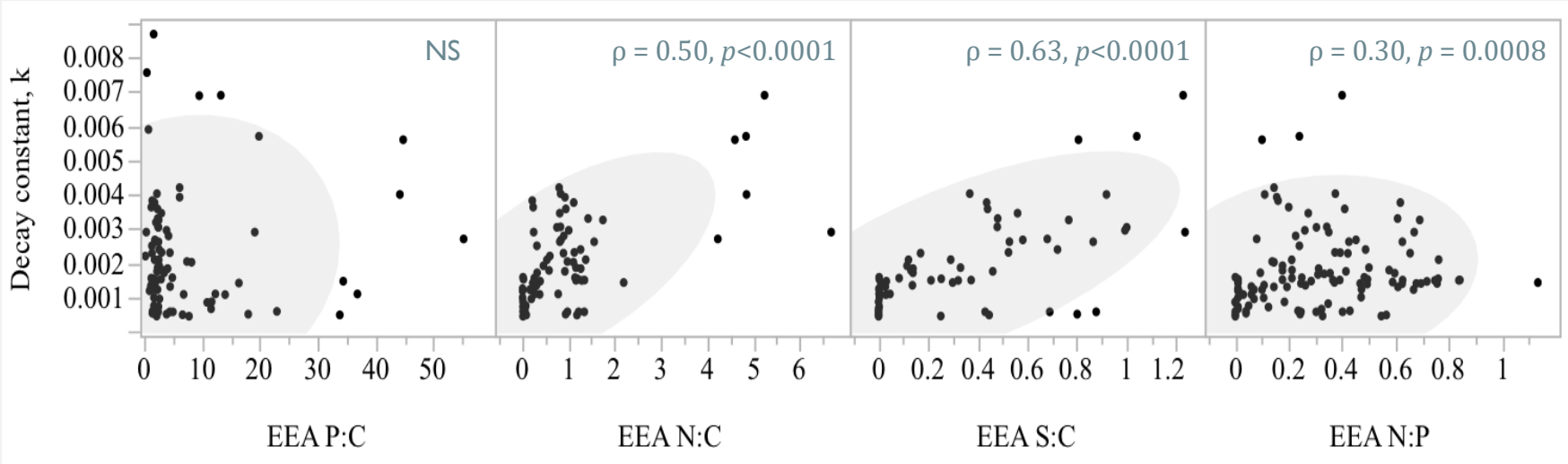
$$S_{enz} : C_{enz}$$

$$N_{enz} : P_{enz}$$

- Spearman's Rank Correlation Coefficient

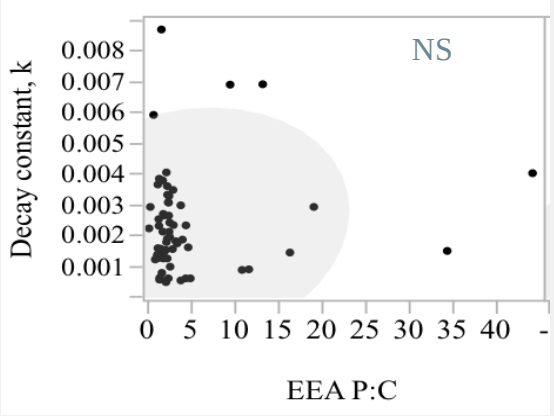
Enzyme	Element	Macromolecule degraded
β-1,4-glucosidase	C	Cellulose
Acid phosphatase Alkaline phosphatase	P	Phosphate esters
Leucine-aminopeptidase β -1,4-N-acetylglucosaminidase	N	Amino acids
Arylsulfatase	S	Sulfate esters

All Data

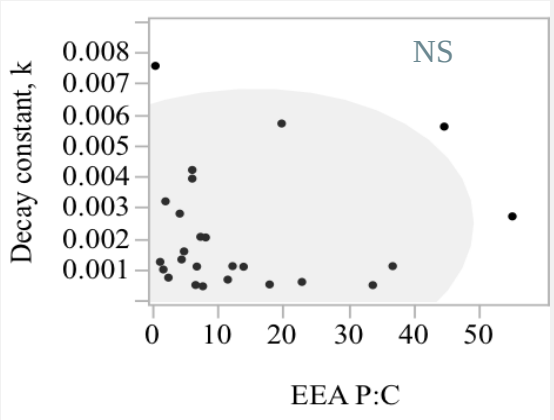


Generally, decay rate increases with increasing enzyme activity

N limitation

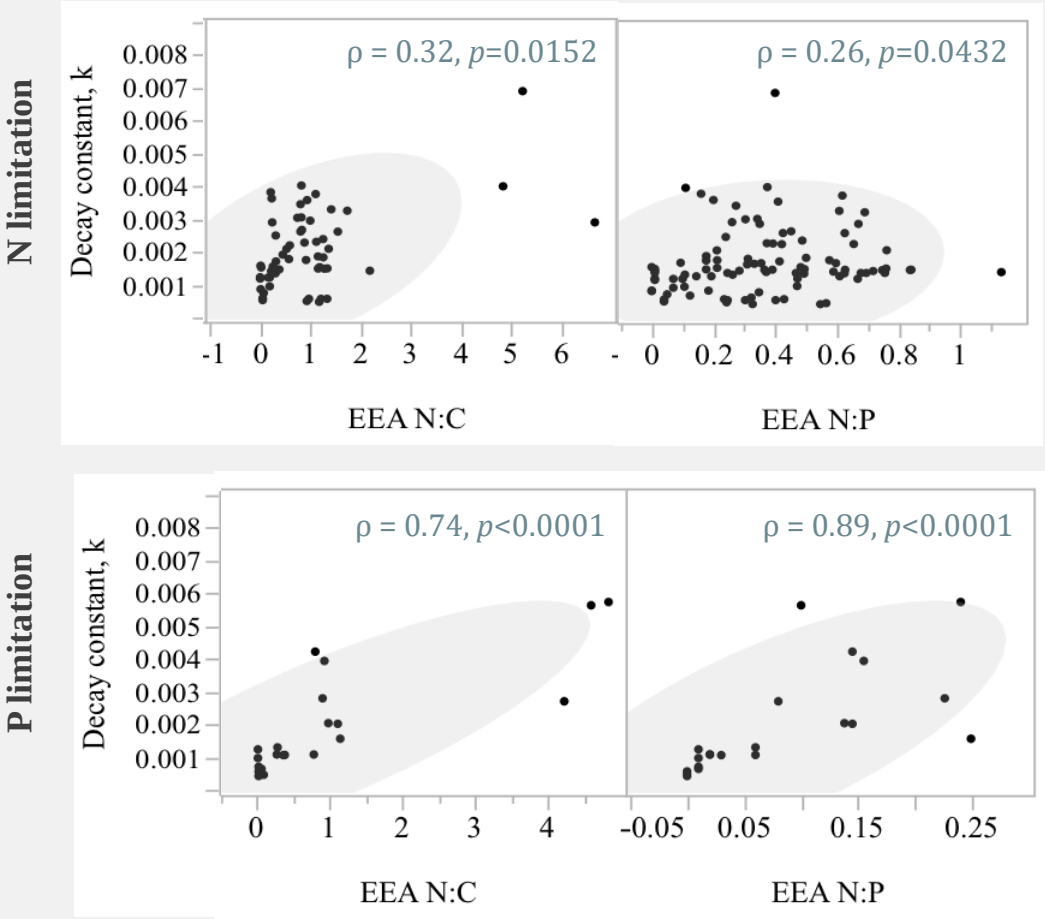


P limitation



No link between P enzymes and decay?

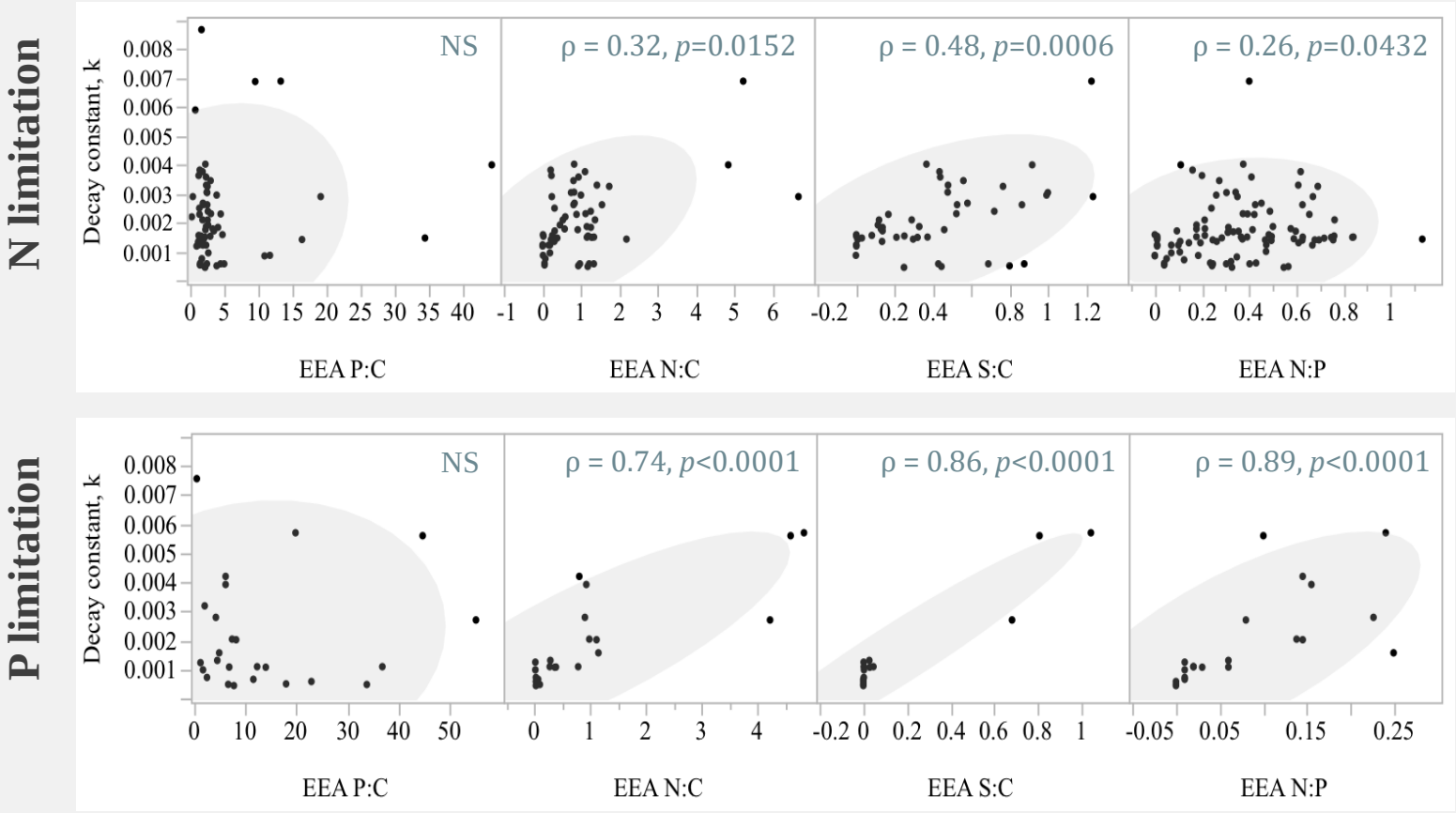
- C and N tightly linked within complex organic matter
- Rates of C cycling may be uncoupled from that of P

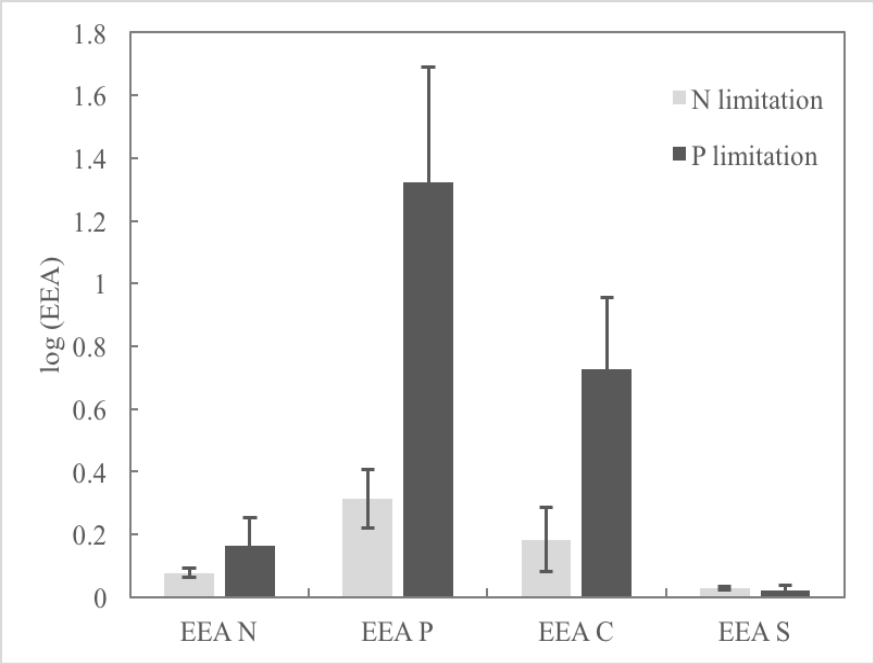


Overarching N limitation of decay processes

- Enzymes are N rich to produce
- Other studies show N limitation of litter decay
- N limitation due to immobilization of N enzymes

Weaker relationships under N limitation?





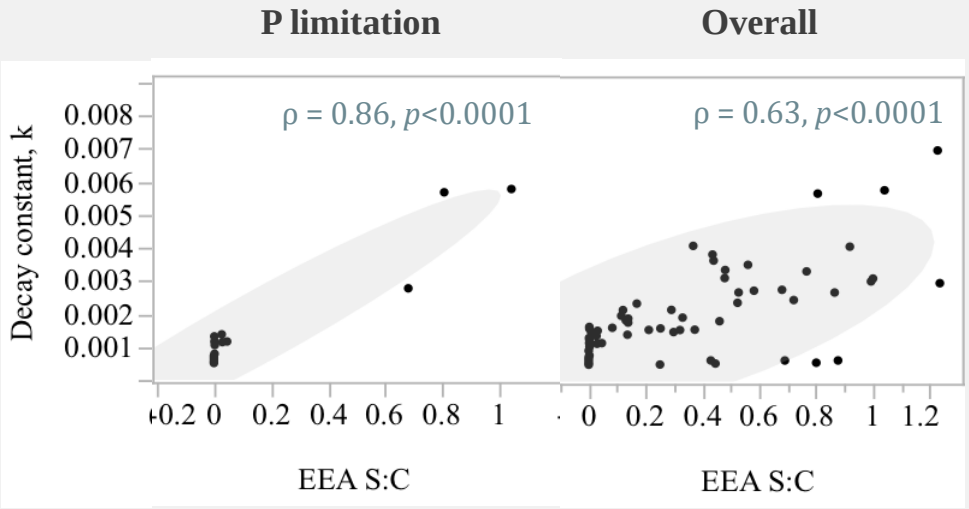
Enzyme dynamics under N limitation

- Severe N limitation down-regulates enzyme production overall
- Co-limitation by N and C
- N enzyme systems are complex

RELATIVE S ENZYME ACTIVITY

What explains the strong relationship between relative S enzyme activity with decay?

- S may be neglected as a limiting nutrient
- S enzymes may be produced constitutively into the environment
- Sulfatase enzymes may play a dual role in nutrient capture



CONCLUSIONS

Strong correlation between relative N_{enz} activity & litter decay rates

- Suggests strong control of litter decay rates by N enzyme activity
- N availability ultimately controls microbial investment into enzyme production
- Relationship is strong even under P limitation

Limited relationship between N_{enz} and litter decay rates under N limitation

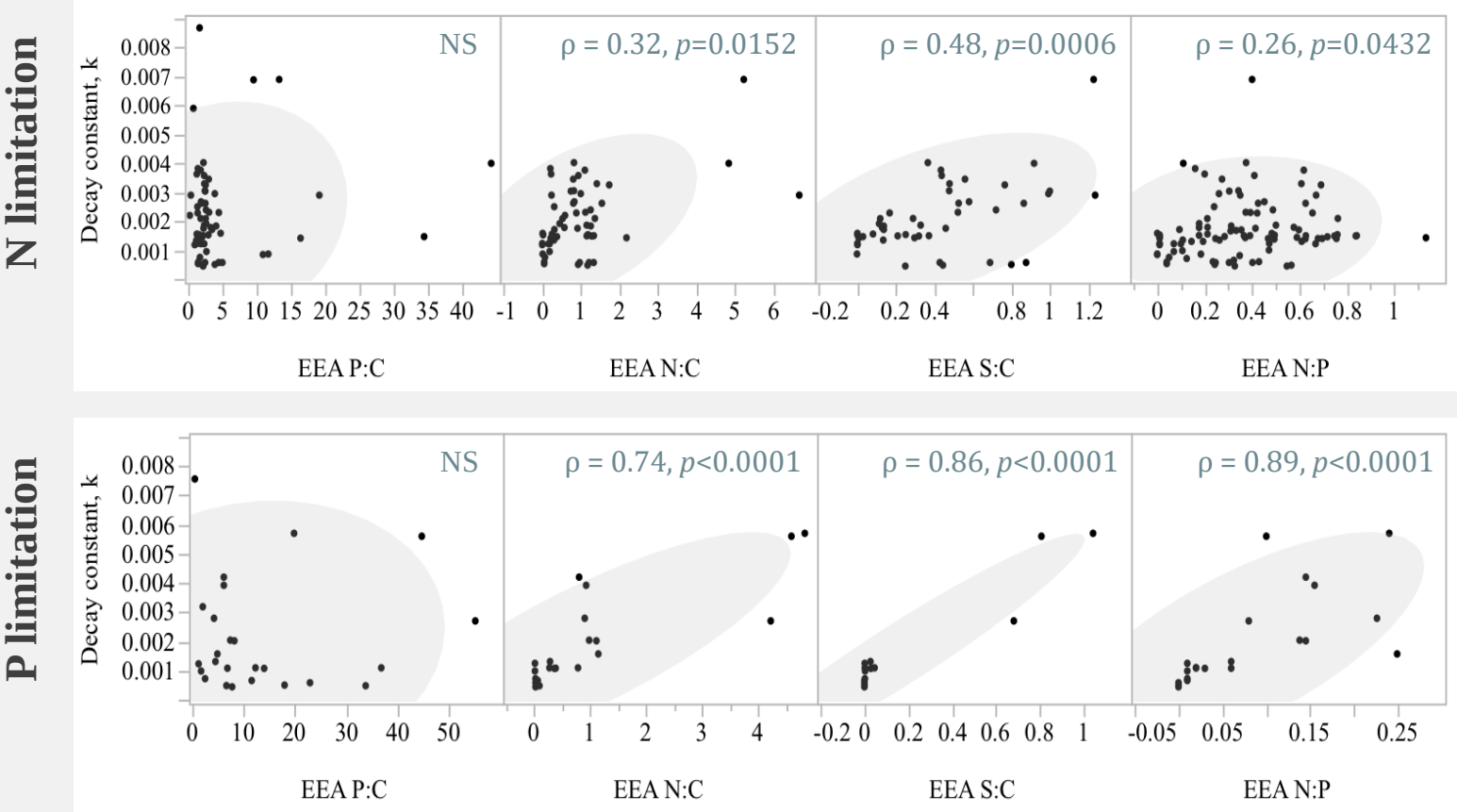
- N limitation limits enzyme production overall

Need further investigation into S_{enz} dynamics and litter decay

THANK YOU FOR YOUR ATTENTION!

stcastle@ucdavis.edu

N *vs.* P limitation



Justification for N:P ratio of limitation

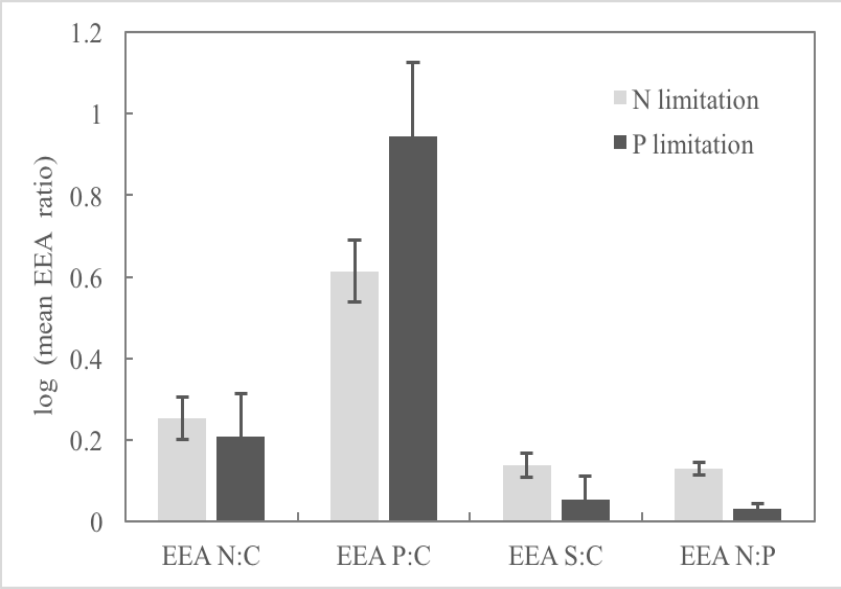
- We use a litter mass ratio of N:P 20:1 as a cutoff for N vs P limitation as it represents the average N:P of deciduous tree and herbaceous leaf litter (Güsewell and Freeman 2005, Cleveland and Liptzin 2007).

- Some may argue that average N:P ratio for microbial decomposers of 3-5:1 should be considered when defining litter substrate as N or P limited for microbial responses.

- However, plant litter with such low N:P simply does not exist. Live plant tissue generally has a much higher N:P ratio of ~14 (Koerselman and Meuleman 1996, Aerts and Chapin 2000) and because of slightly higher proportion of P resorption compared to N in perennial plants (Enriquez et al. 1993, Rejmánková 2005), an N:P ratio of 20:1 is typical for litter – clearly a very imbalanced substrate for microbes.

- Finally, elemental ratios of plant litter provide an indication of site N vs P limitation due to a positive feedback between site quality and plant stoichiometric response (Sterner and Elser 2002, Rejmánková 2005, Rejmánková et al. 2011)

Relative enzyme activity in N and P limited environments.



Overall magnitude of relative enzyme activity un-linked to decay processes does corresponds to underlying nutrient limitation