The Importance of Enzyme Kinetics in the Temperature Sensitivity of Organic Matter Decomposition in Wetlands

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Introduction

❖ Background

Recent developments of organic matter decomposition models highlighted importance of enzyme kinetics with warming. Carbon & nutrient acquisition by enzymes are linked to stoichiometric relationships in soil & microbial biomass. Higher Vmax & lower Km of enzymes in warming world can decrease soil organic matter storage by enhancing nutrient cycling rates. Despite critical importance to organic matter dynamics, measures of enzyme kinetics in wetland soils have not been well-investigated.

❖ Objectives

- Determine enzyme kinetics in subtropical wetlands as a function of temperature.
- Determine relationships of stoichiometry in soil & microbial biomass to enzyme kinetics.

❖ Hypotheses

- Enzyme kinetic parameters will be dependent on prevalent temperature.
- Stoichiometry in soil & microbial biomass will determine enzyme kinetics.

Materials and Methods

❖ Peat soils were collected from subtropical marshes of the Florida Everglades (Fig. 1). To assess effects of warming on enzyme kinetics (Table 1), the experiment was conducted by ramping up temperature @ 0.1°C day^{-1} over the range of 15° C to 25° C.

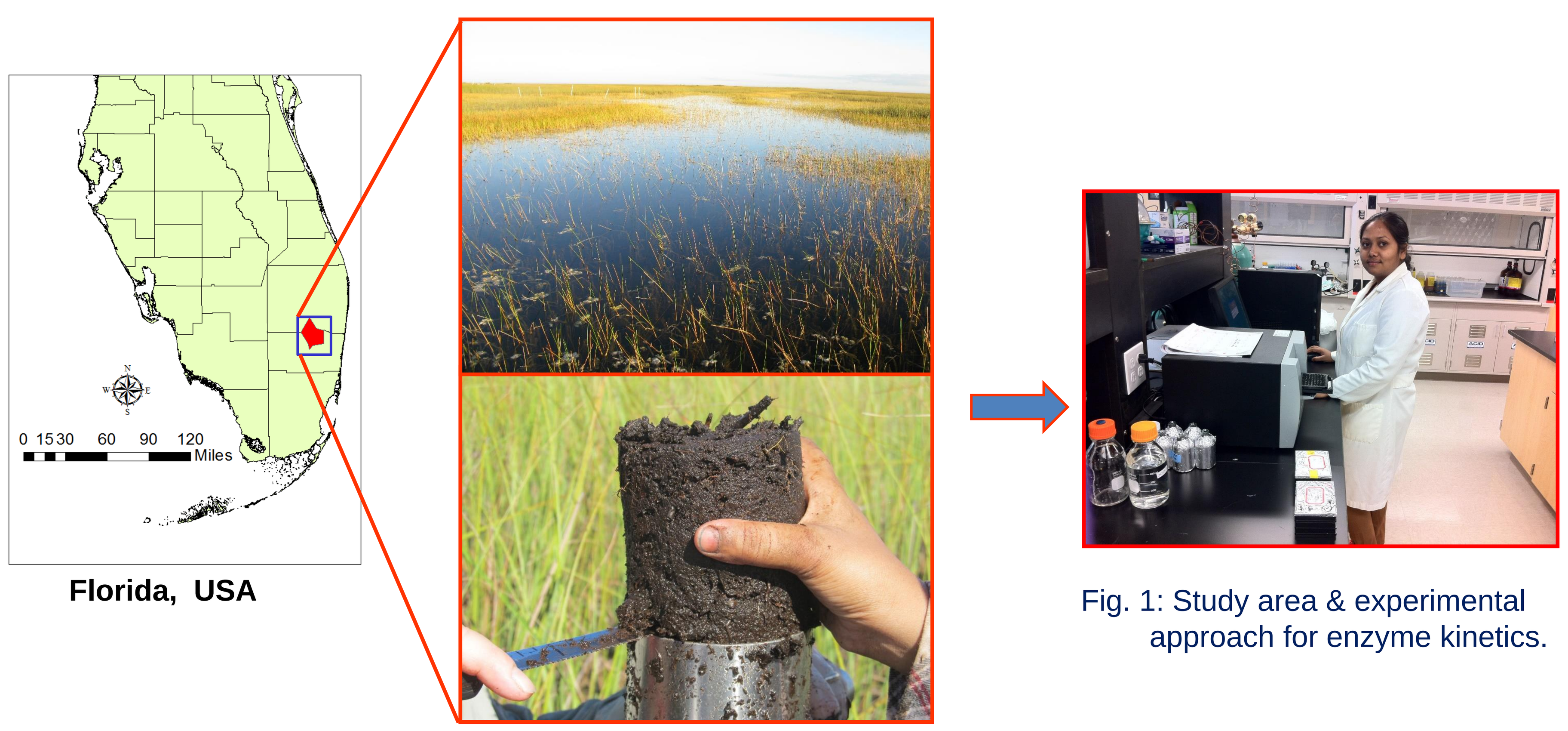

Fig. 1: Study area & experimental approach for enzyme kinetics.

Table 1: Soil extracellular enzymes assayed for kinetic parameters

Enzymes analyzed		Abbreviations	Substrate
Enzyme Group	Enzyme Name		
C acquisition enzyme	ß-D-glucosidase	BG	MUF ß-D-glycopyranoside
	Xylanase	XYL	Xylan
N acquisition enzyme	Leucine aminopeptidase	LAP	L-leucine hydrochloride
	N-Acetyl-ß-D glucosaminidase	NAG	N-MUF ß-D glucosaminide
P acquisition enzyme	Phosphomonoesterase	PHO	MUF phosphate
	Phosphodiesterase	BPHO	Bis-(MUF) phosphate

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Results and Discussion

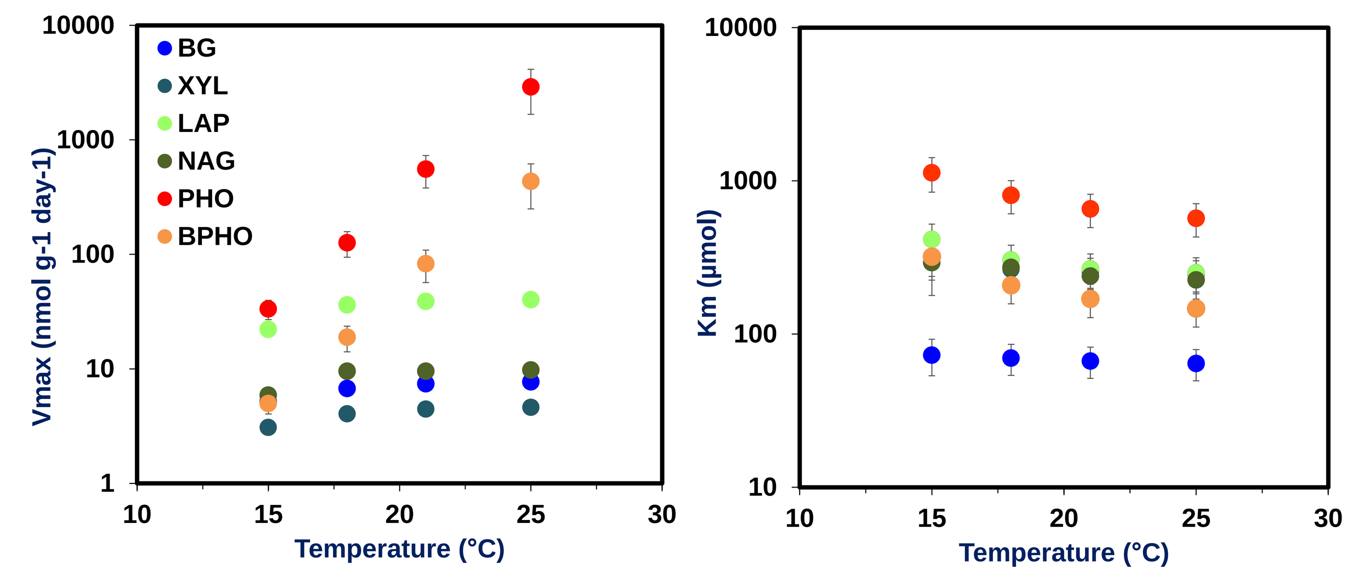

Fig. 2: Enzyme maximum velocity (Vmax) and efficiency (Km) as a function of temperature.

Table 2: Stoichiometric relationships between available pool, microbial biomass and enzymes

Enzymes	Model R^2	Variables included	Estimate
Vmax ratio			
C:N	0.89	DOC:TDN	-0.11
	0.85	MBC:MBN	-0.07
C:P	0.97	DOC:WSP	-0.05
	0.98	MBC:MBP	-0.01
N:P	0.95	TDN:WSP	-2.48
	0.90	MBN:MBP	-1.03
Km ratio			
C:N	0.96	DOC:TDN	0.31
	0.93	MBC:MBN	0.19
C:P	0.94	DOC:WSP	0.02
	0.94	MBC:MBP	0.01
N:P	0.83	TDN:WSP	0.12
	0.80	MBN:MBP	0.05

Abbreviations: DOC: Dissolved organic C, TDN: Total dissolved N, WSP: Water soluble P, MBC: Microbial biomass C, MBN: Microbial biomass N, MBP: Microbial biomass P

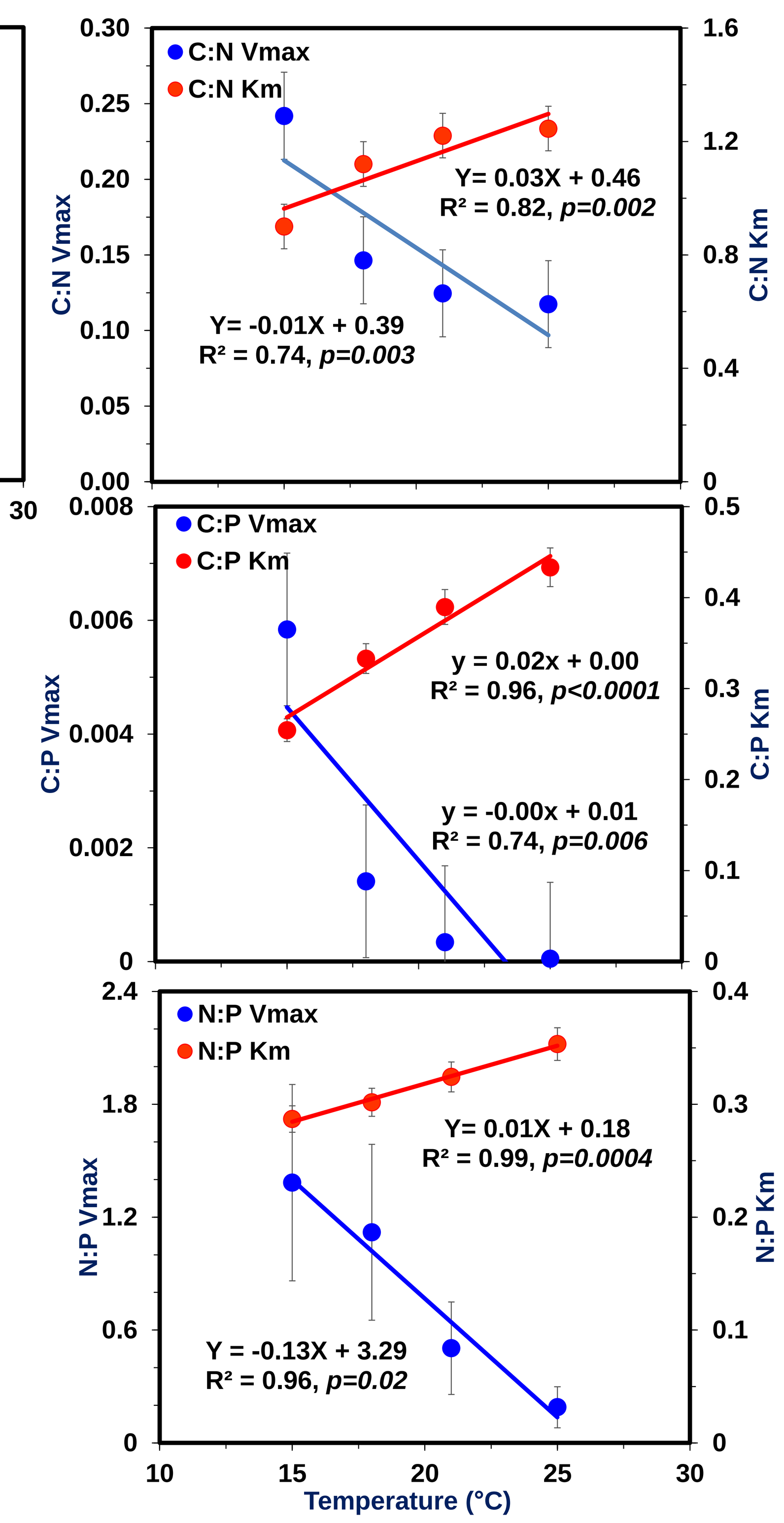

Fig. 3: Stoichiometry of enzyme kinetics as a function of temperature.

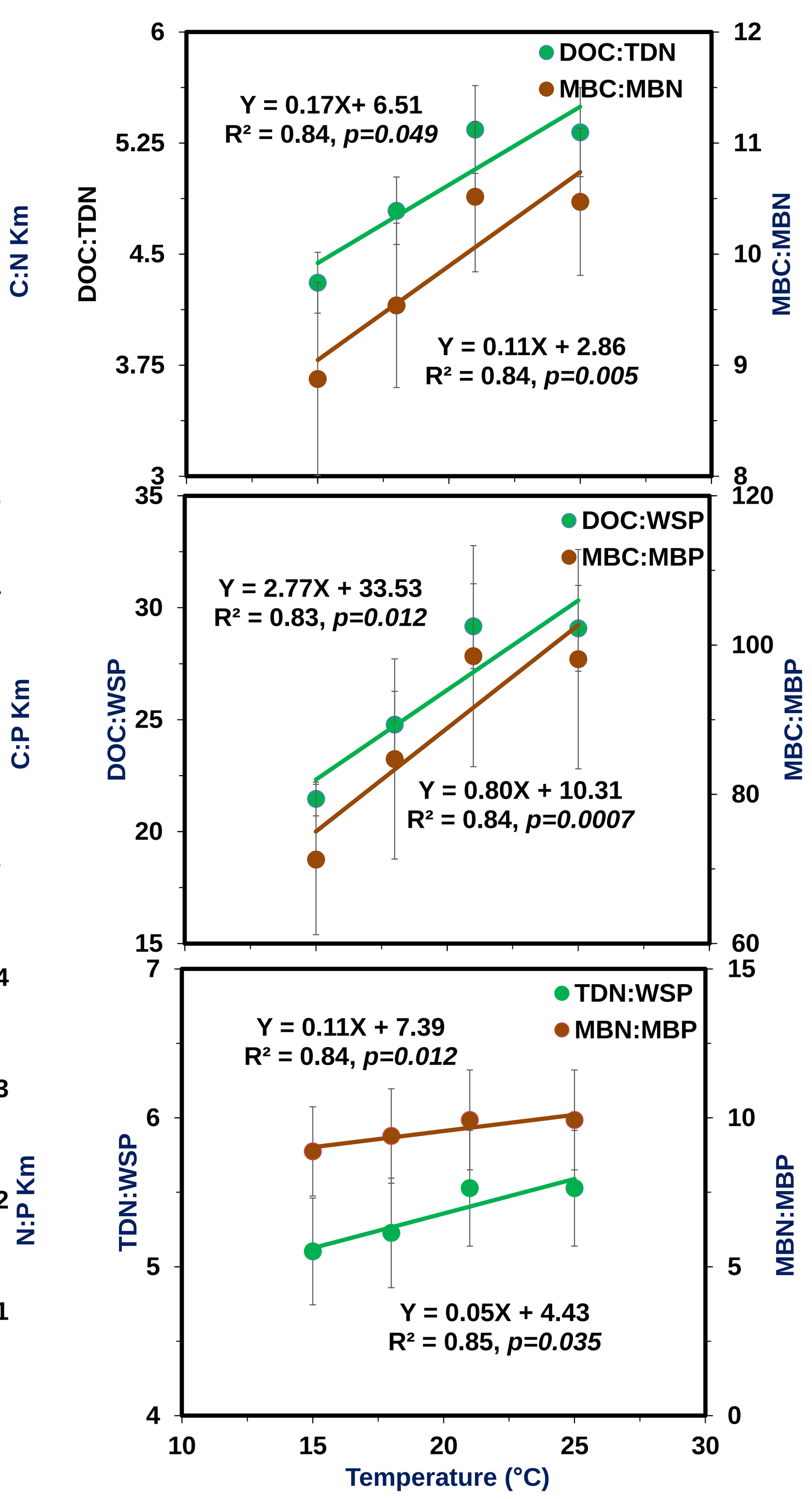

Fig. 4: Stoichiometry of soil nutrients & microbial biomass as a function of temperature.

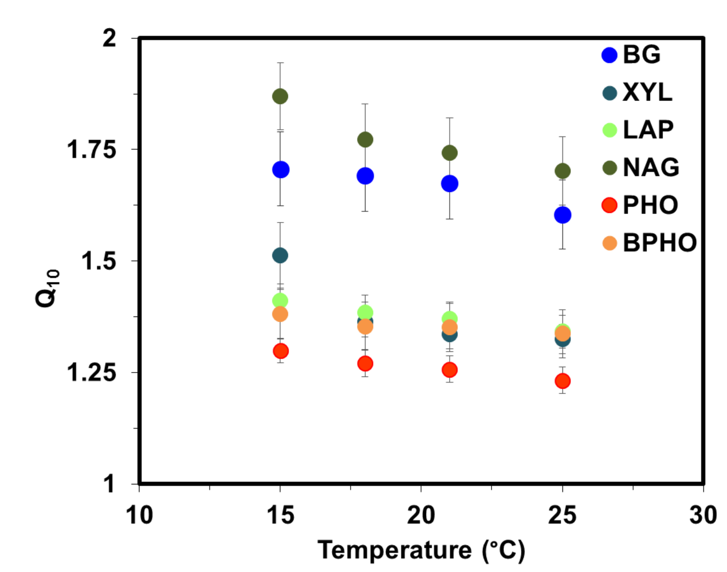

Fig. 5: Temperature sensitivity (Q_{10}) of C, N, & P acquisition enzymes over the range of 15°C to 25°C.

- Warming increased Vmax & decrease Km in all enzyme groups (Fig. 2).
- Relatively higher increase in activity & efficiency of nutrient enzymes were observed than carbon enzymes at higher temperature (Fig. 3).
- Concurrently, it followed a simultaneous increase in carbon to nutrient ratios of available pool & stoichiometry of microbial biomass (Fig. 4).
- Relative to N, P acquisition enzymes win out, which ultimately limited decomposition at higher temperature (Fig. 2).
- Enzyme & nutrient acquisitions by extracellular enzymes were constrained by stoichiometry in available pool & microbial biomass (Table 2).
- Temperature sensitivity (Q_{10}) of enzymes decreased minimally along temperature gradient (Fig. 5).

Conclusions and Implications

- Enzymatic potential to hydrolyzing organic matter increased (higher Vmax & lower Km) as a function of temperature.
- Microbes become increasingly nutrient limited at higher temperature.
  - Nutrient starvation of microbes at higher temperature likely driving enzyme resource allocation.
  - N:P stoichiometry indicated that microbes invest their nitrogen reserve in phosphorus production at higher temperature.
- Temperature response of enzyme kinetics was tied to stoichiometry of microbial nutrient demand.
  - Current biogeochemical models could be improved by incorporating stoichiometry of enzyme kinetics.

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