Is There A Universal Relationship Between Phytoplankton Specific Growth Rate And Temperature?

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A Potential Ecological Law

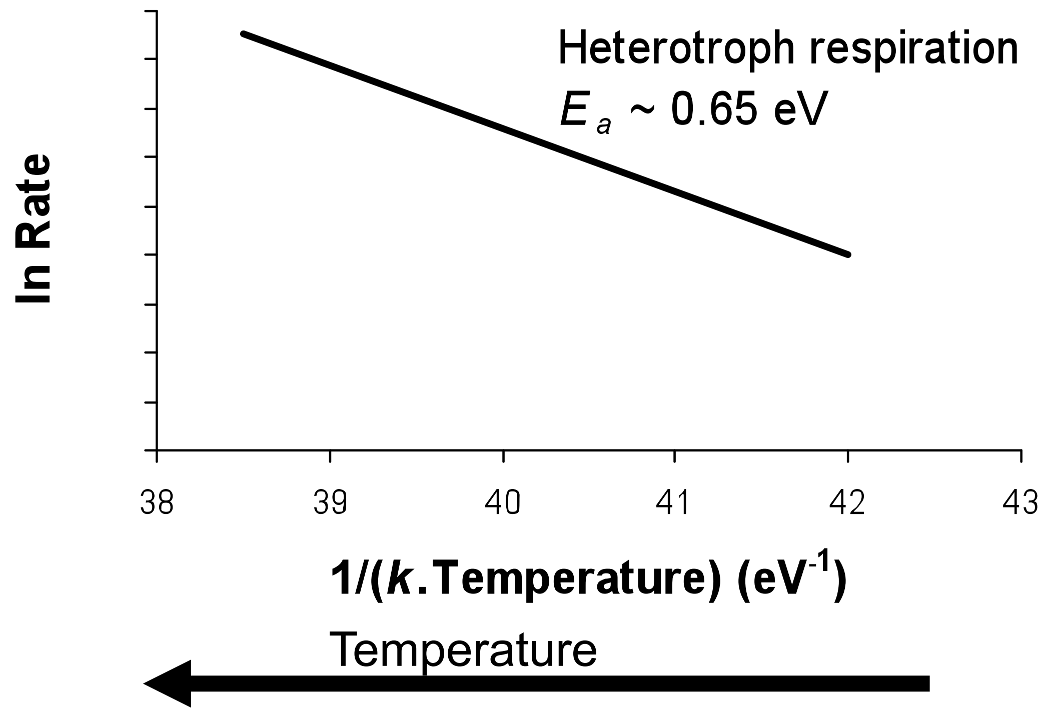
Metabolic Theory of Ecology (MTE)

<u>predicts</u>: thermal sensitivity of a biological rate

= "activation energy" (E_a)

= **-** slope

(Gillooly et al 2001)



Boltzmann constant = ***k*** = 8.62 x 10^{-5} eV. K^{-1}

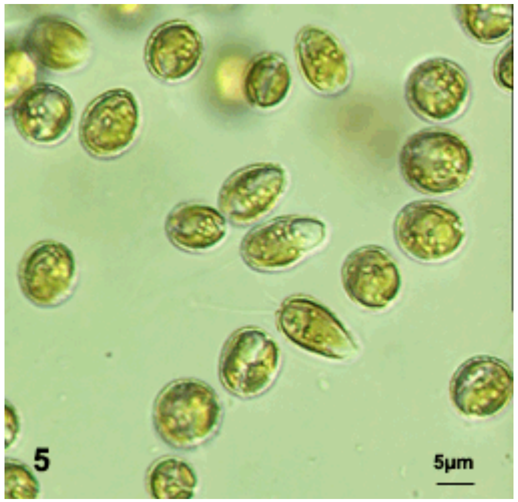
A Potential Ecological Law

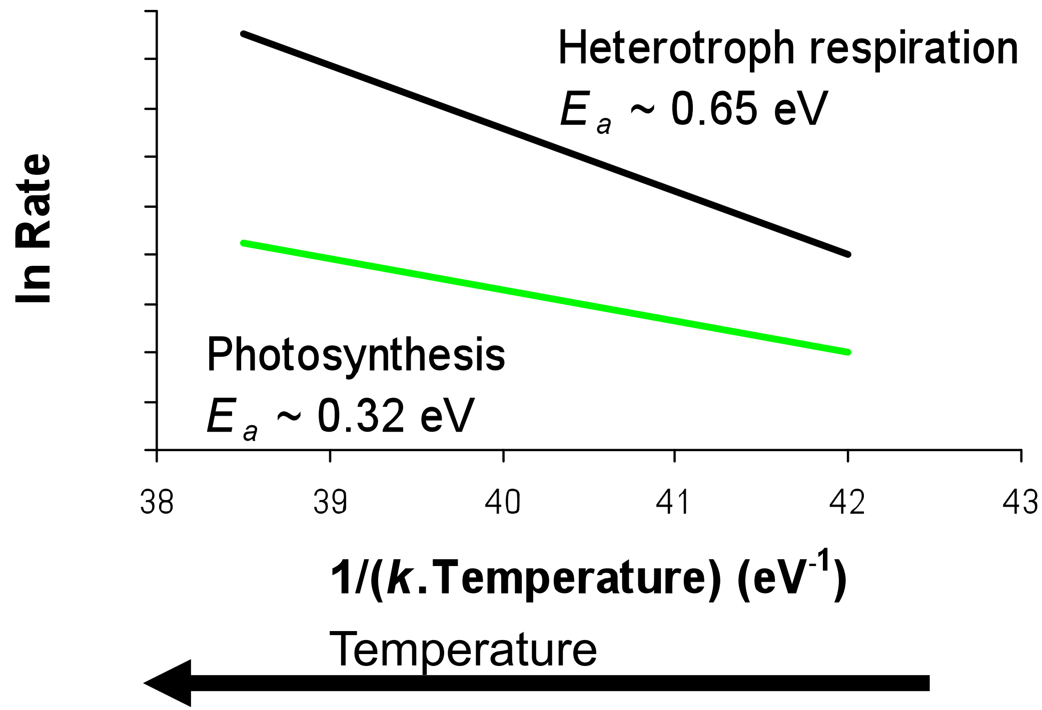
Metabolic Theory of Ecology (MTE)

<u>predicts:</u> E_a ~ 0.32 eV

for photosynthesis

(Allen et al. 2005)





A Potential Ecological Law

Metabolic Theory of Ecology (MTE)

assumes E_a:

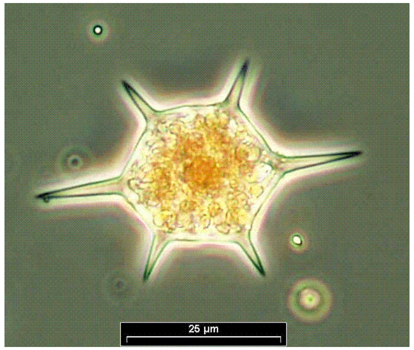
is the same for

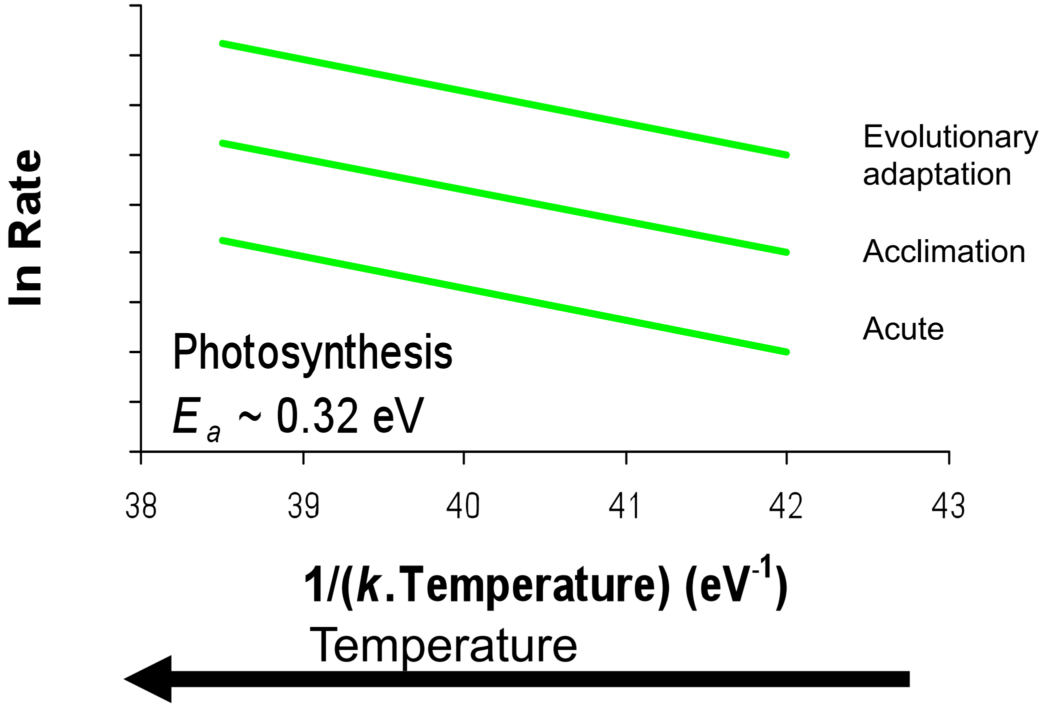
- acute
- acclimatory

  &

- evolutionary

responses to temperature





A Potential Ecological Law

Metabolic Theory of Ecology (MTE)

<u>predicts</u> E_a:

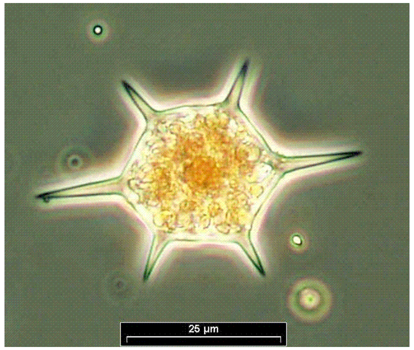
is <u>the same</u> for

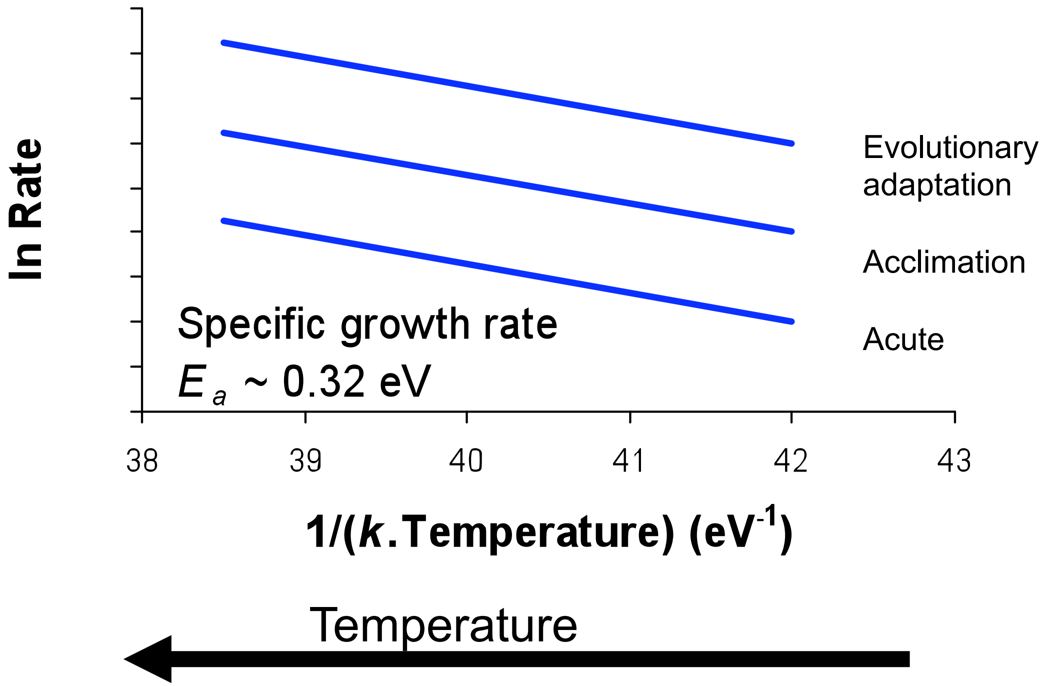
• photosynthesis

&

• specific growth rate, μ (= intrinsic rate of natural increase, r)

(Savage *et al*. 2004)





Tests of Prediction and Assumption

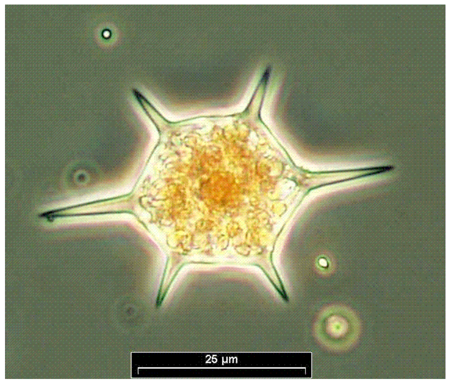
E_a for microalgal specific growth rate is:

i) 0.32 eV

ii) The <u>same</u> for <u>acclimation</u>
(within-species)
and <u>evolutionary adaptation</u>
(across-species)

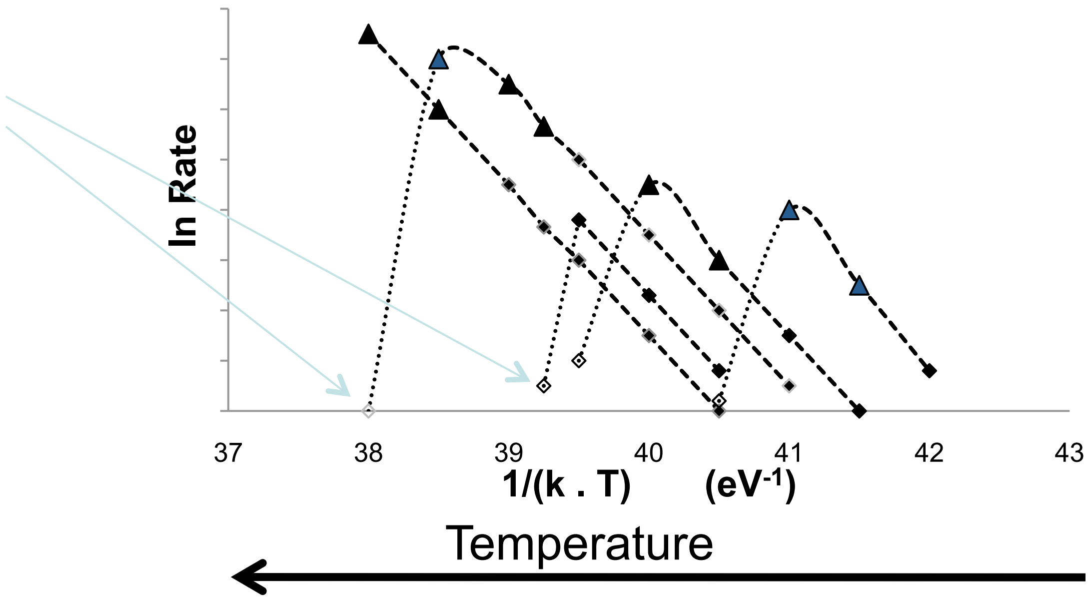
Data

- 30 published single-sp growth responses to acclimation temperature
- Species from 8 divisions (27 spp, 3 strains)
- > 5 orders of magnitude of cell volume
- Temperature range ~30 °C



Methods: Sensitivity of μ to Temperature: Within-spp *versus* Across-spp

Stressfully high, supra-optimal temperatures, not included

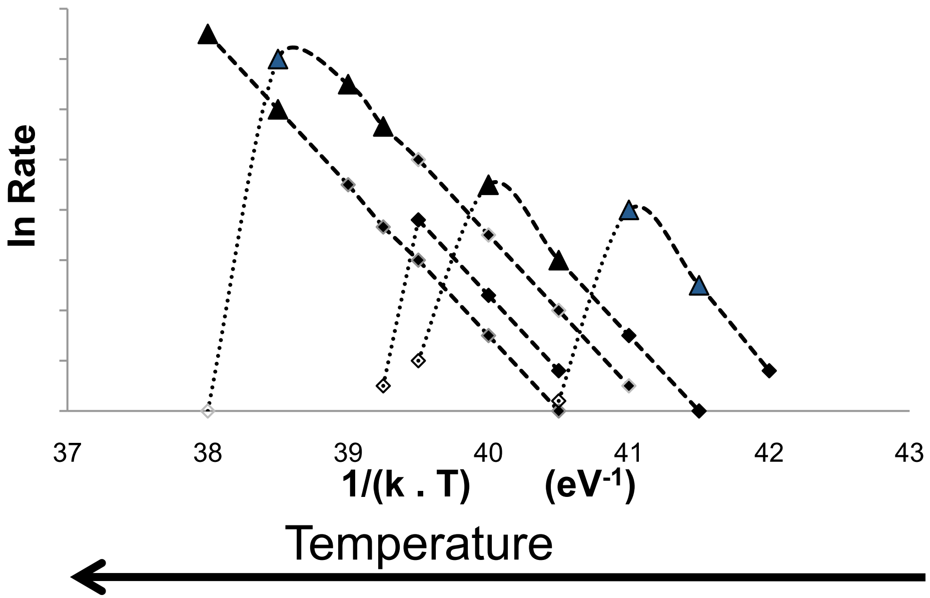


Methods: Sensitivity of *μ* to Temperature: Within-spp *versus* Across-spp

Stressfully high, supra-optimal temperatures, not included

Cell size and light climate corrections followed López-Urrutia et al. (2006)

Ln (Rate. (Cell vol) $^{-b}$). ((PFD. Kpfd)/PFD)



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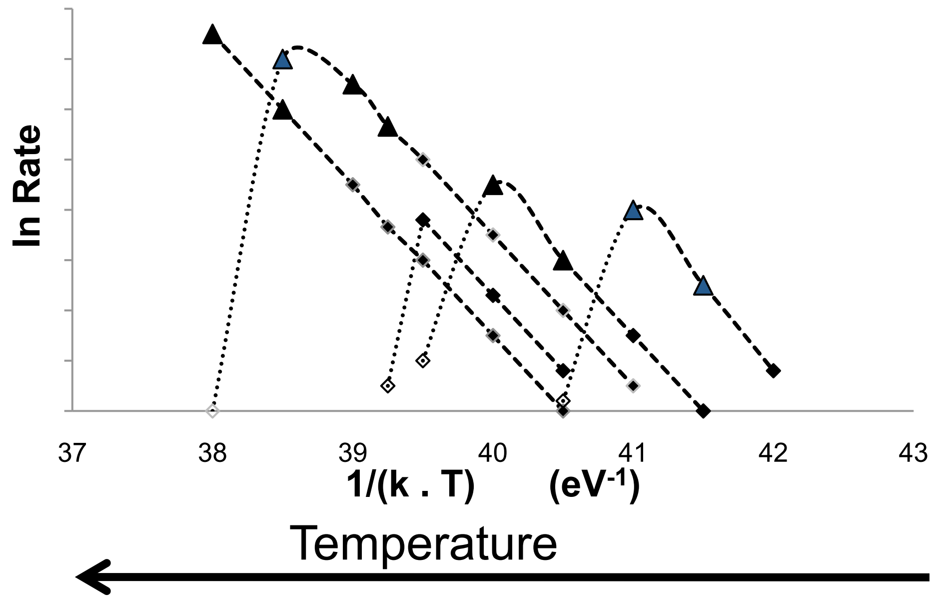
E_a within species
= - slope of dashed lines



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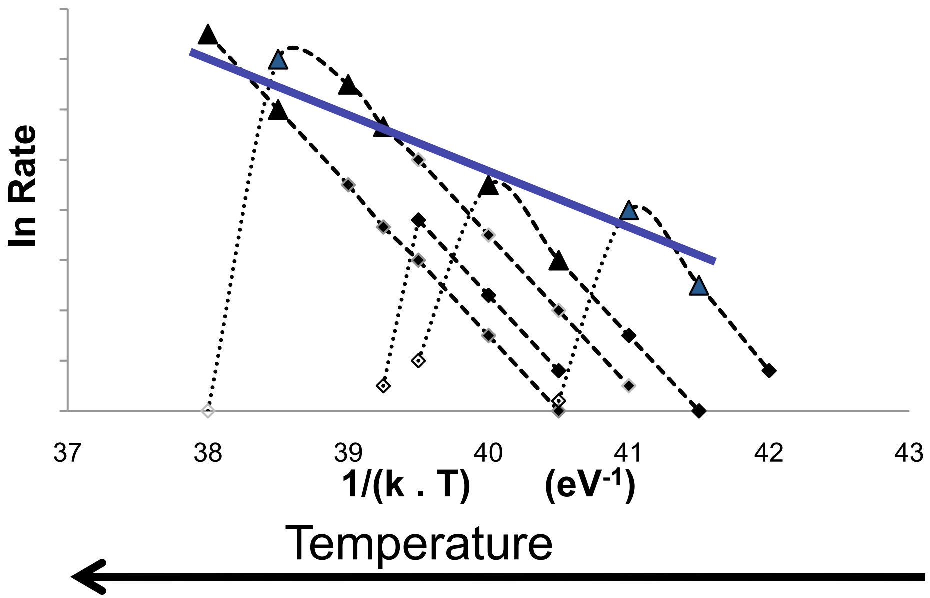
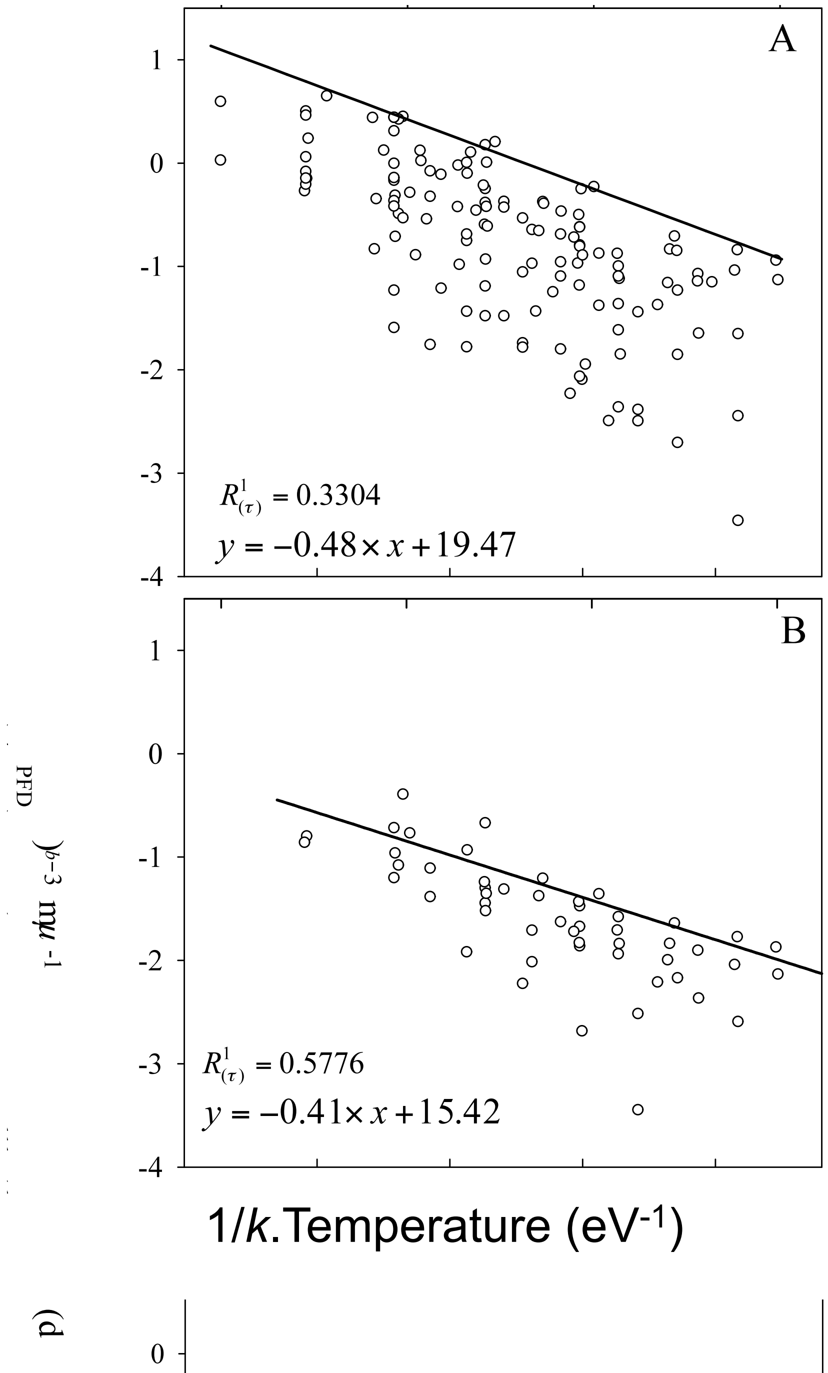


Reduced other confounding effects (e.g. nutrient limitation differences) :
slope of <u>top</u> of data envelope by quantile regression (large triangles)

Results: E_a Across-species

A. Microalgae (N = 138; 96th quantile): E_a = 0.48

C. Diatoms (N = 52; 90th quantile): E_a = 0.41



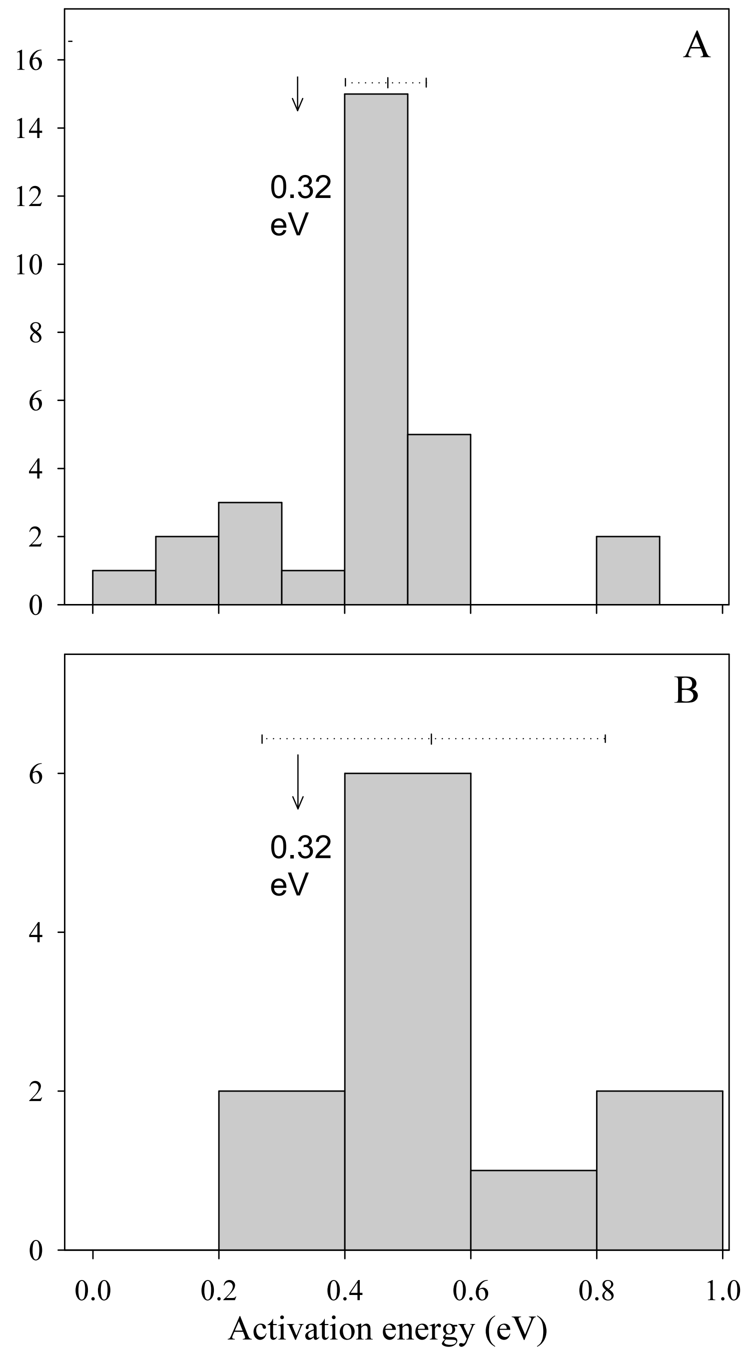
Results: Within-species E_a

Frequency distributions of activation energies

Dotted horizontal lines: weighted means ± 2 SE

A. Microalgae (N = 30 responses).
   Mean E_a = 0.46

B. Diatoms (N = 11). Mean E_a = 0.53



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Frequency distributions of activation energies

Dotted horizontal lines: weighted means ± 2 SE

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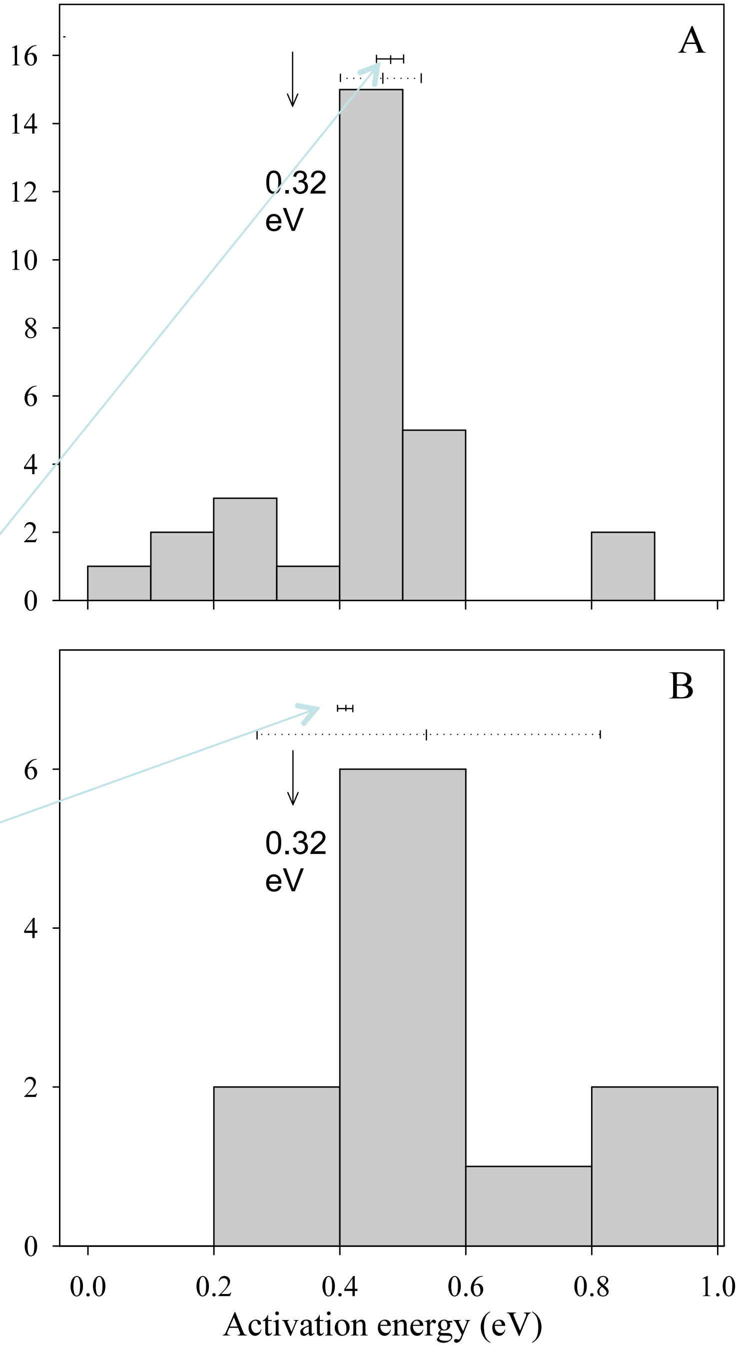
   Mean E_a = 0.46

B. Diatoms (N = 11). Mean E_a = 0.53

Solid line: Mean E_a (± 2 SE) from across-species quantile regression



Tests of Prediction and Assumption

E_a for microalgal specific growth rate is:

i) 0.32 eV

No: Mean E_a = 0.41 - 0.53 eV

$p<0.001$, ex. diatoms within-spp = NS

➡ ~25% higher μ over 10 °C compared with MTE

Tests of Prediction and Assumption

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i) 0.32 eV

No: Mean E_a = 0.41 - 0.53 eV
p<0.001, ex. diatoms within-spp = NS

➡ ~25% higher μ over 10 °C compared with MTE

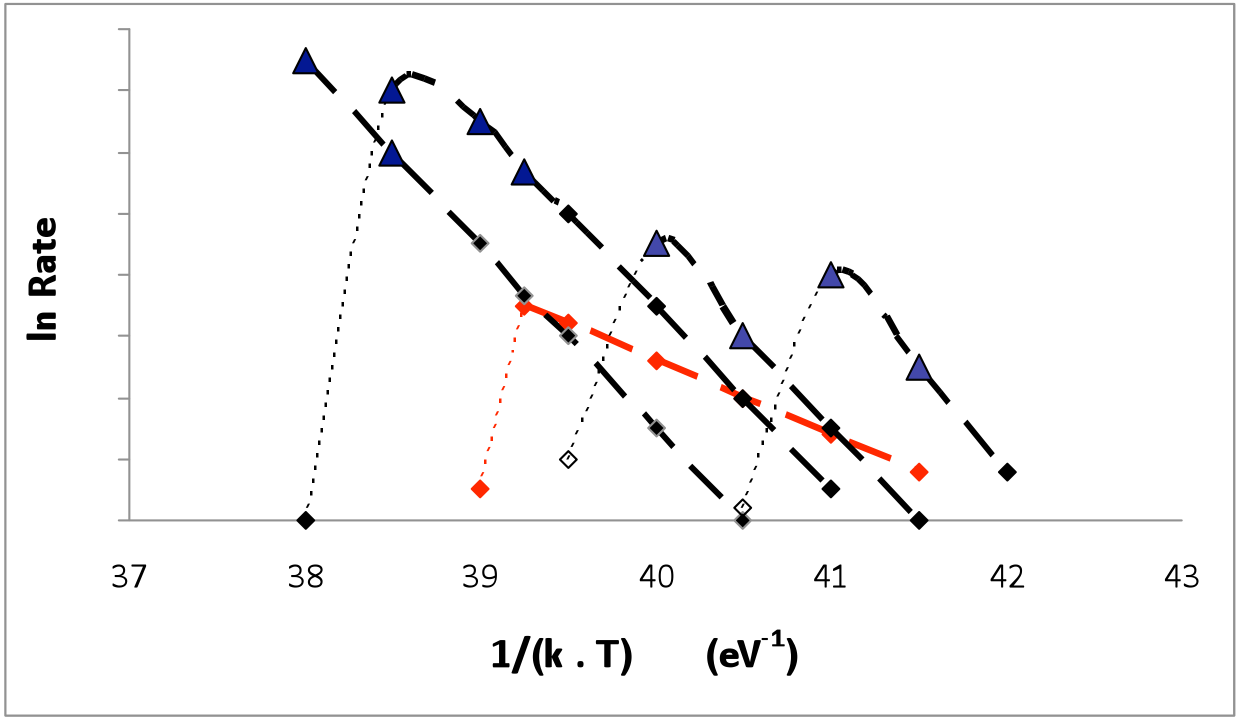
iii) The same for acclimation (within-species) and evolutionary adaptation (across-species)

Yes

Explaining These Patterns of E_a

Hypothesis: Thermal sensitivity is reduced where maximum growth falls below top of data envelope

(e.g. under nutrient limitation, nutrient diffusion (which has low E_a) has larger influence on specific growth rate, thus lowering E_a of μ)

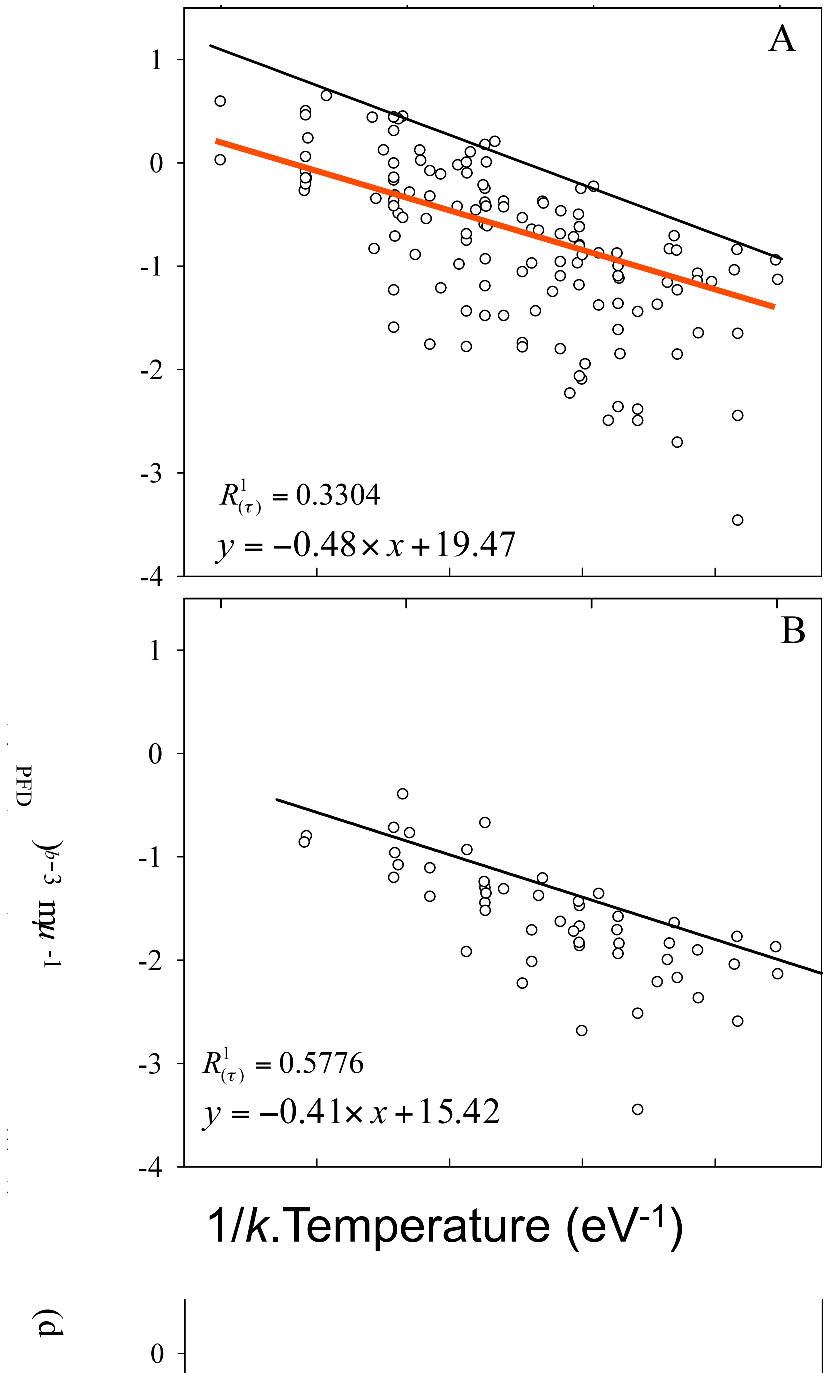


Results: E_a Across-species

A. Microalgae (N = 138; 96th quantile): E_a = 0.48
50th quantile (median): E_a = 0.28

Not significantly diff from 0.32 eV

B. Diatoms (N = 52; 90th quantile):
E_a = 0.41



Conclusions

- Microalgal specific growth rate (*μ*) is 25% higher per 10 °C than expected from MTE, both within species and for μ_{max} across-species

- E_a within species is similar to that across species at maximum μ

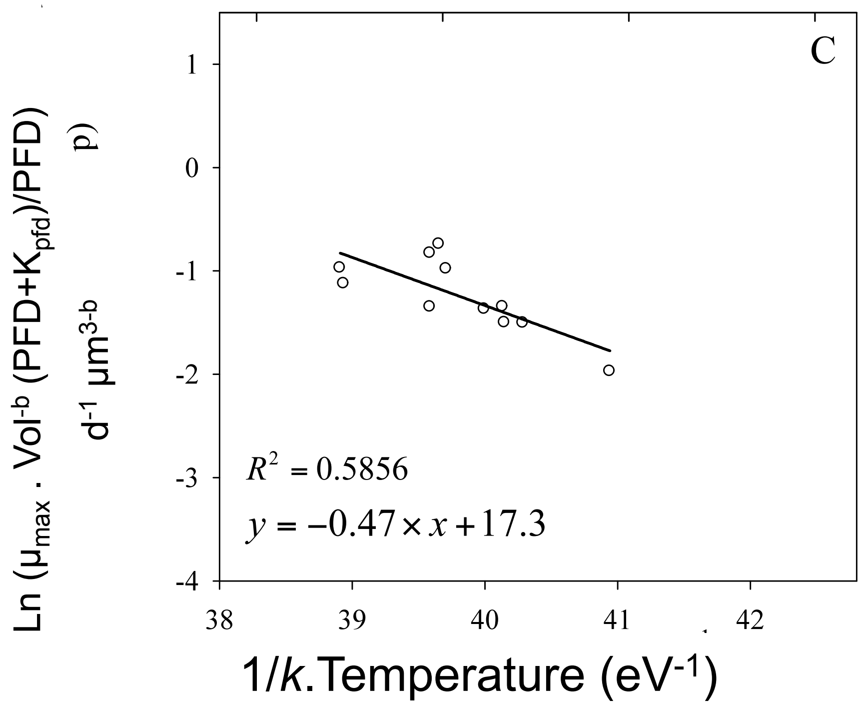
- We hypothesize: E_a is reduced by nutrient limitation of μ *(a nutrient x temperature interactive effect on μ)*. This could explain lower E_a for average community μ (mean or median) compared with maximum μ

- Research needed to better understand nutrient x temperature interactions

Results: E_a Across-species

C. Diatoms (μ_{max} only; N = 11)

E_a = 0.47



[Microalgae (μ_{max} only; N = 16): NS regression, not shown]