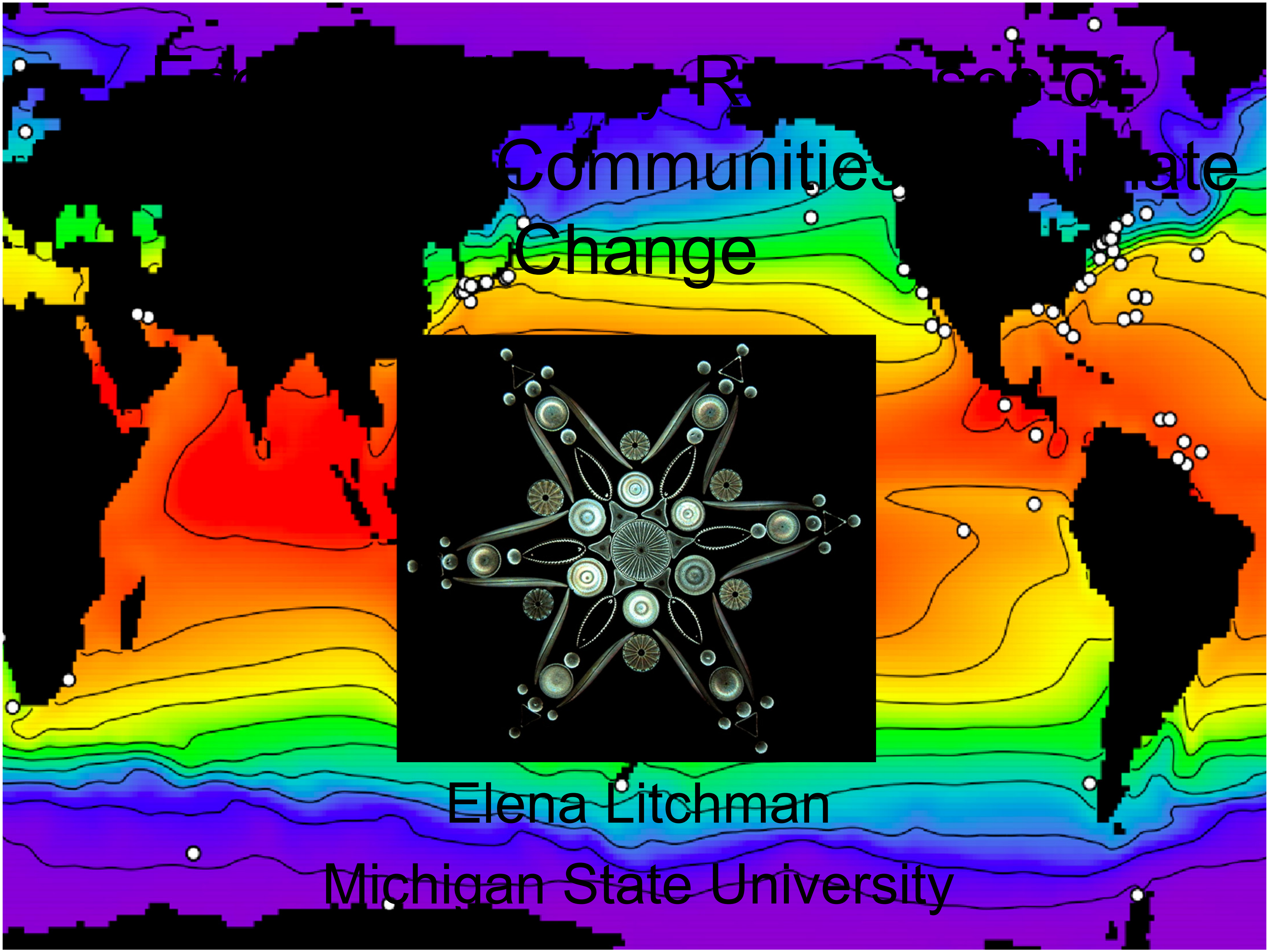
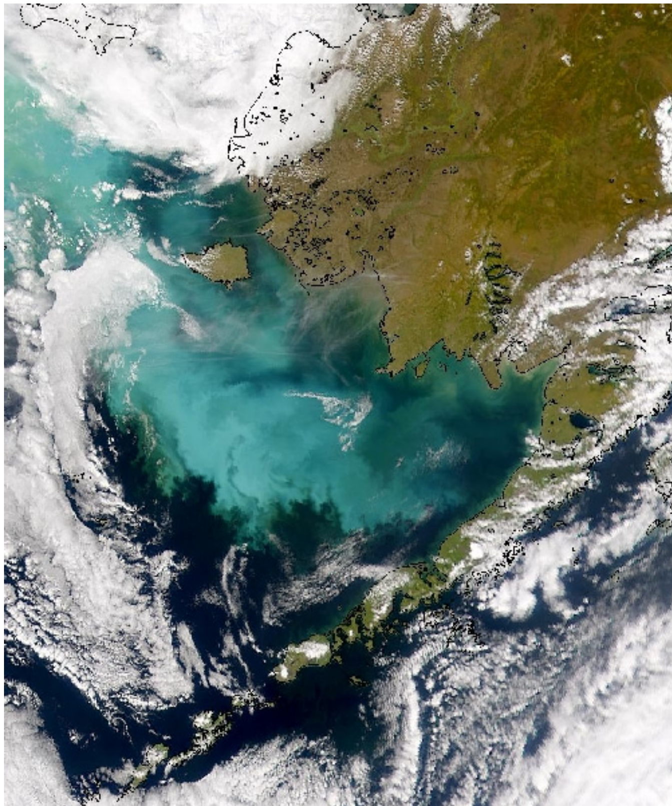
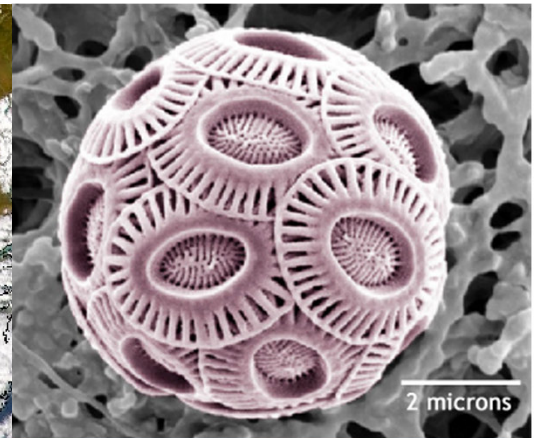
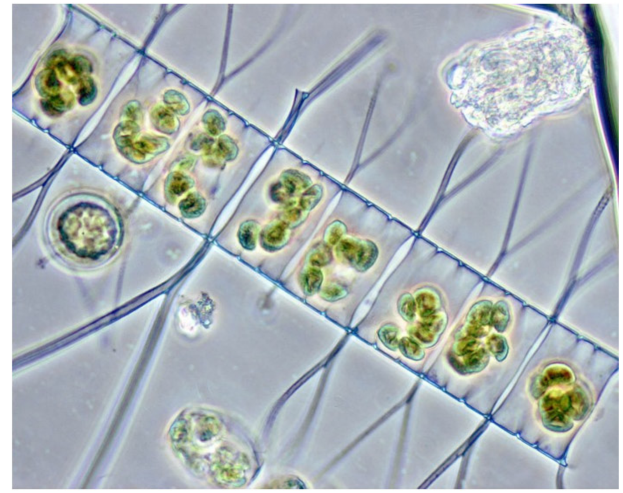
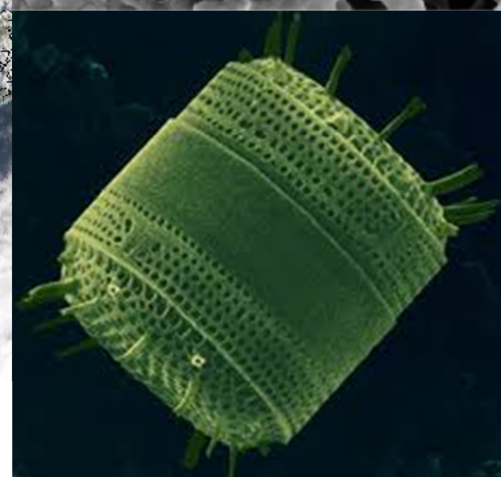
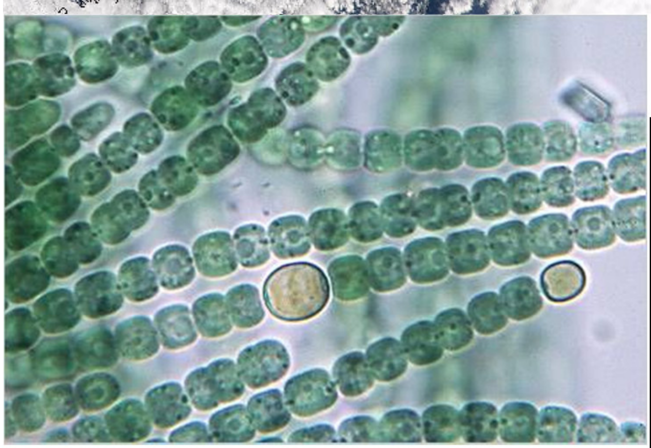
R… of … Communities … Change



Elena Litchman

Michigan State University



2 microns



@ PJS Franks



Climate Change Impacts on Phytoplankton

- Increase in CO_2 (acidification)
- Increase in temperature
- Change in stratification, nutrient and light availability
- Changes in other trophic levels (predators and parasites)

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Responses of Phytoplankton Communities to Climate Change

- Dispersal
- Phenotypic plasticity
- Selection on new mutations
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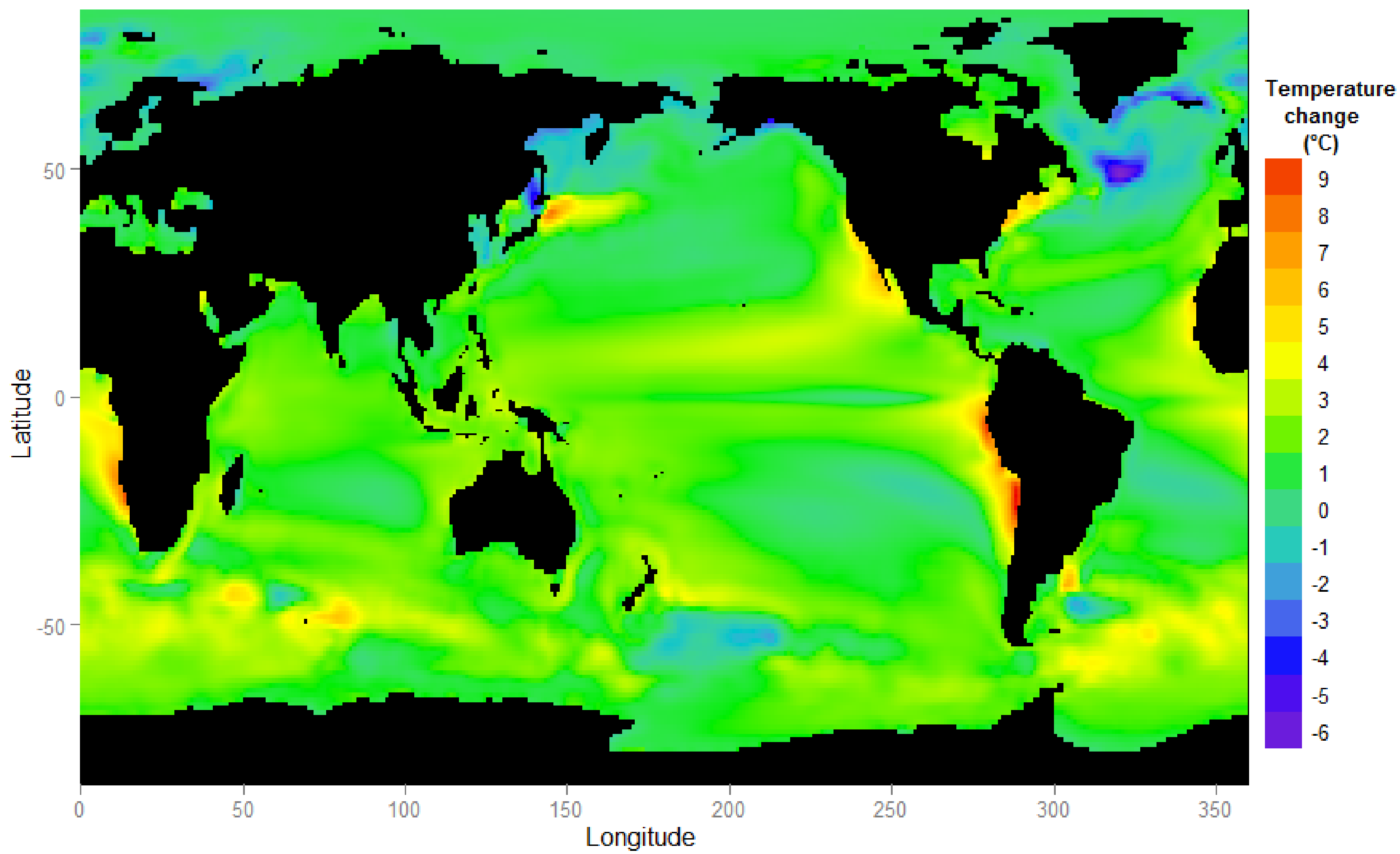
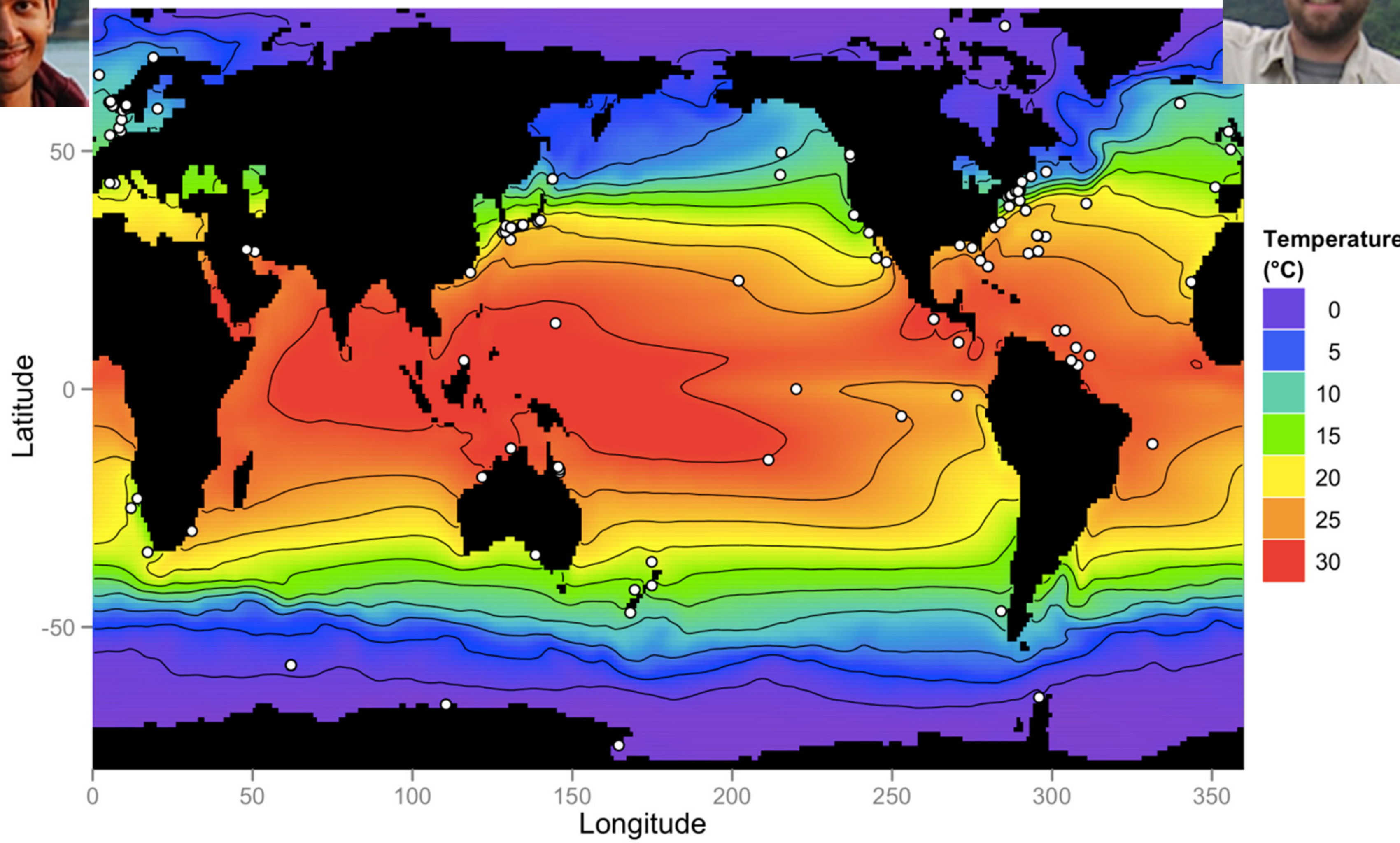
Evolution

Temperature change Present-2100

Warming at least 2 - 4°C in most of the ocean



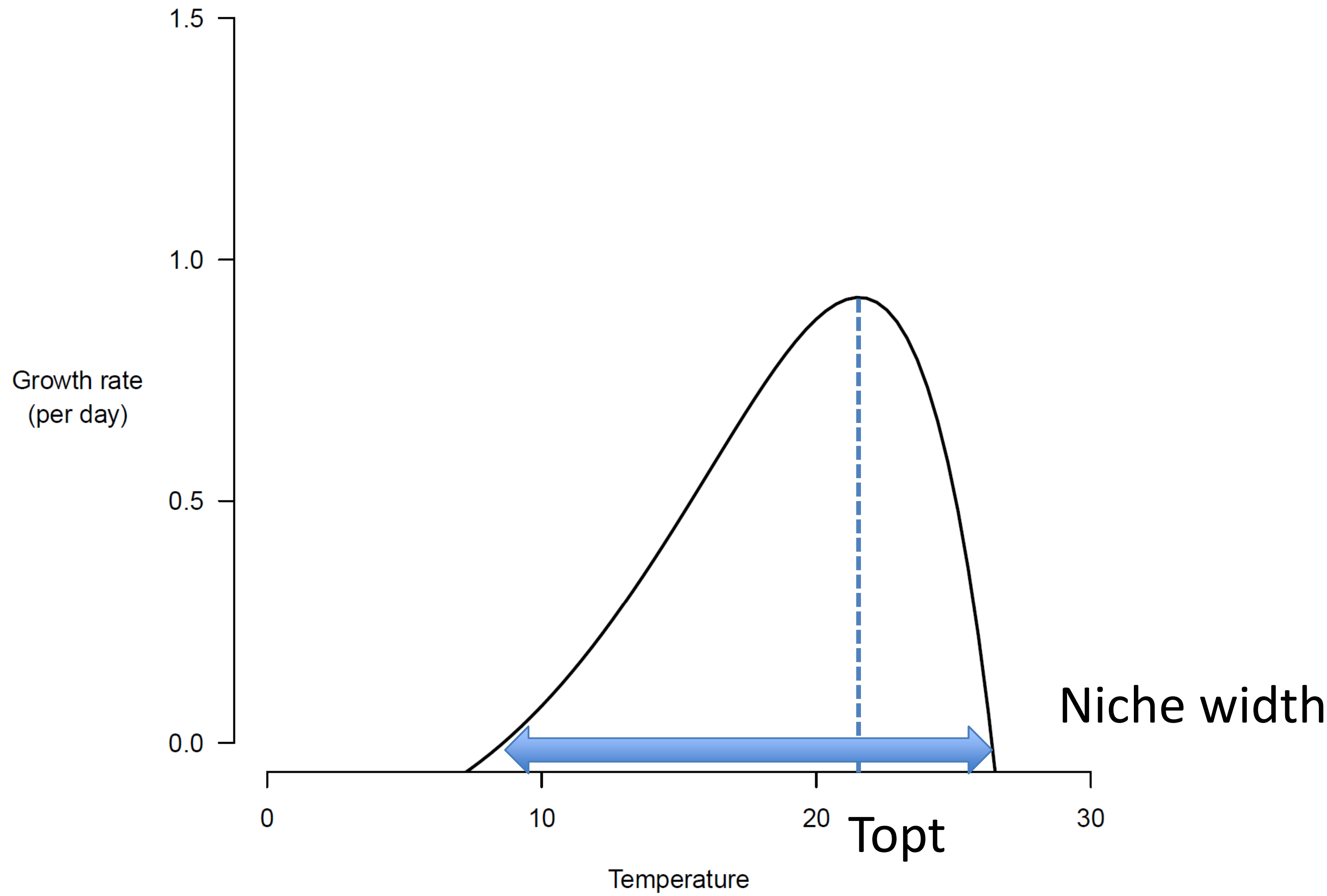
Thermal responses of phytoplankton



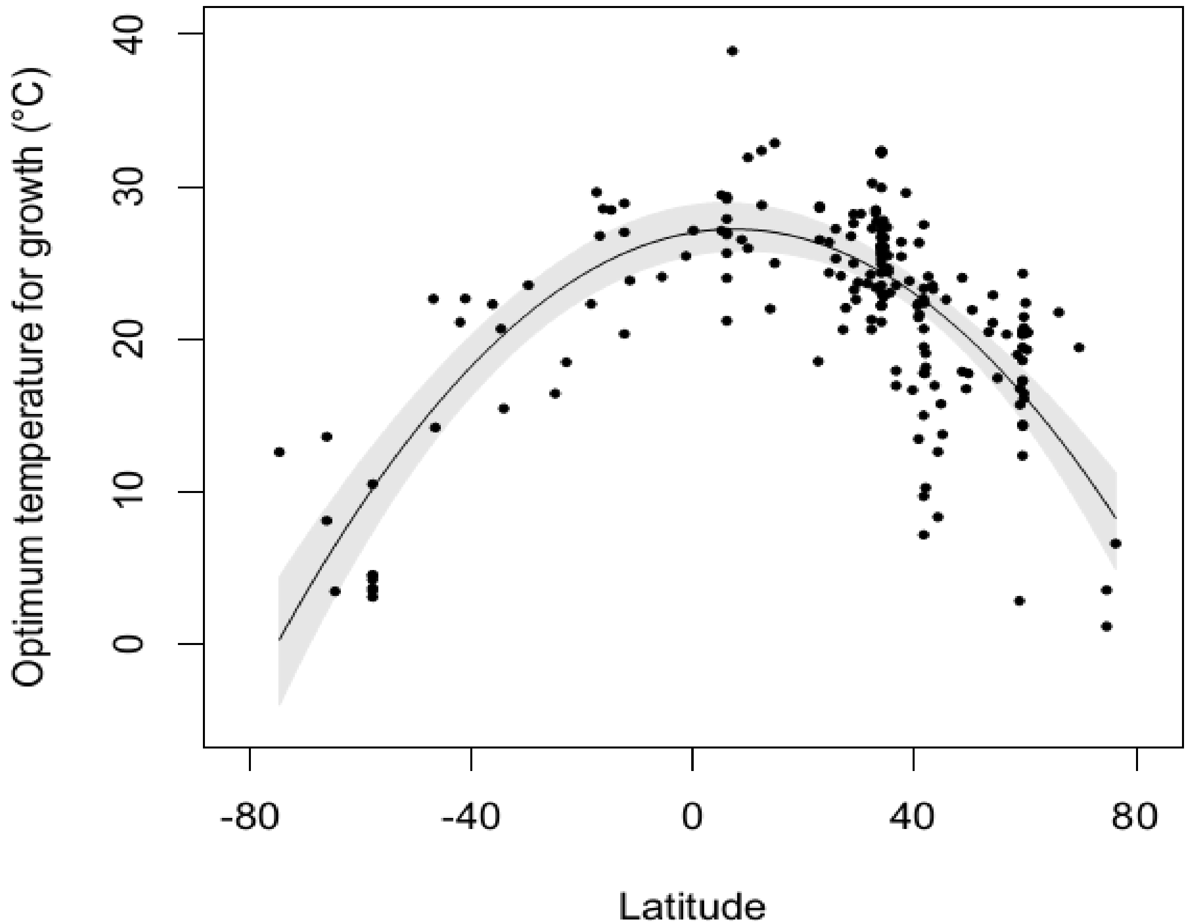
Data analysis

- Collected published data/curves for 194 phytoplankton isolates across >100 different locations from 76°N to 75°S
- Fit growth function to the curves
- Determined optima and niche widths

Thermal tolerance curve

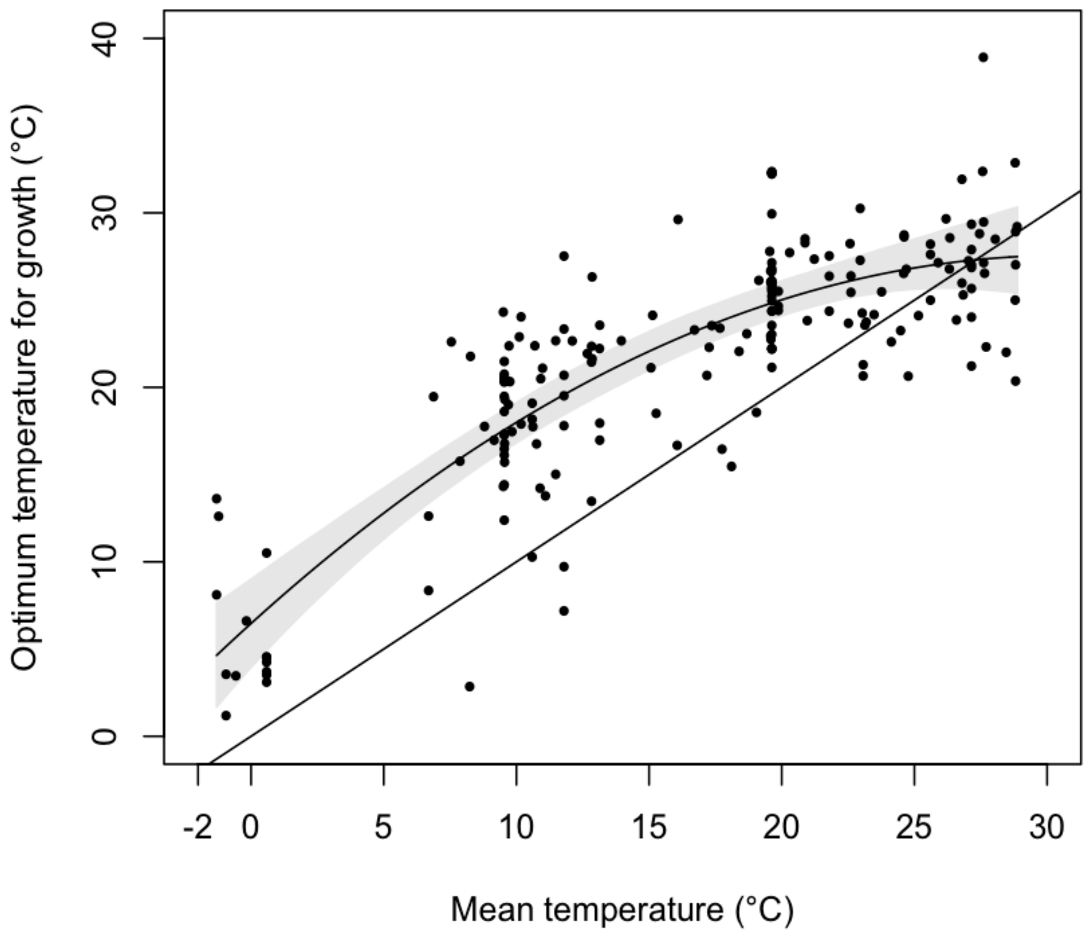


Strong latitudinal gradient in optimal temperature



Thomas et al. Science 2012

Adaptation to mean ambient temperature



Thomas et al. Science 2012

Eco-evolutionary modeling (Adaptive Dynamics)

- Determine optimal thermal strategy (ESS) under different temperature regimes

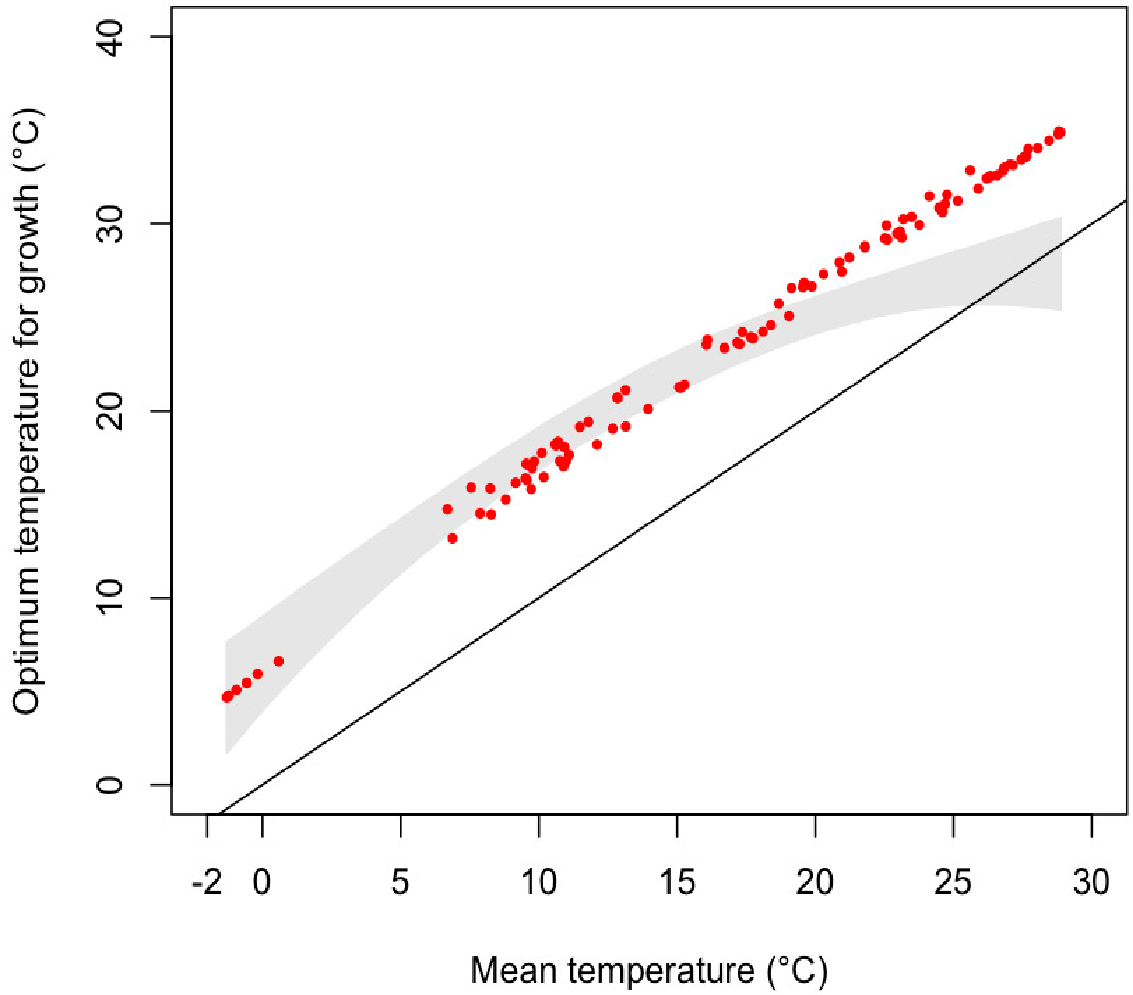
Eco-evolutionary dynamics

$$\frac{dN}{dt} = N \cdot \left(f(Z,T) \cdot \frac{R}{R+k} - m \right)$$

$$R = R_{in} - a \sum_{j=1}^{n} N_i(t)$$

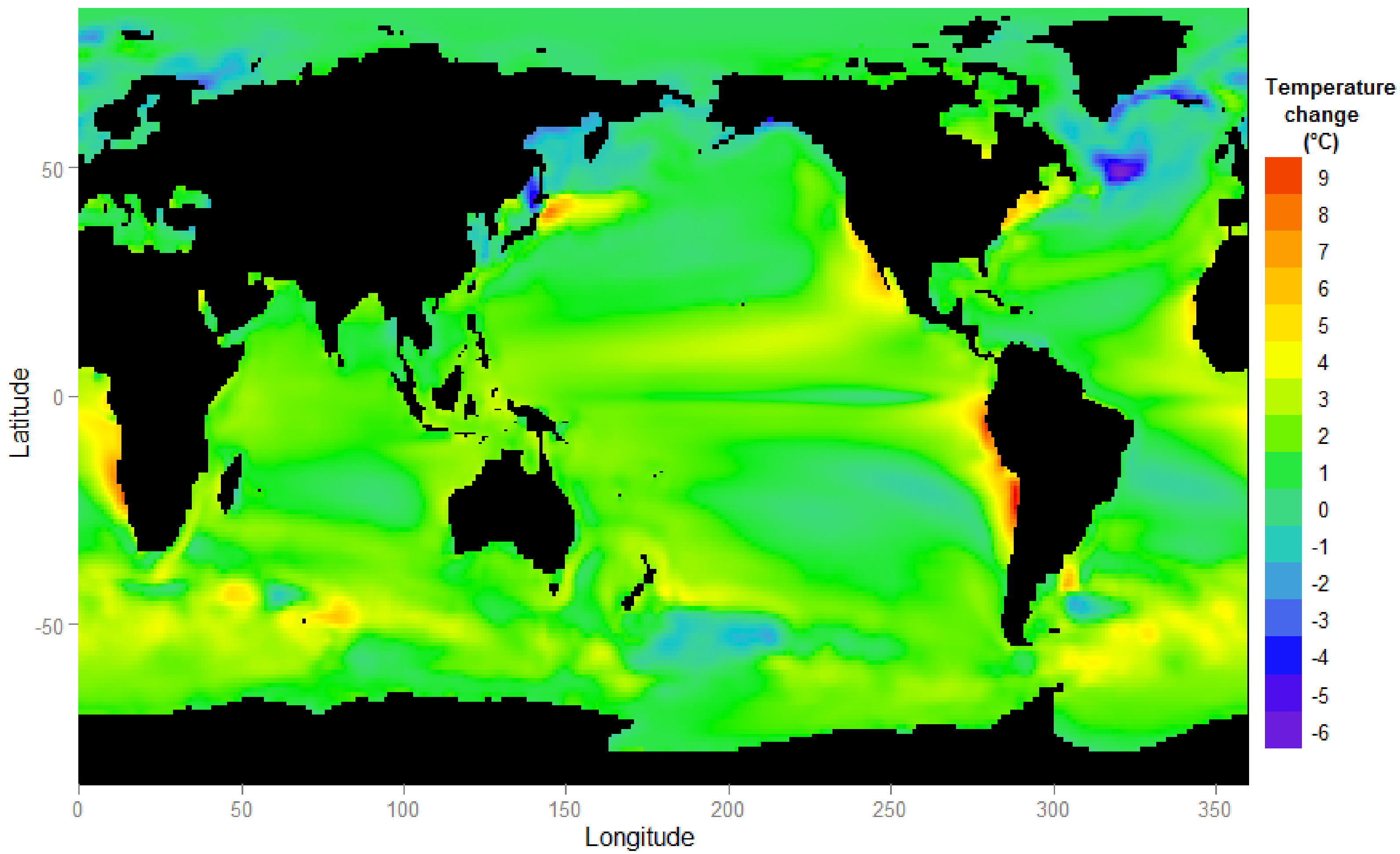
$$\frac{dZ_i}{dt} = \varepsilon \cdot \frac{dg_i}{dZ_i}$$

Observed and predicted temperature optima

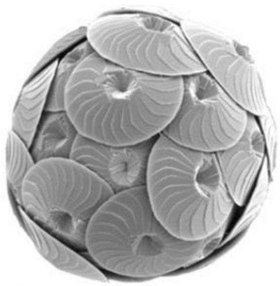


Thomas et al. Science 2012

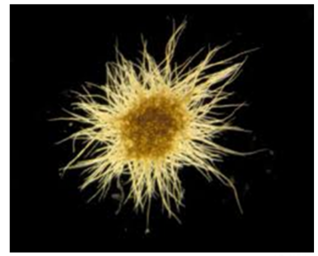
Temperature change
Present-2100



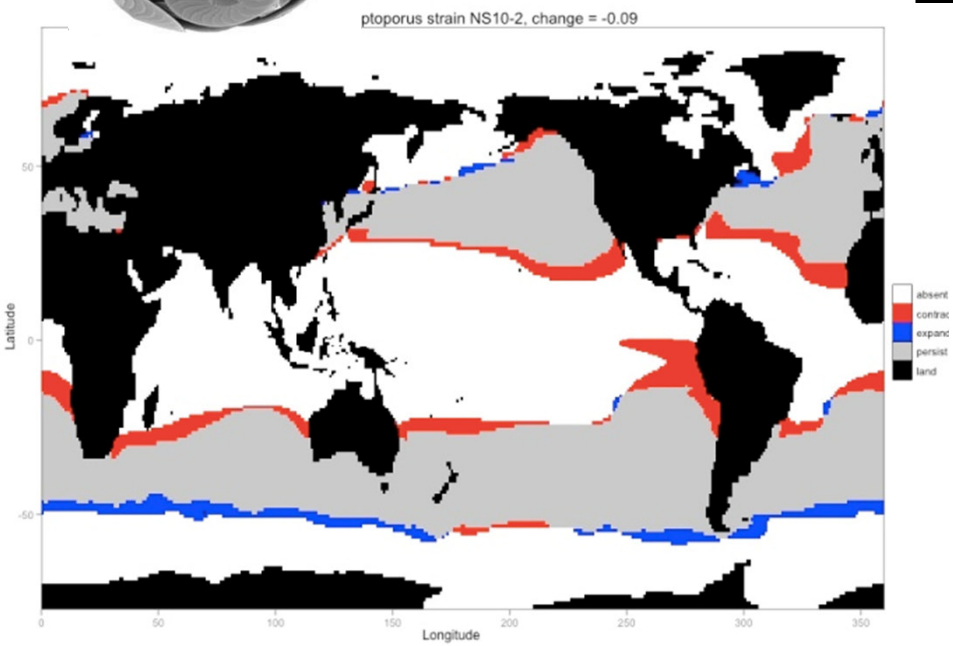
Shifts in Fundamental Thermal Niche

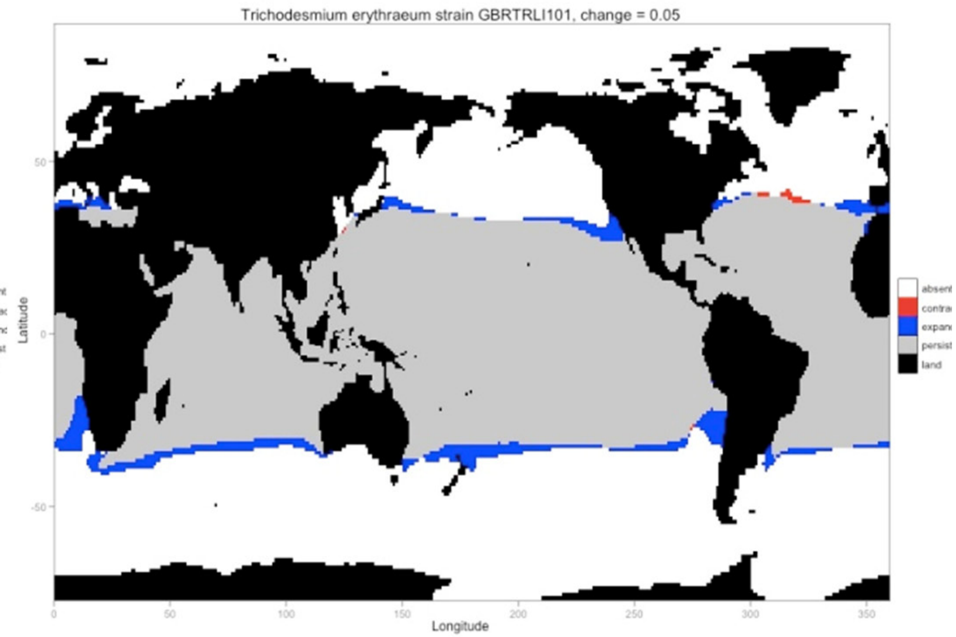


Calcidiscus leptoporus

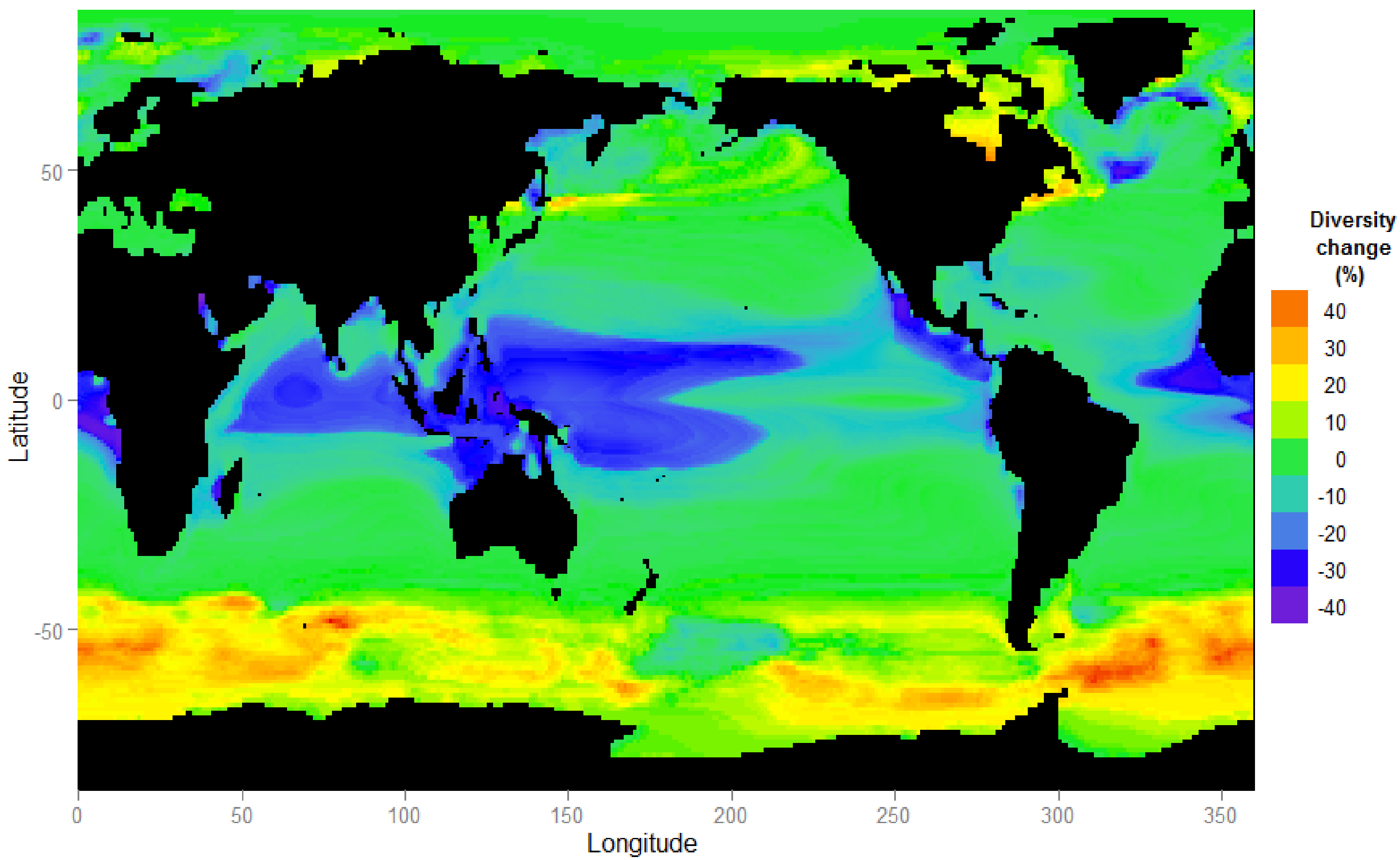


Trichodesmium erythraeum

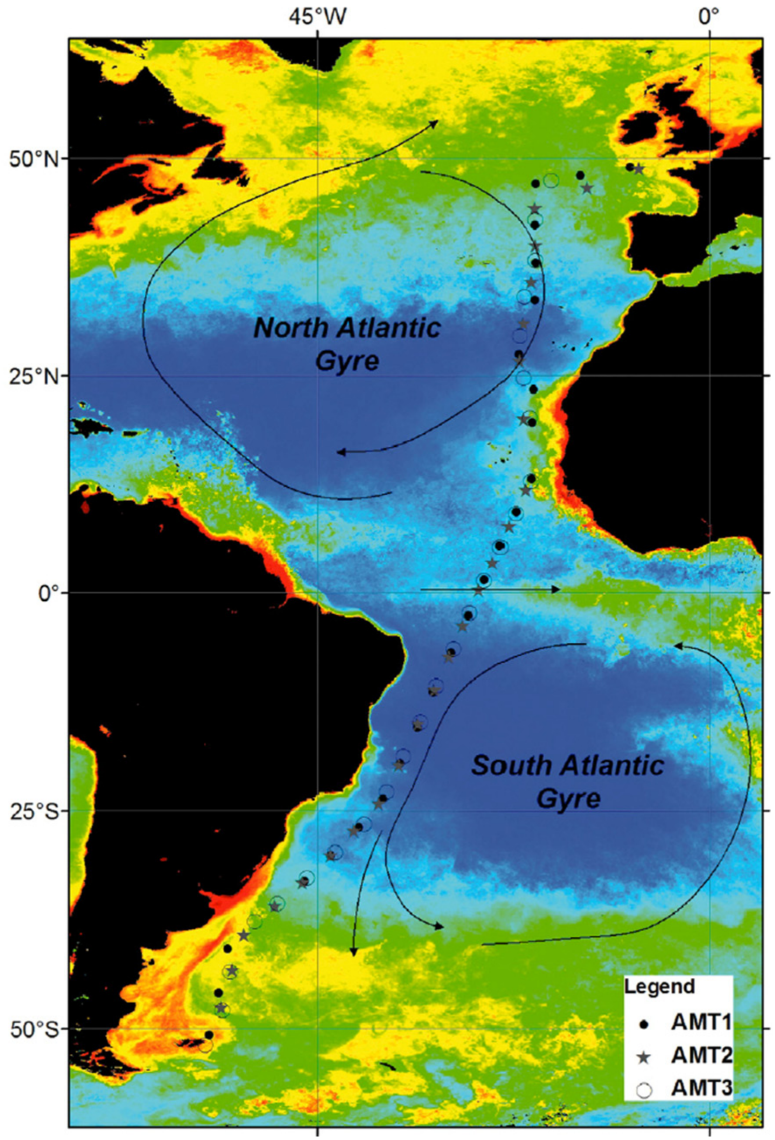




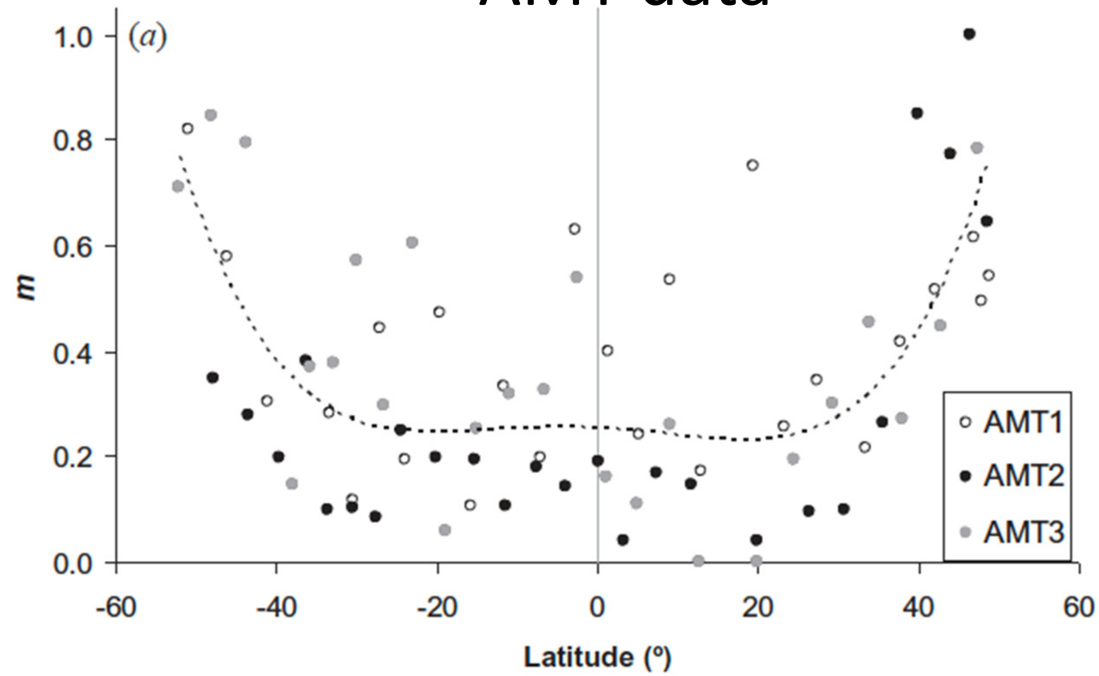
Potential diversity changes due to shifts in thermal niche



Dispersal



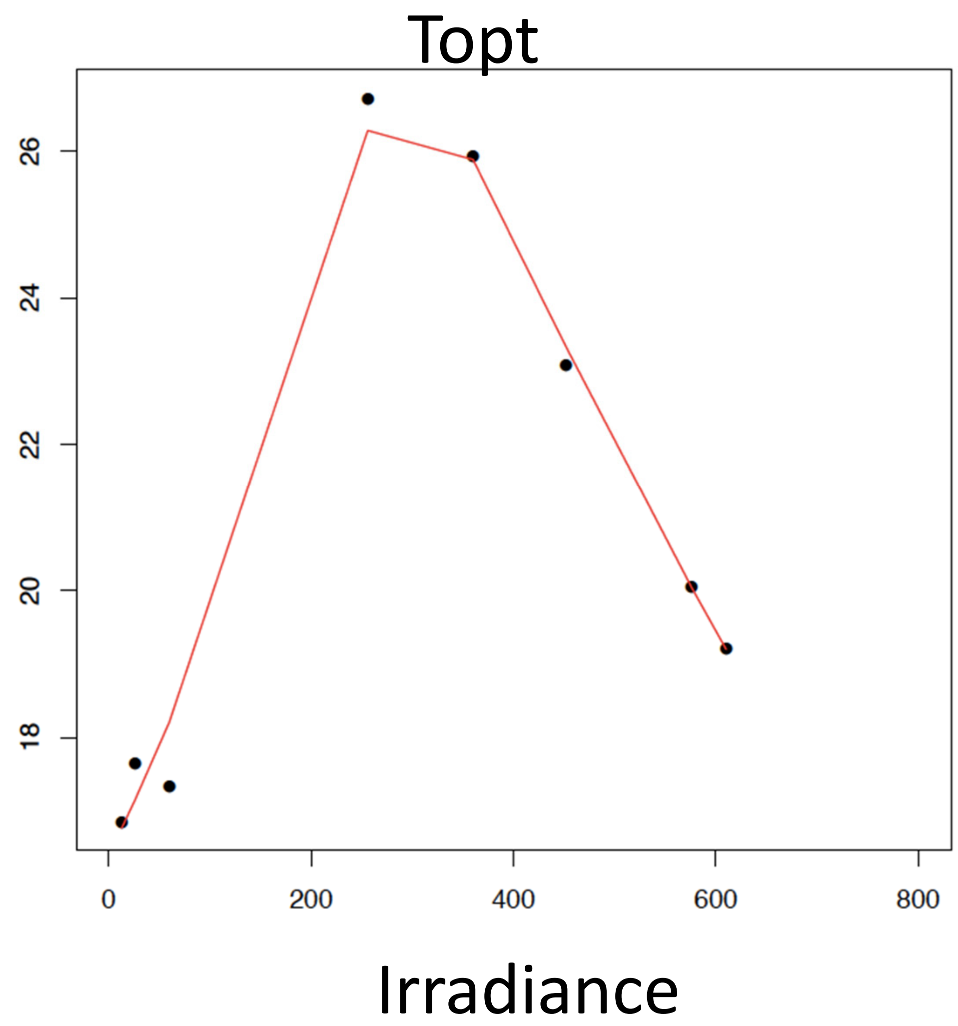
Immigration rate
AMT data



Chust et al. Glob Ecol Biogeogr 2012

Phenotypic Plasticity

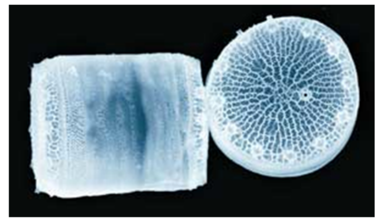
- Important in all organisms
- Not much is known how thermal traits change due to acclimation

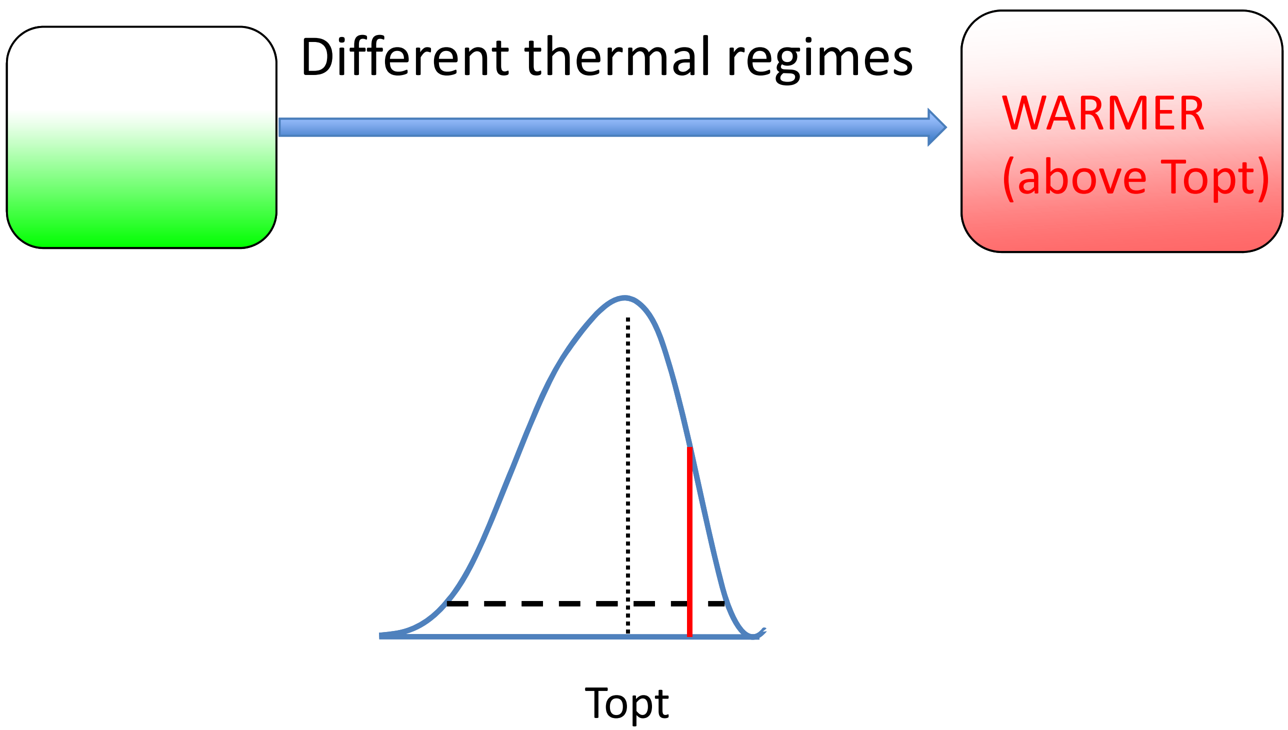


Thomas et al. in prep.

Selection on New Mutations: Evolution Experiments

Thalassiosira pseudonana





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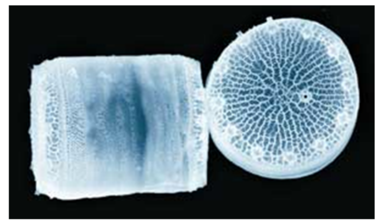
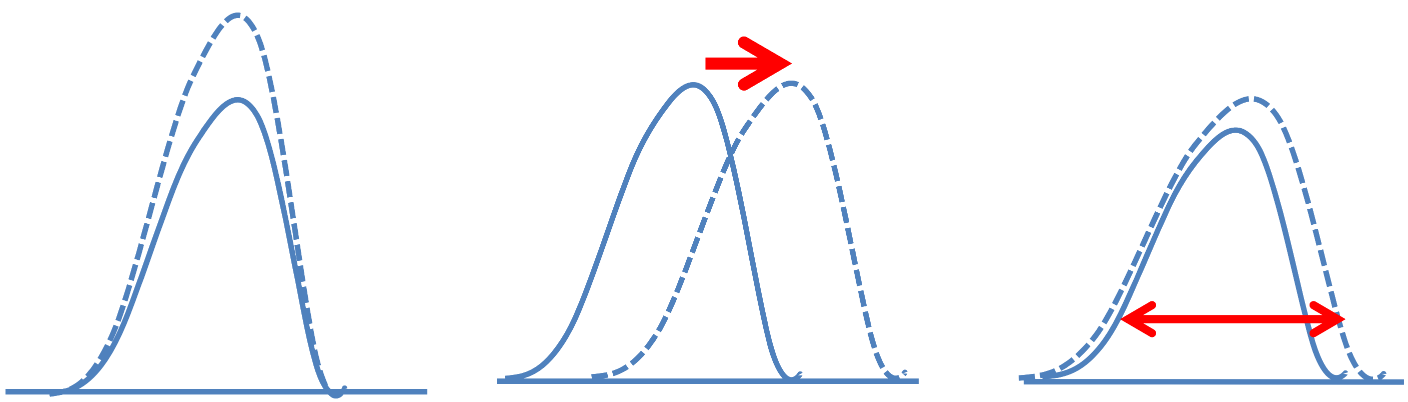


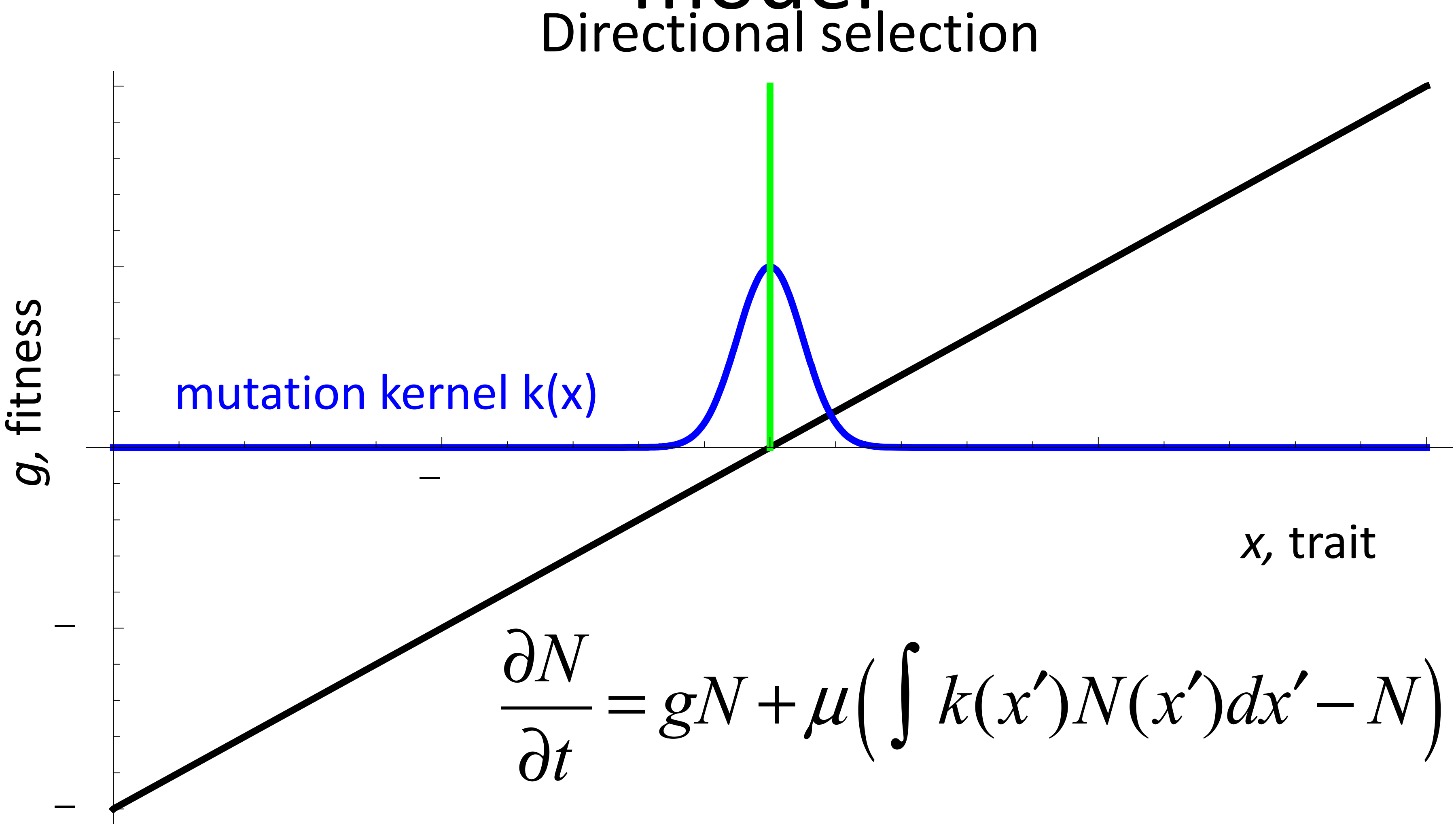
Possible adaptation scenarios



Increase in growth rate | Topt change | Niche width change

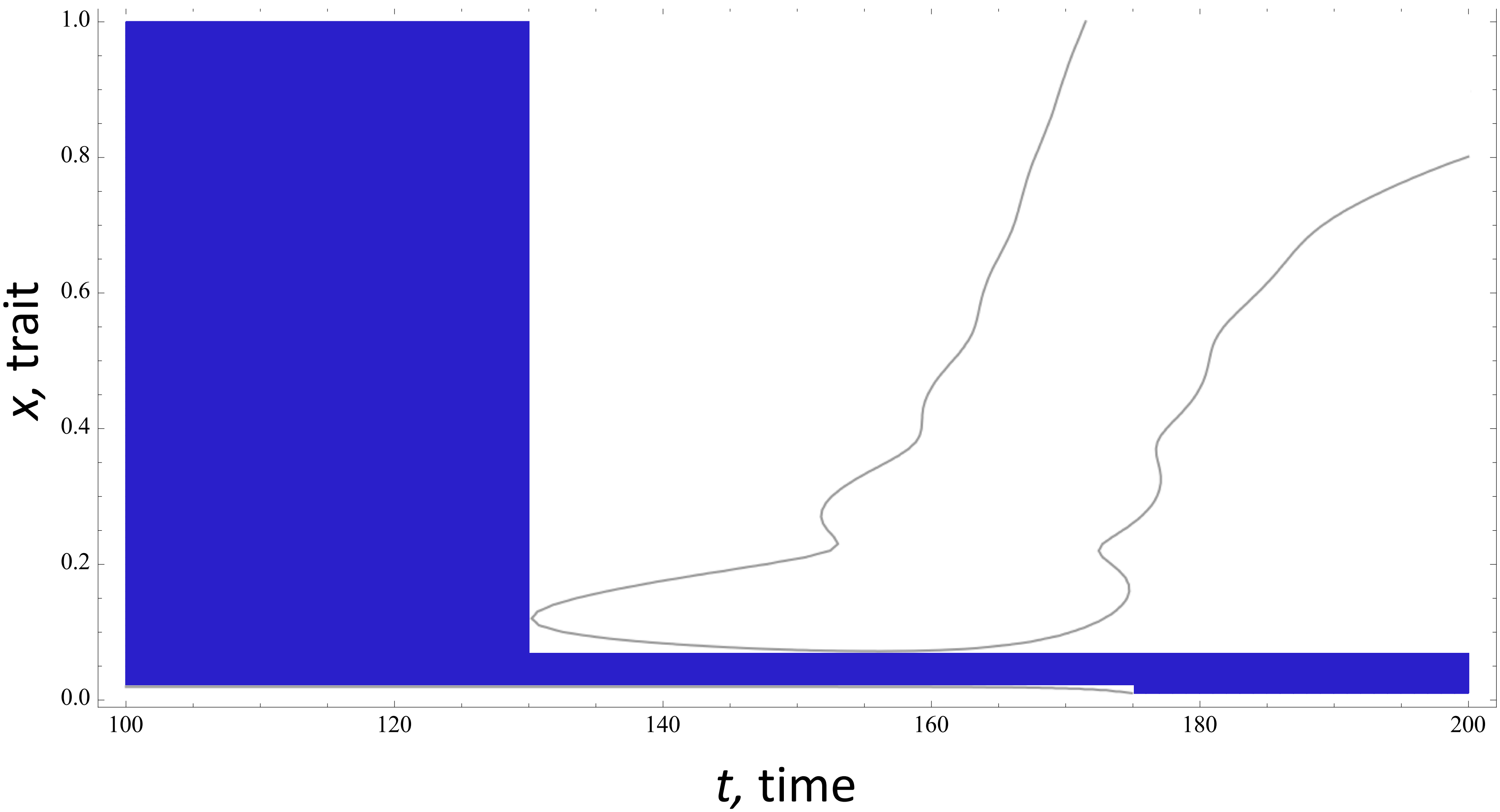
What is the genetic basis of thermal adaptation?

Selection on new mutations: model



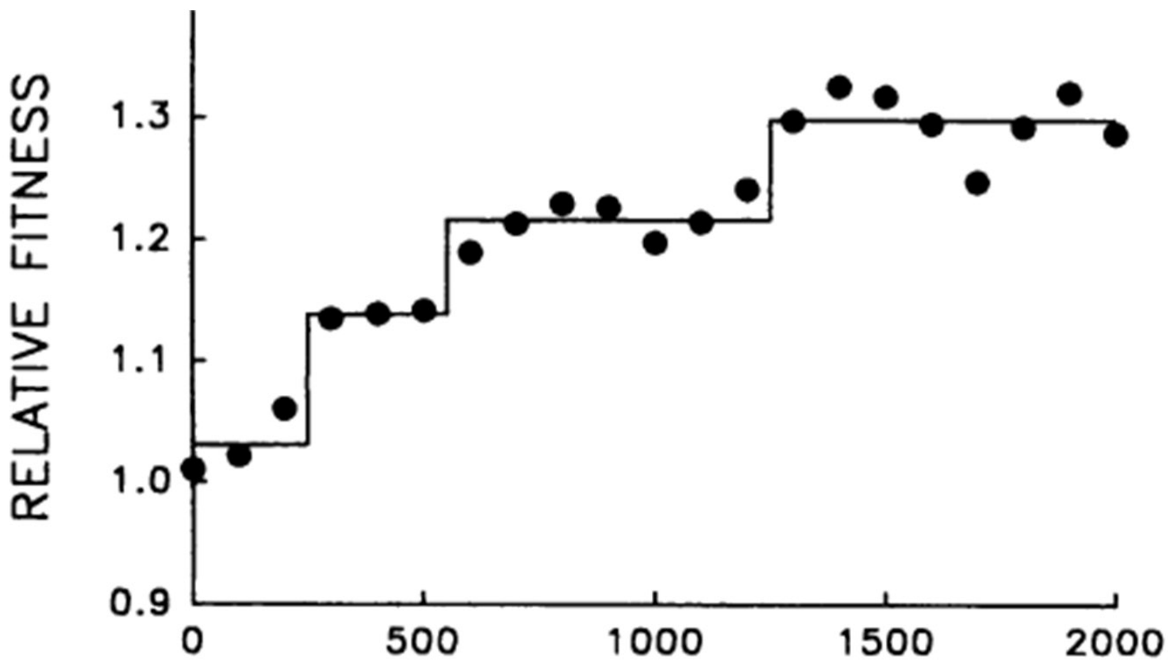
$$\frac{\partial N}{\partial t} = gN + \mu\left(\int k(x')N(x')dx' - N\right)$$

Dynamics of adaptation: jumps



Adaptive jumps: data

Evolution of glucose-limited *E. coli*

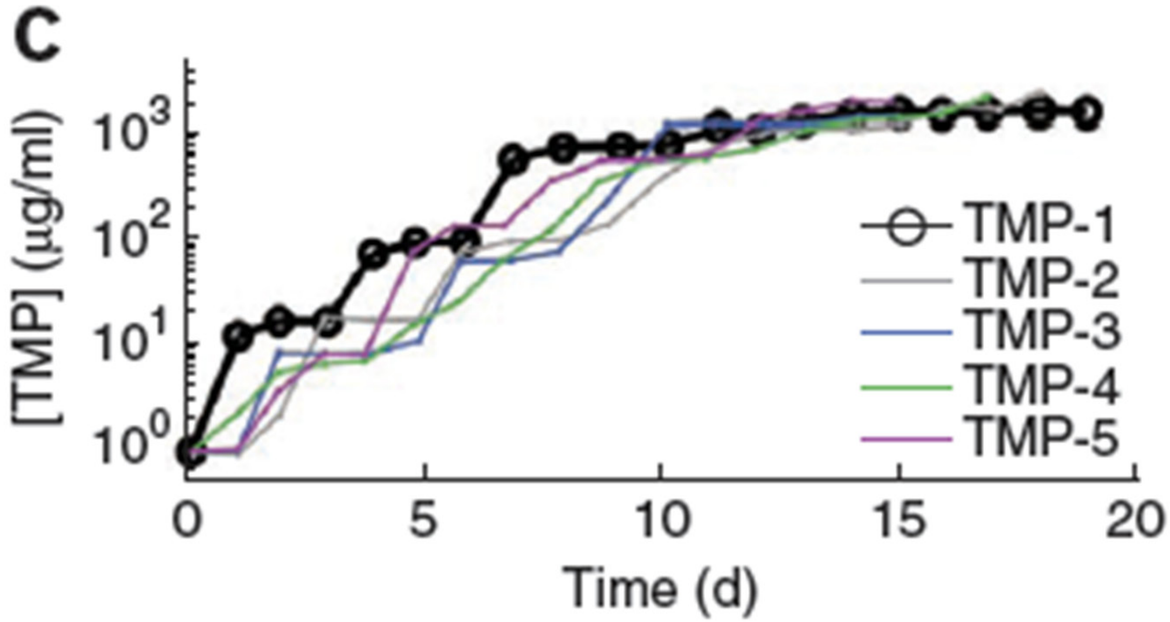


Lenski and Travisano PNAS 1994

Adaptive jumps: data

Evolution of antibiotic resistance
(*E. coli*)

resistance



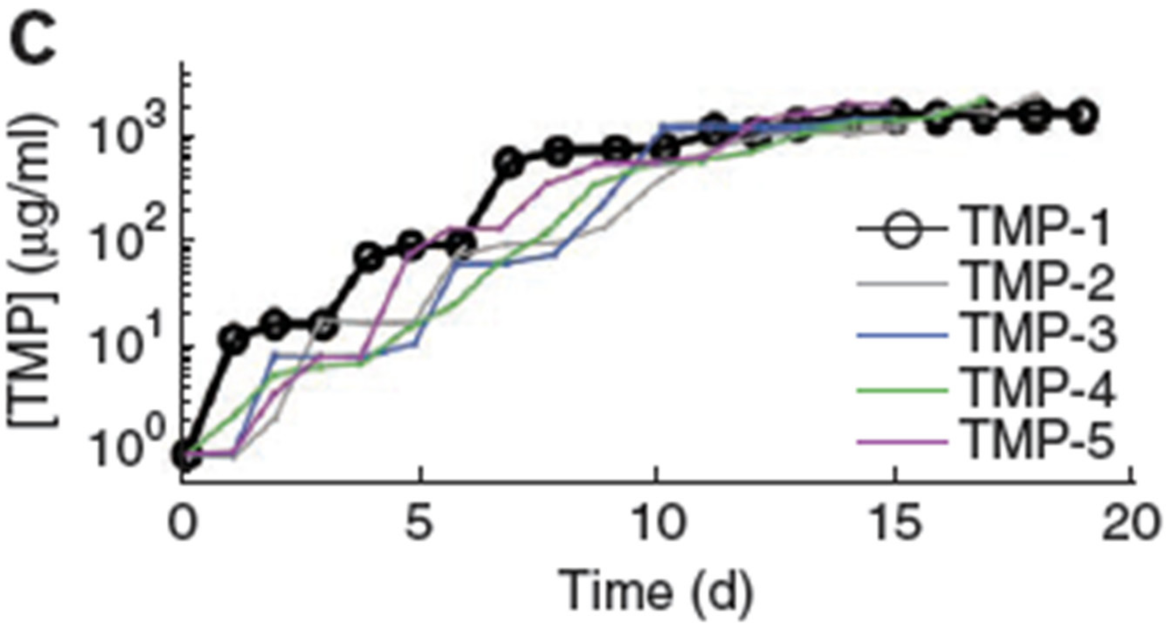
Increasing antibiotic concentration

Toprak et al. Nature Gen. 2012

Adaptive jumps: data

Evolution of antibiotic resistance
(*E. coli*)

resistance

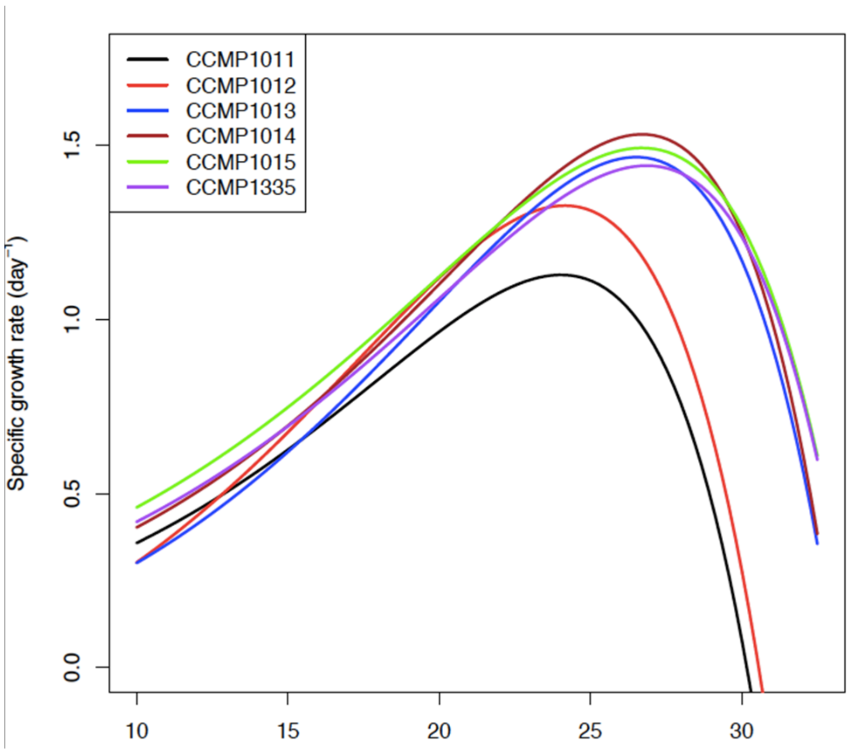


Insights into evolution under climate change

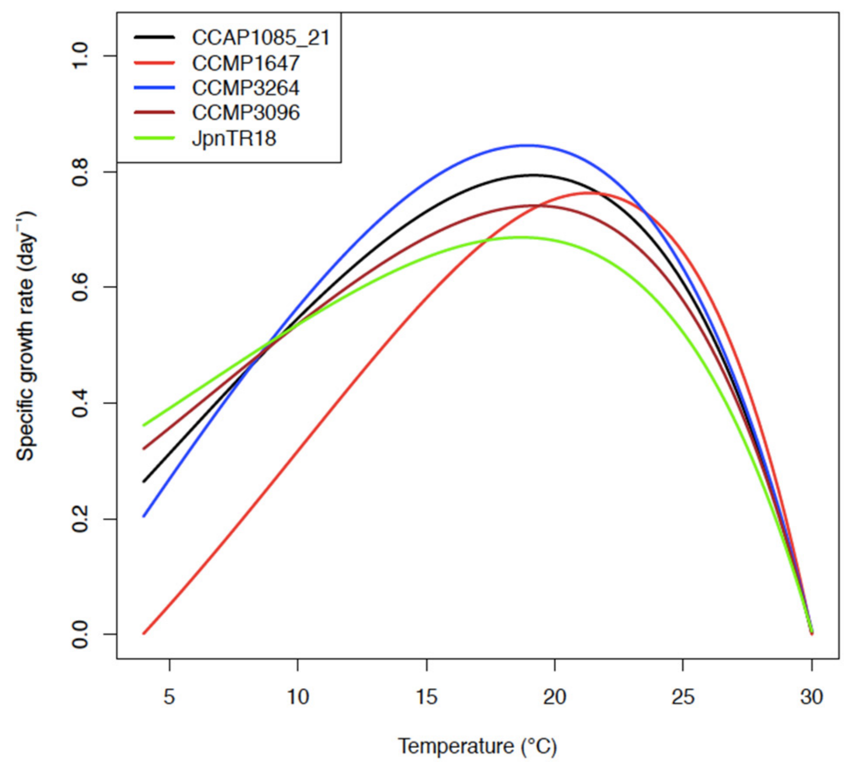
Toprak et al. Nature Gen. 2012

Selection on standing variation

Thalassiosira pseudonana

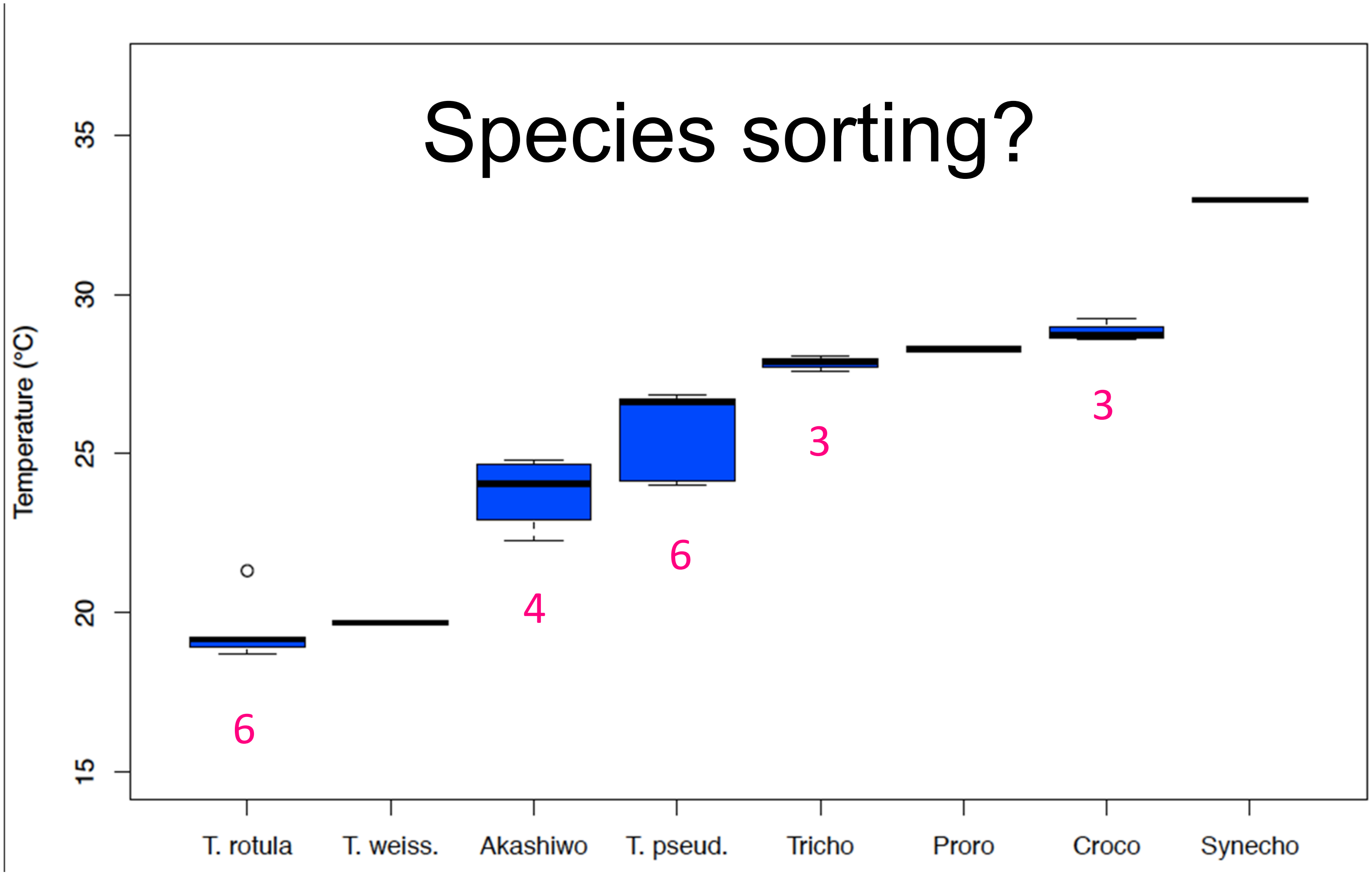


Thalassiosira rotula



Boyd et al. PLoS ONE 2013

Intraspecific vs interspecific variation in temperature optima



Boyd et al. PLoS ONE 2013

Community Responses to Climate Change: Eco-Evolutionary Models

- Need to include multiple mechanisms (phenotypic plasticity, dispersal, evolution, species sorting)
- Example: Norberg et al. 2012

nature climate change

LETTERS

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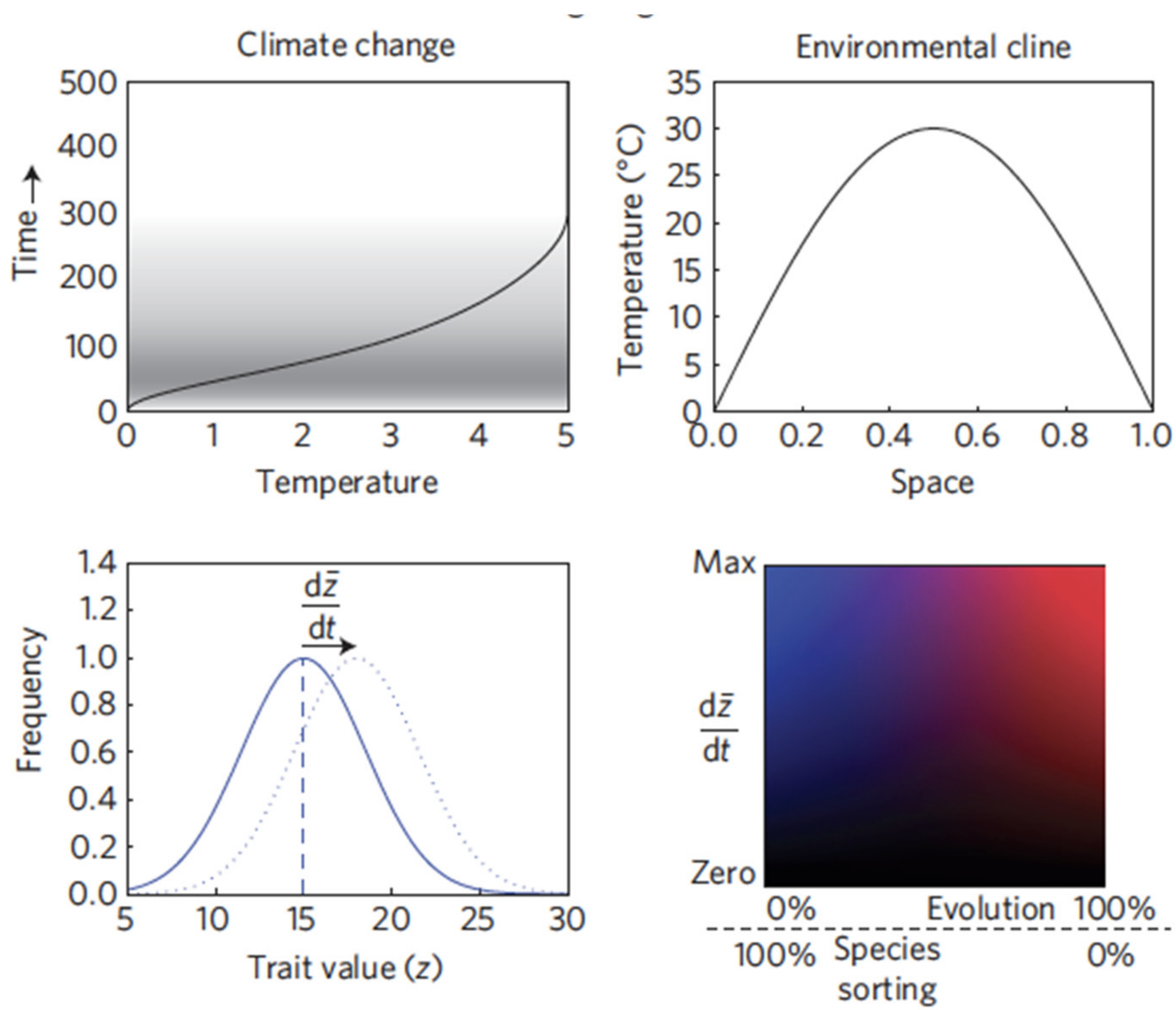
Eco-evolutionary responses of biodiversity to climate change

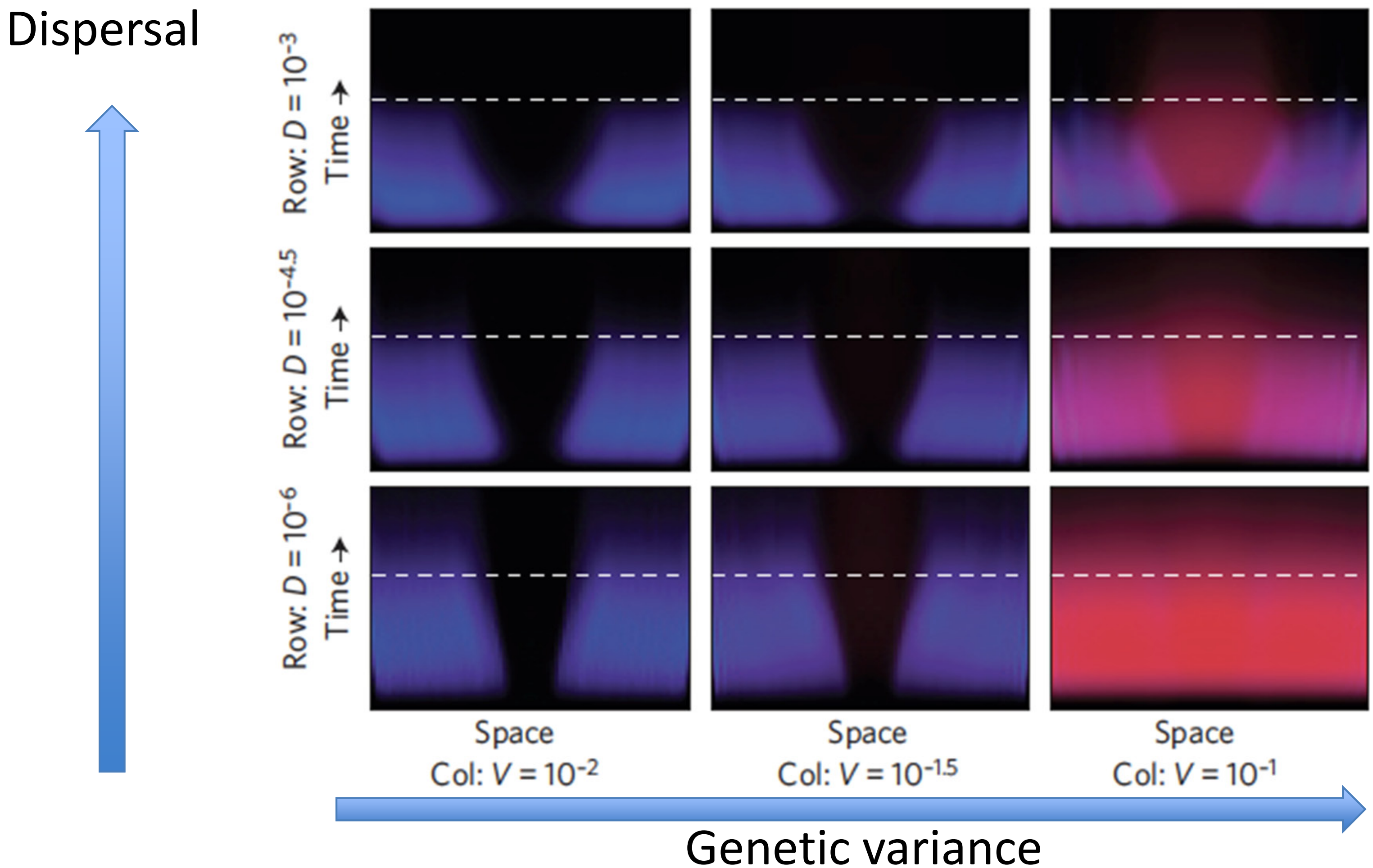
Jon Norberg[1,2]★, Mark C. Urban[3], Mark Vellend[4], Christopher A. Klausmeier[5] and Nicolas Loeuille[6]

Different contribution of Ecological and Evolutionary Processes



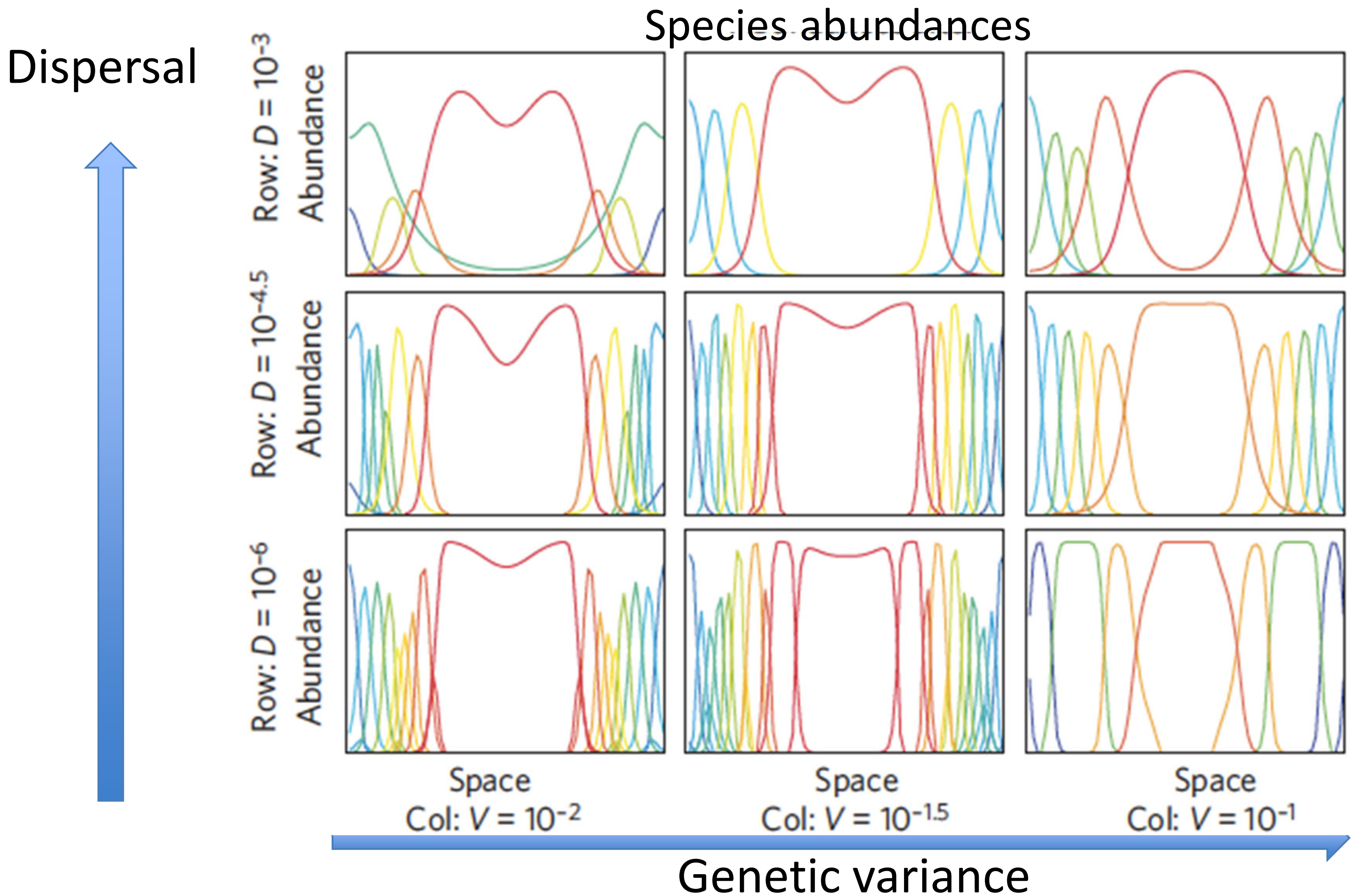
Norberg et al. Nature Climate Change 2012

Different contribution of Ecological and Evolutionary Processes



Norberg et al. Nature Climate Change 2012

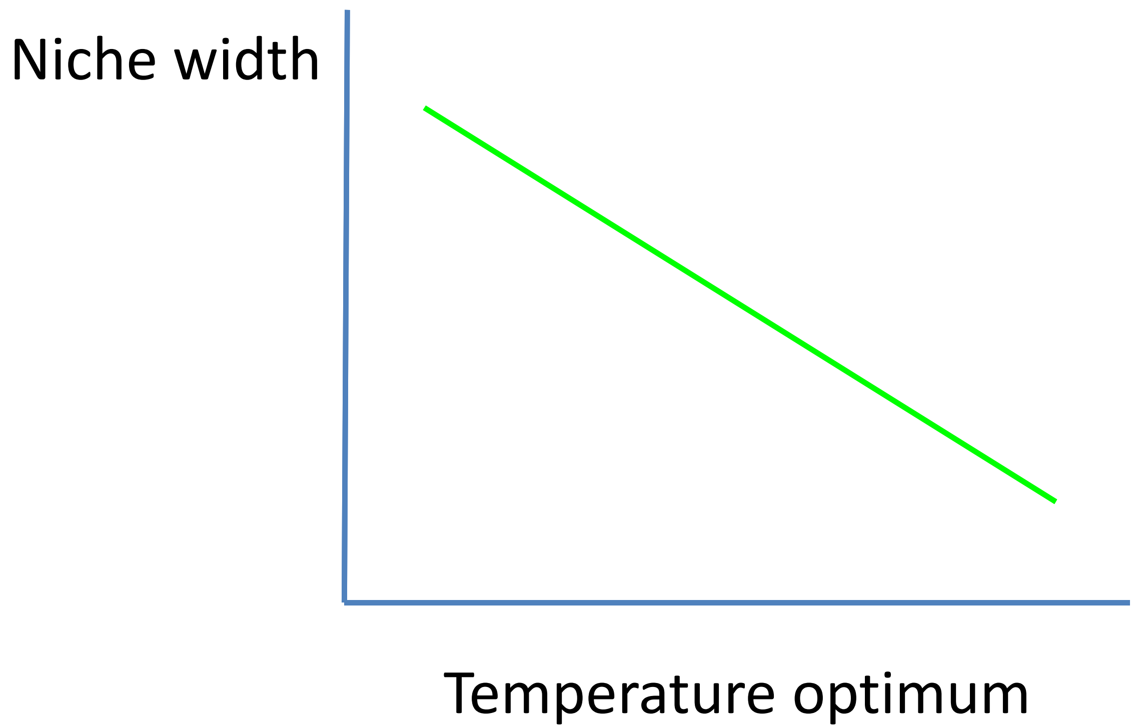
Different contribution of Ecological and Evolutionary Processes



Norberg et al. Nature Climate Change 2012

Even More Complexity

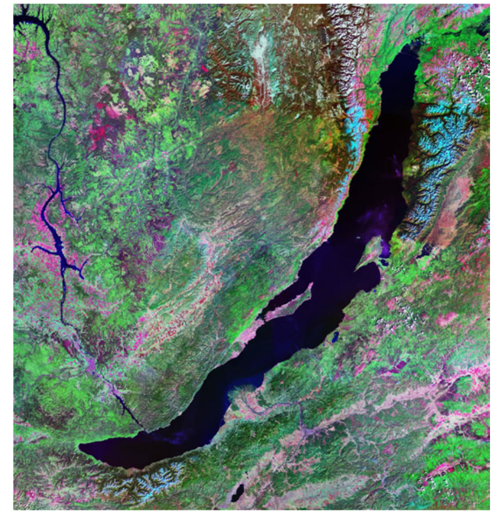
- Trade-offs among traits (pairwise, multidimensional)



Conclusions

- Temperature optima in phytoplankton exhibit strong latitudinal pattern
- Species appear adapted to local temperature regimes
- In the absence of evolution, species diversity may dramatically decline in the tropics due to warming
- Dispersal, evolutionary adaptation and species sorting may counteract negative effects of rising temperature
- Need to get estimates of various components of eco-evolutionary responses to parameterize models

Lake Baikal, Siberia under Climate Change



spans > 3° latitude

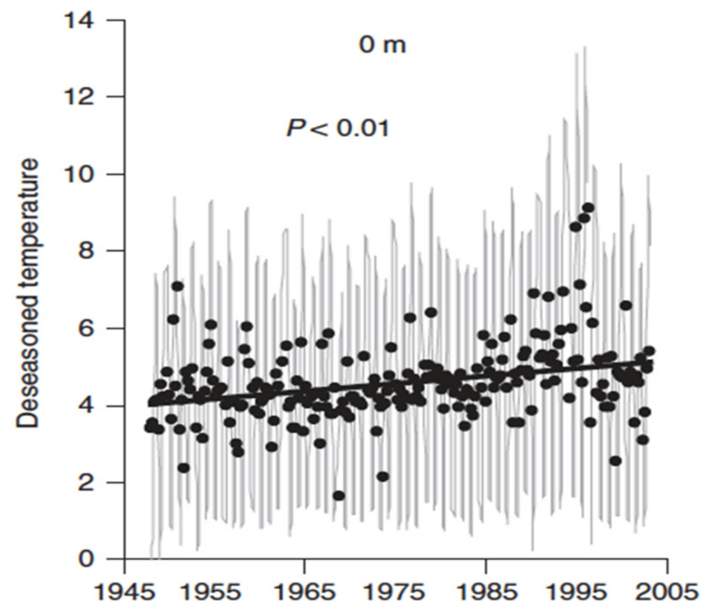
World's

oldest (25 MY)

deepest lake (>1600m)

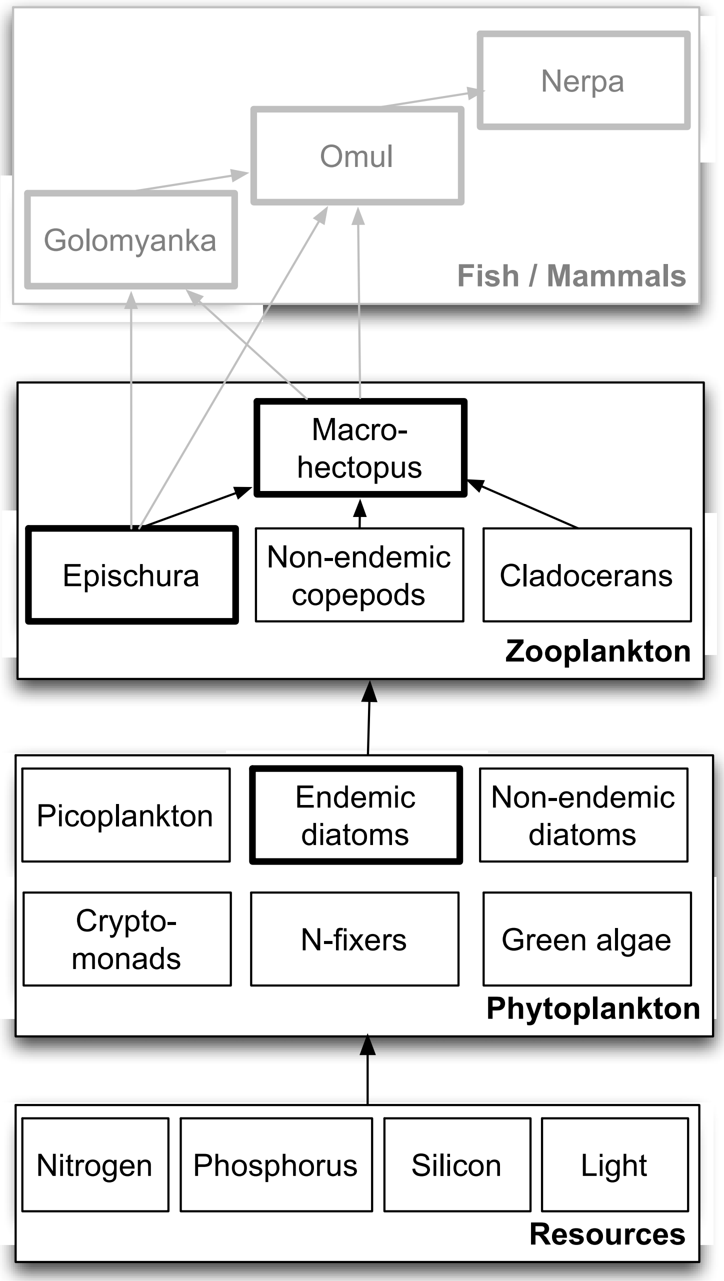
holds 20% of all unfrozen freshwater on Earth

UNESCO World Heritage Site

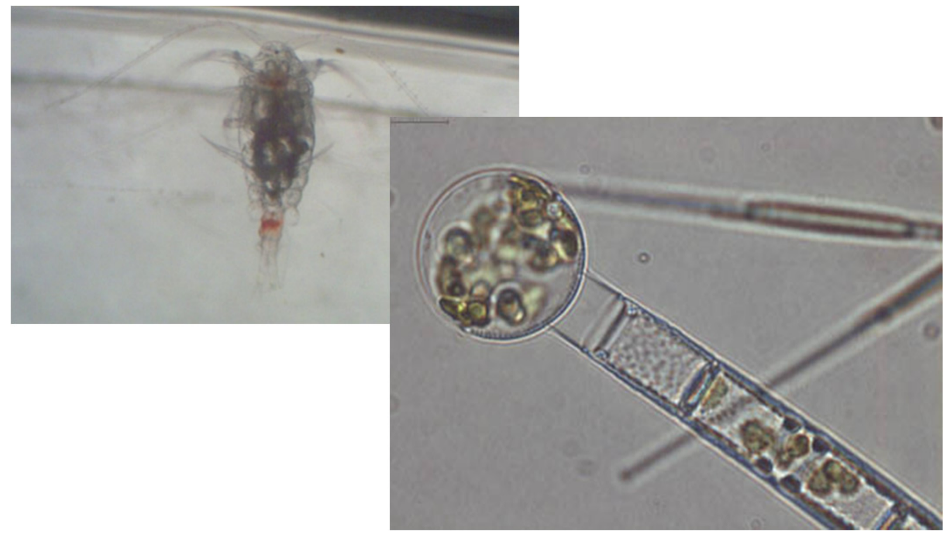


UNESCO: “Baikal is one of the most biodiverse lakes on Earth, with 1,340 species of animals (745 endemic) and 570 species of plants (150 endemic).
As the 'Galápagos of Russia', the lake is of exceptional value to evolutionary science”

Plankton Food Web in Lake Baikal



Endemic stenotherms



Enough evolutionary potential to adapt?

NSF Dimensions of bioiversity: *Lake Baikal Responses to Global Change: the Role of Genetic, Functional and Taxonomic Diversity in the Plankton*