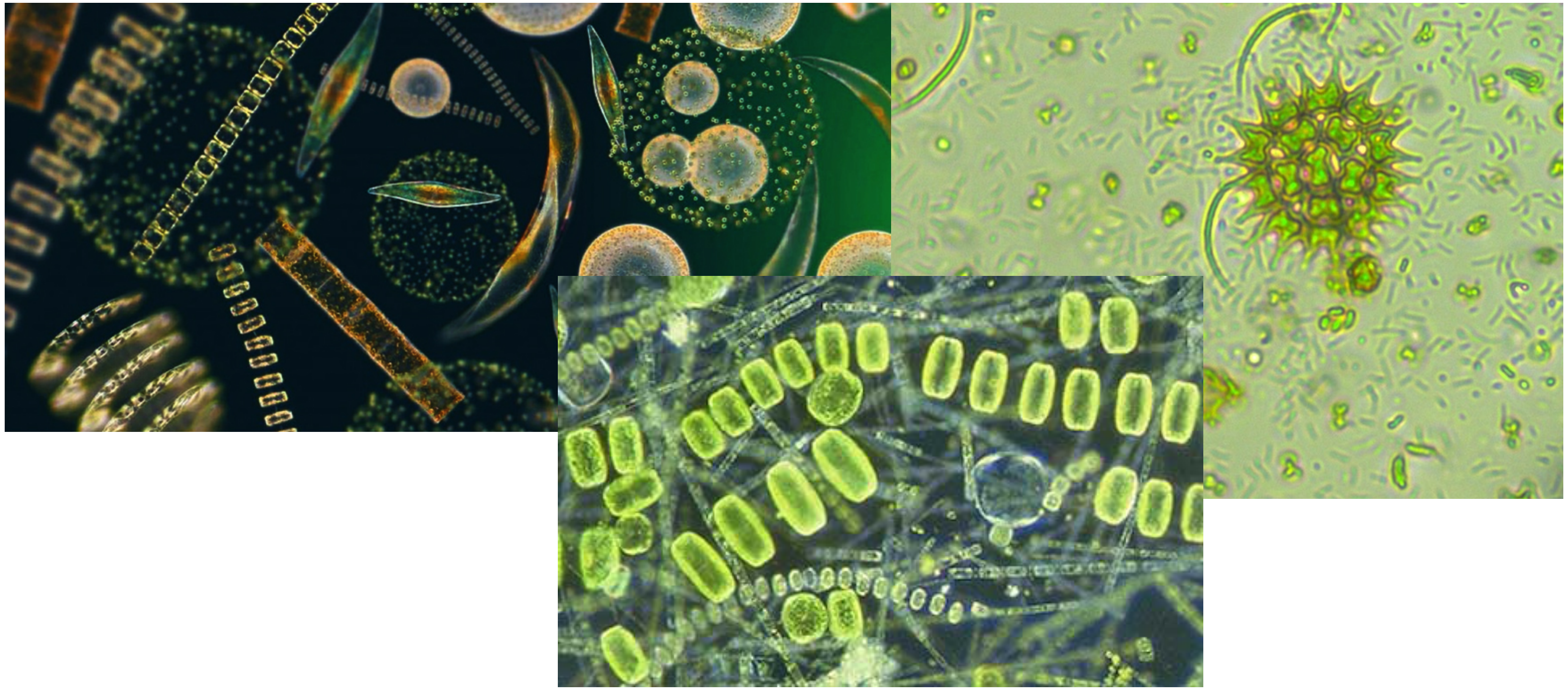
Predicting phytoplankton metabolism from the individual size distribution

Daniel Padfield

Phytoplankton are key for the carbon cycle

- ~50% of annual carbon fixation
- Fuel entire ocean food webs



Current measurements of metabolism

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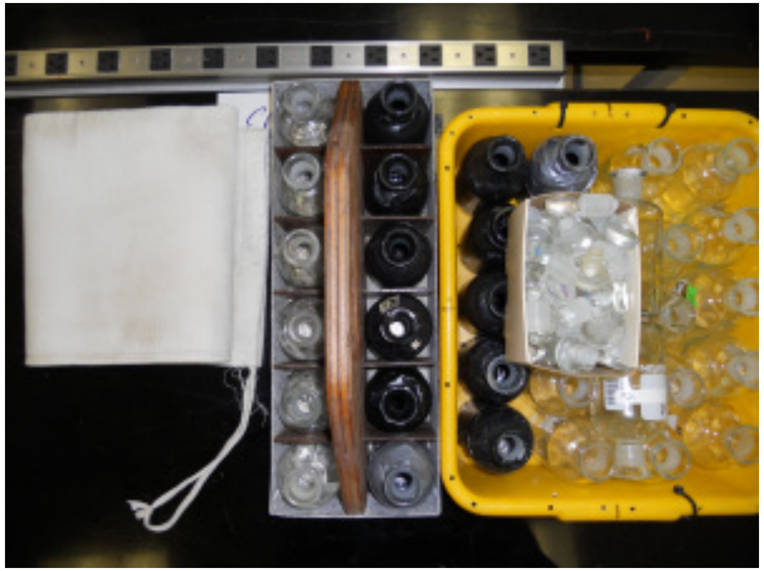
Bottle incubations – *in vivo*



- Snapshot in time
- Single community
- Control over environmental variables

Current measurements of metabolism

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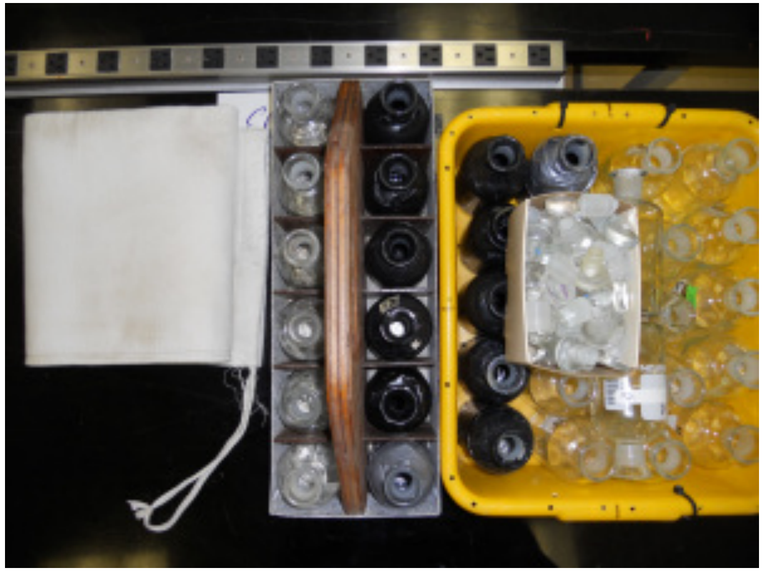


- Snapshot in time
- Single community
- Control over environmental variables

Gas measurements – *in situ*

- Integrates over large areas
- Many communities and many different environmental conditions

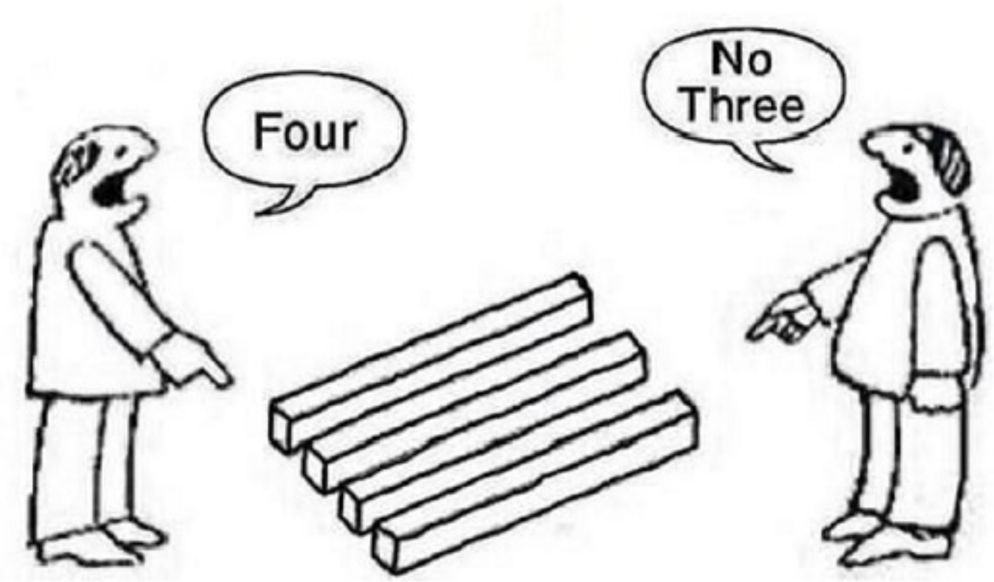
Current measurements of metabolism

Bottle incubations – *in vivo*

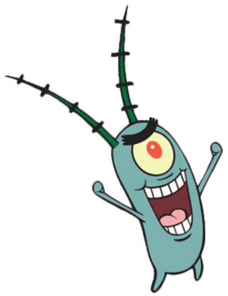
- Total photosynthesis < total respiration

Gas measurements – *in situ*

- Total photosynthesis > total respiration



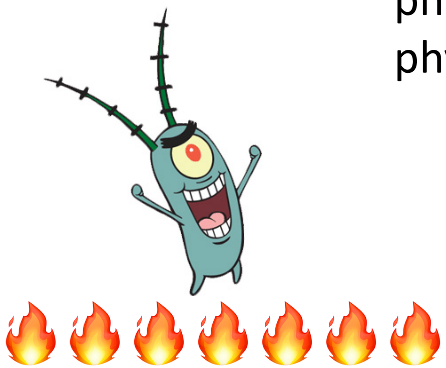
Crash course in metabolic theory



Crash course in metabolic theory

$$e^{E\left(\frac{1}{kT_c}-\frac{1}{kT}\right)}$$

E previously found to be around 0.8 eV for photosynthesis and > 1 for respiration in phytoplankton



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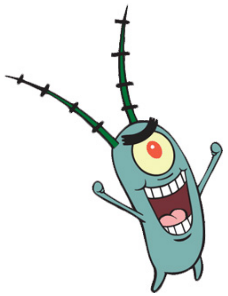

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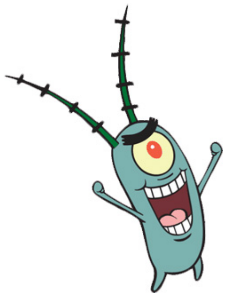
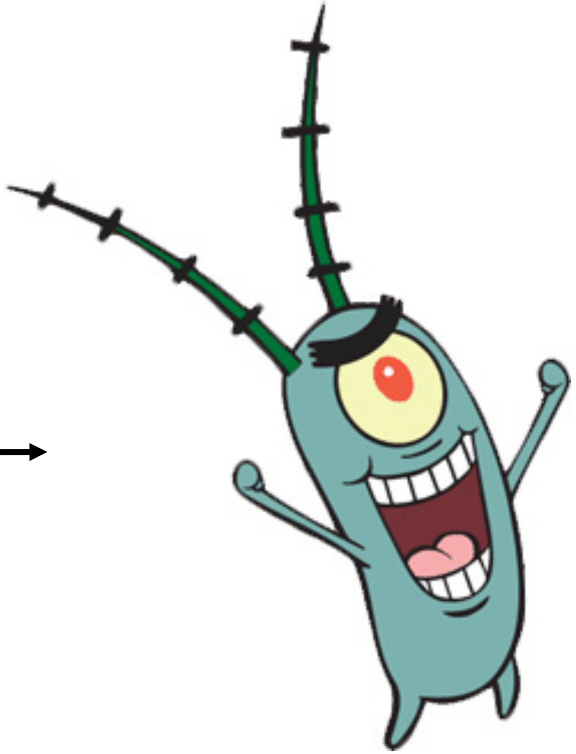


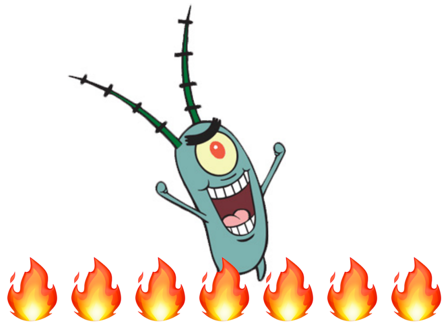
$$m_i^a$$

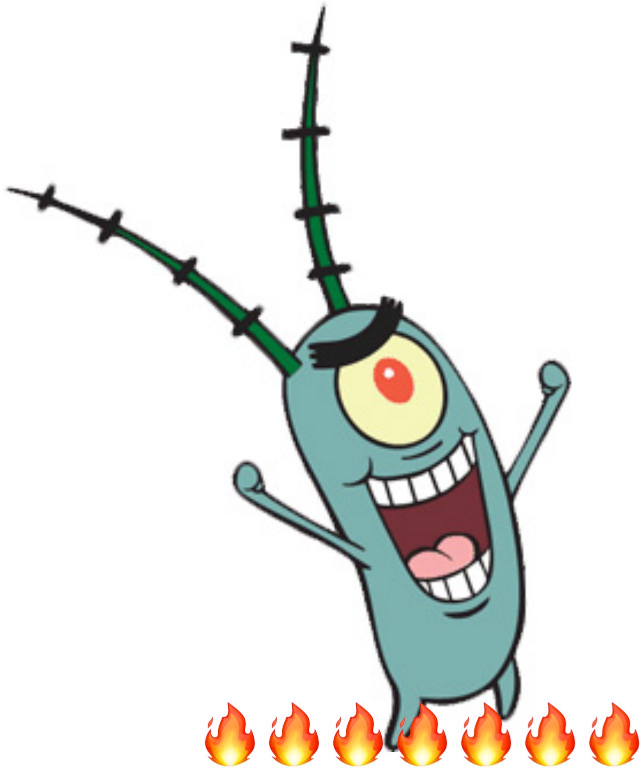
a previously found to be around 0.75 in most animals, but around 1 for phytoplankton



Crash course in metabolic theory

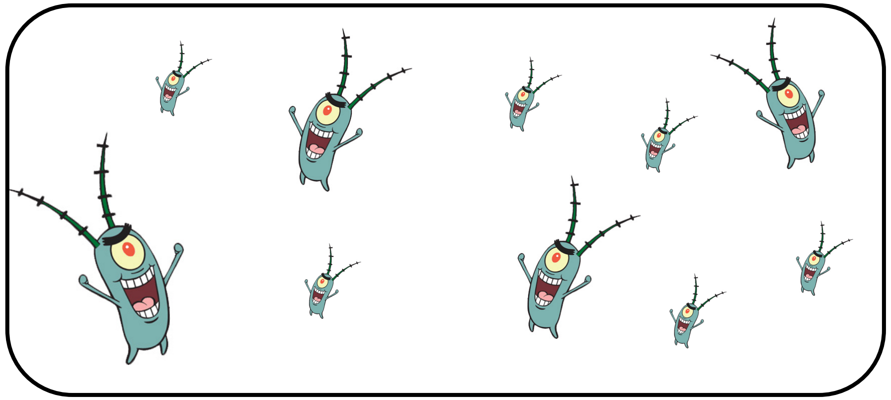
$$b_i(T_c)m_i^a e^{E\left(\frac{1}{kT_c}-\frac{1}{kT}\right)}$$





Crash course in metabolic theory

$$\sum_{i=1}^{n_{tot}} b_i(T_c)\, m_i^a e^{E\left(\frac{1}{kT_c}-\frac{1}{kT}\right)}$$



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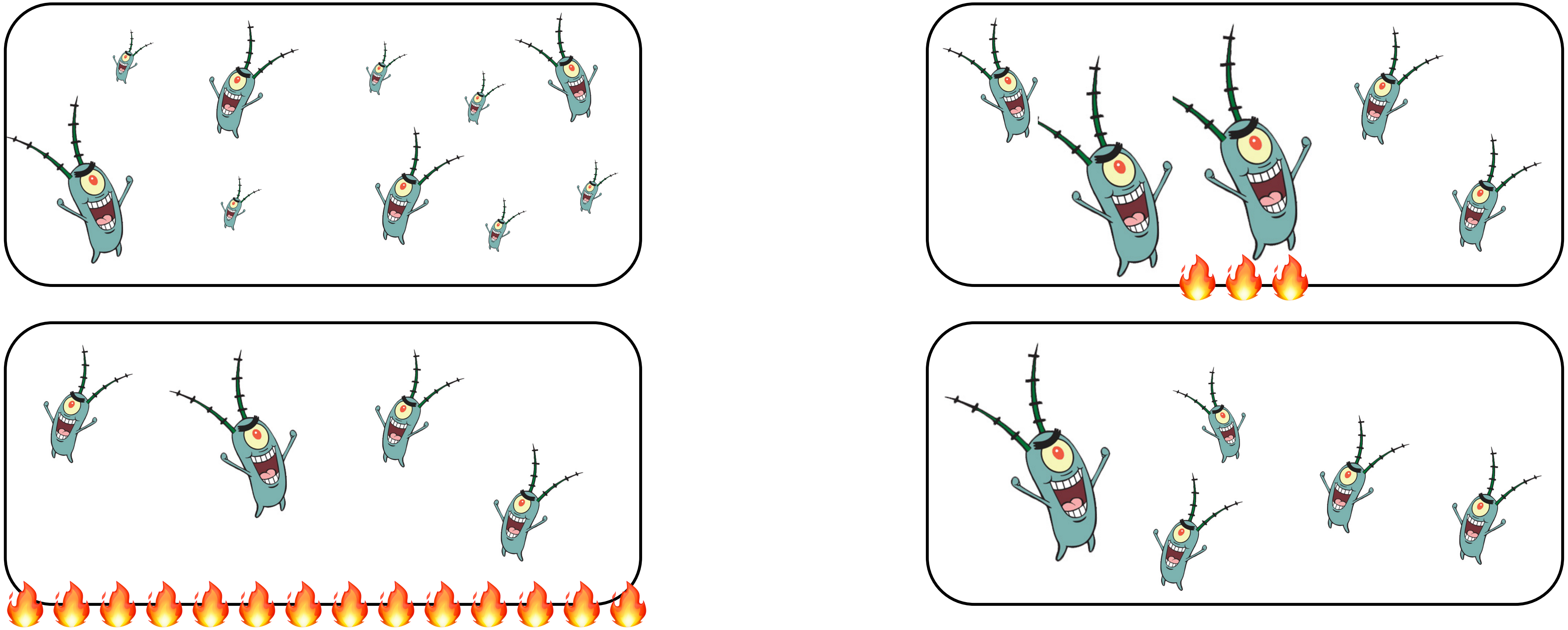
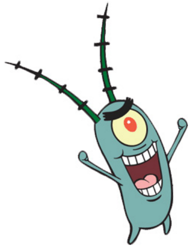
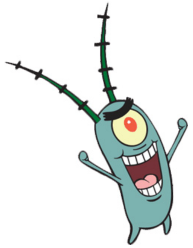
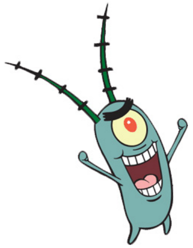
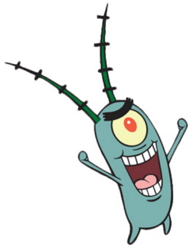
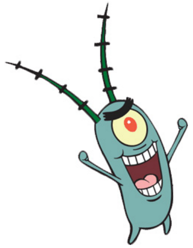
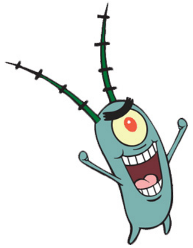
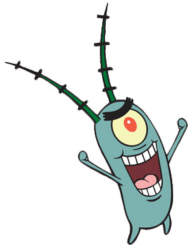
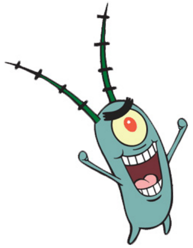
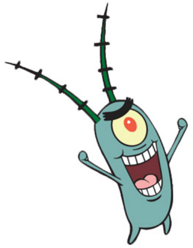


Zero-sum dynamics

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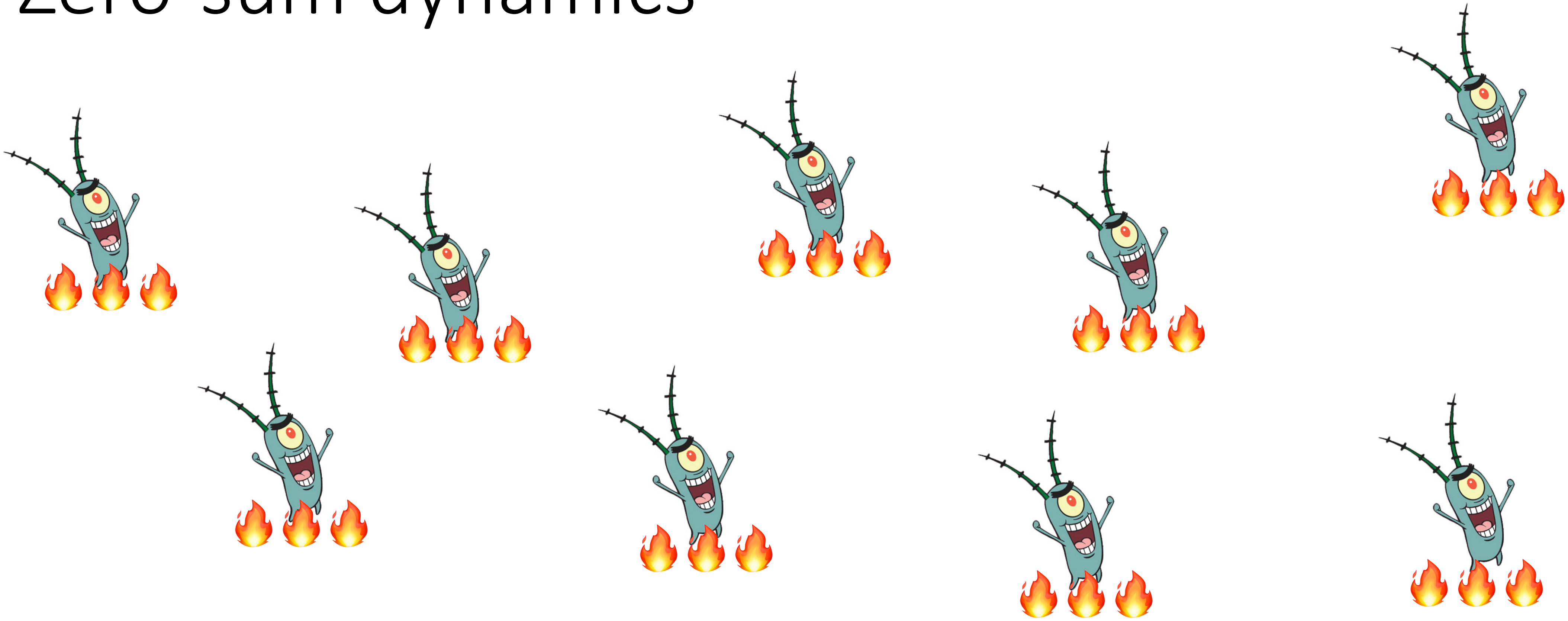
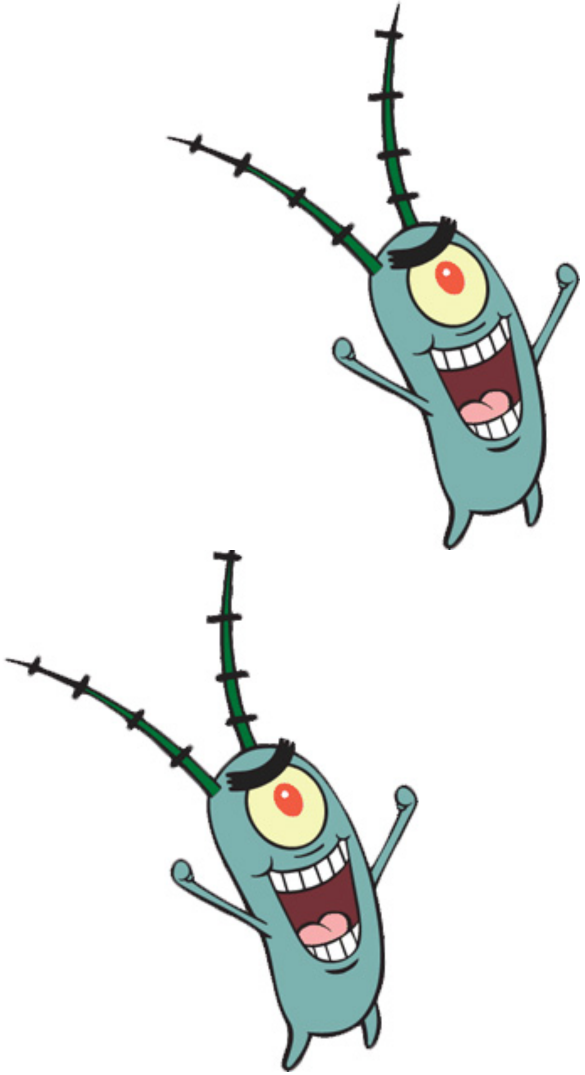
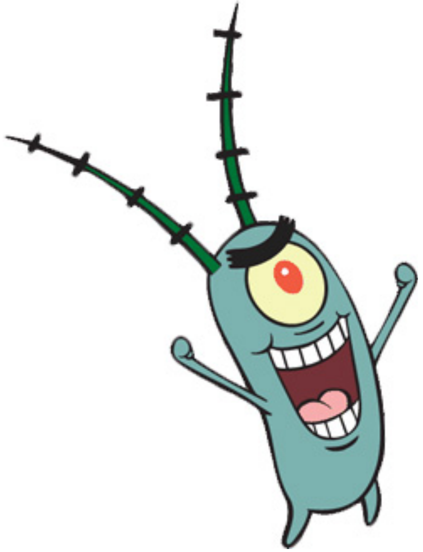
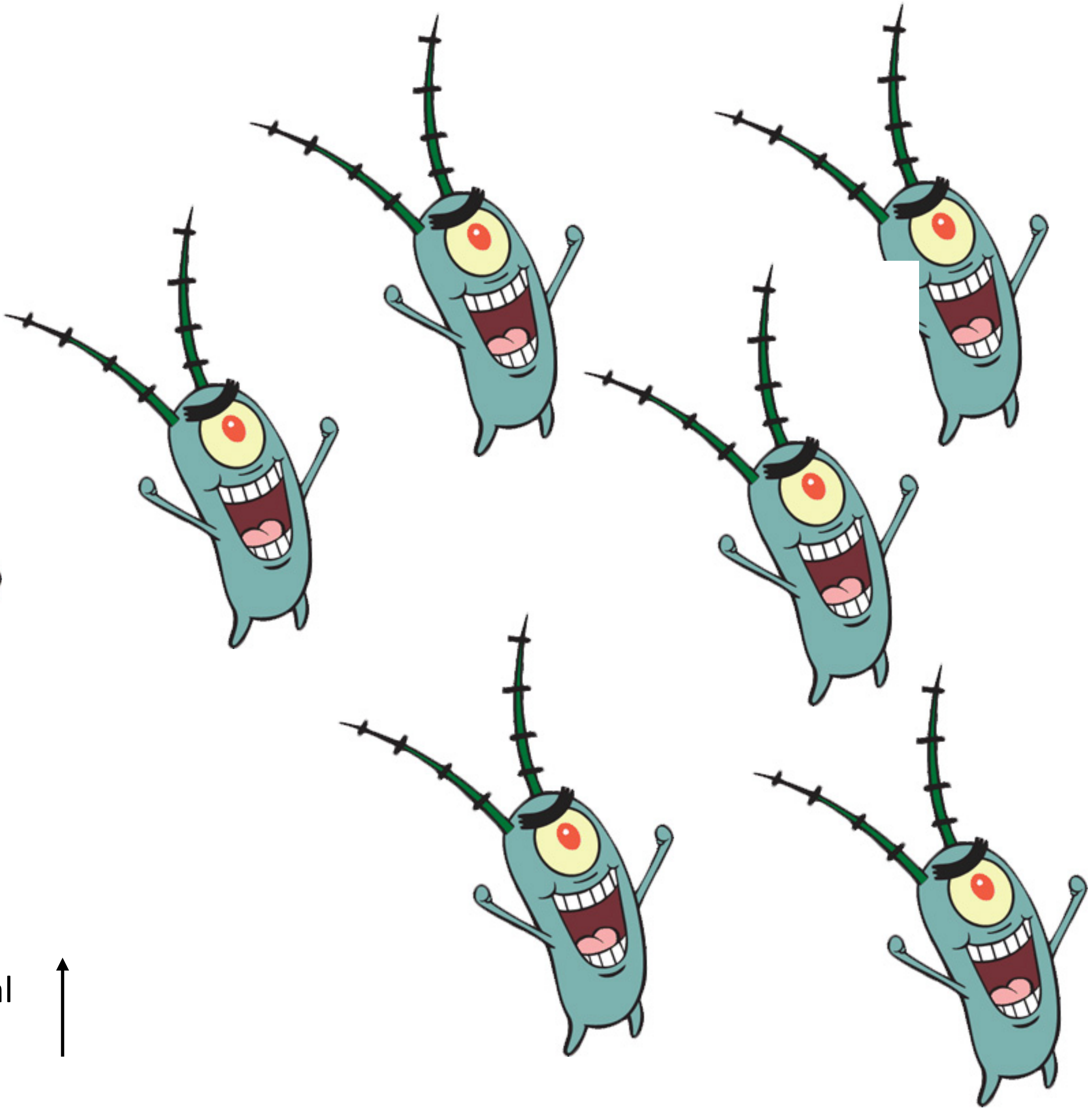


Average individual
metabolic rate

Zero-sum dynamics







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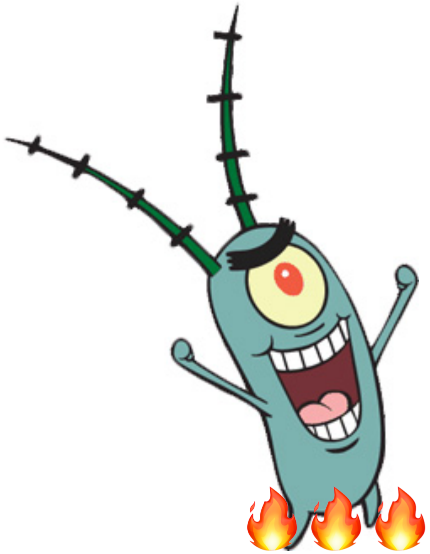
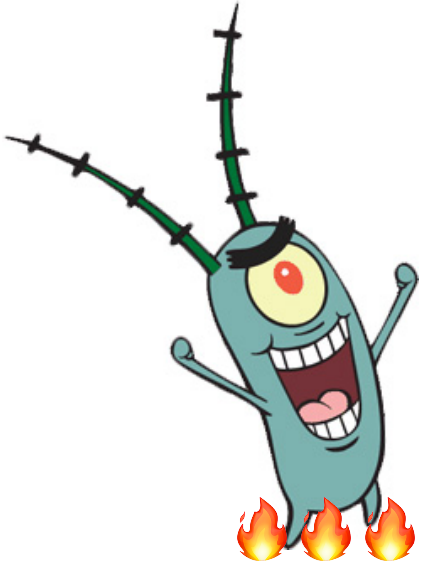
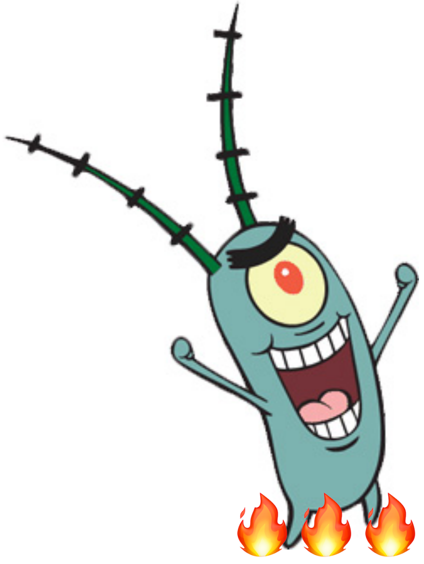






Average individual metabolic rate ↑ Total abundance ↓

Predictions

- Predict community metabolic rates from the size- and temperature-dependence of individuals in the size distribution
- Across-communities, there will be a trade off between total abundance and average individual metabolic rate
- Trade offs between community properties may impact community flux

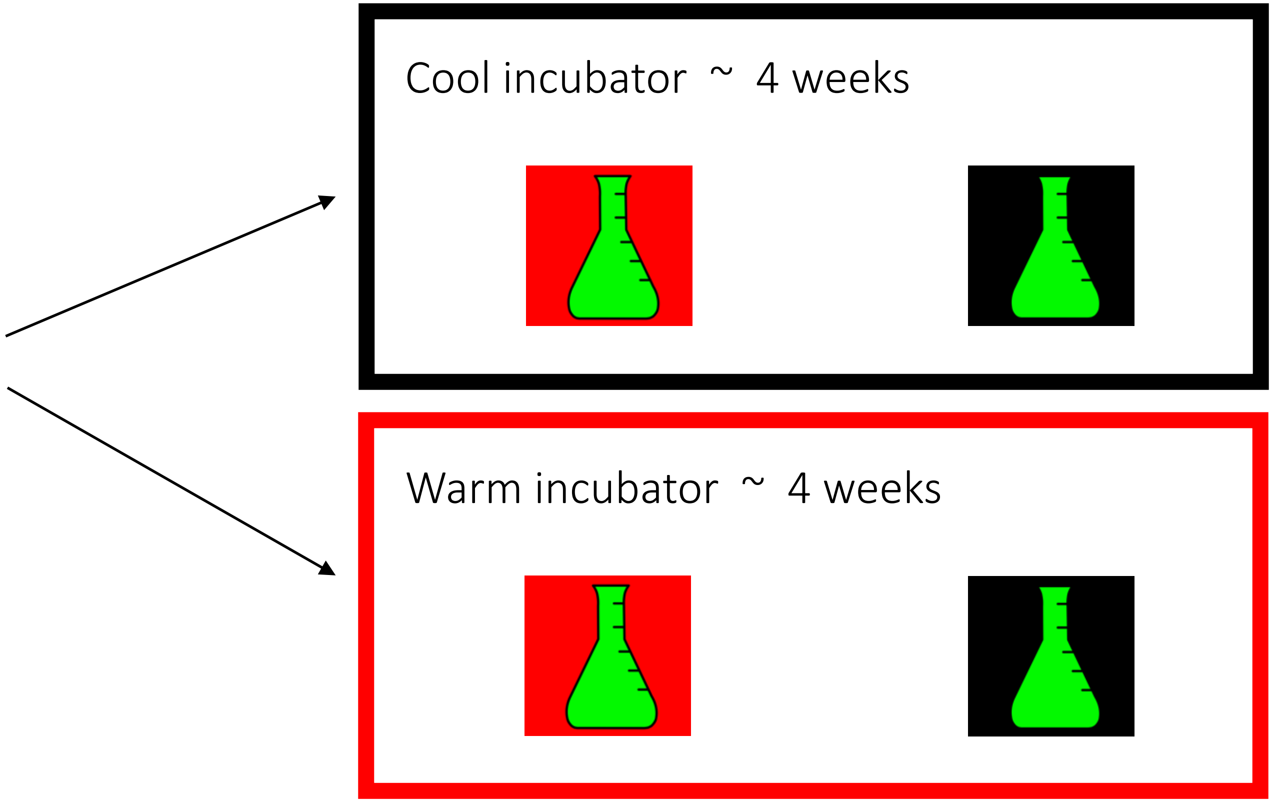
Experimental setup

10 years warming : half 4ºC above ambient

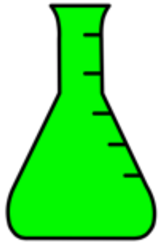
Experimental setup

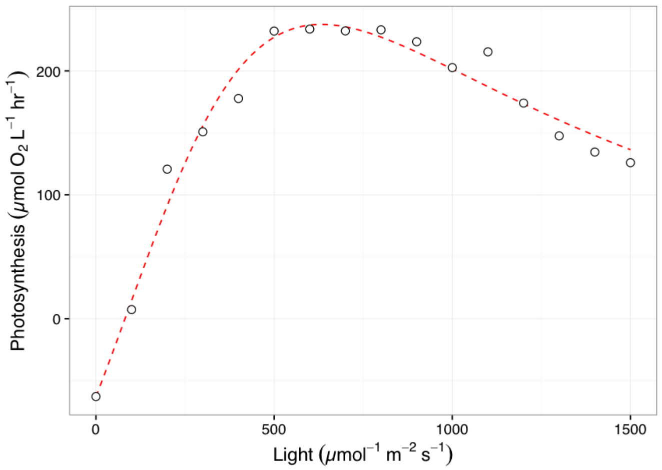
How do the communities and their functioning change in response to long-term and short-term warming

10 years warming : half 4ºC above ambient

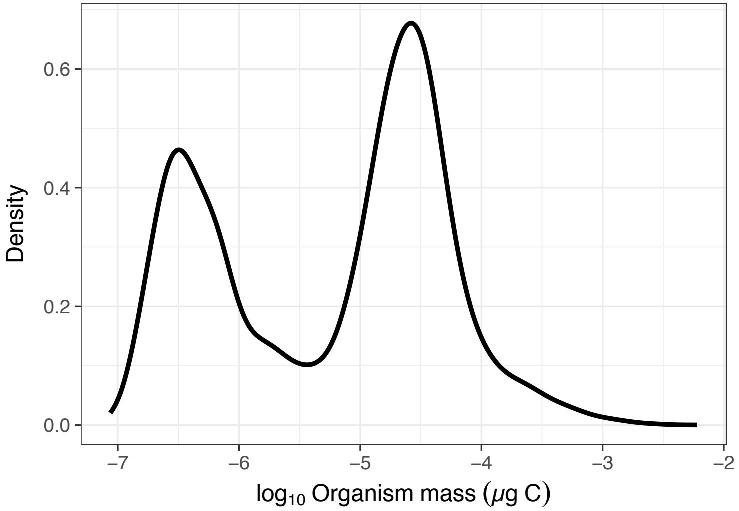


Measurements



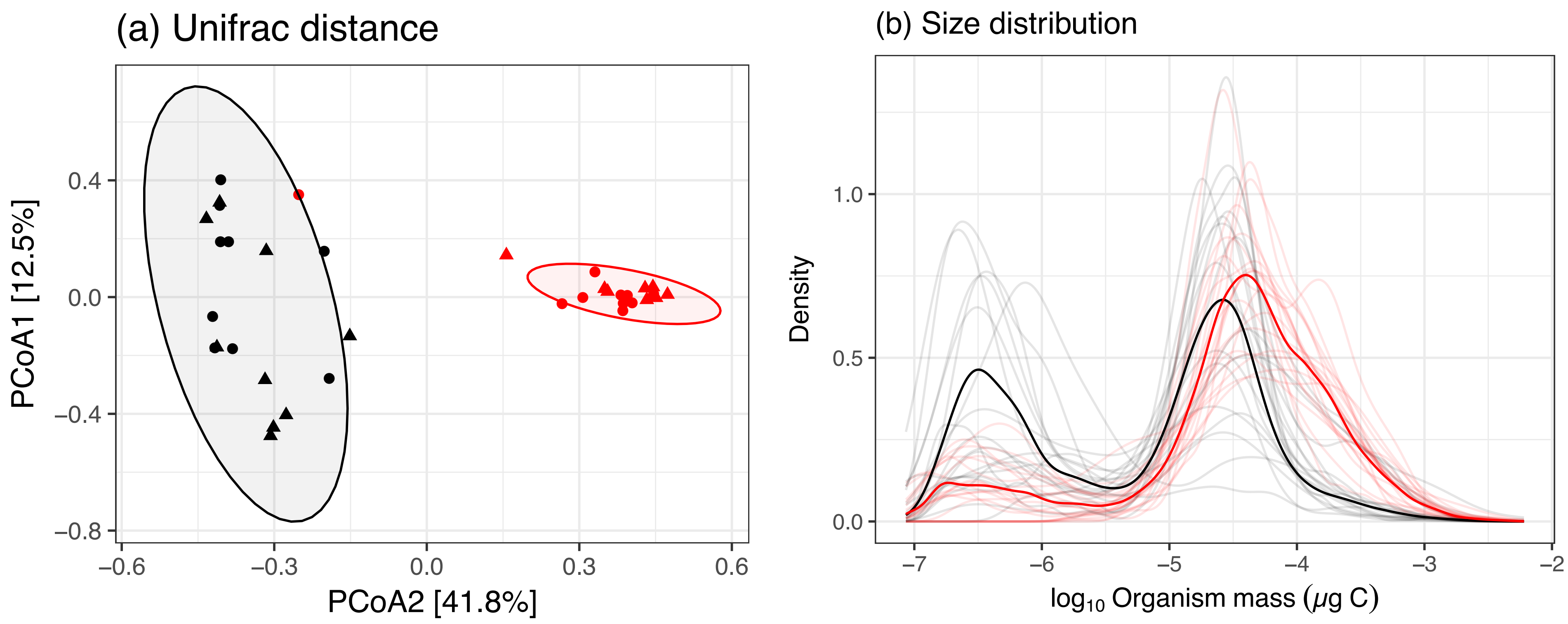


Metabolism @ incubator temperature
1 point for each microcosm

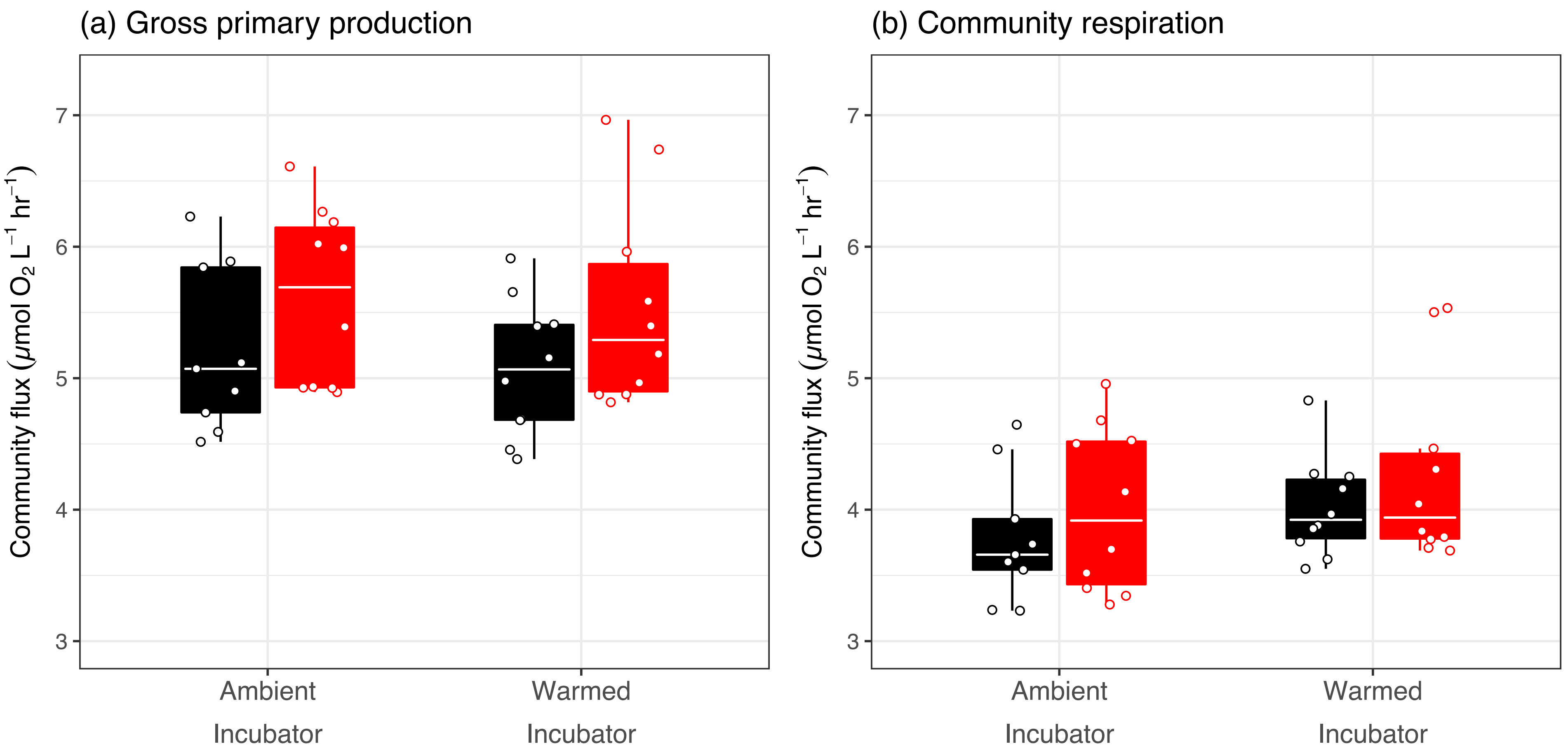


Size distribution
> 300 points per sample!

Long-term warming changes communities



No difference in measured raw metabolism



Model

$$B_j(T) = \sum_{i=1}^{n_{tot}} b_i(T_c)\, m_i^a e^{E\left(\frac{1}{kT_c} - \frac{1}{kT}\right)}$$

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$b_i(T_c)$ - the individual normalisation constant

Model

$$B_j(T) = \sum_{i=1}^{n_{tot}} b_i(T_c)\,\overbrace{m_i^a}^{a\text{ - how rates change with body size}}\,e^{E\left(\frac{1}{kT_c}-\frac{1}{kT}\right)}$$

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Model predicts size and temperature-dependence

parameter	units	estimate	95% confidence interval
E_{GPP}	eV	0.741	0.196 - 1.286
E_{CR}	eV	1.417	0.853 - 1.982
α_{GPP}	-	0.887	0.567 - 1.174
α_{CR}	-	1.101	0.743 - 1.412
$\ln GPP(T_c)$	µmol O_2 L^{-1} hr^{-1}	-3.426	-6.335 - -0.989
$\ln CR(T_c)$ **(ambient mesocosm)**	µmol O_2 L^{-1} hr^{-1}	-2.717	-5.943 - -0.150
$\ln CR(T_c)$ **(warm mesocosm)**	µmol O_2 L^{-1} hr^{-1}	-3.110	-6.126 - -0.650

Predicted vs Observed flux

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$+$

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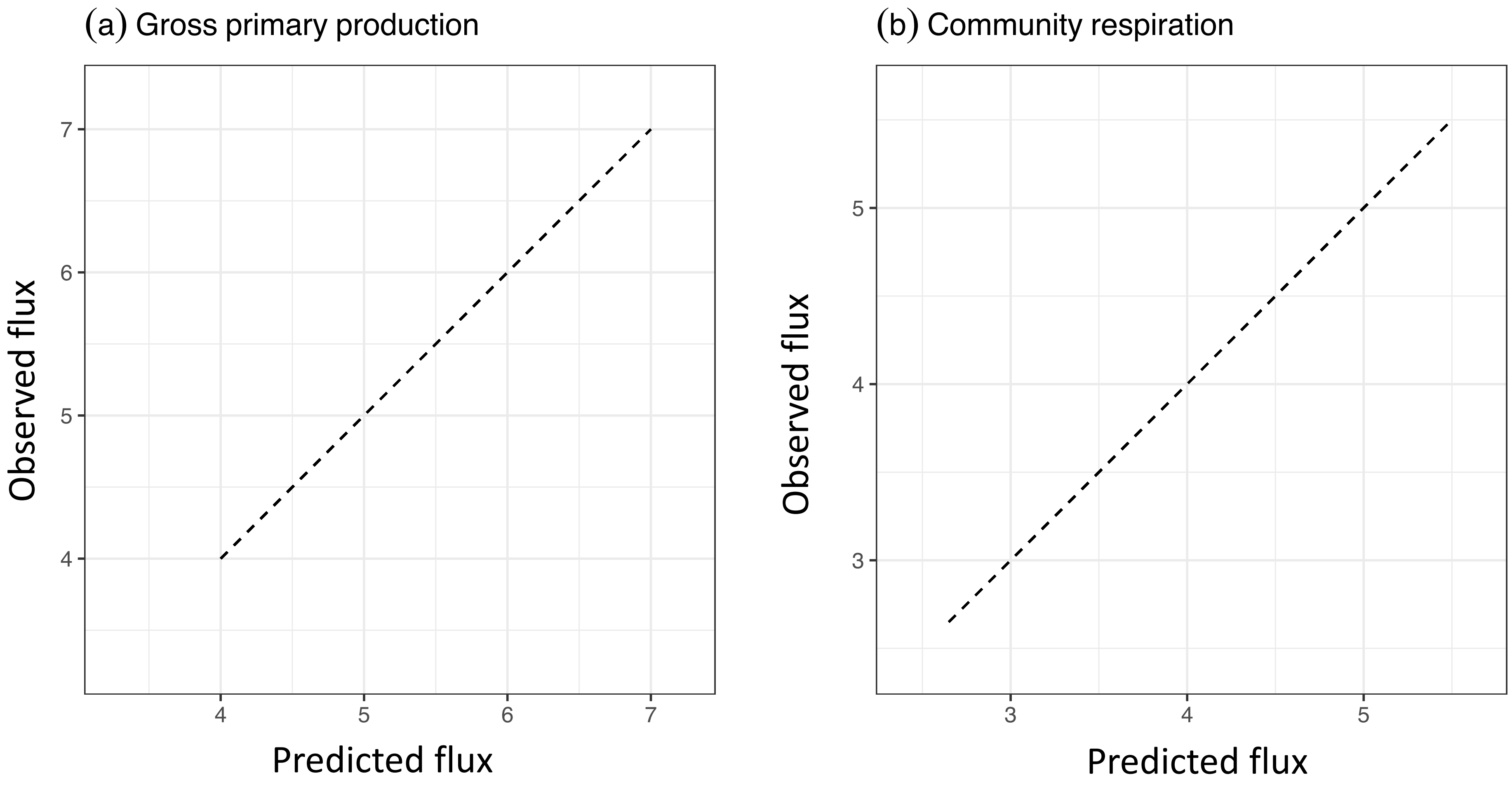
Model does a pretty good job!



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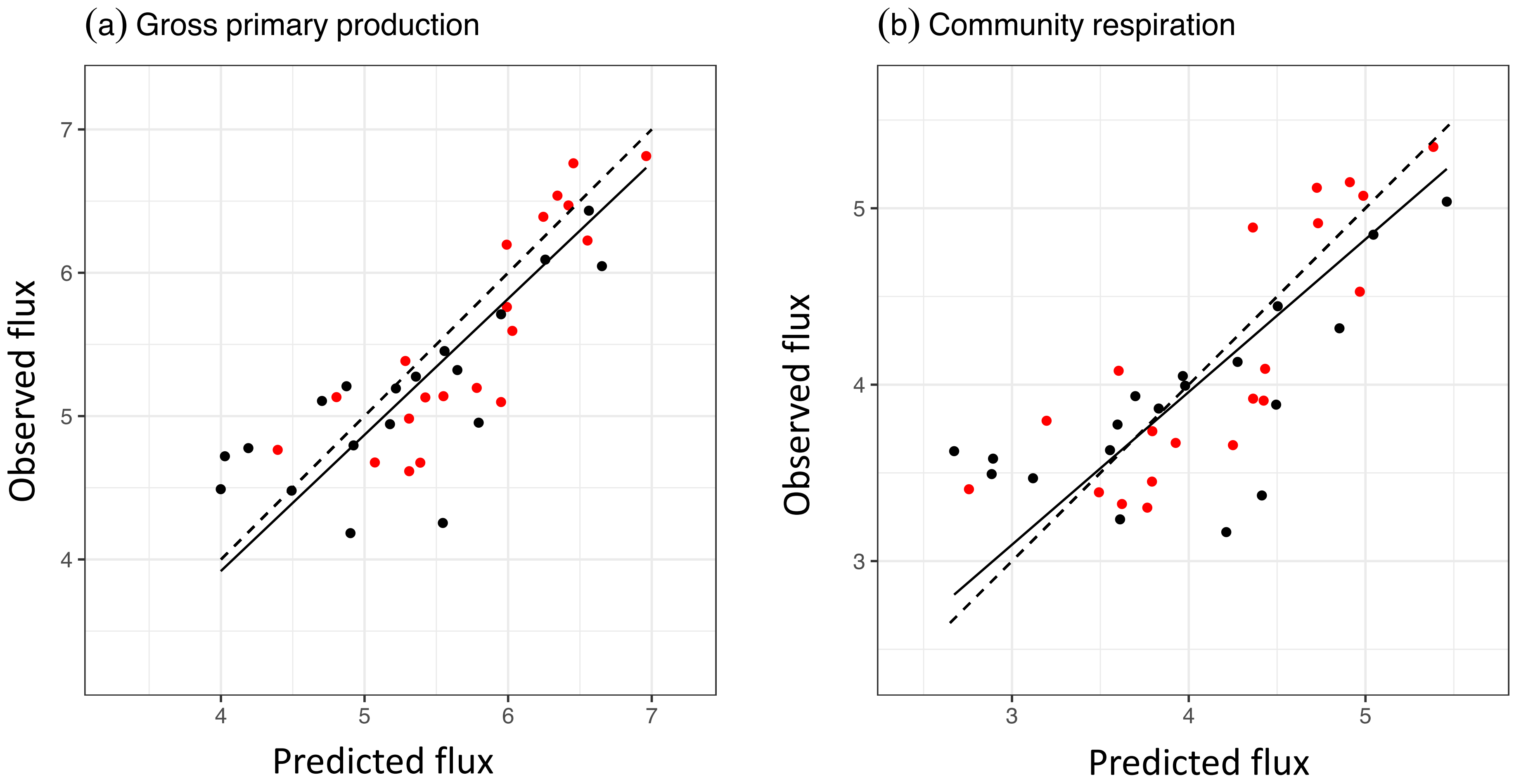
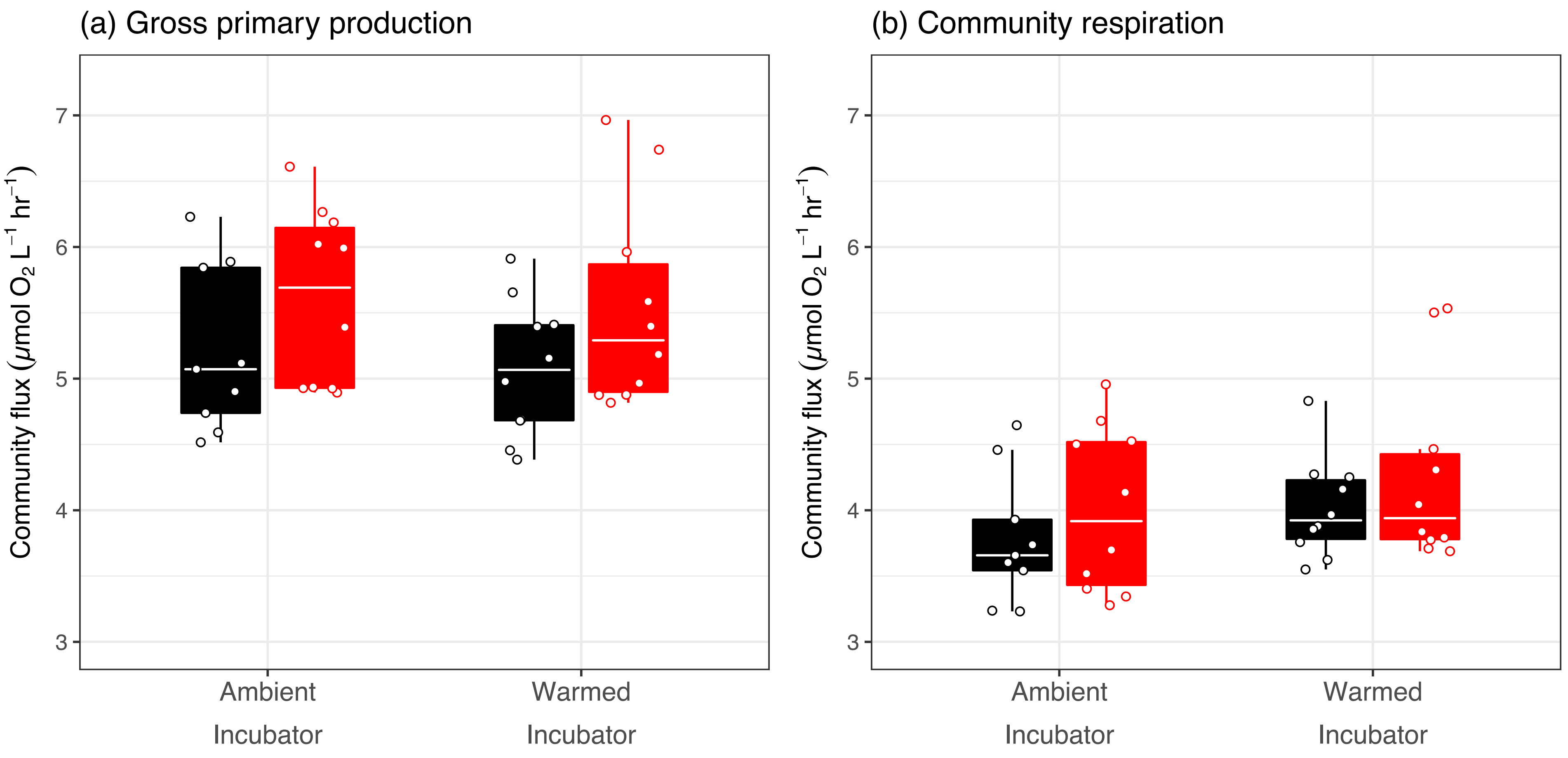
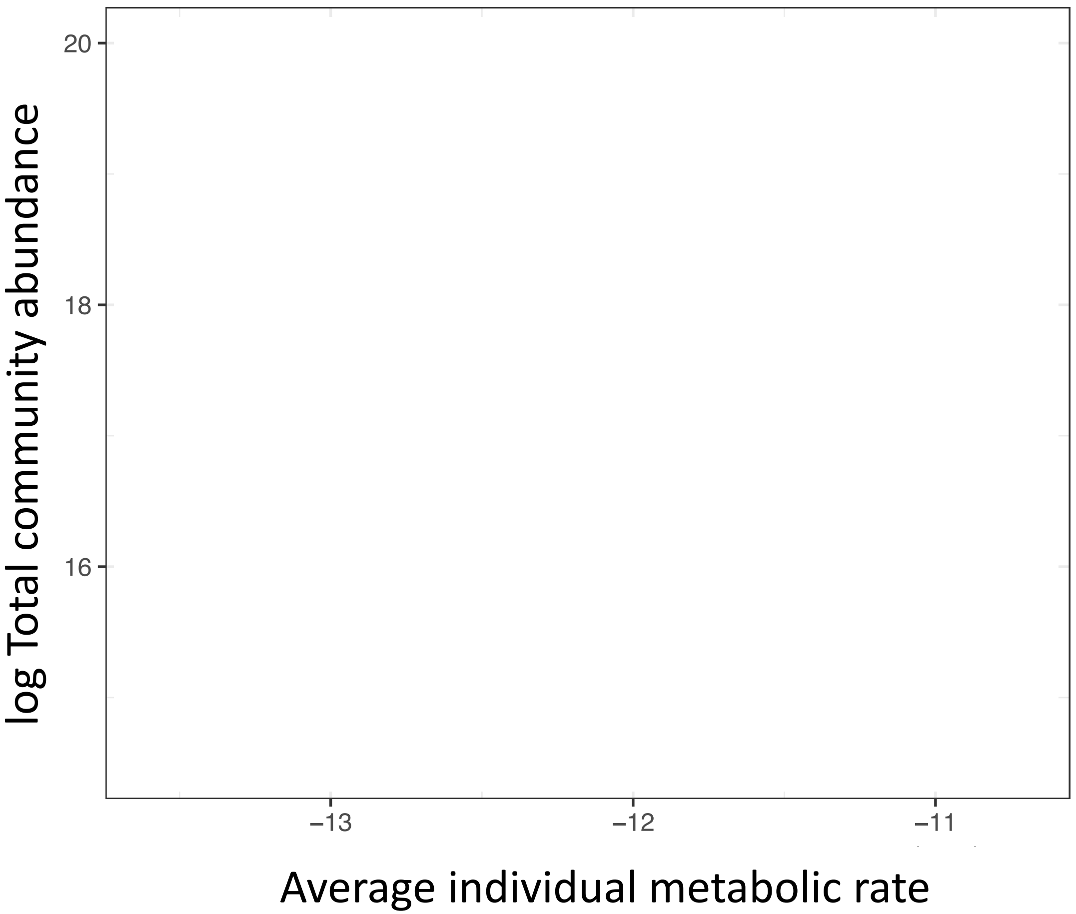


Paradoxical result?

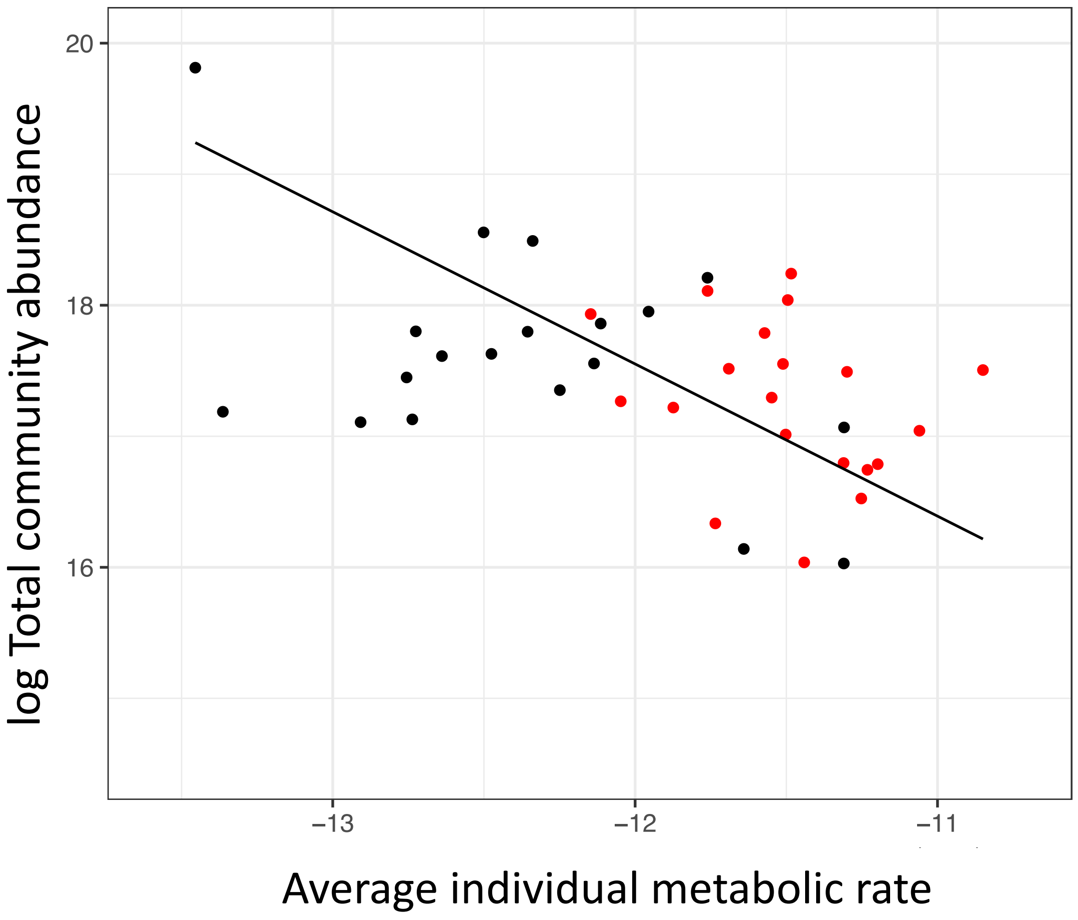


Zero-sum dynamics



Zero-sum dynamics

Average individual metabolic rate ↑ Total abundance ↓



Conclusions

- Linked the metabolic rates of whole communities to the individual size distribution
- Flow cytometry routinely taken in scientific ship voyages
- As a bonus, validated some key assumptions of metabolic scaling theory

Thanks for listening!