TOWARDS BRIDGING THEORY AND PRACTICE TO CONSIDER BIODIVERSITY AND RESILIENCE FOR ECOSYSTEM SERVICES

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How do Ecosystem Services depend on Biodiversity?

Recent Theoretical Results for Phytoplankton show that the answer depends on the Frequency of Environmental Disturbance.

Smith et al. *Scientific Reports*, 2016
Observed Patterns of Plankton Biodiversity

R/V Mirai

sub-arctic

sub-tropical
Biodiversity: Size and other Traits of Phytoplankton

Species of different size typically are adapted (have evolved) for different environmental conditions.

Here are just a few typical species/types arranged by increasing size.

Size-based models of plankton Biodiversity use size as a Master Trait.
Observed differences in the plankton in different regions

Size and many other traits differ.

- **sub-tropical:**
  - calmer waters,
  - lower nutrients
  - Smaller Plankton

- **sub-arctic:**
  - rougher waters,
  - higher nutrients
  - Larger Plankton
Mixing and Nutrient Supply in the Ocean

In calm regions, nutrients become depleted near-surface.

Disturbances mix the water and supply nutrients from below.

**Nutrient Concentration**

- Low near-surface
- High from below
‘Leaving mis-leading legacies behind in plankton ecosystem modelling’
Smith, Merico, Wirtz and Pahlow (*J. Plankton Res.* 2014)

**Overall Approach to Modelling Adaptive Response**

Combine Traits and Trade-offs

Typical small cell adapted to high-light, low-nutrients

Typical large cell adapted to low-light, high-nutrients
A Physiological Trade-off for humans

No one is Superman.

Trade-offs abound in physiology, ecology, economics...
Typical for small cells.

Tend to grow faster, and hence dominate, in nutrient-poor waters.

Typical for large cells.

Tend to grow faster, and hence dominate, in nutrient-rich waters.

This and similar trade-offs are important determinants of competition, and are central to our understanding of biodiversity.

We considered Phytoplankton Communities

Different levels of Biodiversity,
Different frequencies of Disturbance.

In addition to their important role as the base of aquatic food webs, Phytoplankton are also excellent model organisms for understanding ecology.
The mean of trait $x$, e.g., size, should change in proportion to its effect on fitness, $F$:

$$\frac{dx}{dt} = \delta_x \frac{\partial F(x,E)}{\partial x}$$

in the direction that increases Fitness.

For plankton, we assume $F = \text{Growth rate}$ (Smith et al. L&O, 2011).

$\delta_x$: diversity of trait distribution

$E$: Environment (nutrients, light, temperature, etc.)

More Diverse Communities adjust faster:

Less Diverse Communities adjust more slowly:

‘Adaptive Dynamics’: evolutionary changes

‘adaptive dynamics’: species succession, communities
Disturbance Frequency varies naturally

Regionally and over time

Calm sub-tropics

Rough sub-arctic, storms
More diverse phytoplankton communities are more productive under frequent or intense disturbance, but tend to be slightly less productive during long periods of relatively stable conditions.

Smith et al., *Scientific Reports* 2016
Theoretical Diversity-Productivity Relationships

Greater Biodiversity does not in all cases enhance productivity.

The optimal level of diversity depends on timescale and disturbance frequency.

This is a community-level trade-off, not the physiological (individual-level) trade-off that we assumed.

The benefits of biodiversity depend on the disturbance regime.

Smith et al., Scientific Reports 2016
Implications: Resource allocation & What level of Biodiversity is Healthy?

Given limited resources for management / conservation, our results suggest that it may be more cost effective to concentrate efforts on areas with more frequent or intense disturbance. At least for Services that are proportional to the productivity of phytoplankton.

In other cases it may be desirable to sustain greater biodiversity in order to decrease plankton productivity.

Santa Fe river, Florida