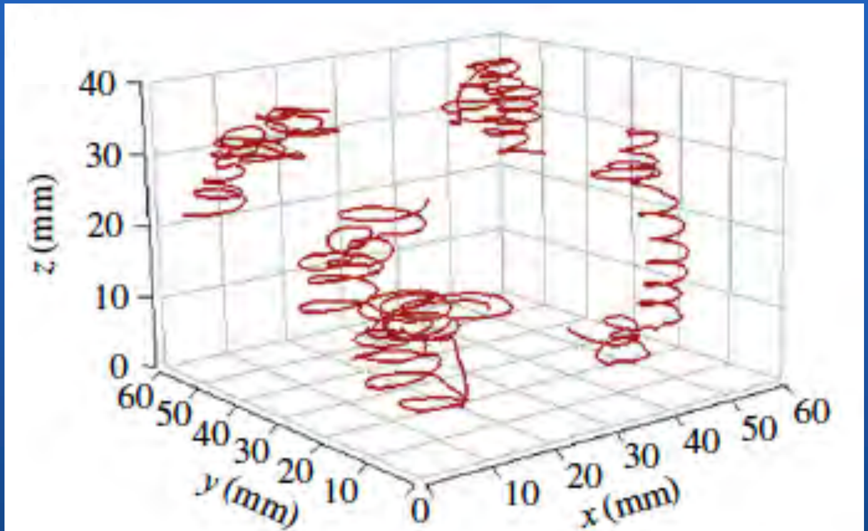
Why put mechanics into food web studies?



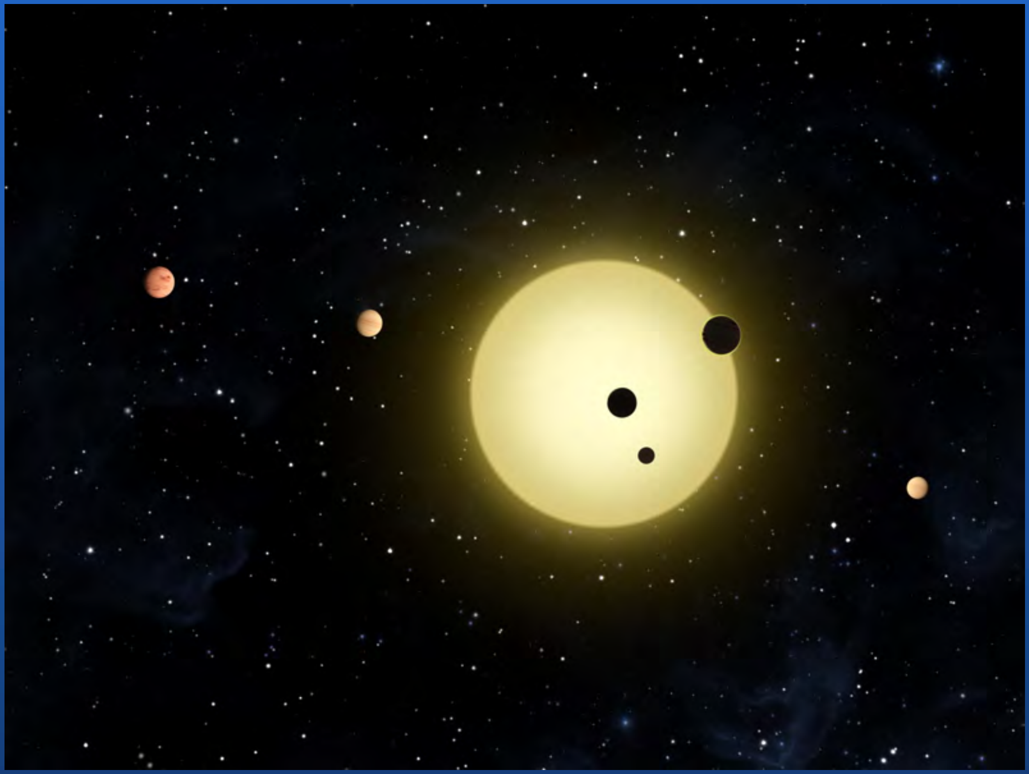
Bianco et al (2014)

Mehdi Cherif*, Sébastien Portalier¶, Gregor Fussmann¶, Michel Loreau§, Danielle Wain&, Russell Arnott&

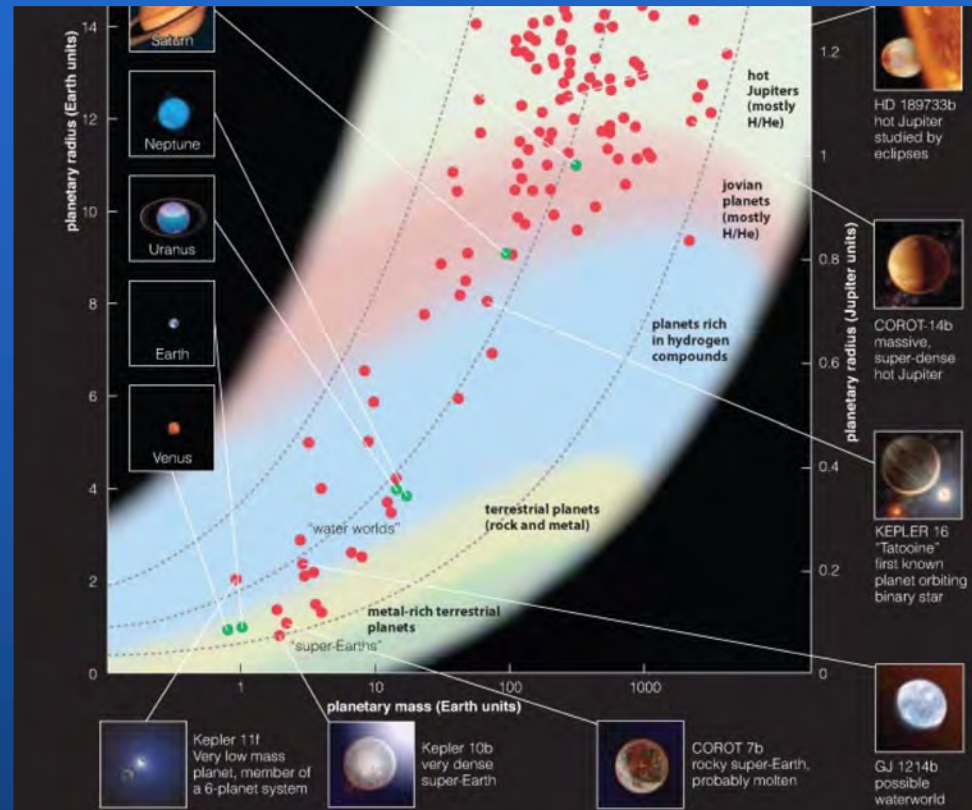
*Ecology and Environmental Science, Umeå University, Sweden
¶Biology Department, McGill University, Québec, Canada
§Centre for Biodiversity Theory and Modelling, CNRS, Moulis, France
&Department of Architecture and Civil Engineering, University of Bath, UK

Life!

Life?



Physical properties of exoplanets



- Radius
- Mass
- Radiation
- Surface t° (sometimes)
- Atmospheric composition (sometimes)
- Composition (inferred)

Earth as seen by an alien astronomer?

- Light curves:

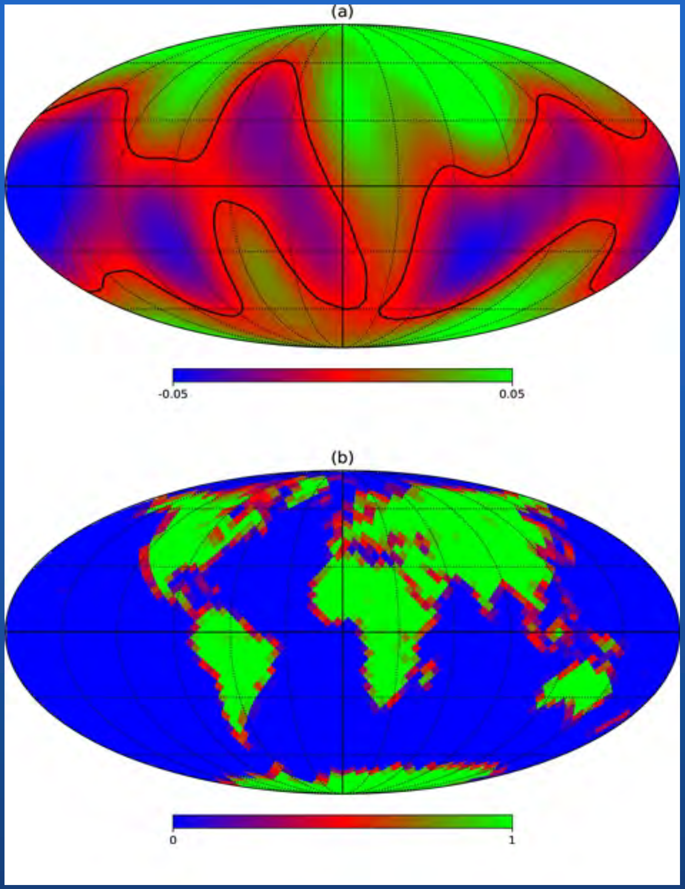


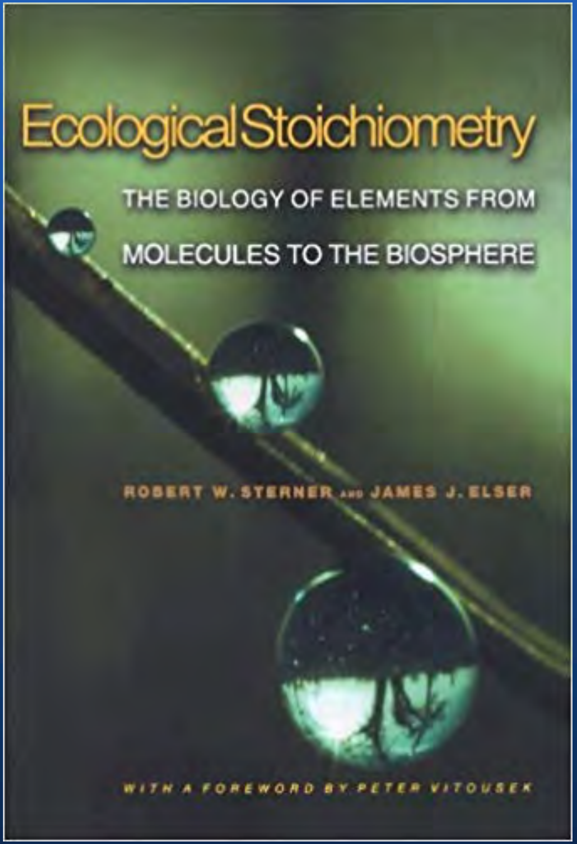
Figure 4 from Earth as an Exoplanet: A Two-dimensional Alien Map
Siteng Fan et al. 2019 ApJL 882 L1 doi:10.3847/2041-8213/ab3a49

How much of Life's structure is determined by the physical properties of the habitat?

©Higham et al (2015)

How much of Life's structure is determined by the elemental properties of the habitat?

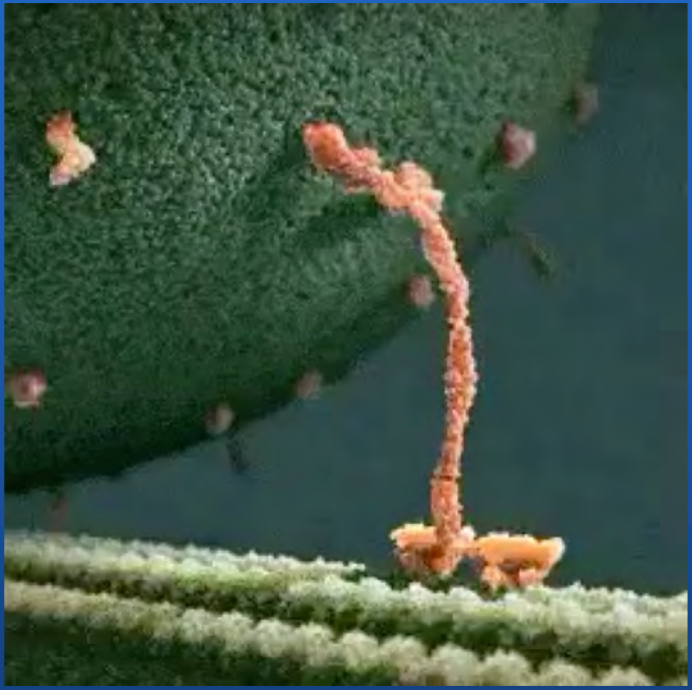
Analogy:



Sterner & Elser (2002)

What is mechanical in biology?

Everything?



Field: Biophysics

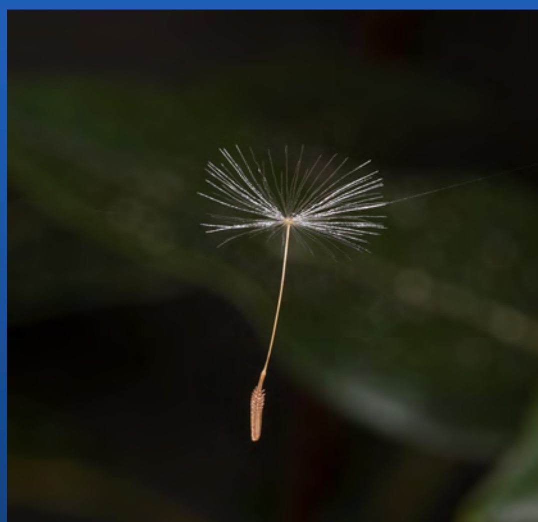
What is mechanical in ecology?

Morphological adaptations

Field: Biomechanics

What is mechanical in ecology?

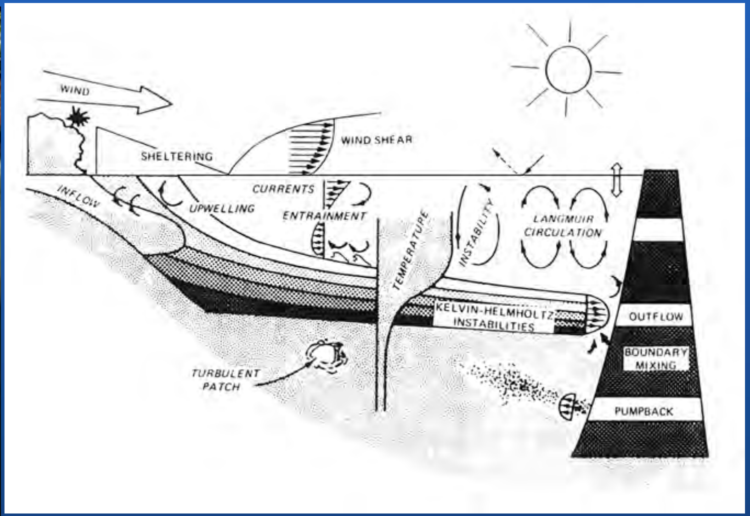
Dispersal, movement




Field: Spatial/landscape/movement ecology

What is mechanical in ecology?

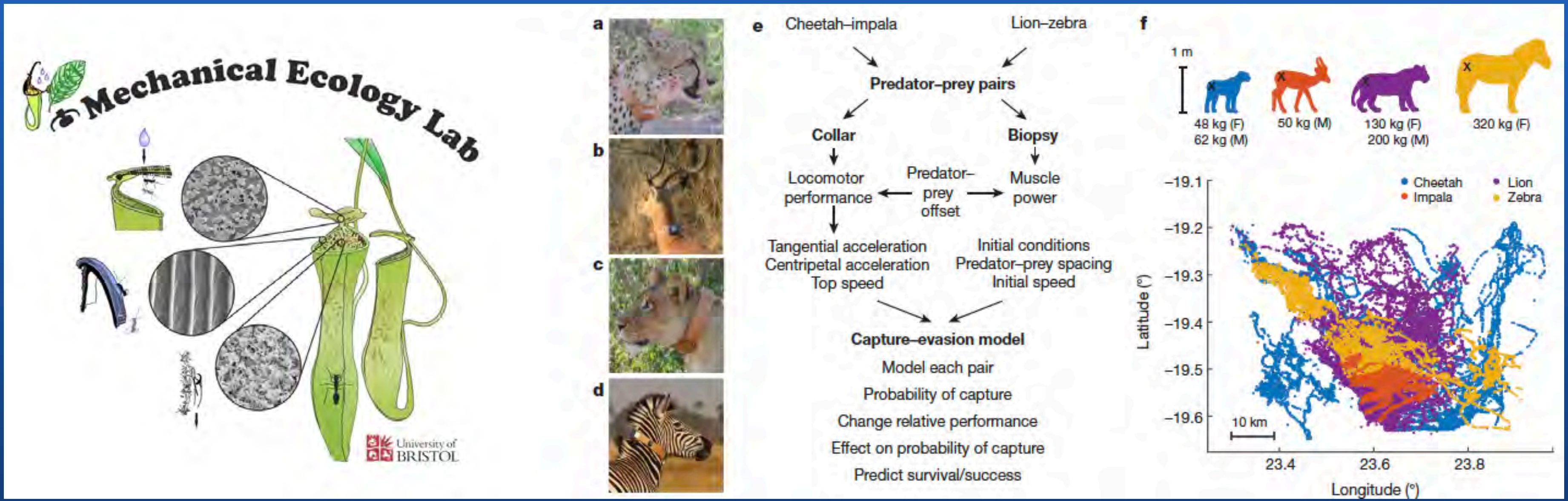
Fluid, resource movements



Field: Limnology/oceanography/hydroecology

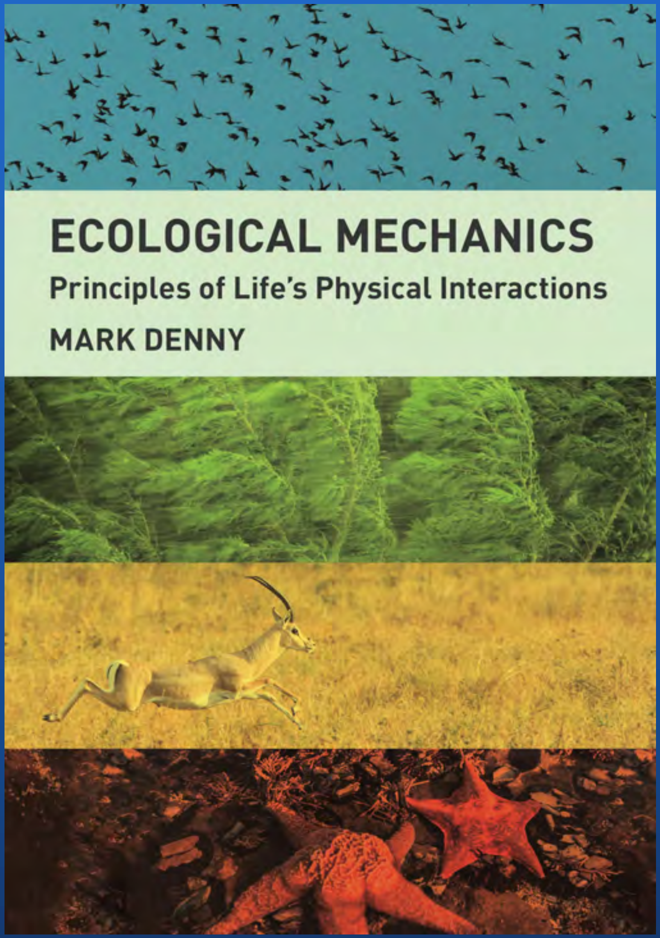
What is mechanical in ecology?

Ecological interactions



Field: Trophic ecology

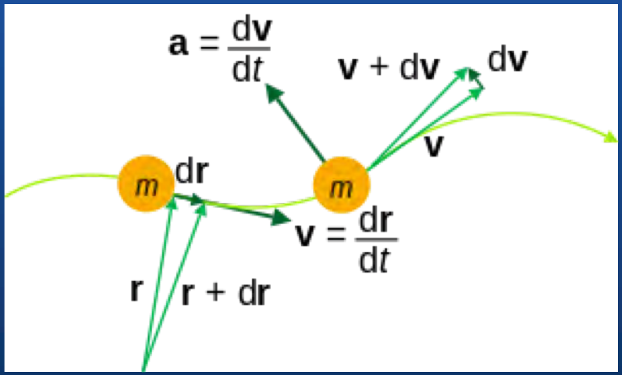
Expansion of the theory

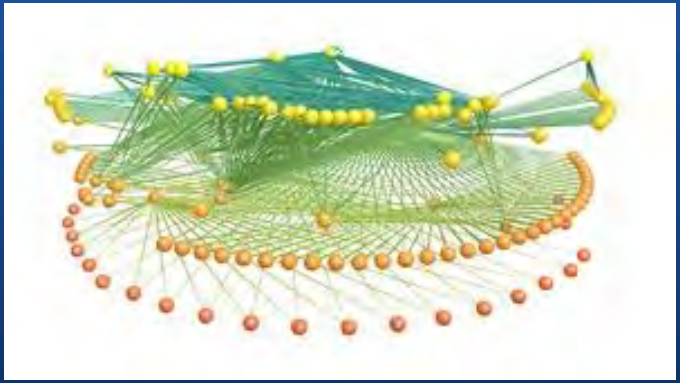


Field: Ecomechanics

Expansion of the theory

Ecomechanics of food webs





How much of food webs' structure and dynamics is determined by the mechanical properties of species and habitats?

- Species richness
- Size spectrum
- Connectance
- Nestedness
- Interaction strengths
- …

Mechanics:

Pros:

- Some ”laws” and relationships are known
- and are general
- Traits are “easy” to measure
- Predict existing and potential food webs

Cons:

- Organisms are not particles.
- Physiology and evolution have to be accounted for

Forerunners

Luckinbill, 1973, *Ecology*

- Lab experiments
- Didinium nasutum feeding on Paramecium aurelia
- Viscosity of the medium manipulated by adding Methyl Cellulose:

TABLE 1. Comparison of the average swimming velocity of *P. aurelia* and *D. nasutum* for both Cerophyl medium and the Methyl Cellulose experimental medium

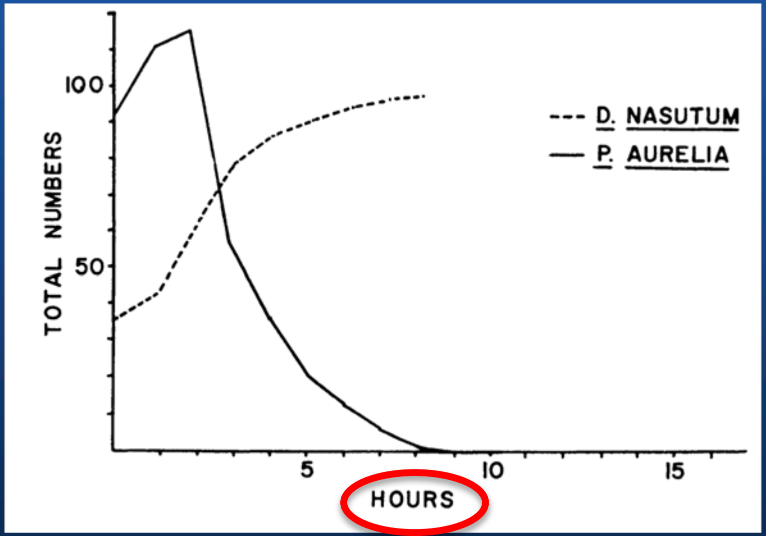
	Cerophyl only		Methyl Cellulose mixture	
	P. aurelia	*D. nasutum*	*P. aurelia*	*D. nasutum*
Mean time (seconds)	2.6	5.5	53.0	87.5
Standard deviation	1.13	2.40	35.57	44.09
Linear distance traversed	5000μ		2500μ	
Average velocity (μ/sec)	1923	909	47.0	29.0

Forerunners

Luckinbill, 1973, *Ecology*

- Lab experiments
- Didinium nasutum feeding on Paramecium aurelia
- Viscosity of the medium manipulated by adding Methyl Cellulose:

Without methyl cellulose

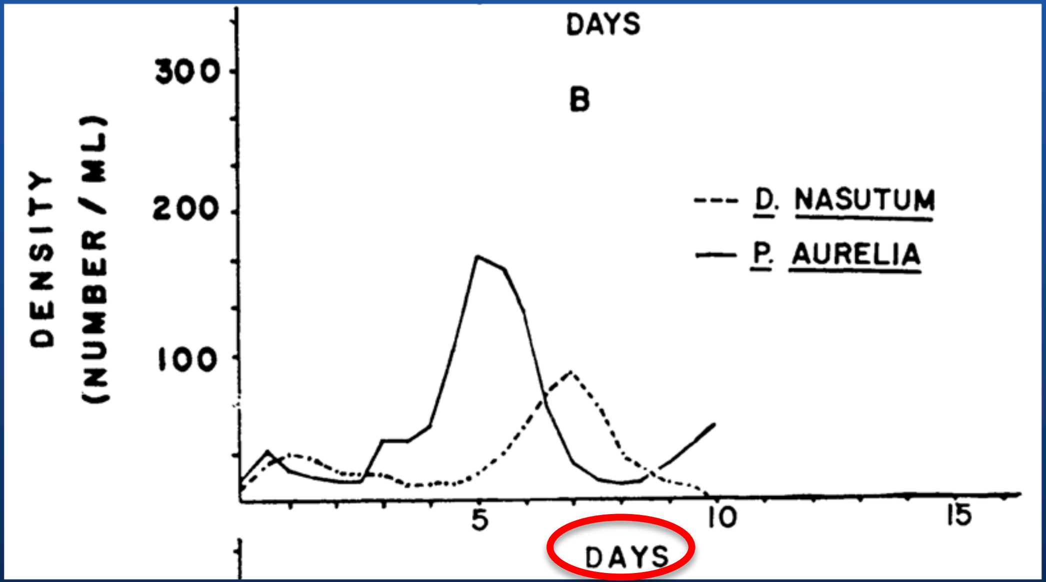


Forerunners

Luckinbill, 1973, *Ecology*

- Lab experiments
- Didinium nasutum feeding on Paramecium aurelia
- Viscosity of the medium manipulated by adding Methyl Cellulose:

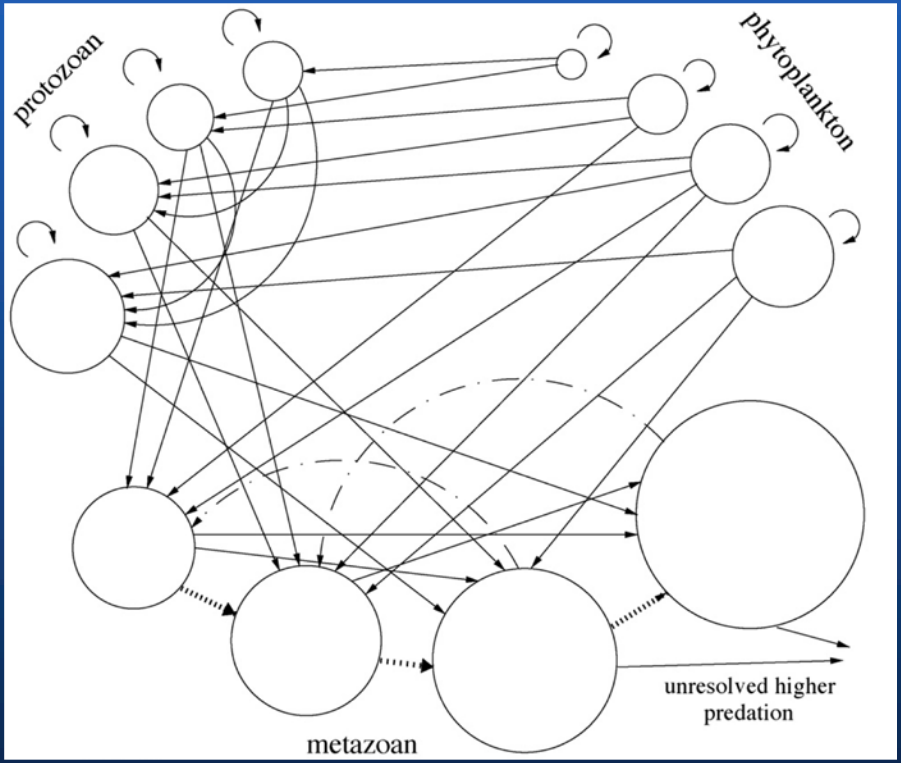
With methyl cellulose



Forerunners

Baird et al, 1999, 2007, 2010:

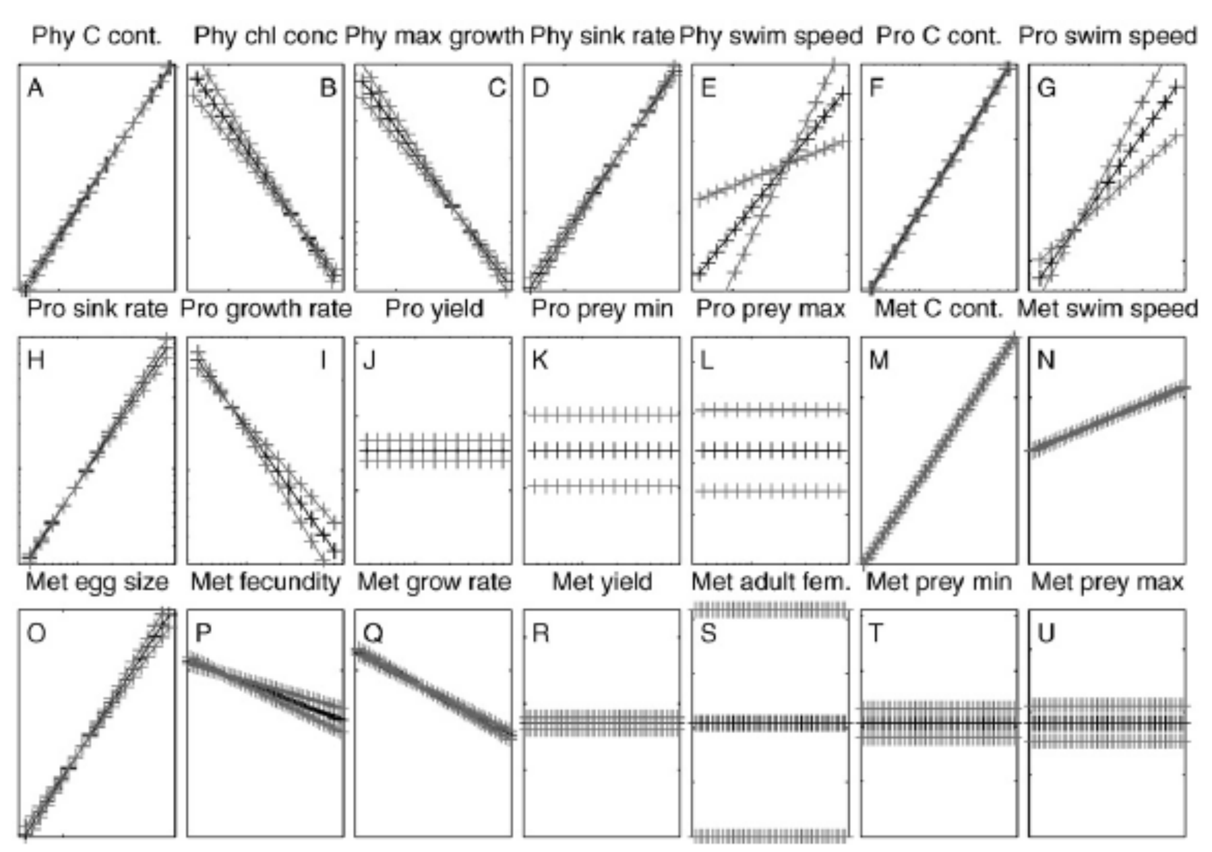
- Size-resolved planktonic food web:



Forerunners

Baird et al, 1999, 2007, 2010:

- Allometric relationships:



Forerunners

Baird et al, 1999, 2007, 2010:

- Mechanistic functions:

Shape	Absorption cross-section for random orientation, $\overline{aA}$ (m^2)	Reference
Sphere	$\pi r_1^2 \left(1 - \frac{2\left(1-(1+2\overline{\gamma C}r_1)\, e^{-2\overline{\gamma C}r_1}\right)}{(2\overline{\gamma C}r_1)^2}\right)$	Kirk (1975b)
Spheroid	$\int_0^{\pi/2} \pi L v \cos\theta \left(1 - \frac{4}{\pi L v}\int_0^s \int_0^L e^{-2\overline{\gamma C}R}\sqrt{1-\frac{Z^2}{s^2}}\, dX dZ\right) d\theta$	Kirk (1976)
$r_1 \geq r_2 \geq r_3$	$L = \sqrt{w^2\cos^2\theta + v^2\sin^2\theta}$	
	$s = v\sqrt{1-\frac{X^2}{L^2}}$	
	$R = \frac{wv\sqrt{v^2 + w^2\cot^2\theta - X^2\csc^2\theta}}{\sin\theta\,(v^2 + w^2\cot^2\theta)}$	
	prolate spheroid $r_1 = w \quad r_2 = r_3 = v$	
	oblate spheroid $r_1 = r_2 = v \quad r_3 = w$	
Cylinder	$\int_0^{\pi/2} 2 r_1 h \cos^2\theta \left(1 - \frac{1}{r_1}\int_0^{r_1} e^{-2\overline{\gamma C}r_1 \sec\theta \sqrt{\left(1-\frac{Z^2}{r_1^2}\right)}} dZ\right) d\theta$	Kirk (1976)

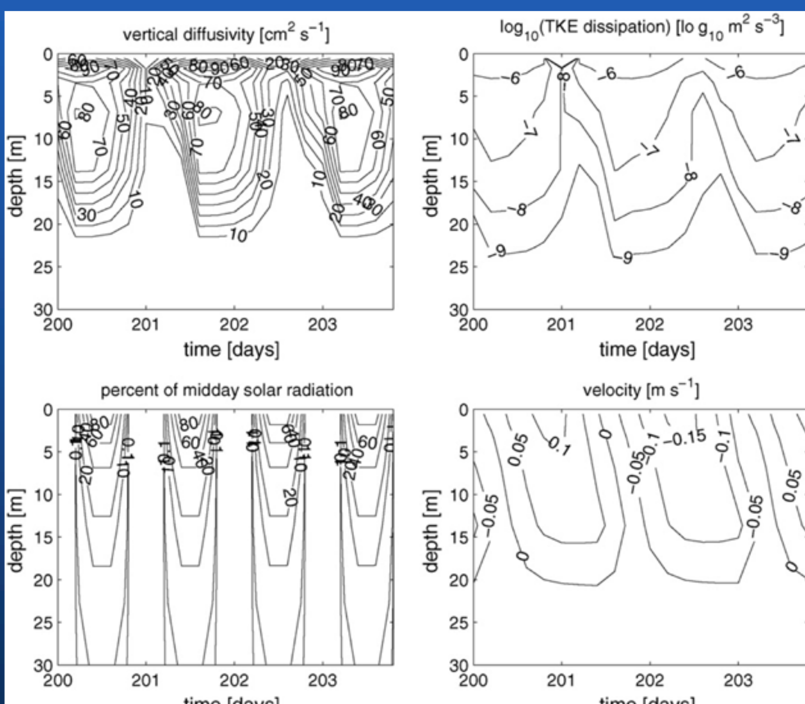
$$\left(\frac{dP_j}{dt}\right)_{sinking} = -\frac{gV_j\,(\rho_j - \rho_{water})}{C_{D,j}\nu M}\,P_j$$

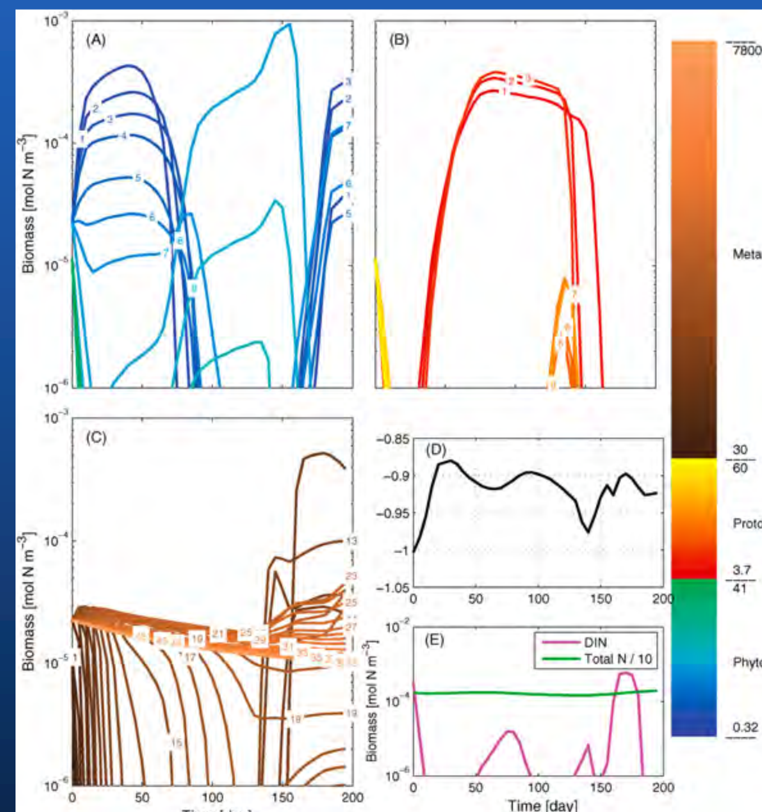
$$U_{swim,j,k} = \frac{U_{slow}^2 + 3U_{fast}^2}{3U_{fast}}$$

Forerunners

Baird et al, 1999, 2007, 2010:

- Focus on simulation and ecosystem-level properties:

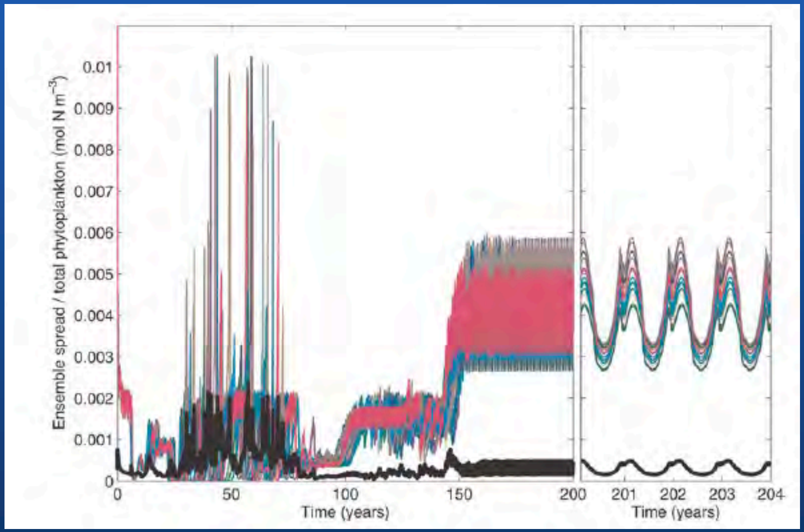




Forerunners

Baird et al, 1999, 2007, 2010:

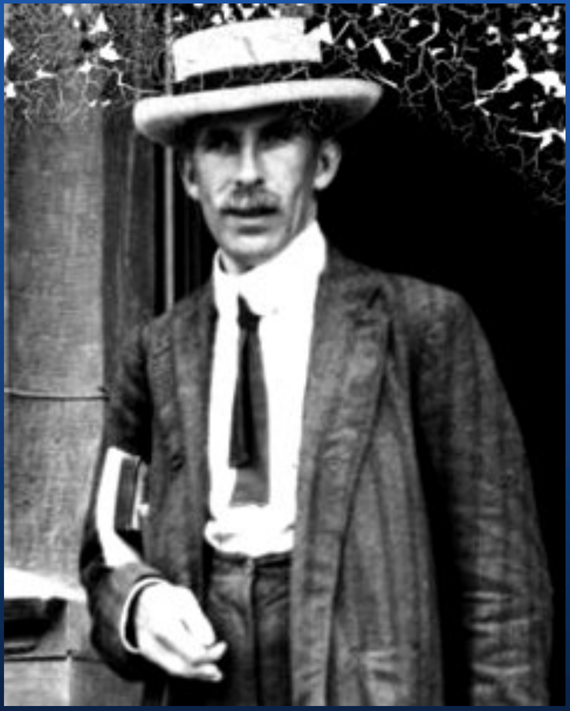
- Focus on accuracy and precision:



An ecosystem approach at heart

"Though the organisms may claim our prime interest, when we are trying to think fundamentally, we cannot separate them from their special environments, with which they form one physical system"

A. Tansley, 1937



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