Zooplankton in end-to-end models

Øyvind Fiksen

University of Bergen

& Hjort Center for Marine Ecosystem Dynamics

http://bio.uib.no/te/

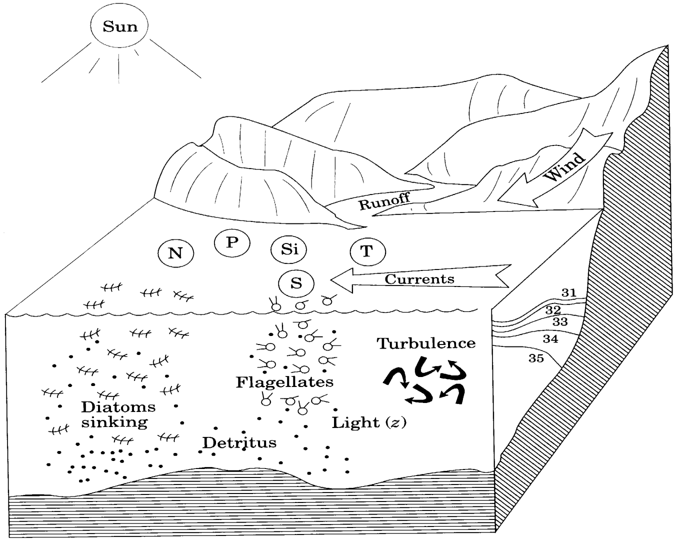
Marine ecosystem models 'end to end'?

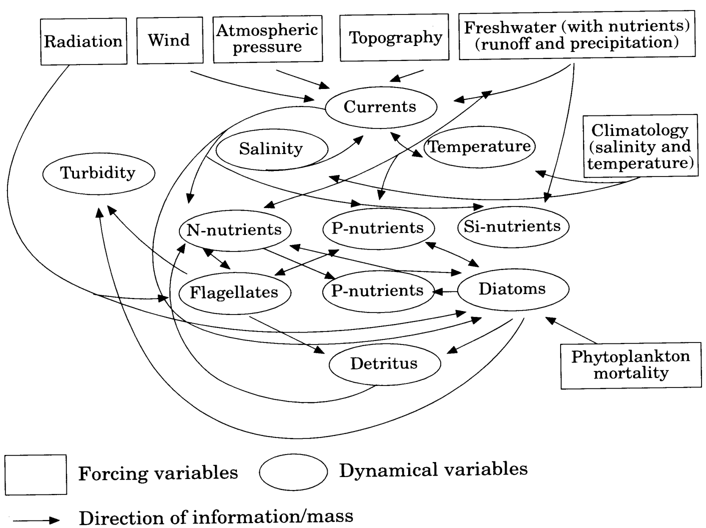
- Mass balance
- Closure terms are not important – everything is linked

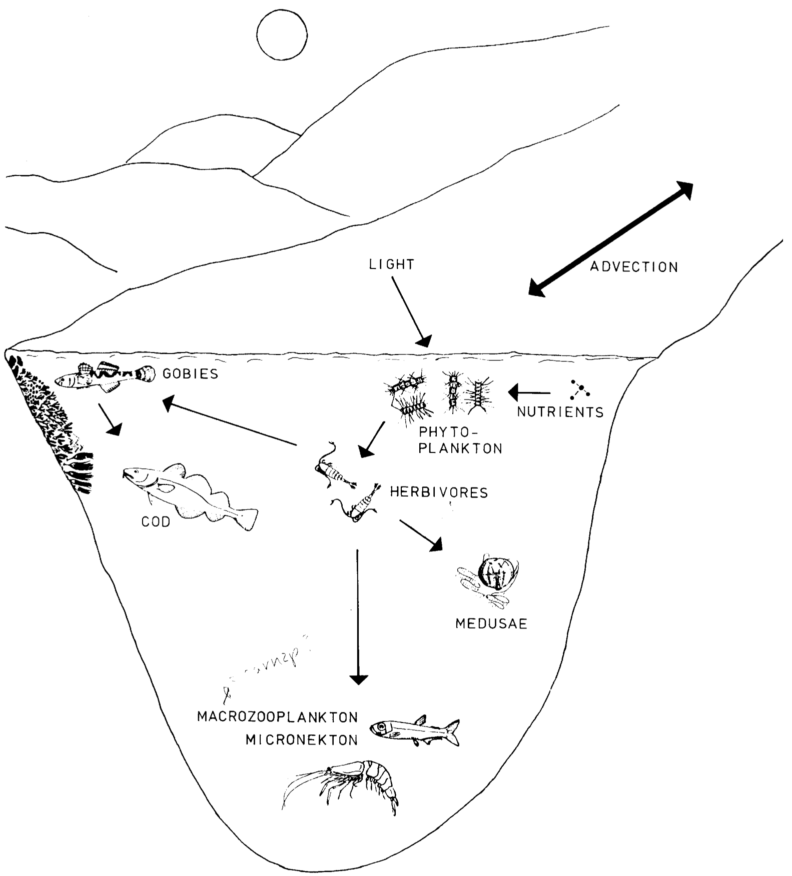
- Two traditions:
  – Biogeochemistry: zooplankton is a closure term
  – Fisheries: zooplankton is a basic resource

E2E – the link between the physics+climate+LTL + HTL+fisheries

Local history: E2E, 25 years ago







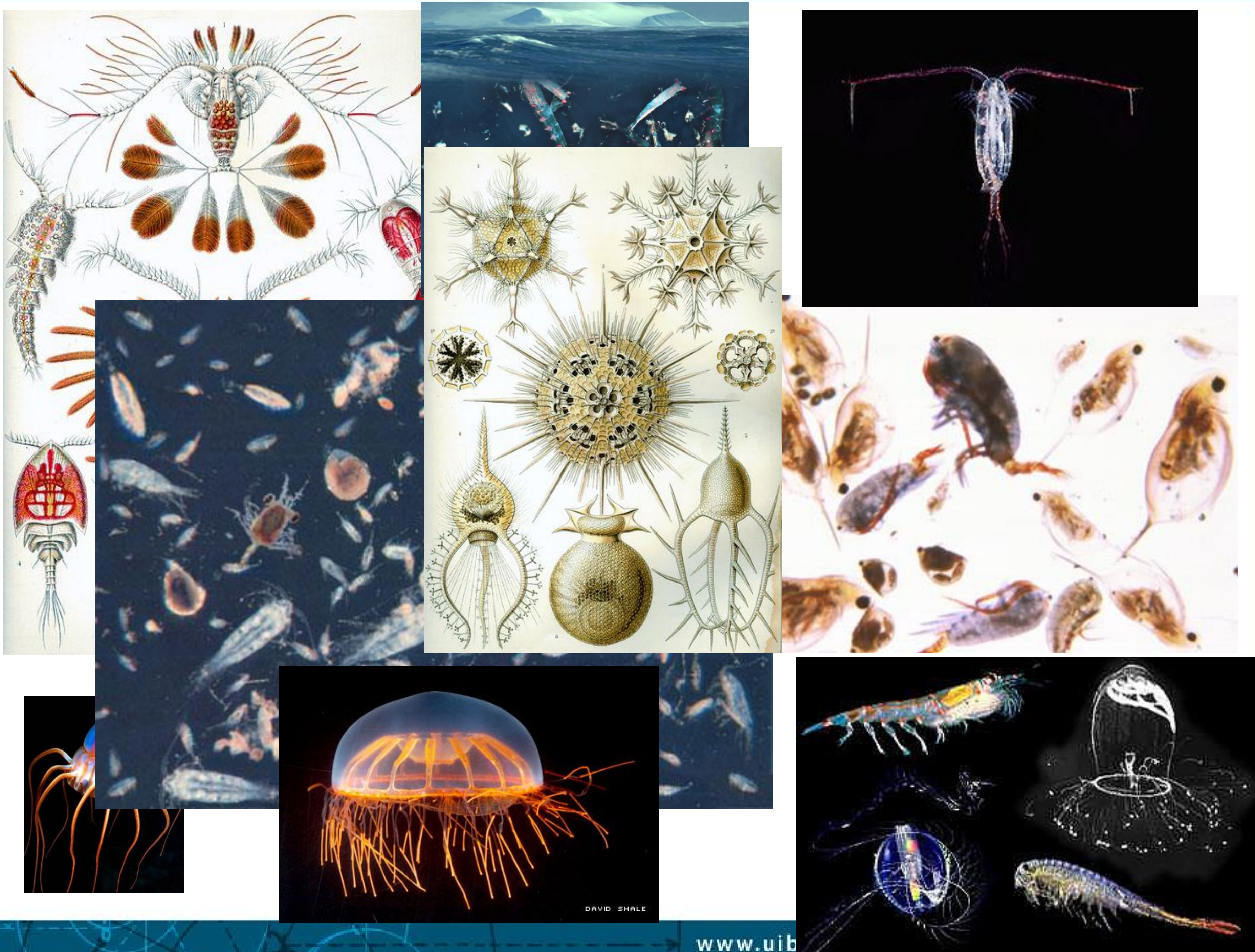
Aksnes & Lie 1990, Skogen & al. 1995

A weatherforecast for plankton?

- The ultimate test of theory is reproducibility and predictability

- Physics and chemistry are mature sciences by these criteria
- Biology is less successful – and ecology is weak

- Ecosystem model = weatherforecast of plankton and fish?
- ..with a consensus on the processes and parameters?


DAVID SHALE

Challenges and deep concerns about the ‘to’

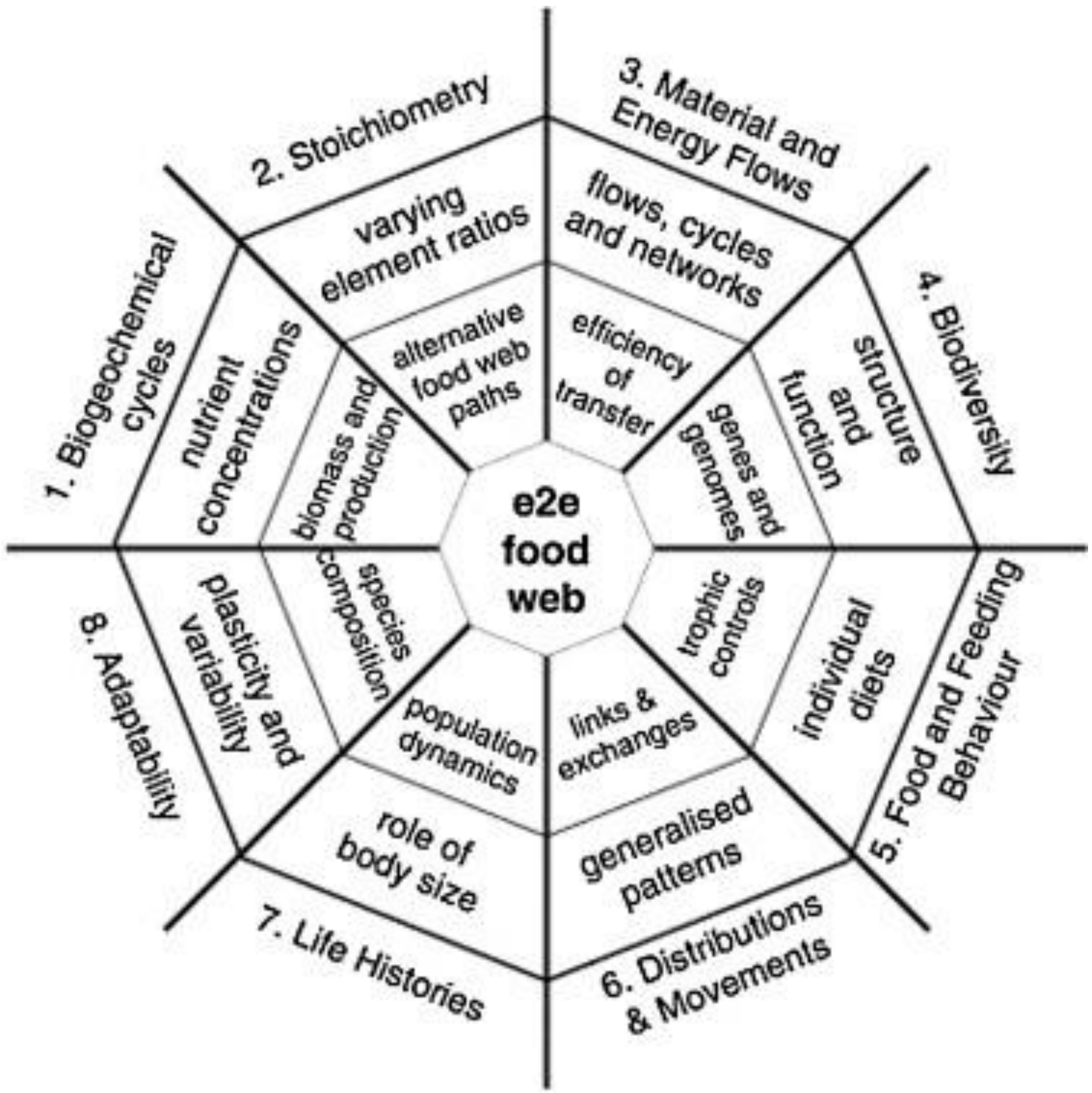
Representation of:

- Feeding
- Diet selection
- Behaviour
- Size-structure
- Life-cycle
- Mortality
- Stoichiometry
- Lagrangian/Eulerian
- …

Some references

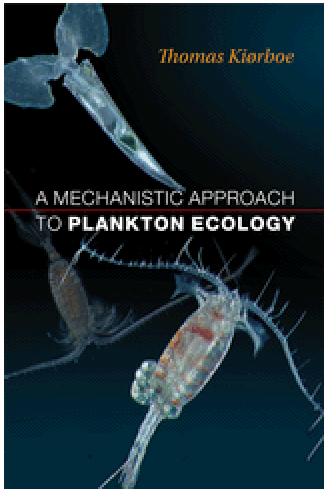
- Cadiz in 2010, vol 84, 1-2 Prog Oceanogr.
- Rose & al 2010
- Moloney & al 2011
- Mitra & al 2014

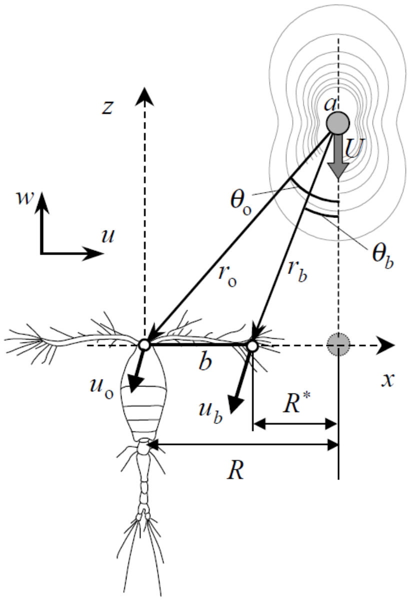
..

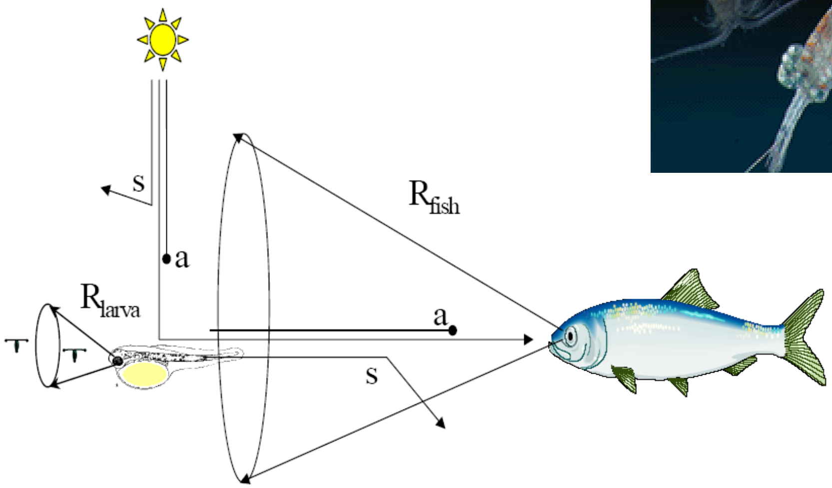


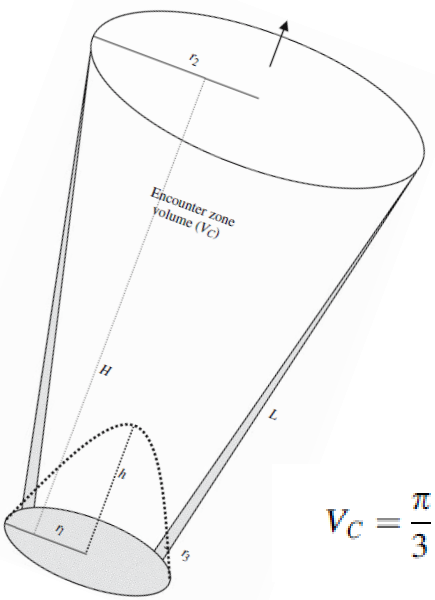
Moloney & al. 2011. Weaving marine food webs from end to end under global change. JMS. 84:106-116.

Use mechanistic foraging models









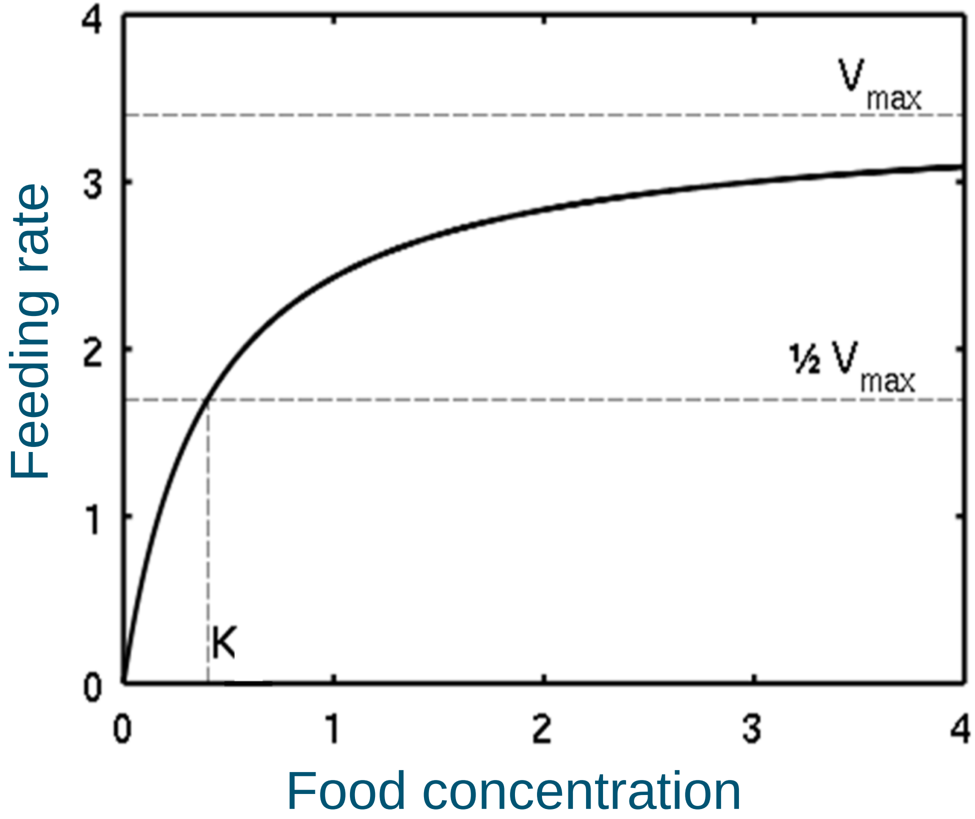
$$f = \frac{h^{-1}N}{\left(h\pi(r\sin\theta)^2 v\right)^{-1} + N}$$

$$r^2\exp(cr) = |C_0|A_p E' \frac{E_b}{K_e + E_b}$$

$$V_C = \frac{\pi}{3}H(r_1^2 + r_2^2 + r_1 r_2) - \frac{\pi}{3}r_1^2 h$$

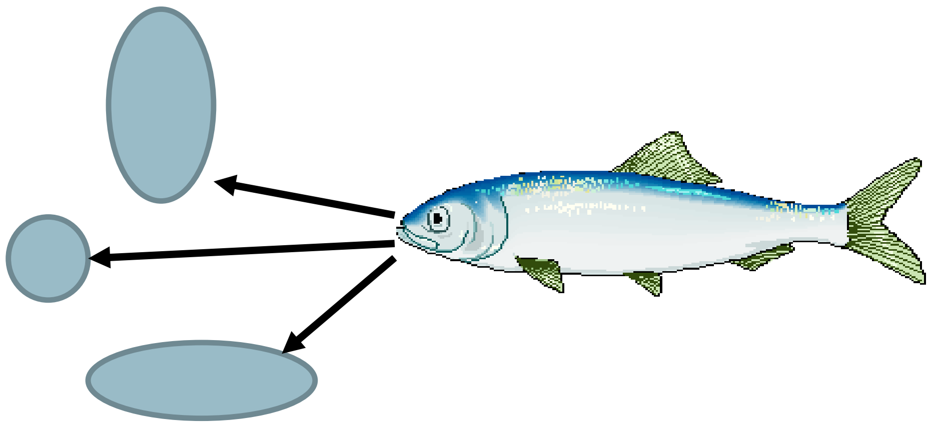
$$D_t = \frac{12 r_3^2 L}{H(r_1^2 + r_2^2 + r_1 r_2) - r_1^2 h}$$

NB – the half saturation constant is not mechanistic



$$f = V_{\max} \frac{N}{K + N}$$

Diets, food selection foraging modes



Vol. 473: 91–101, 2013
doi: 10.3354/meps10079

MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser

Published January 21

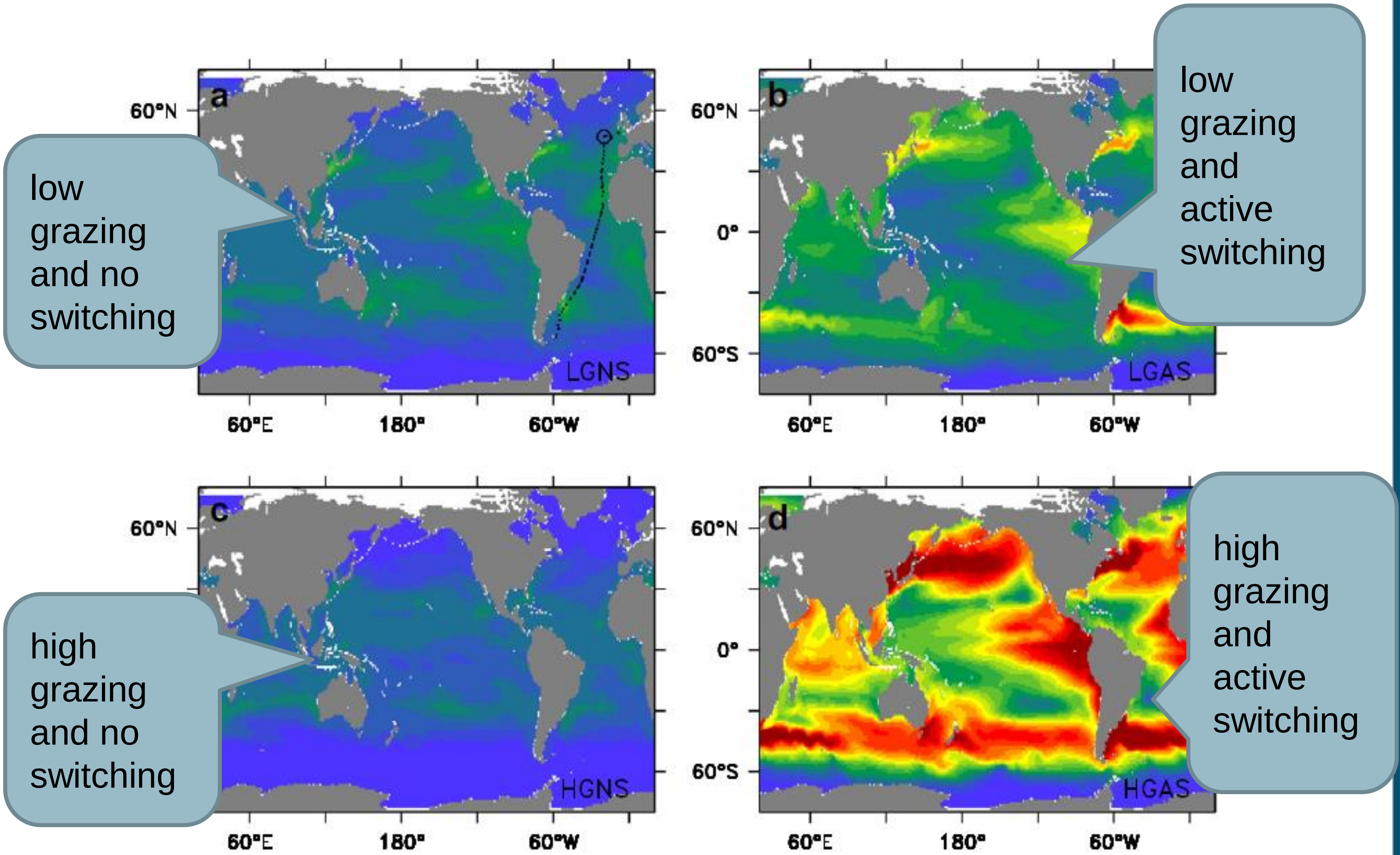
Optimal foraging in marine ecosystem models: selectivity, profitability and switching

André W. Visser[1,*], Øyvind Fiksen[2,3]

[1]Centre for Ocean Life, National Institute for Aquatic Resources, Technical University of Denmark, Kavalergaard 6, 2920 Charlottenlund, Denmark

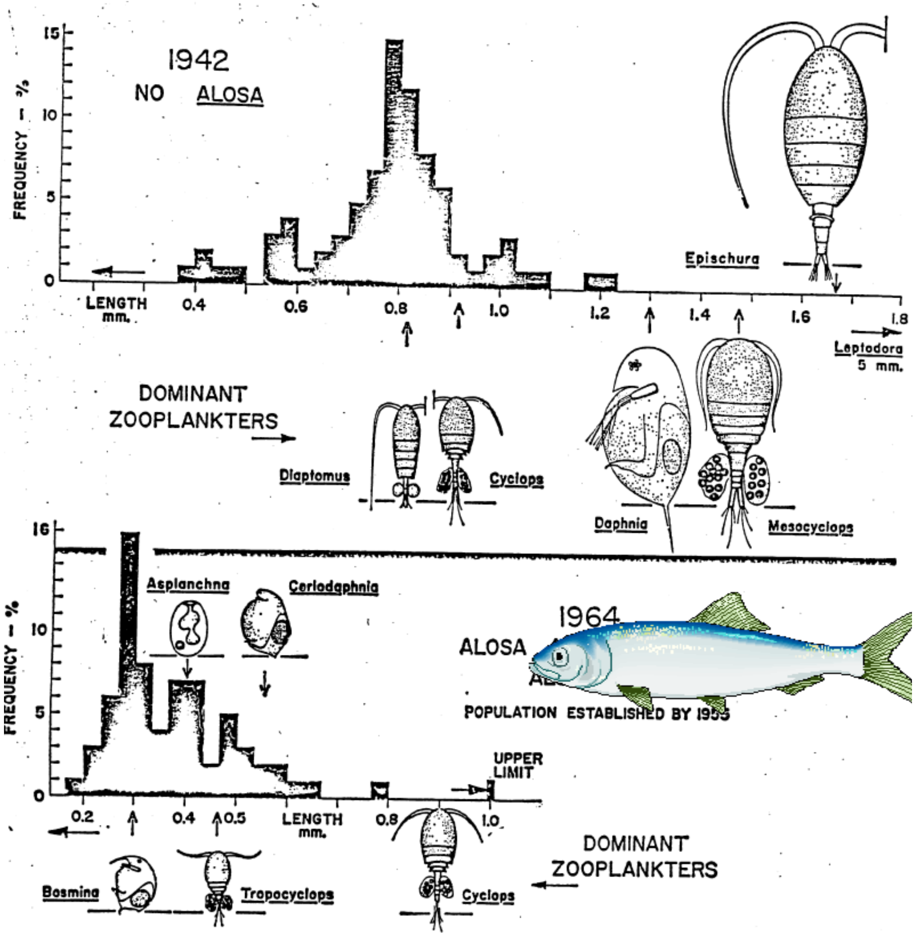
[2]Department of Biology, University of Bergen, 5020 Bergen, Norway

[3]Uni Research, 5020 Bergen, Norway

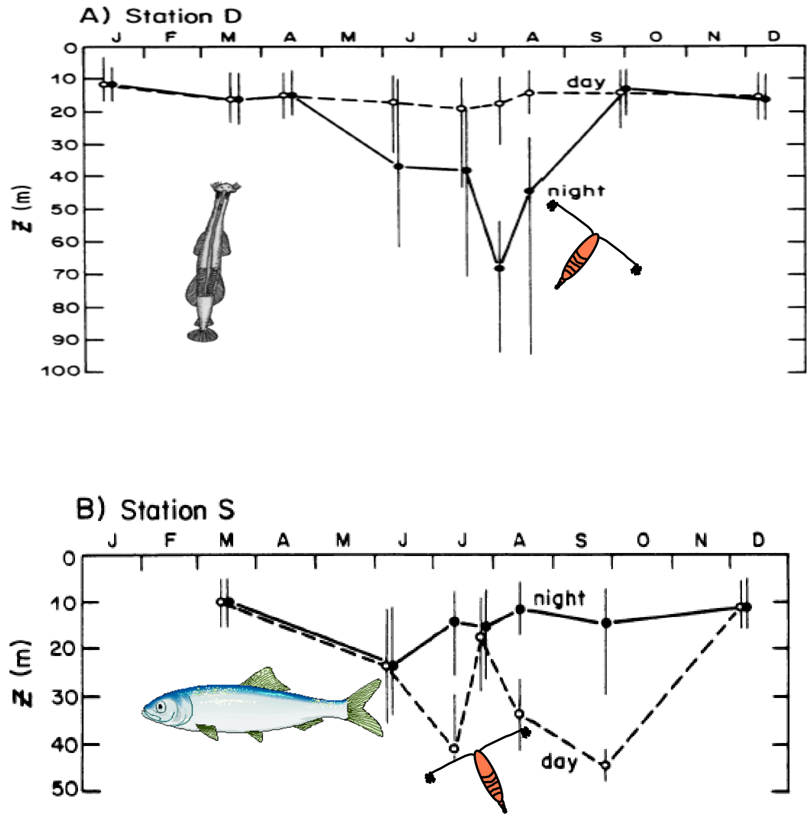


Prowe & al 2012. Top-down control of marine phytoplankton diversity in a global ecosystem model. Prog Oceanogr. 101:1-13

Fish and zooplankton behaviour

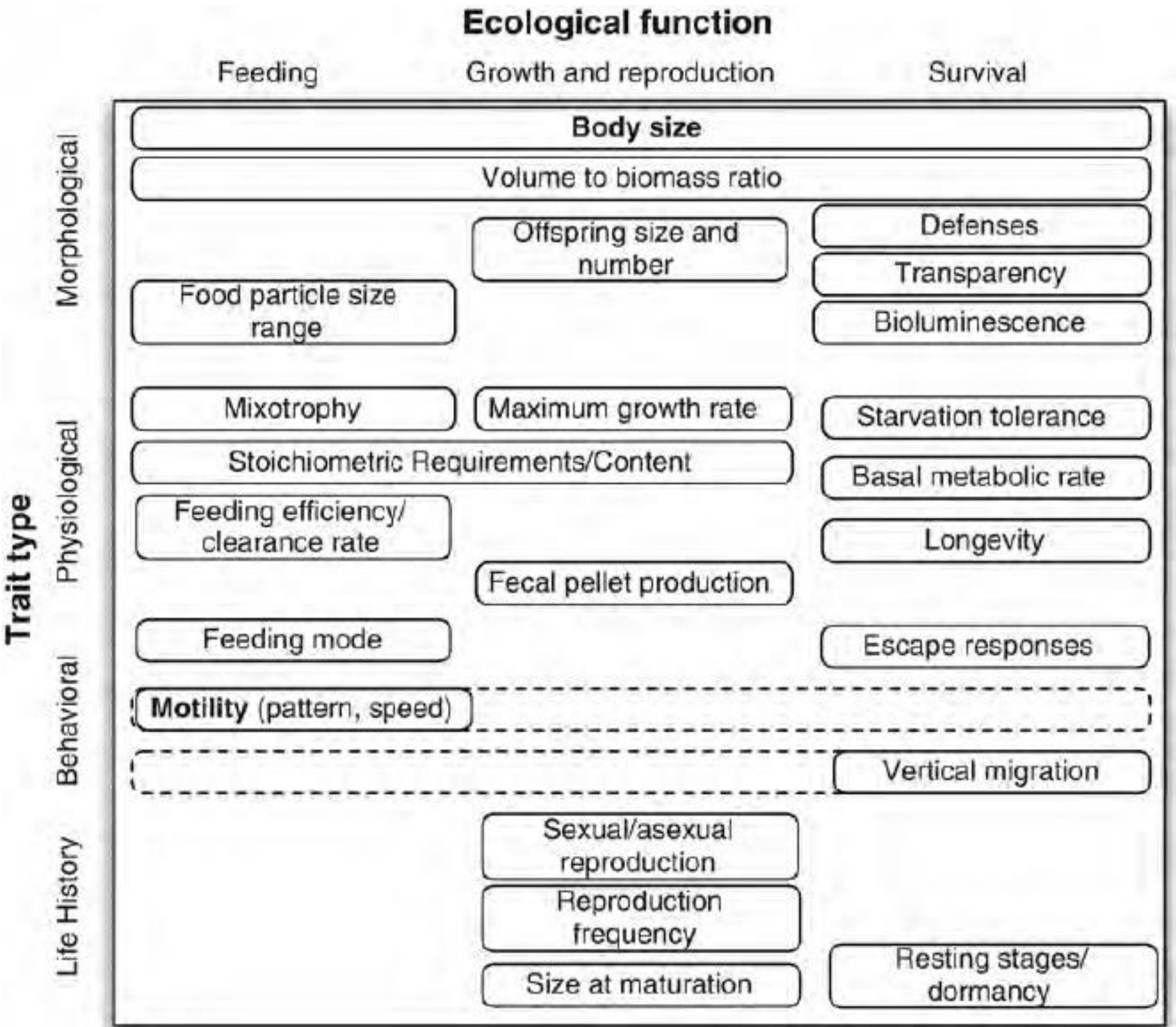


Brooks & Dodson 1965



Ohman 1990

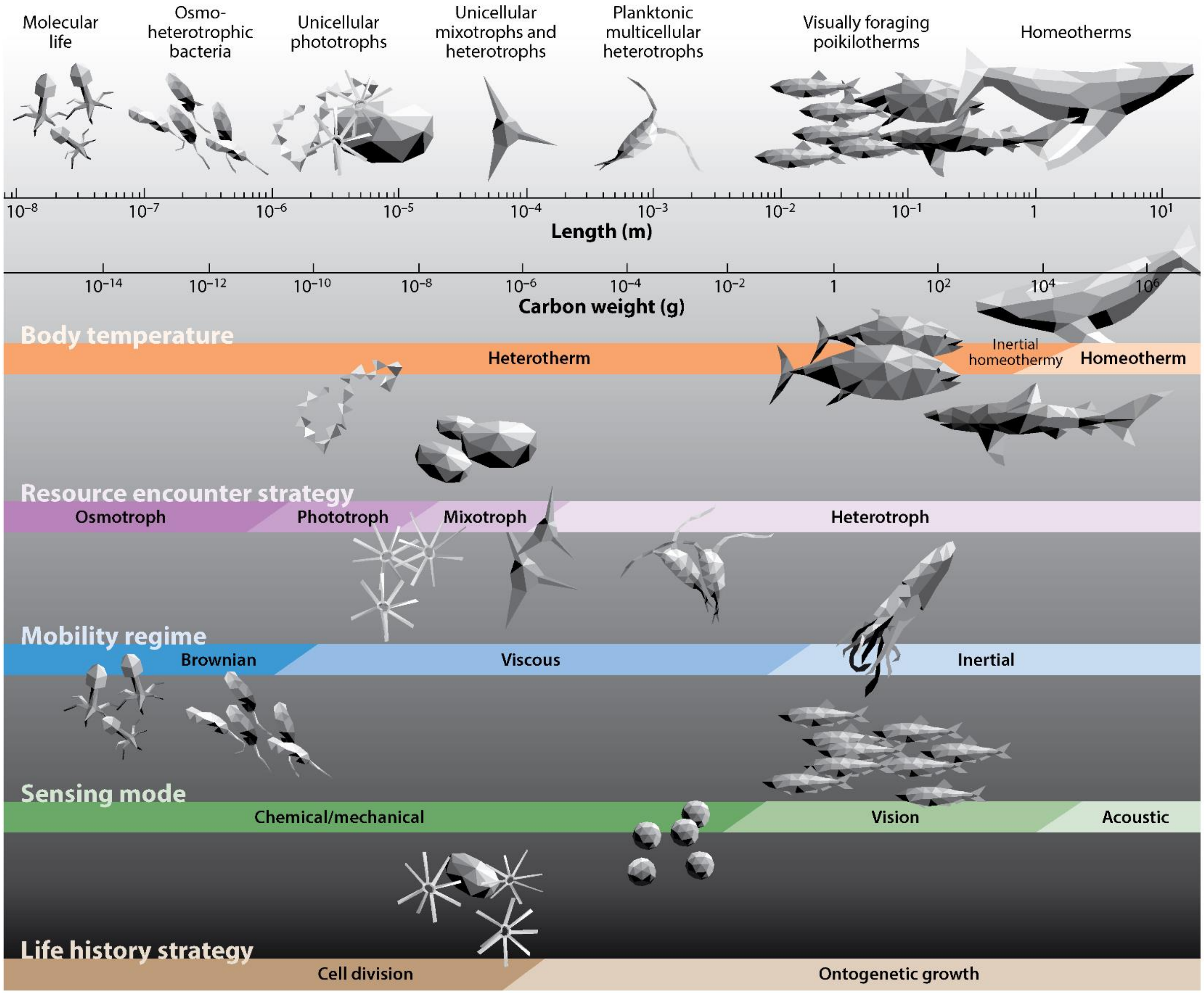
A trait-based topology of zooplankton



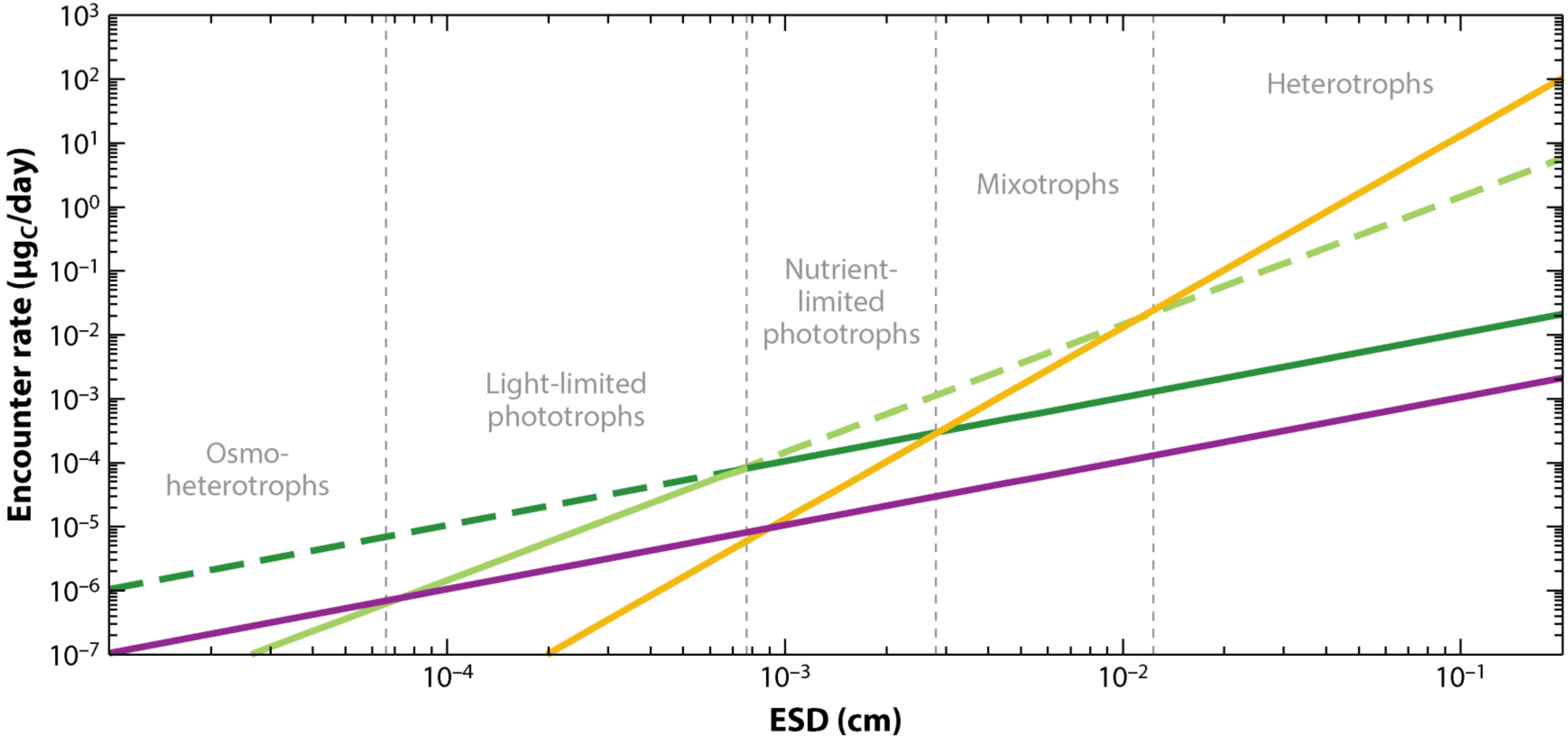
Litchman, Ohman and Kiørboe. 2013.Trait-based approaches to zooplankton communities. J. Plankton Res. 35(3): 473–484

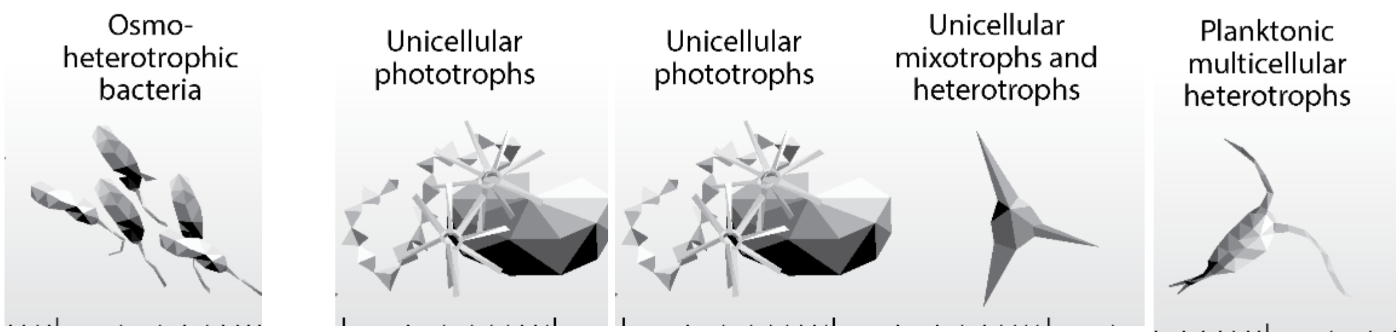
Trait-based approaches to zooplankton may in the future be integrated into a general trait-based framework for modeling not only planktonic communities (bacterioplankton, phytoplankton and zooplankton) but the whole aquatic ecosystem as well, including end-to-end models encompassing multiple trophic levels and organismal groups, from bacteria, to plankton to fish and to mammals and birds.

Litchman, Ohman and Kiørboe. 2013.Trait-based approaches to zooplankton communities. J. Plankton Res. 35(3): 473–484

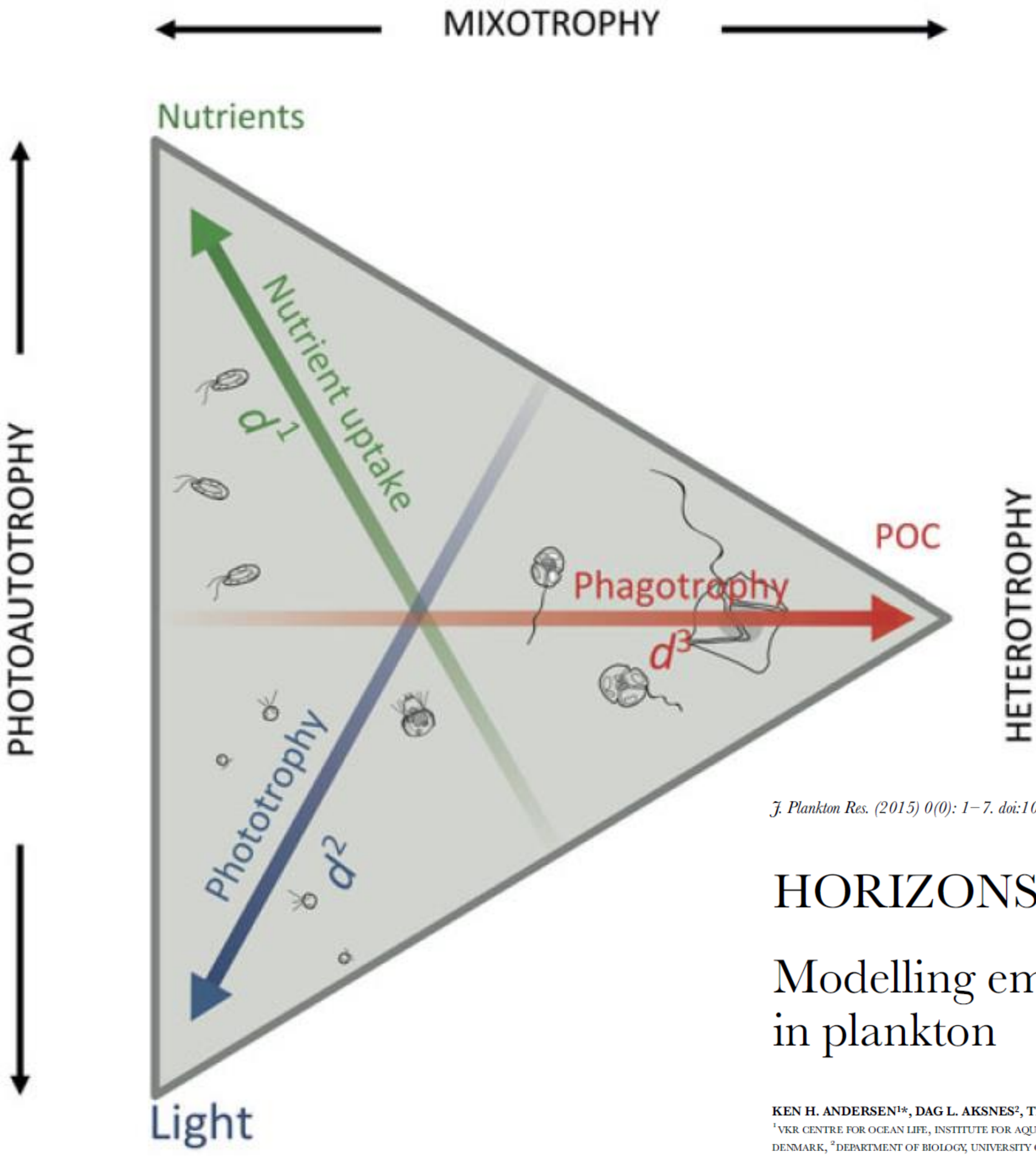


Andersen KH, et al. 2016.
Annu. Rev. Mar. Sci. 8:217–41





Andersen & al 2016. Characteristic Sizes of Life in the Oceans, from Bacteria to Whales. Annual Review of Marine Science, Vol 8



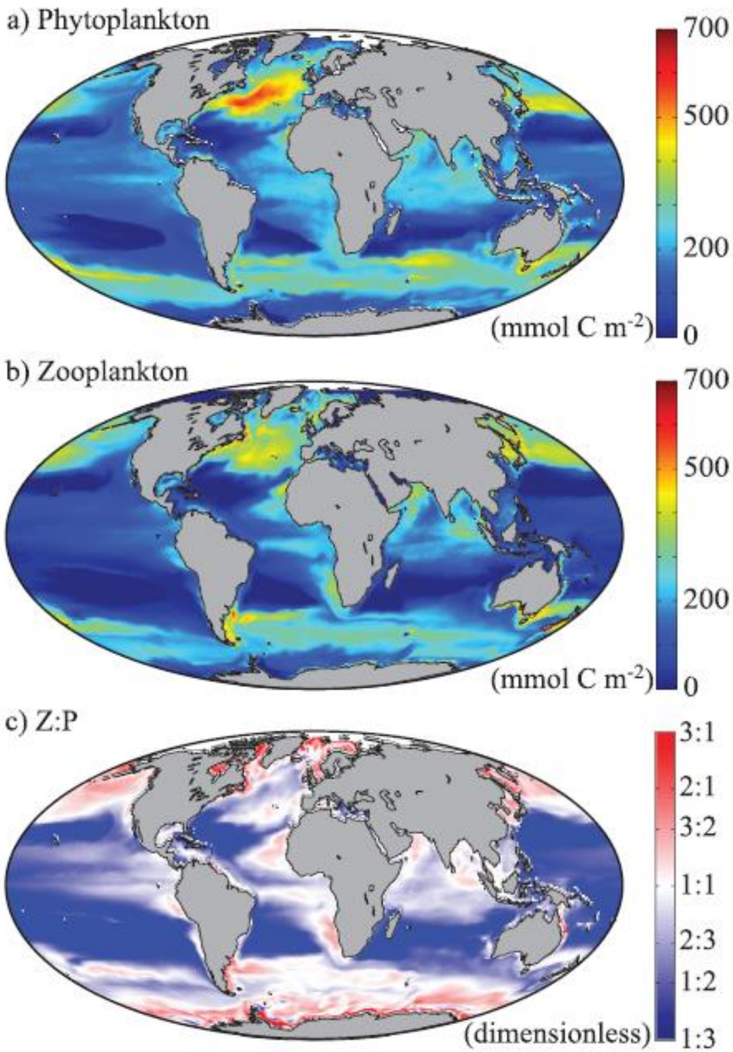
J. Plankton Res. (2015) 0(0): 1–7. doi:10.1093/plankt/fbv054

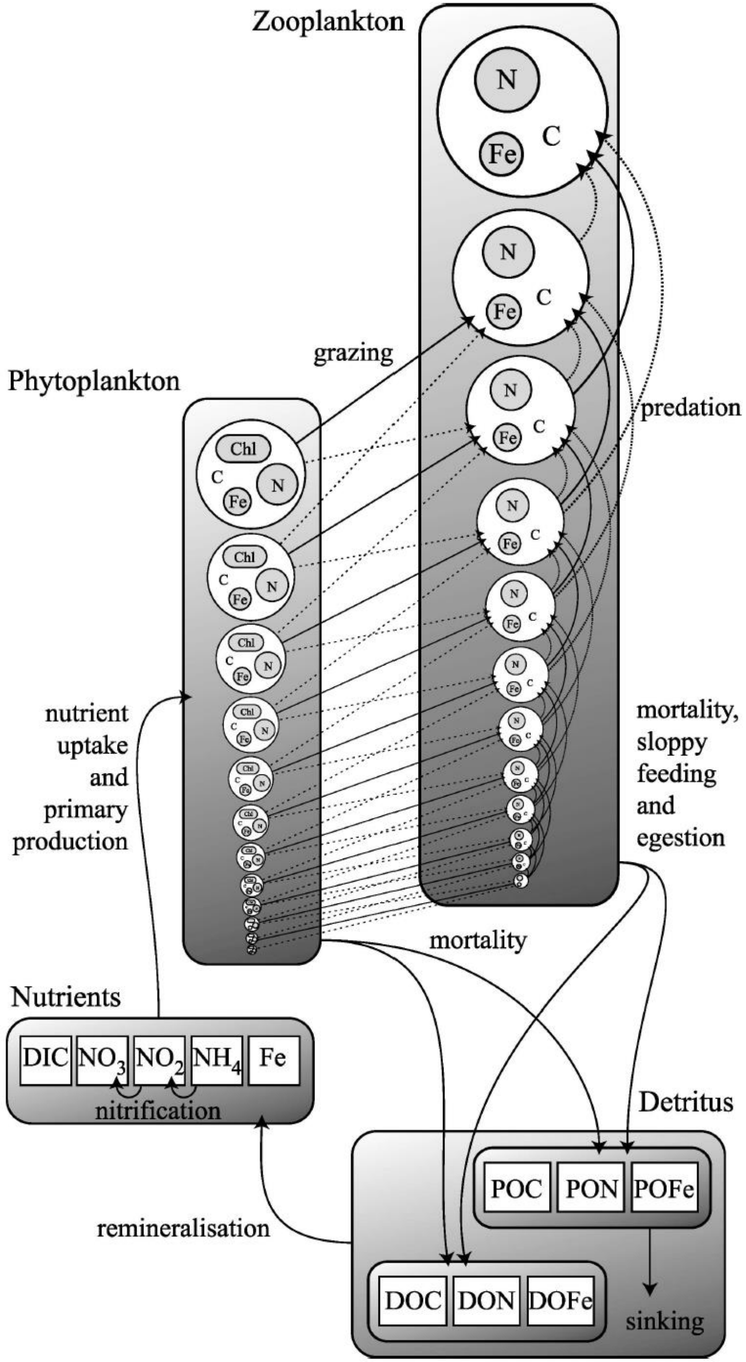
HORIZONS

Modelling emergent trophic strategies in plankton

KEN H. ANDERSEN[1]*, DAG L. AKSNES[2], TERJE BERGE[3], ØYVIND FIKSEN[2] AND ANDRÉ VISSER[1]
[1]VKR CENTRE FOR OCEAN LIFE, INSTITUTE FOR AQUATIC RESOURCES, TECHNICAL UNIVERSITY OF DENMARK, JÆGERSBORG ALLÉ 1, 2920 CHARLOTTENLUND, DENMARK, [2]DEPARTMENT OF BIOLOGY, UNIVERSITY OF BERGEN AND HJORT CENTRE FOR MARINE ECOSYSTEM DYNAMICS, THORMØHLENSGT. 53 A/B, N-5020 BERGEN AND [3]VKR CENTRE FOR OCEAN LIFE, MARINE BIOLOGICAL SECTION, UNIVERSITY OF COPENHAGEN, STRANDPROMENADEN 5, 3000 HELSINGØR, DENMARK

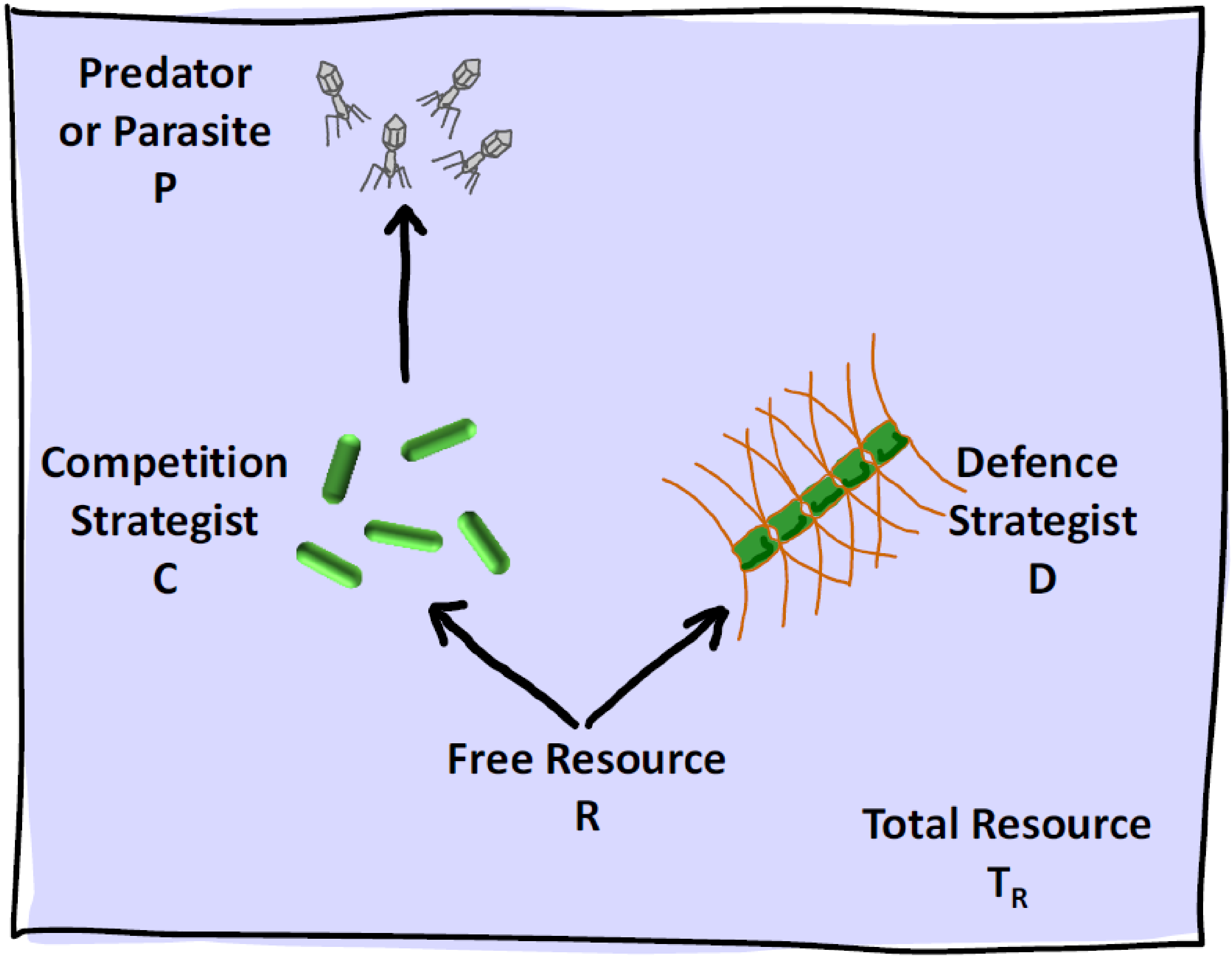
Size-structured zooplankton





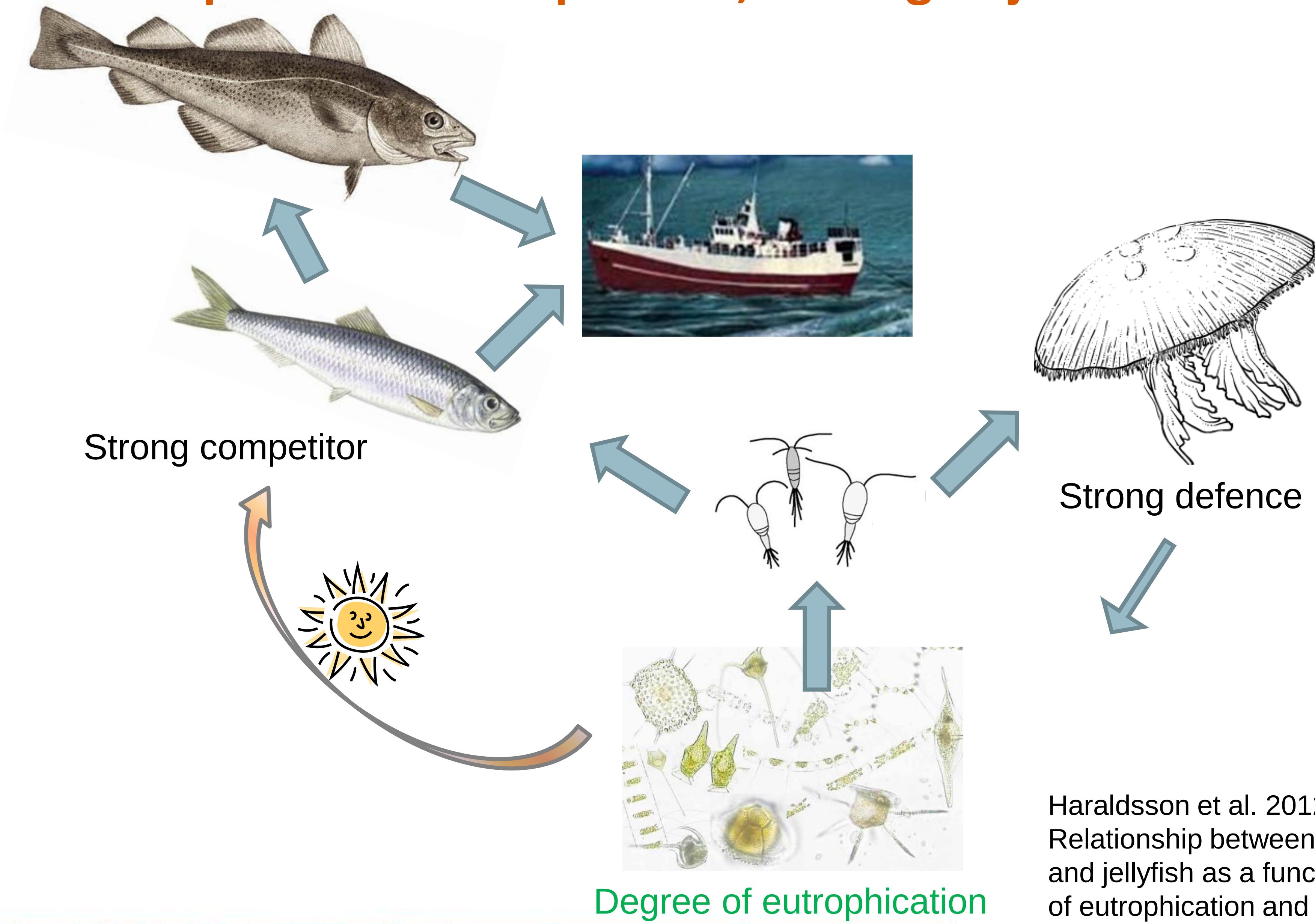
Ward & al. 2012. A size-structured food-web model for the global ocean. L&O 57:1877-1891

A simpler route to complex models?



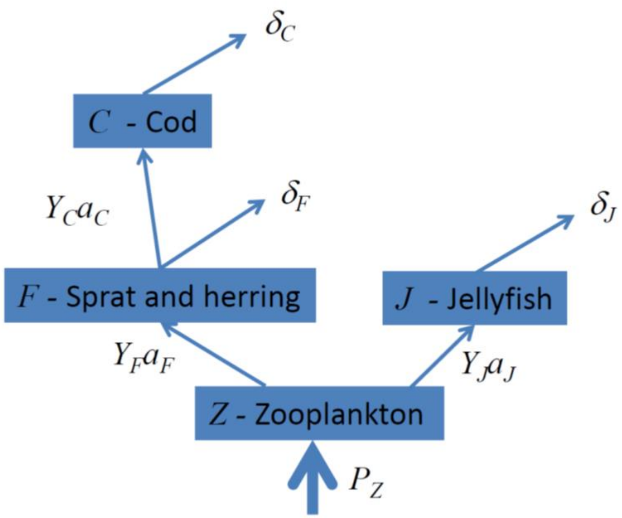
Thingstad et al. 2010. Stepwise building of plankton functional type (PFT) models: A feasible route to complex models? Prog Oceanogr 84:6-15.

Do zooplankton end up in cod, herring or jellies?



Haraldsson et al. 2012. Relationship between fish and jellyfish as a function of eutrophication and water clarity. MEPS 471:73-85

A simple model of the Baltic Sea ecosystem



$$\frac{dZ}{dt} = P_Z - a_F ZF - a_J ZJ$$

$$\frac{dJ}{dt} = Y_J a_j ZJ - \delta_j J$$

$$\frac{dF}{dt} = Y_F a_F ZF - a_C CF - \delta_F F$$

$$\frac{dC}{dt} = Y_C a_C FC - \delta_C C$$

Solving for steady state:

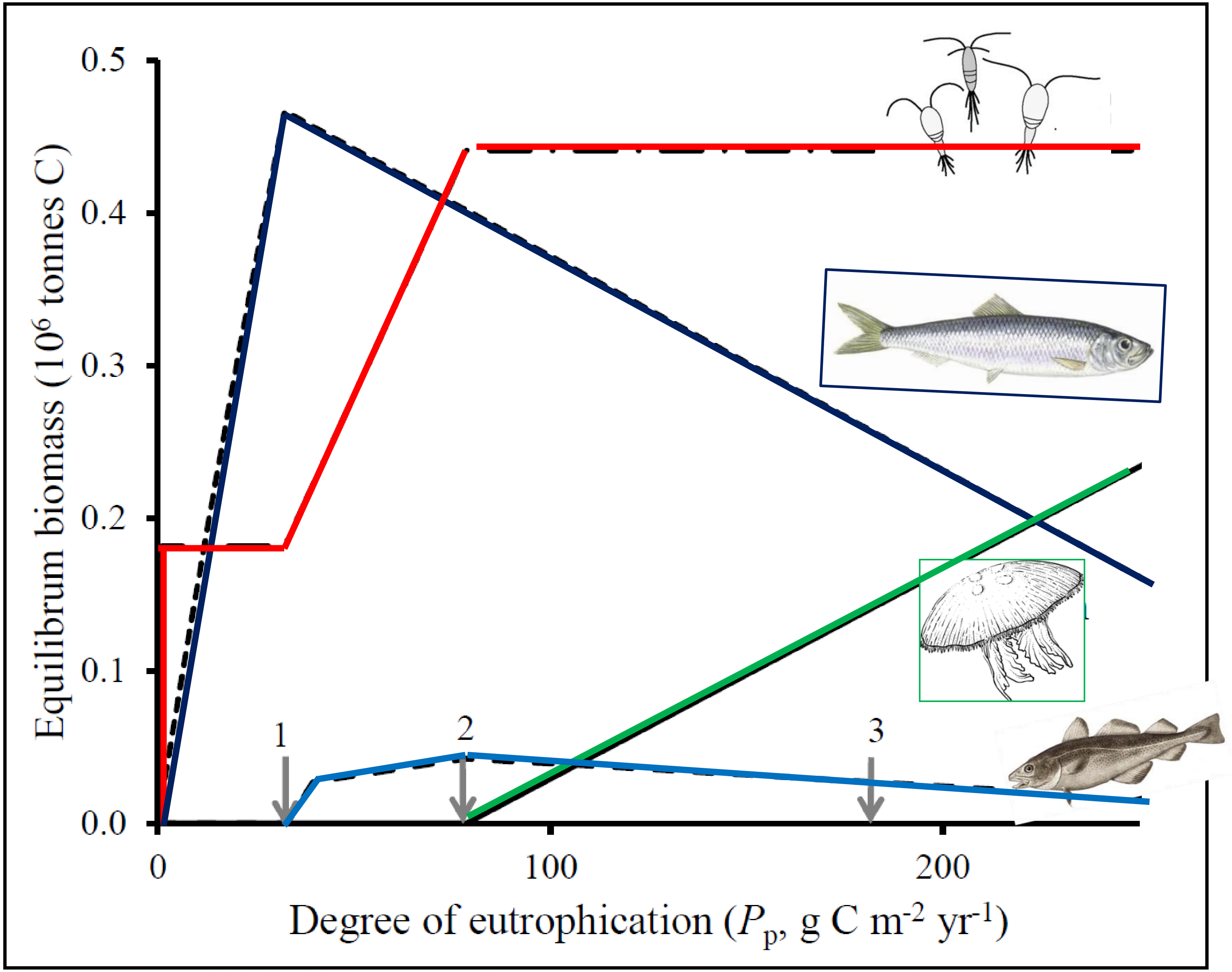
$$Z^* = \frac{\delta_J}{Y_J a_J}$$

$$J^* = \frac{Y_J}{\delta_J} P_Z - \frac{a_F}{Y_C a_C a_J} \delta_C$$

$$F^* = \frac{\delta_C}{Y_C a_C}$$

$$C^* = a_C^{-1} \left(\frac{Y_F}{Y_J} \frac{a_F}{a_J} \delta_J - \delta_F \right)$$

Analysis of trophic pathways in the Baltic



Haraldsson et al. 2012

Summary

- Develop simple end-to-end models also
- Build (Lagrangian) 1D models of the ecosystem
- Be mechanistic (and learn what that means)
- Use evolutionary theory as null-hypothesis

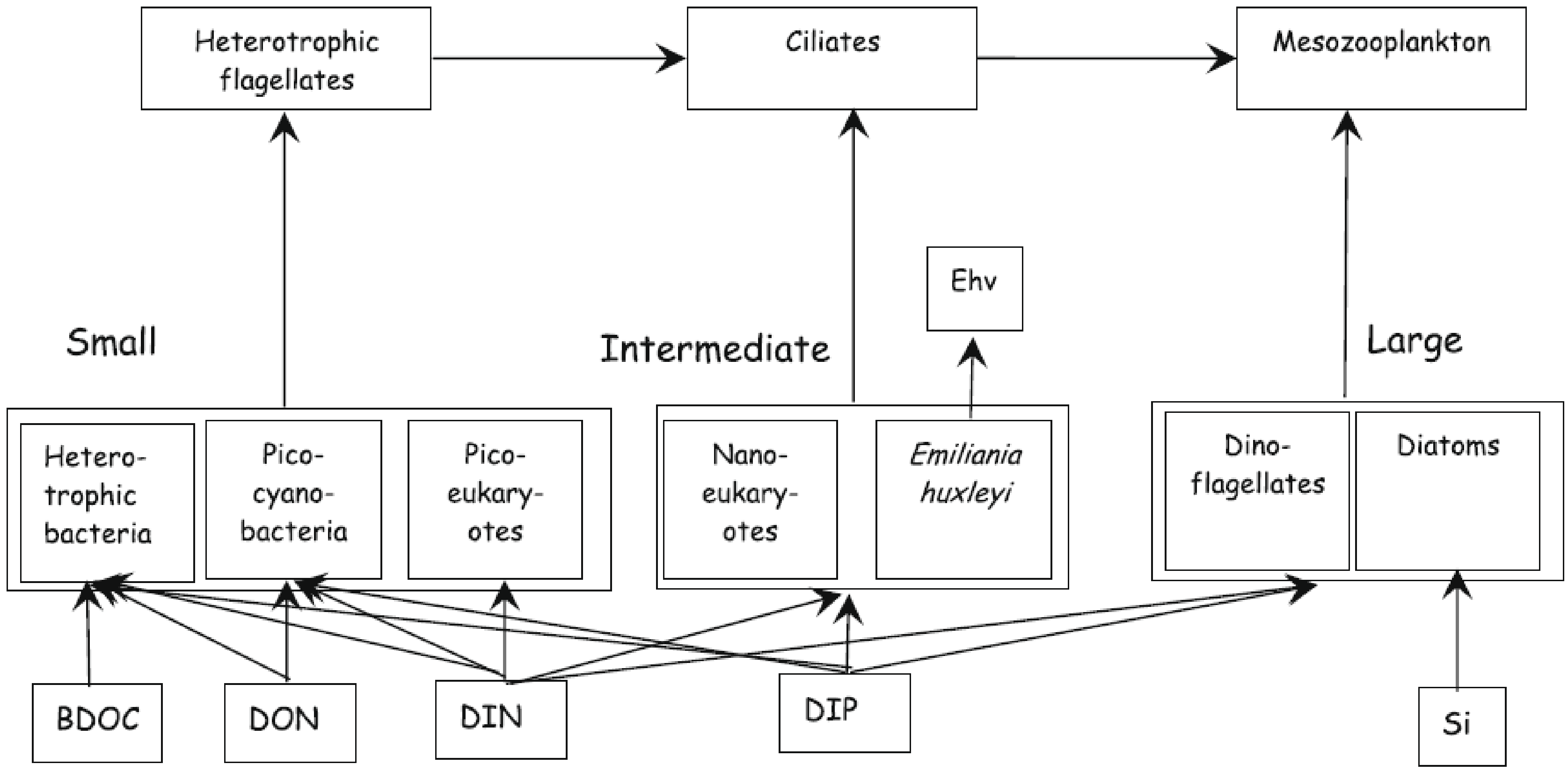
We urge restraint in using end-to-end models in a true forecasting mode until we know more about their performance. …

End-to-end modeling is in its early developmental stages and thus presents an opportunity to establish an open-access, community-based approach supported by a suite of true interdisciplinary efforts.

Rose & al 2010. End-To-End Models for the Analysis of Marine Ecosystems: Challenges, Issues, and Next Steps. Marine and Coastal Fisheries 2:115-130

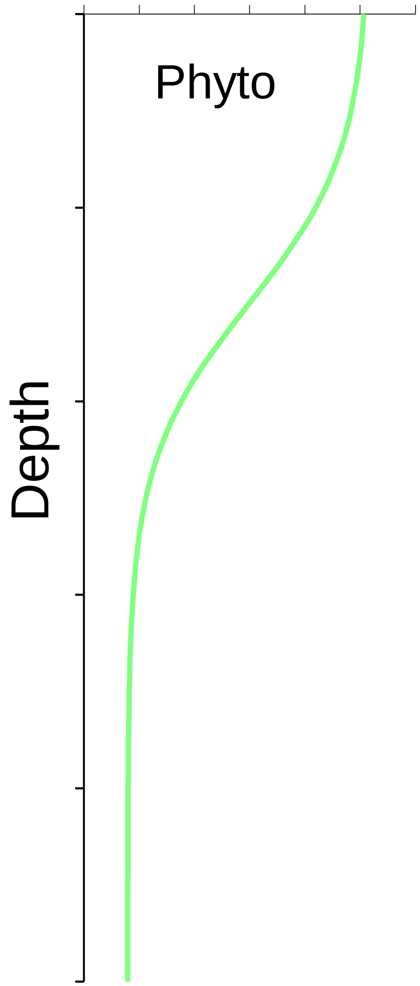

E2E

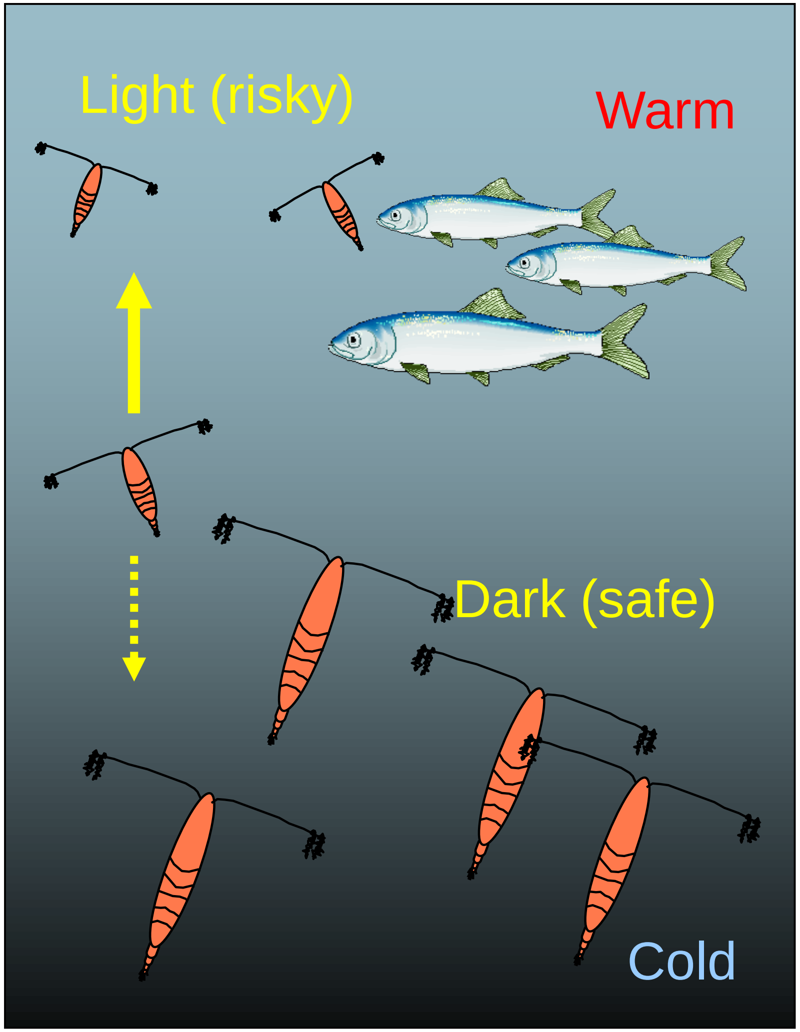
Traits, trade-offs and less complex models?



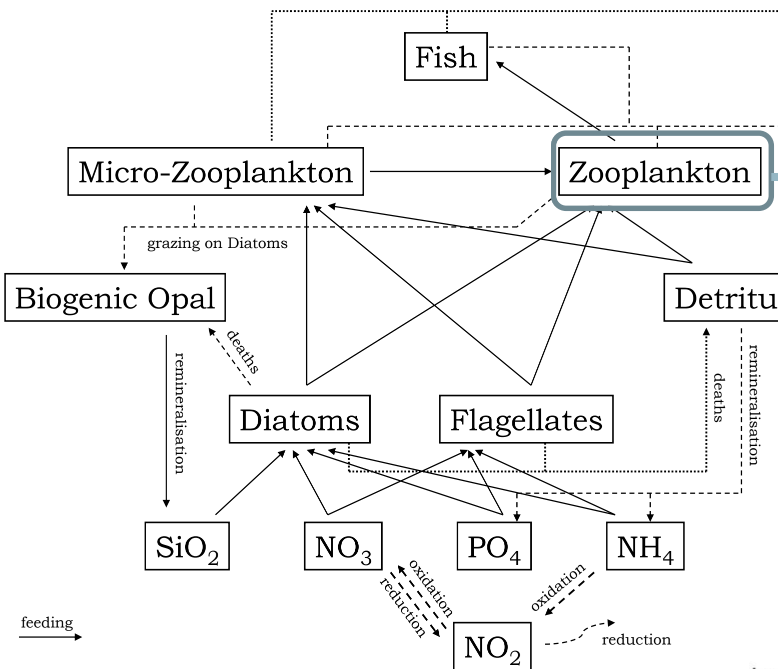
Thingstad et al. 2010. Stepwise building of plankton functional type (PFT) models: A feasible route to complex models? Prog Oceanogr 84:6-15.

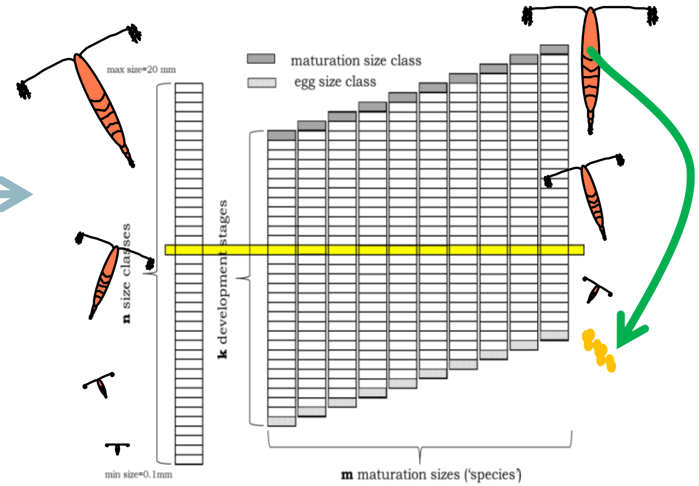
Spatial gradients and ‘risk sensitivity’

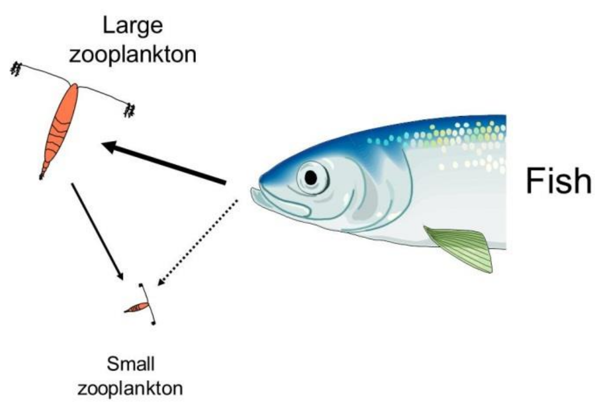


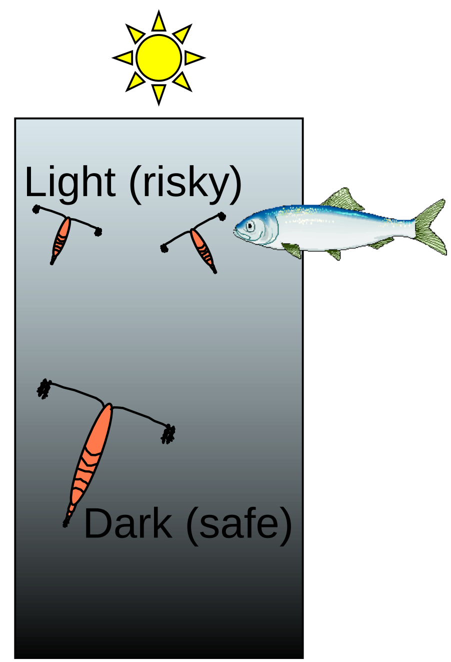


A mass-balanced pelagic ecosystem model with size-structured behaviourally adaptive zooplankton and fish









Castellani, Rosland, Urtizberea, Fiksen. 2013. Ecological Modelling

An ecosystem model with behavioural cascades