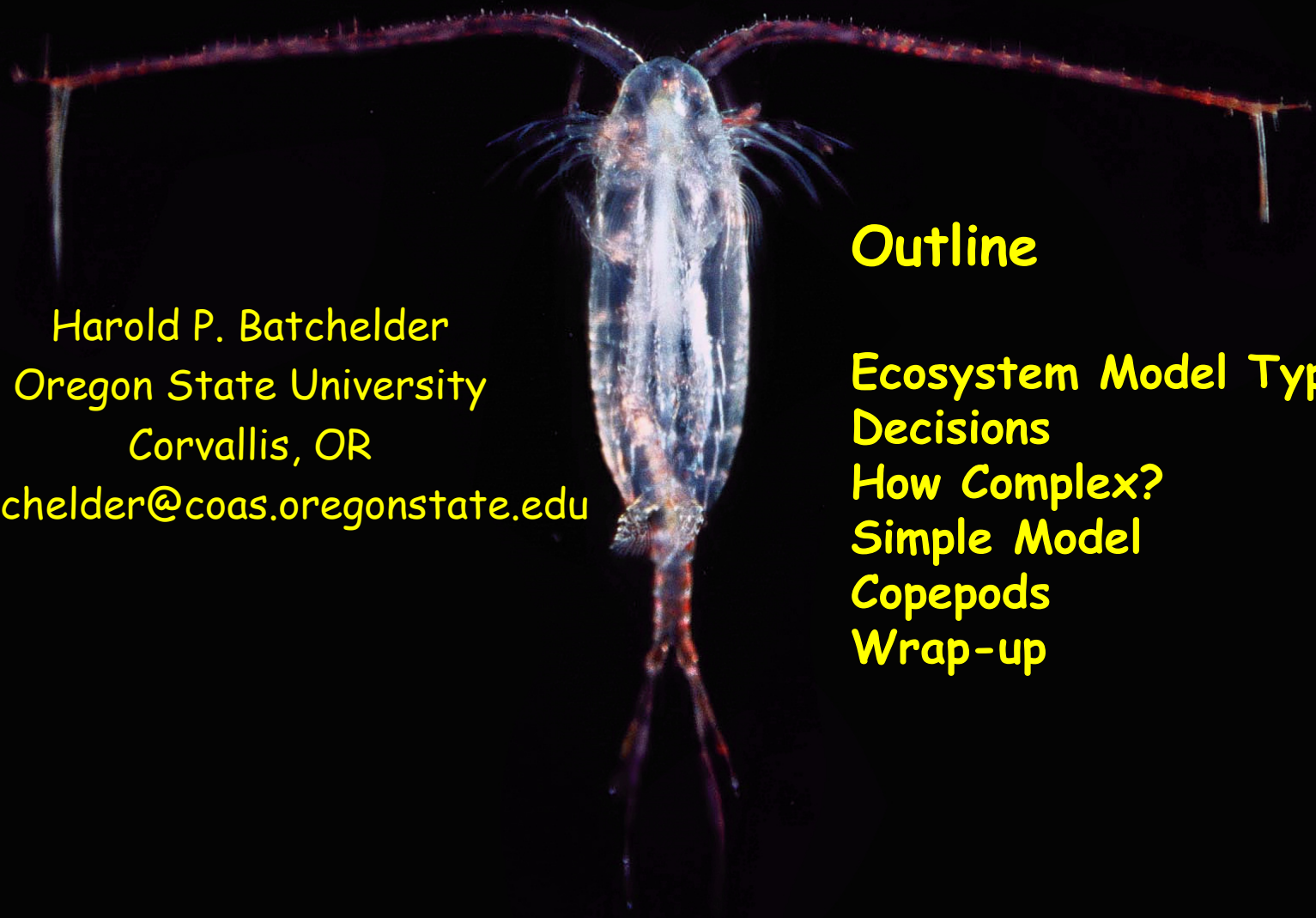
Copepods as indicator species for comparing pelagic ecosystem models



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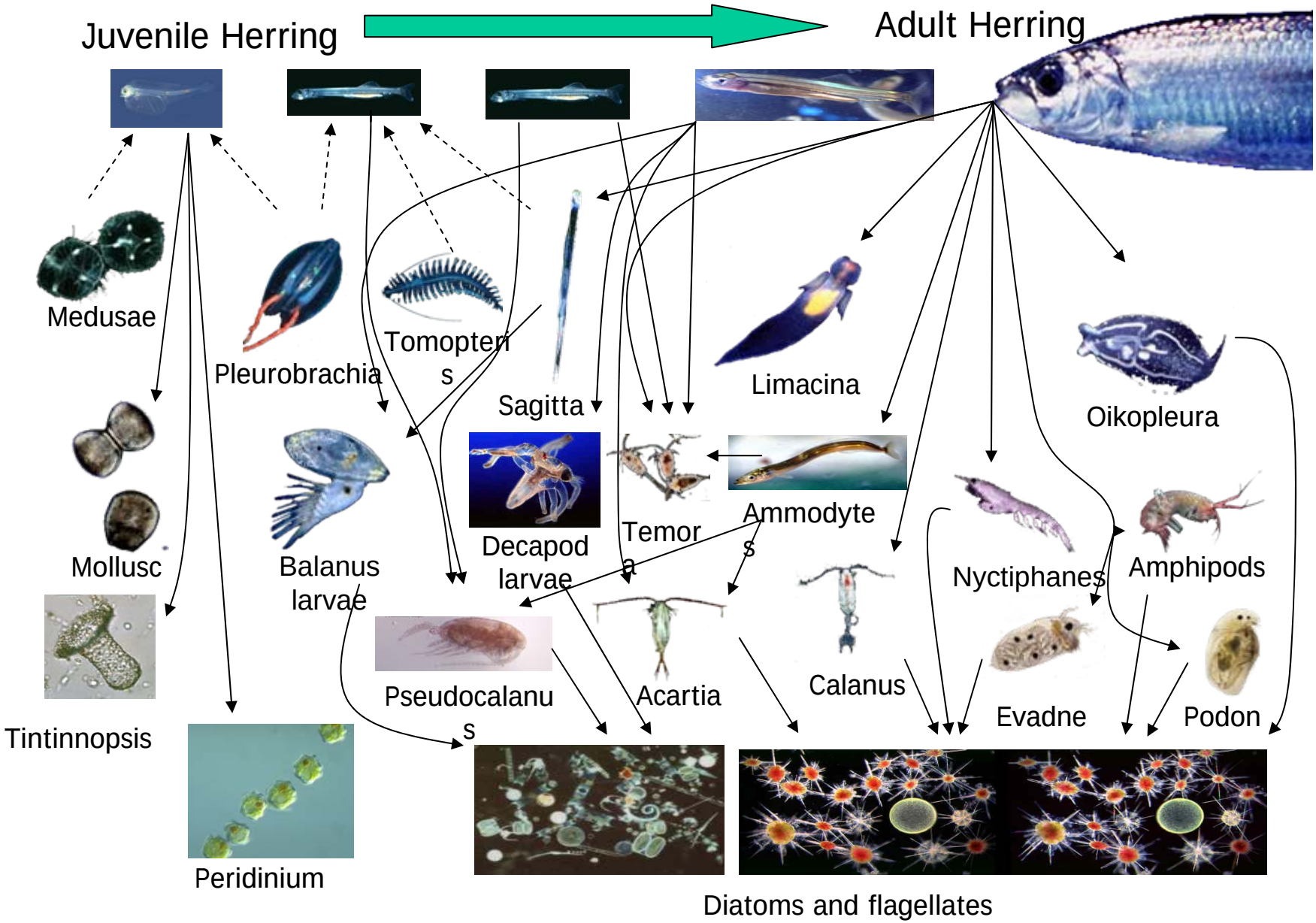
Outline

Ecosystem Model Types
Decisions
How Complex?
Simple Model
Copepods
Wrap-up

Image from Uwe Kils

A Sketch of Herring Population Model (from A.C. Hardy, 1924)



One Hierarchical Structure of Biological & Ecosystem Models

Eulerian

- Ecosystem
  - Pelagic LTL
    - Functional Groups
      - Few

        Single compartment States (e.g., Fasham et al, 1990; Spitz et al. 2003)

        Multi compartment States
      - Many (e.g., stage-based models)
    - Taxonomic-based Groups
      - Simple/Few spp.
      - Complex/Many spp.
    - Size-based Groups (e.g., Moloney and Field,1991; Carr 1998; Gin et al. 1998)
  - Coupled pelagic-benthic (e.g., Lancelot et al., 2005)
  - Coupled LTL – HTL (e.g., recent NEMURO herring effort; Megrey et al. in press)
- Biogeochemical
  - Carbon Export and Production Models (e.g., Moore et al., 2002, 2004)
  - Oxygen/Water Quality Models

Lagrangian

- Age/Stage-structured
- Individual-based
  - Uncoupled to LTL (particle tracking only; e.g., Fox et al. 2006)
  - Coupled to LTL (particle tracking & vital rates; e.g., Batchelder et al. 2002)

Decisions, decisions, decisions…

Nutrients: How many (1 to full N,P,C,Si,Fe) ?

Phytoplankton: How many? Functional groups or species? State variables per functional group?

Zooplankton: How many? Functional groups, species, by size? How is prey selection specified? Refuges for prey?

Microbial: How complex?

Nitrogen fixation?

Detritus: How many classes? Biodegradability of each? Sinking rate of each?

DOM: How many? Biodegradability?

Carbon:Chlorophyll or Nitrogen:Chl ratio of P fixed or time-space variable?

Nutrient Ratios of P & Z fixed at Redfield or time-space variable?

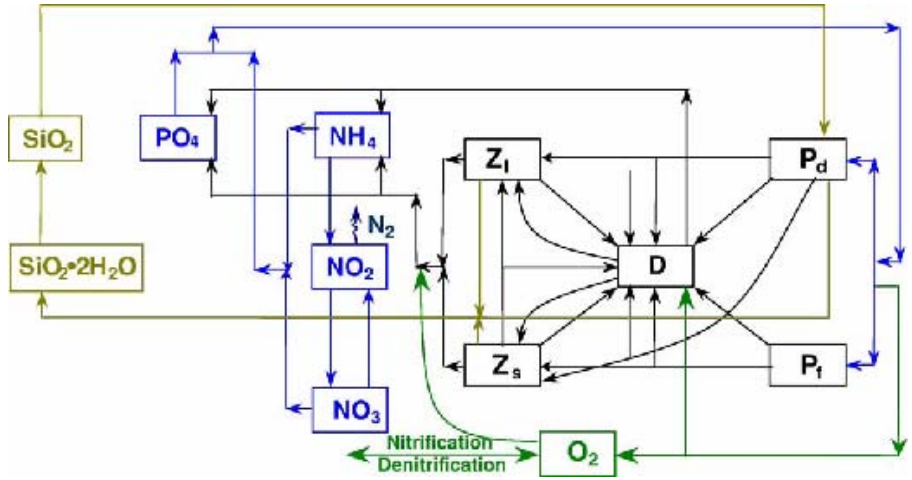
Animal behavior/movement: Important or not?

Benthos: How complex?

Schrum et al. (J.Mar.Syst. 2006)

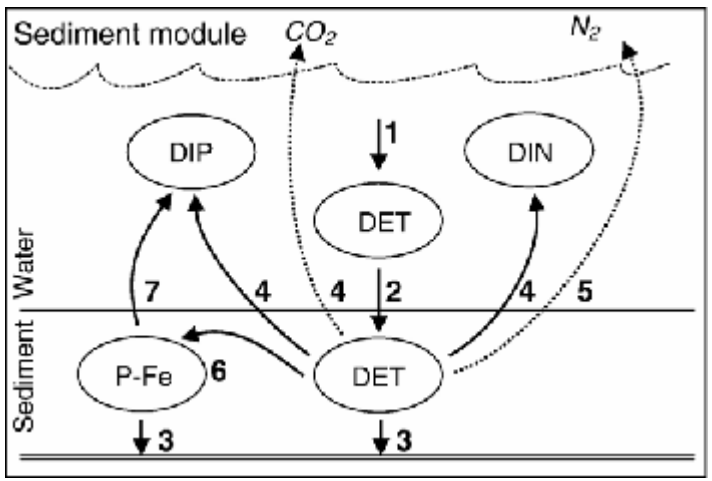
Multiple Nutrient (N,P,Si,C)

ECOSMO. blue line represents the pathways of the nutrients nitrogen and phosphorus; green line represents the pathways of oxygen; the black line is the flow of organic carbon; the brown line represents the pathways of silica.



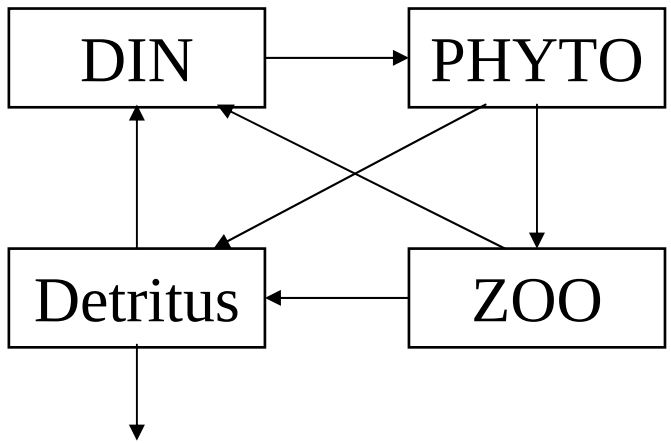
Kiirikki et al. (J.Mar.Syst. 2006)

Sediment/benthic Processes.

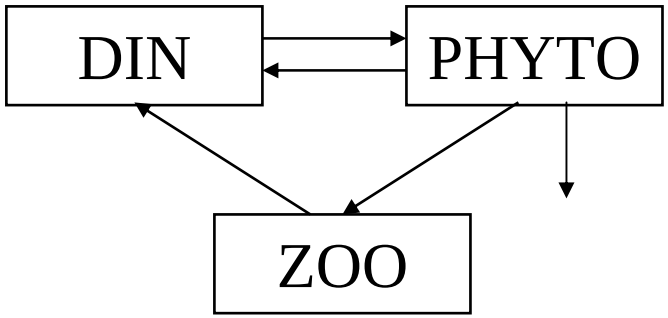


Denman and Peña (1999)

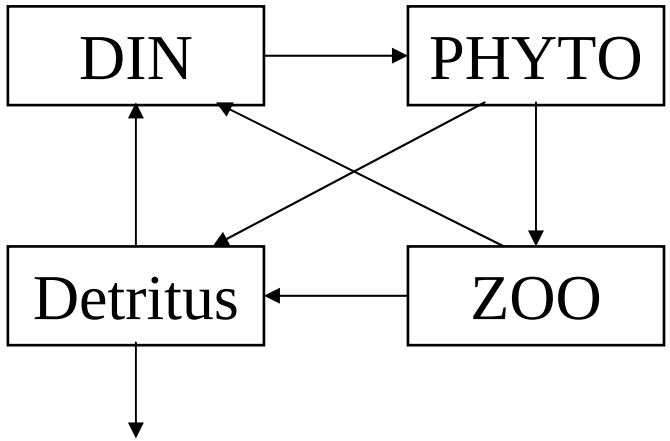
Few compartment FUNCTIONAL NPZD model.

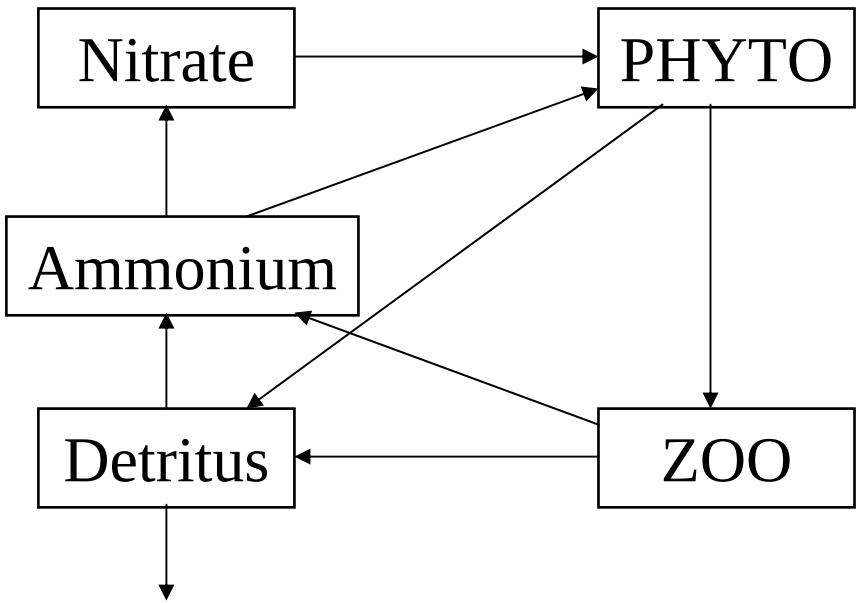


Franks et al. (1986)



Denman and Peña (1999)



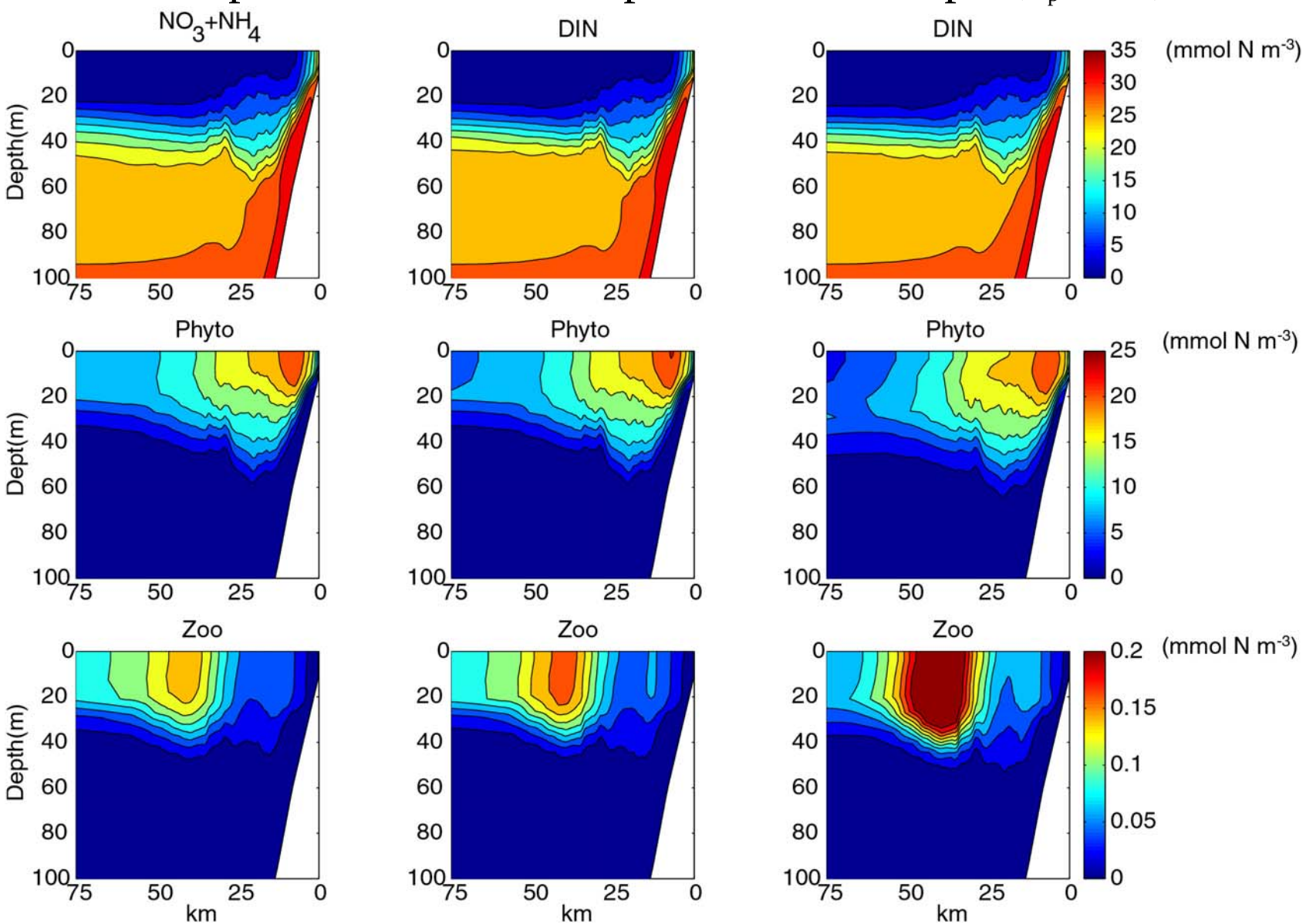


Wroblewski (1977)

DIN=Nitrate+Ammonium

Three models compared in Spitz et al. (2003)

Mean from July 8 to August 16, 1999



Three models compared in Spitz et al. (2003)

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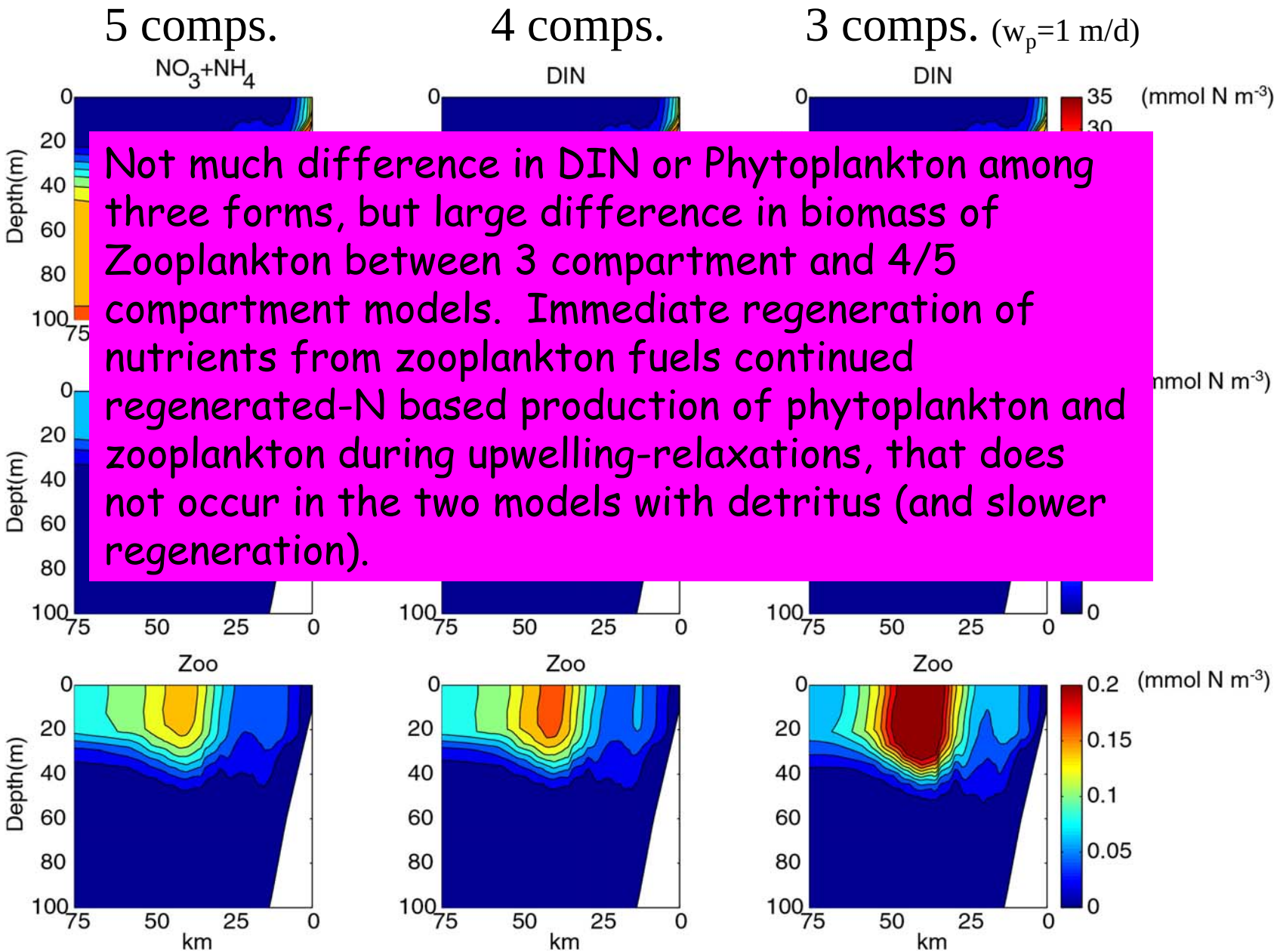
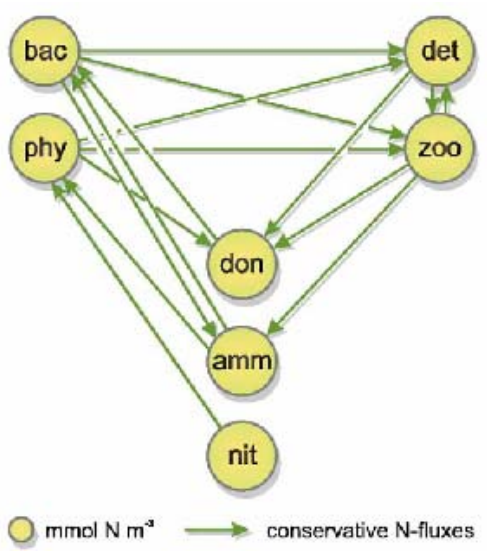
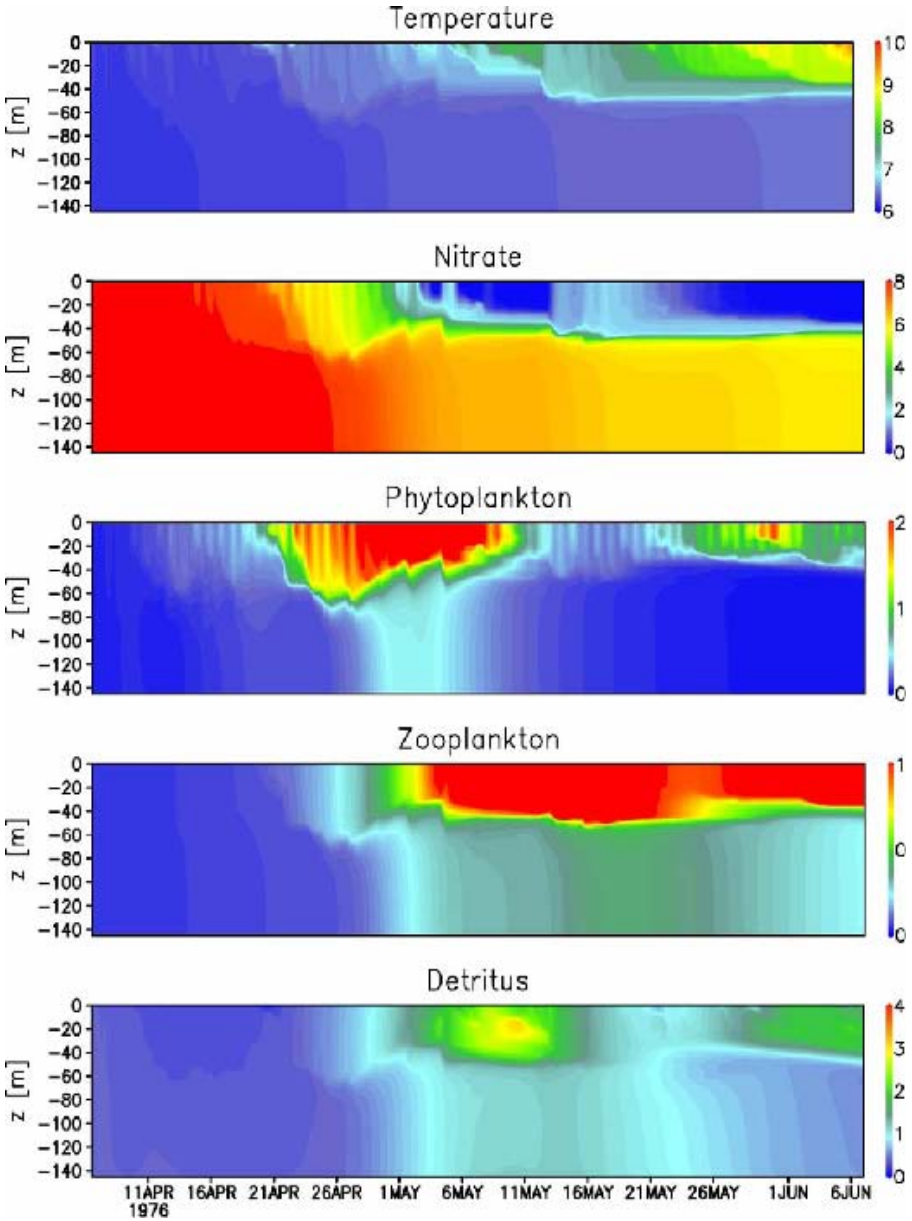


Three models compared in Spitz et al. (2003)

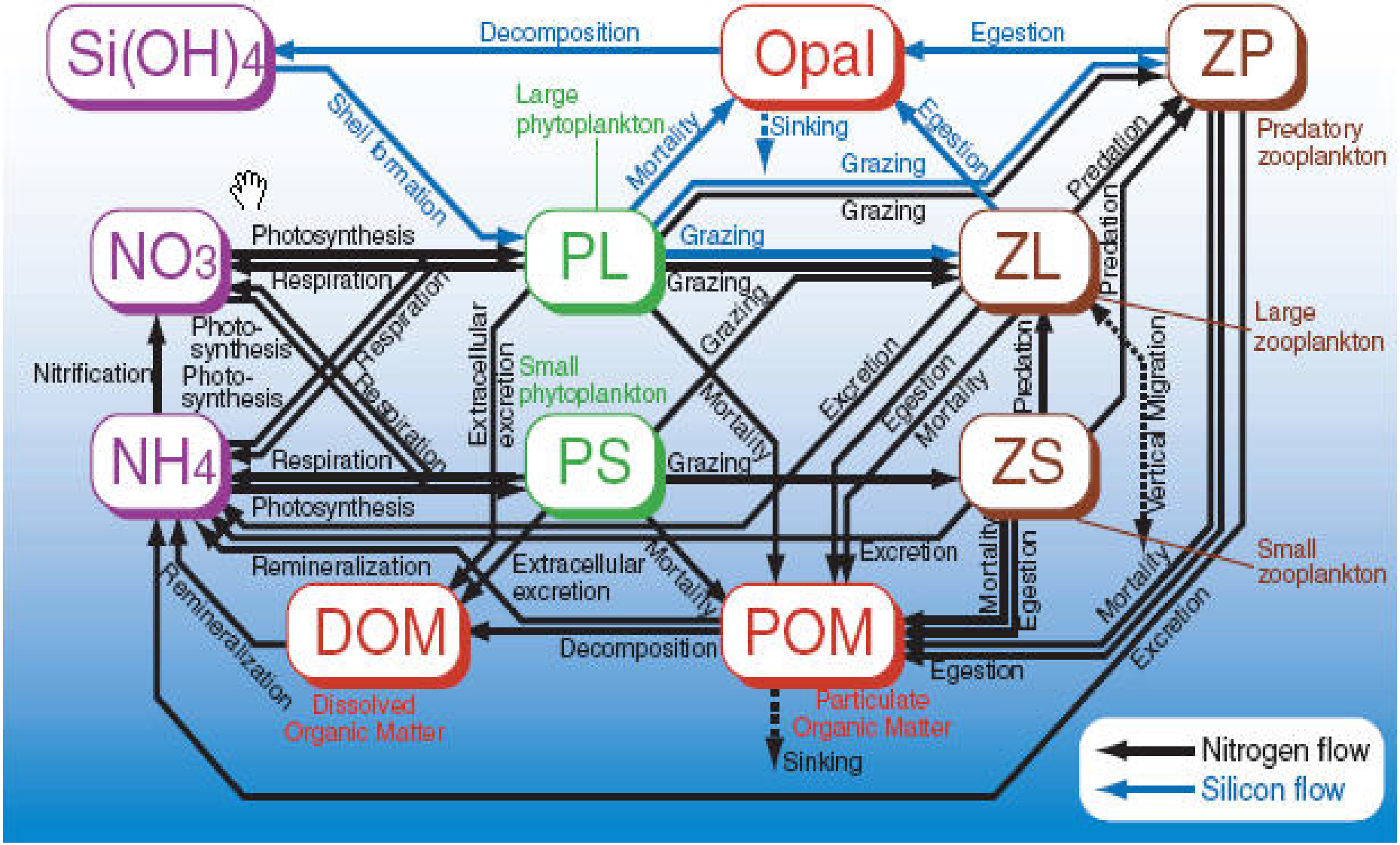
"Fasham type" model of the Northern North Sea





Burchard et al. (J. Mar. Syst., 2006)

North Pacific Ecosystem Model for Understanding Regional Oceanography (= NEMURO)



Moore et al. 2002. An intermediate complexity marine ecosystem model for the global domain. DSR2, 49, 403-462.

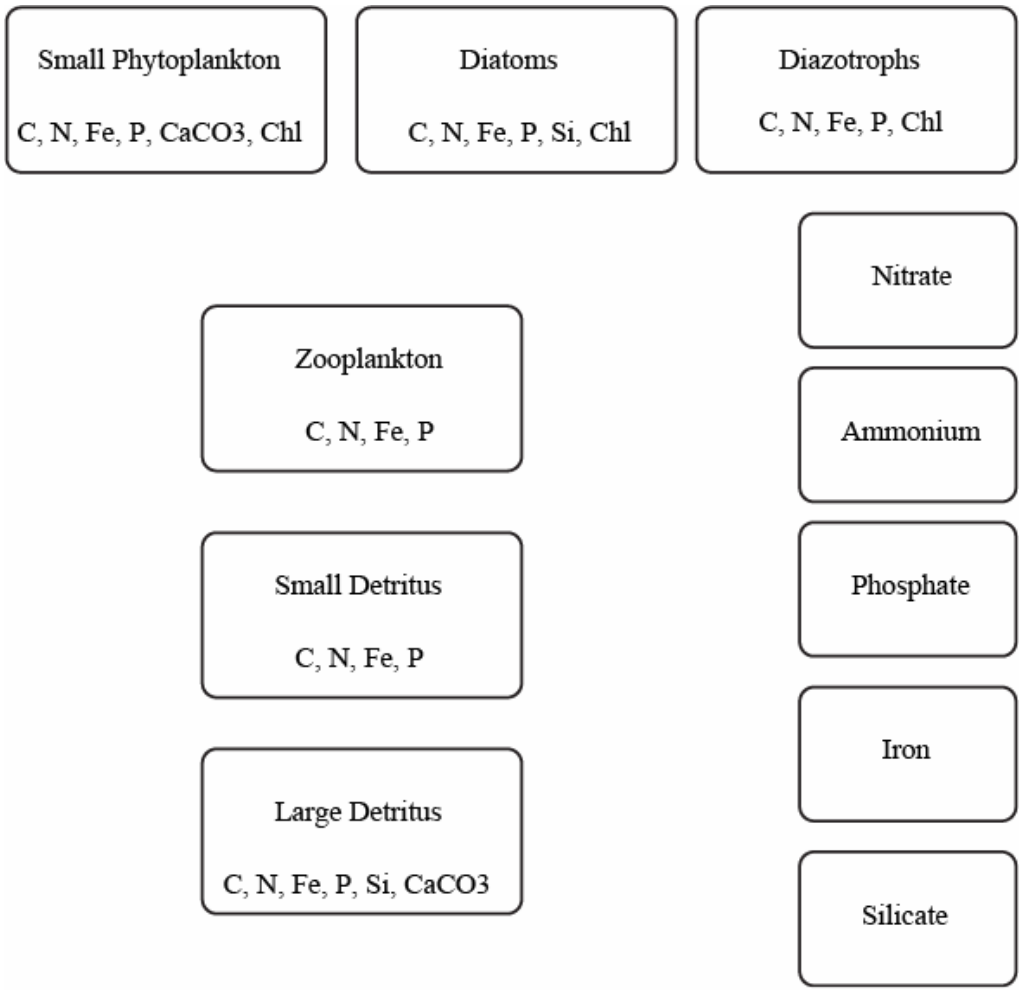


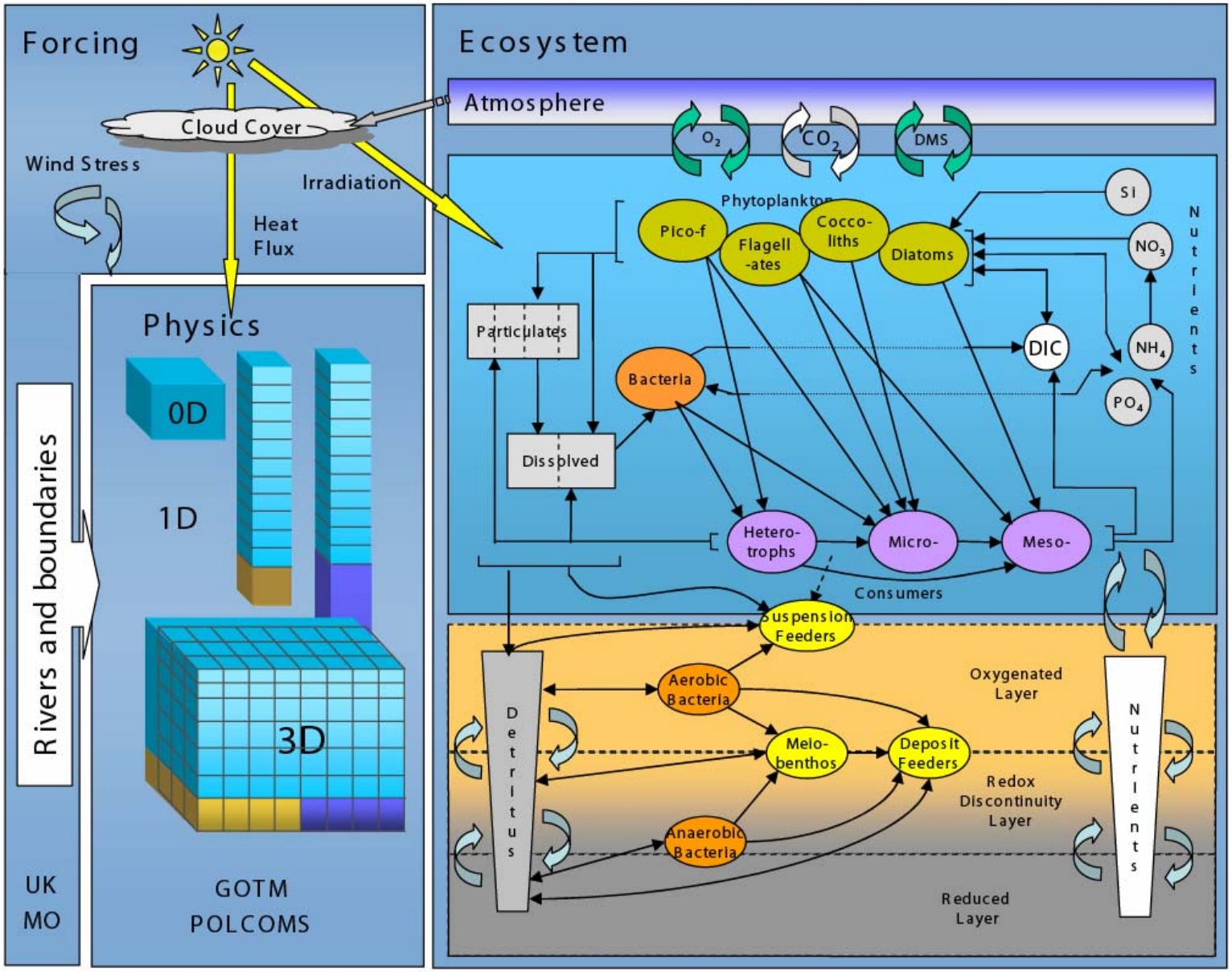
Fig. 1. Schematic summary of the marine ecosystem model components.

N5P3ZD2 – 11 "boxes"

But with separate internal "pools", a total of 36 dynamic states.

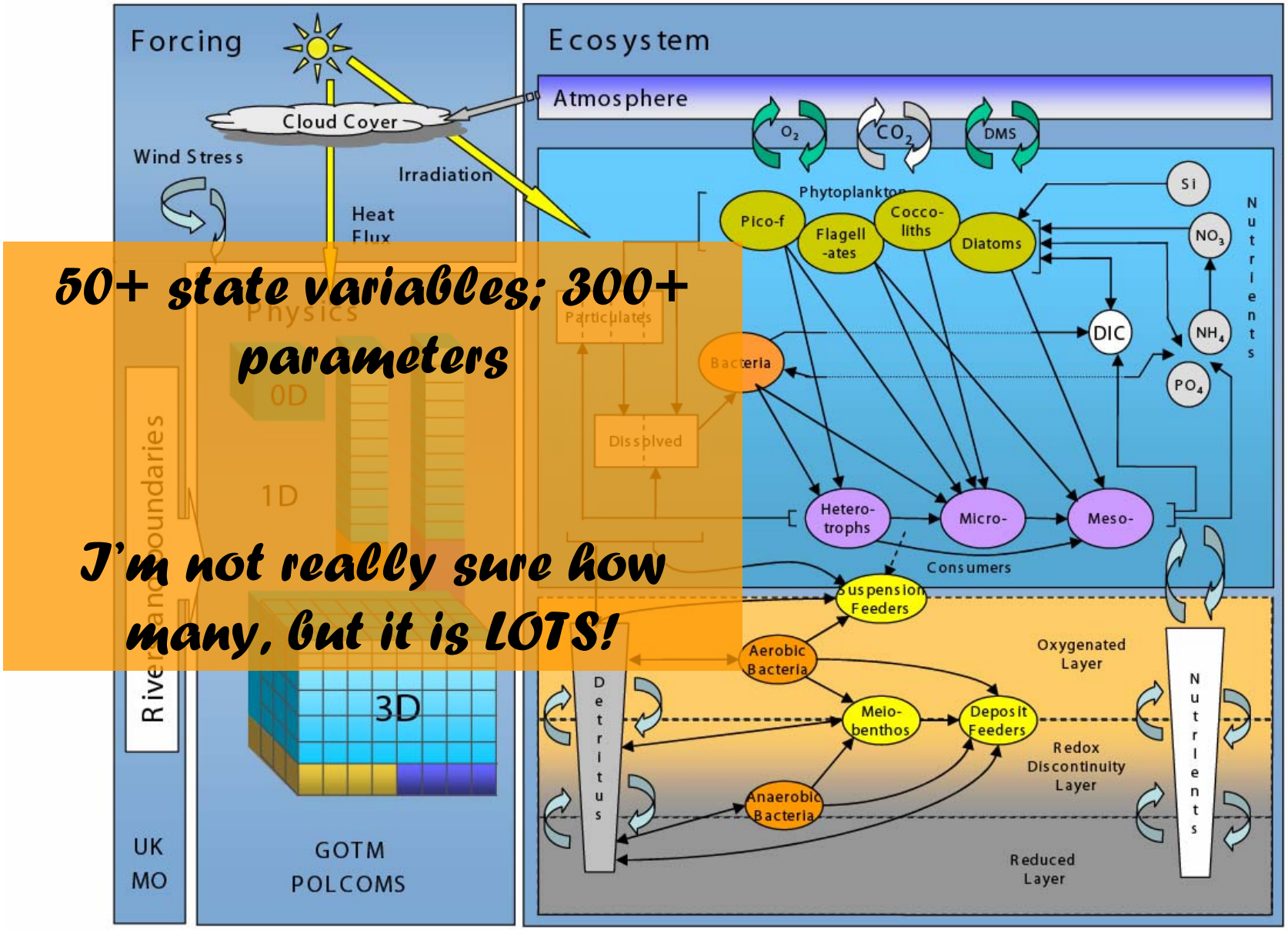
Multi-nutrient limitation, sinking and non-sinking detritus, with nutrient specific remineralization rates, DOM included in Ds; includes photoacclimation of [chl]

Would not be the appropriate model for examining "fish food" or "zooplankton spp. composition" or for examining carbon export on shelves.



Plymouth Marine Laboratory

ERSEM model schematic



50+ state variables; 300+ parameters

I'm not really sure how many, but it is LOTS!

Plymouth Marine Laboratory

ERSEM model schematic

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Why focus on copepods?

Metridia pacifica, from dfo-mpo website

Euchaeta elongata female
life.bio.sunysb.edu/marinebio/pl_25.jpg

Neocalanus plumchrus adult female
http://tnfri.fra.affrc.go.jp/personal/HP_E/index_e.html

Acartia hudsonica, from dfo-mpo website

http://www.todayinthegulfofmaine.com/?p=221

Calanus finmarchicus, from Erica Head

Diversity – No. of Species

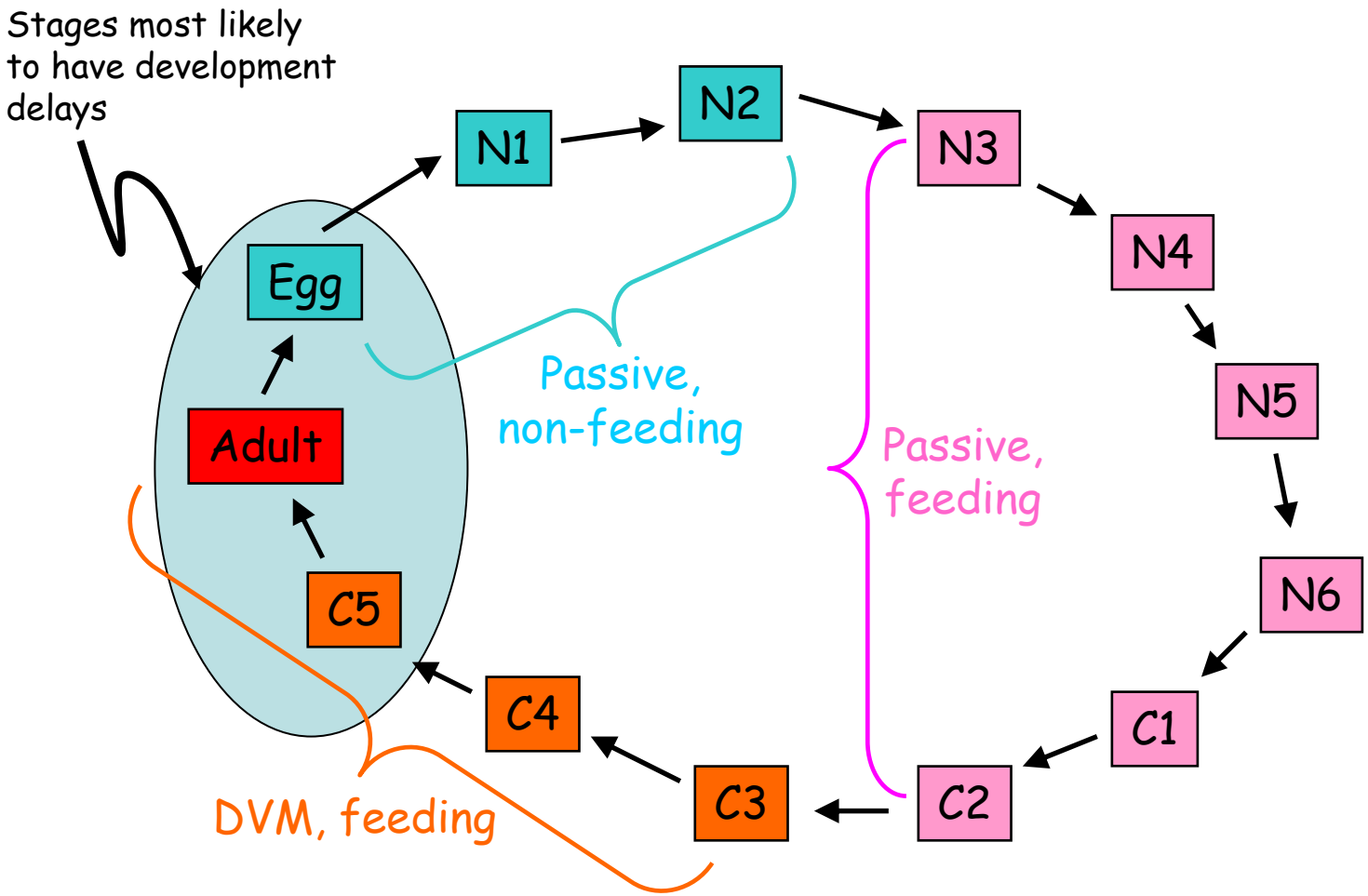
Phyla	Group	World diversity
Cnidarians	hydromedusae	650
	siphophores	190
	scyphozoans	150
Ctenophores		80
Nemertines		97
Annelids	polychaetes	120
Mollusks	heteropods	35
	pteropods	160
	cephalopods	370
Crustaceans	cladocerans	8
	ostracods	169
	copepods	2000
	mysids	700
	amphipods	400
	euphausiids	86
	Decapods	?
Chaetognaths		80
Tunicates	appendicularian/larvacean	64
	pyrosomes	8
	dolioids	17
	salps	45

(from Ocean Exploration website)

Free-living copepod habitats

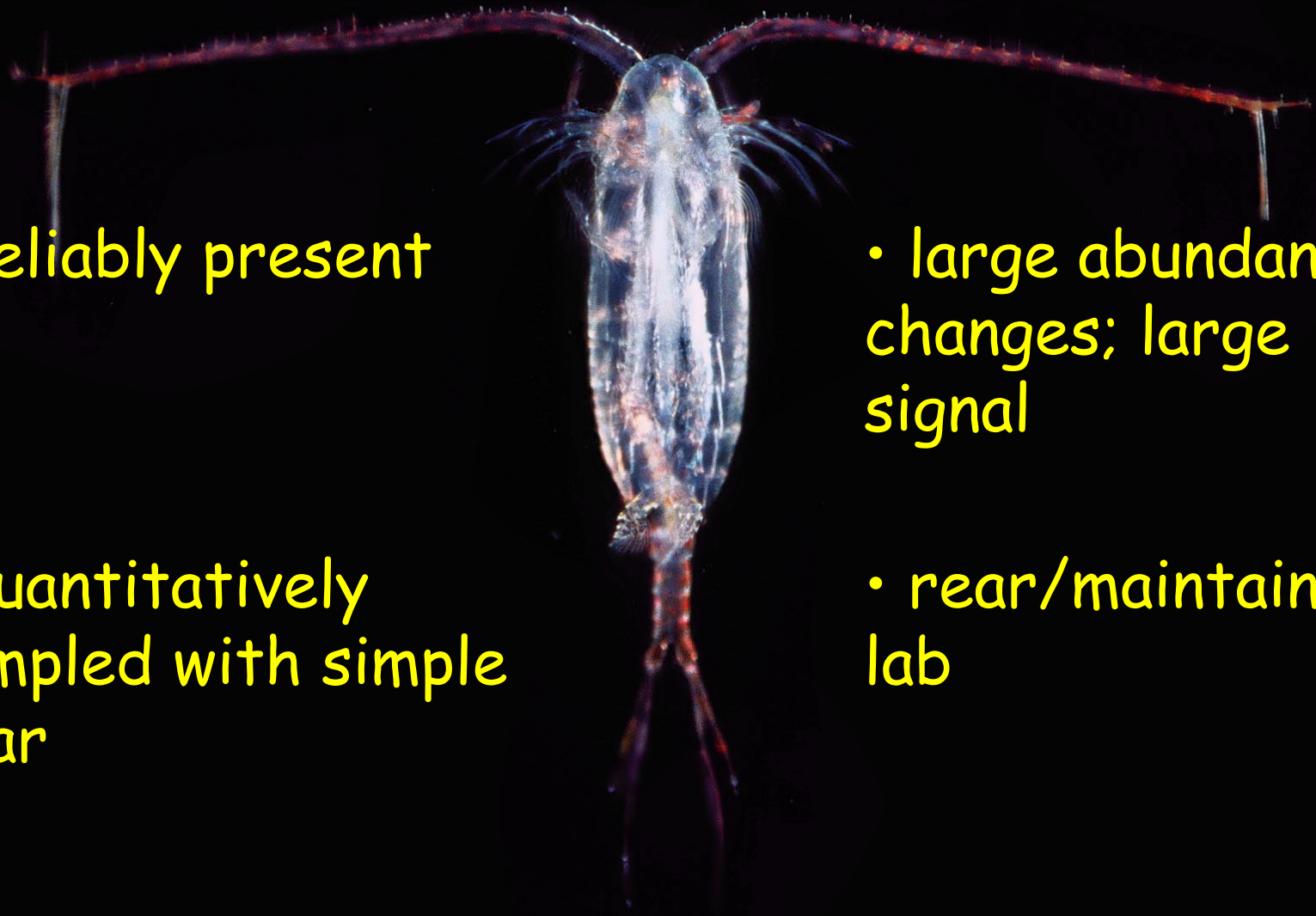
- Fresh-water
- Brackish estuaries/fjords
- River plumes
- Coastal/Shelf
- Oceanic; surface to bottom
- Marine caves
- Neuston
- Under/assoc. w/ ice
- Hyperbenthic

Calanoid copepod life-cycle, important events & idosyncrasies



Copepods for comparing ecosystem models

Advantages - logistics



- reliably present
- large abundance changes; large signal
- quantitatively sampled with simple gear
- rear/maintain in lab

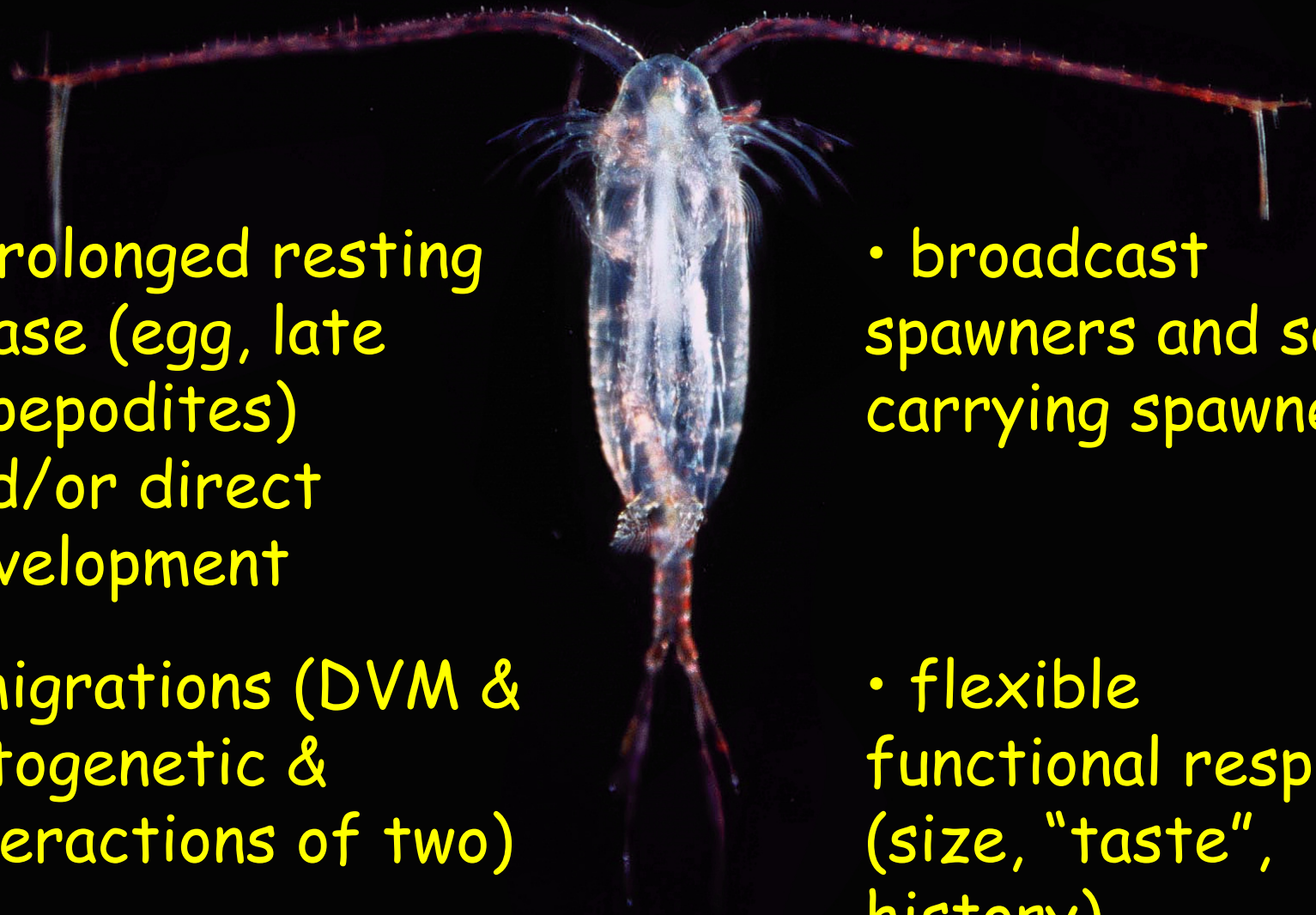
Image from Uwe Kils

Copepods are **hard-bodied**, just like the young Arnold Schwarzenegger.

They can take the abuse of plankton nets, even plankton nets, e.g., CPR, towed at 20+ knots, so there are long-term records of abundance (or relative abundance).

Copepods for comparing ecosystem models

Advantages – interesting diversity of life-history patterns

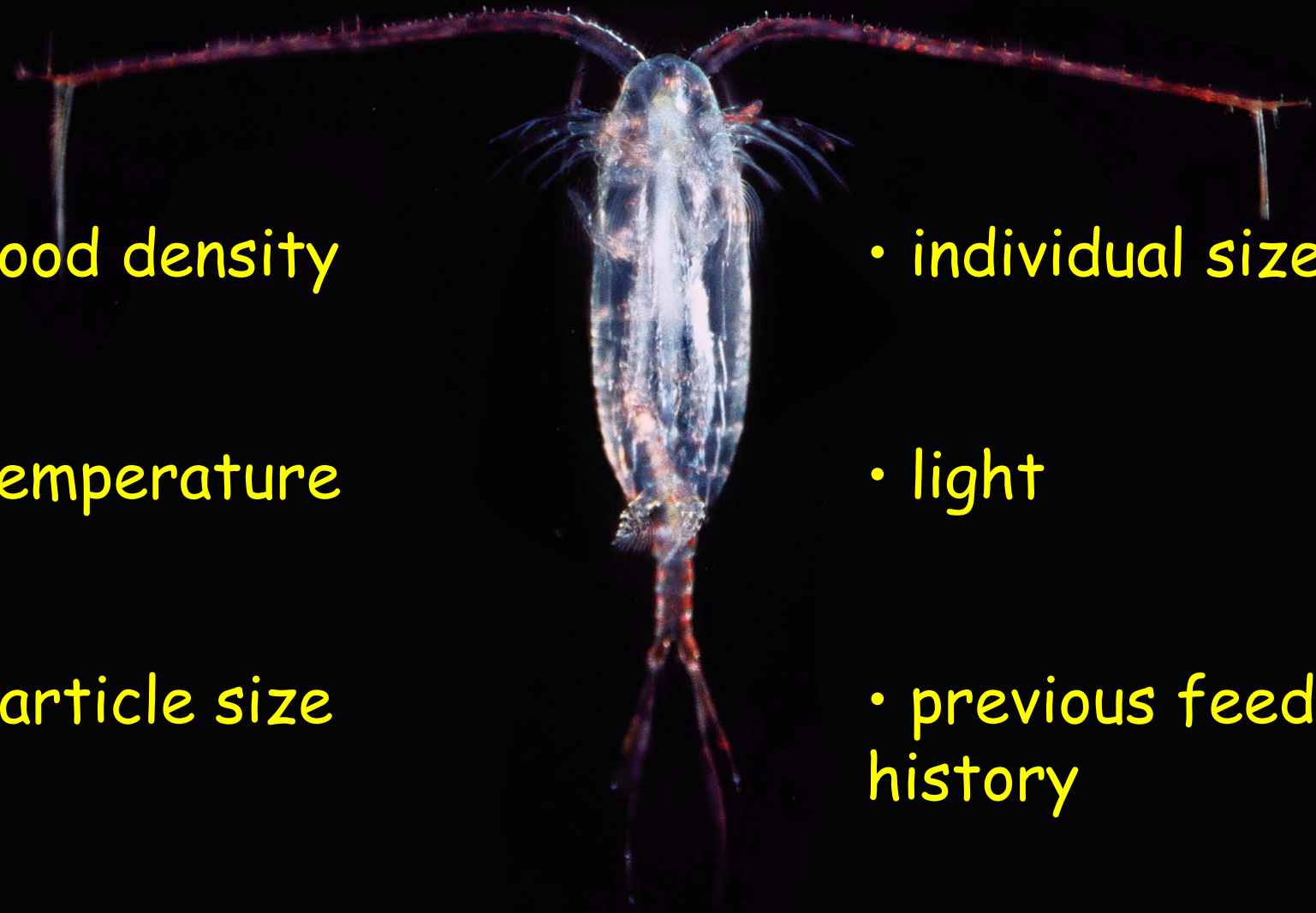


- prolonged resting phase (egg, late copepodites) and/or direct development
- migrations (DVM & ontogenetic & interactions of two)
- broadcast spawners and sac-carrying spawners
- flexible functional response (size, "taste", history)

Image from Uwe Kils

Copepods for comparing ecosystem models

Advantages – feeding functional responses well studied

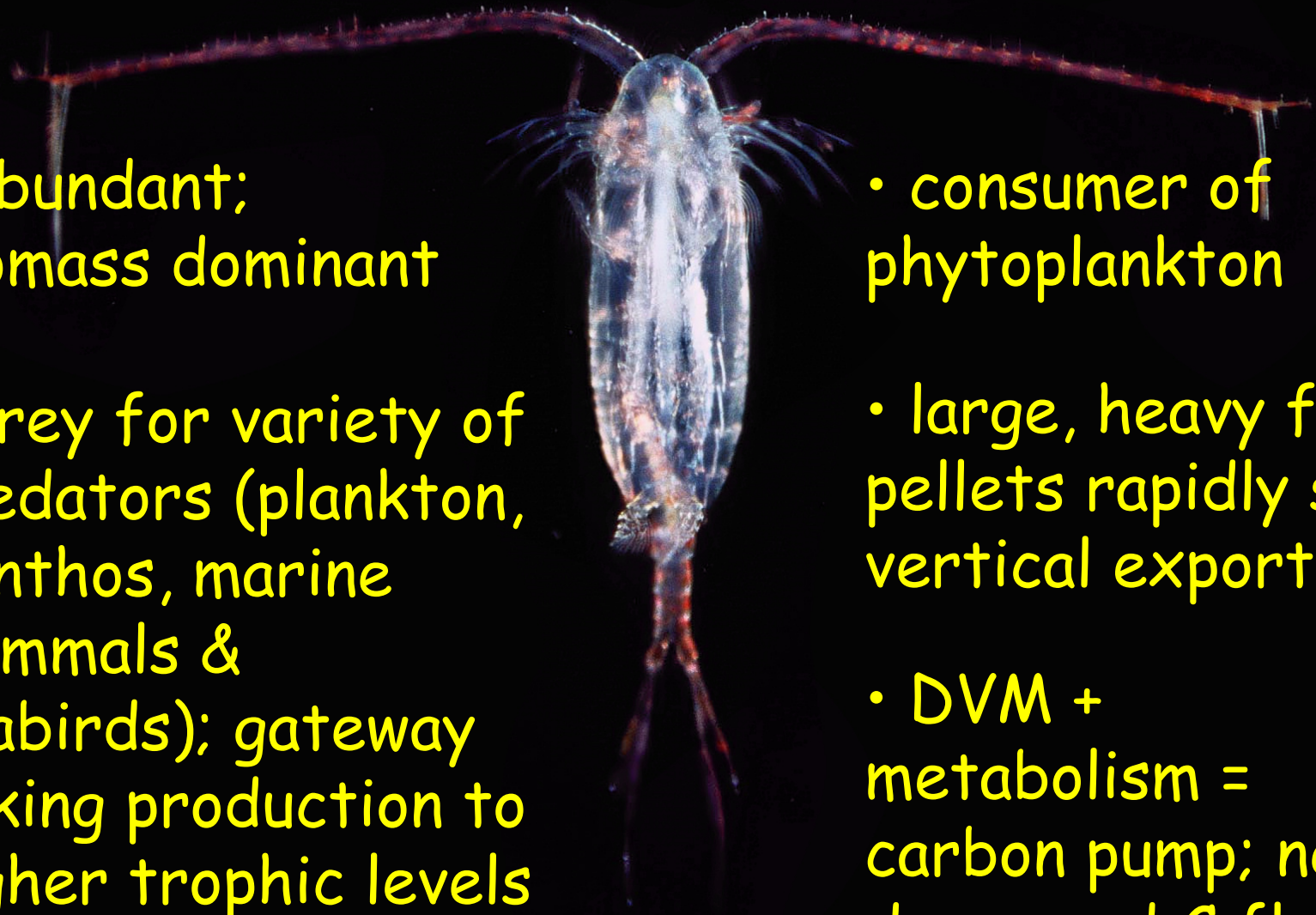


- food density
- temperature
- particle size
- individual size
- light
- previous feeding history

Image from Uwe Kils

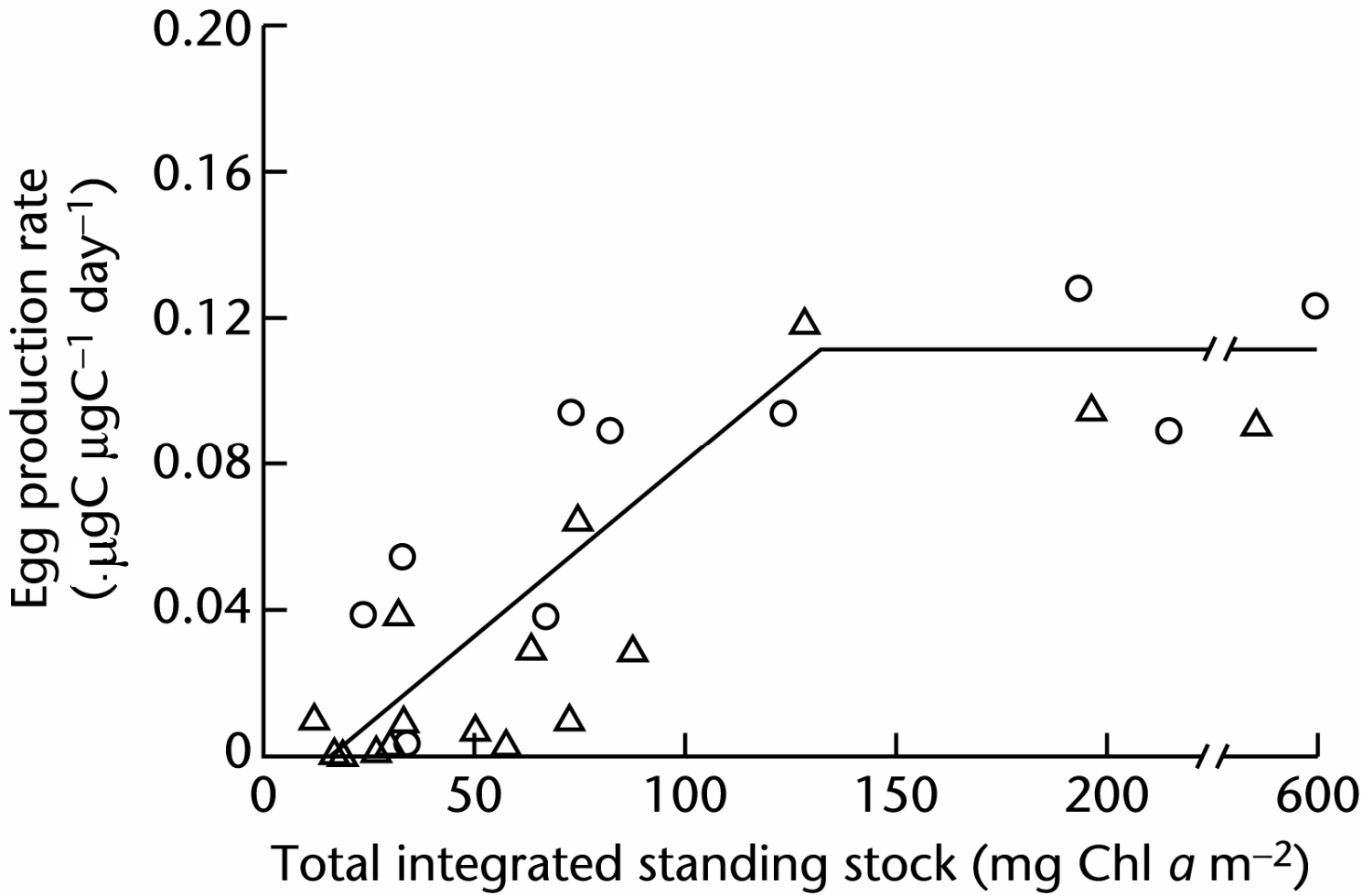
Copepods for comparing ecosystem models

Advantages – strong functional role in ecosystems

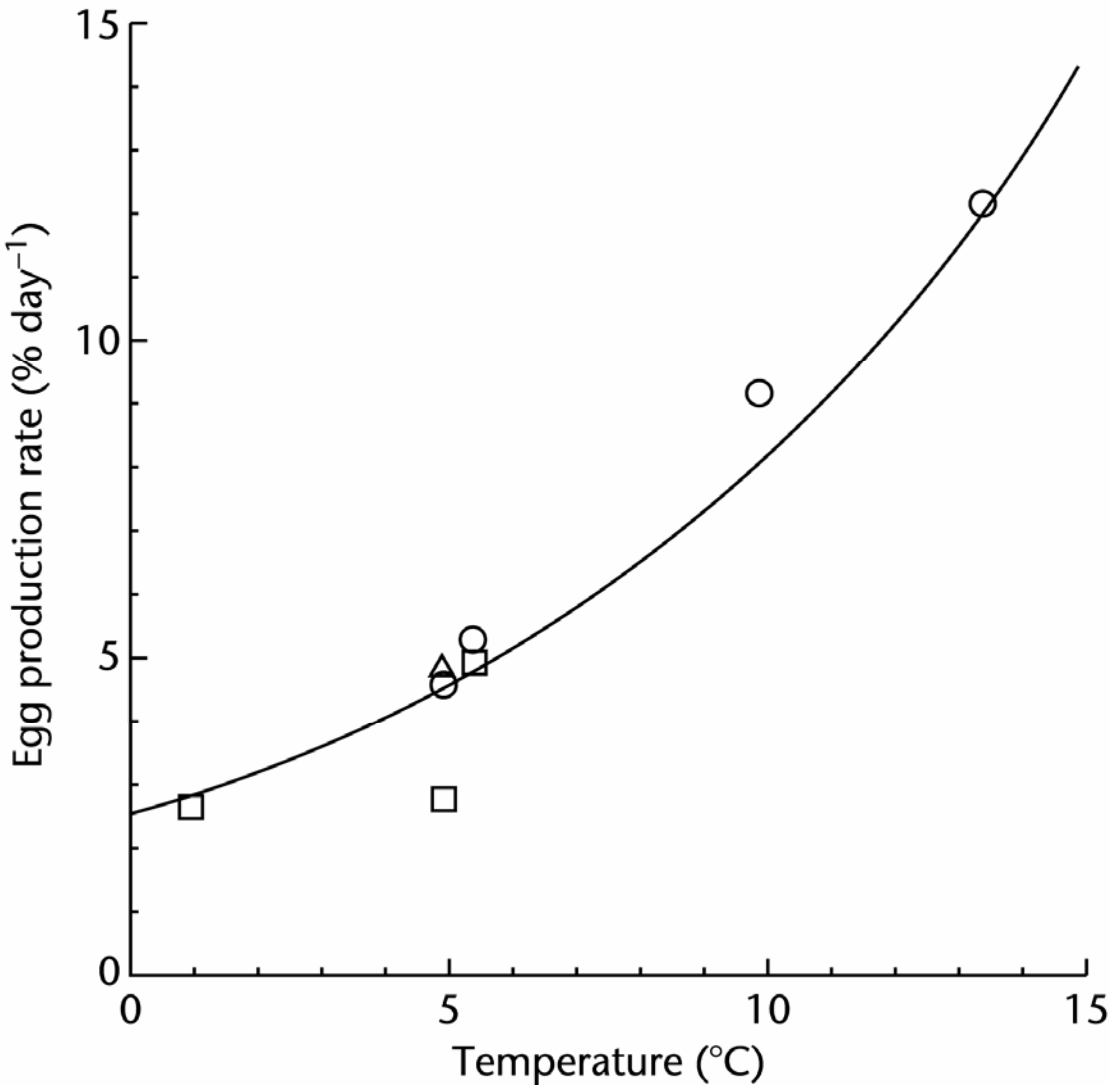


- abundant; biomass dominant
- prey for variety of predators (plankton, benthos, marine mammals & seabirds); gateway linking production to higher trophic levels
- consumer of phytoplankton
- large, heavy fecal pellets rapidly sink; vertical export
- DVM + metabolism = carbon pump; net downward C flux

Image from Uwe Kils

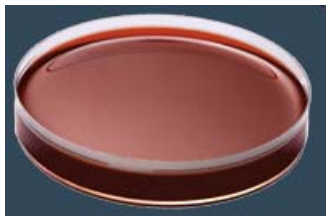


Egg production of *C. pacificus* in the day after capture vs. previous water column chl. After Runge 1985.



Maximum egg production rates as %C/day of *C. finmarchicus* females with surplus of several food types at different temperatures. After Runge and Plourde 1996.

Commercial harvest of copepods, esp. *Calanus finmarchicus* (off Norway)



Calanus oil; omega-3 rich diet supplement

'*Calanus* powder' - flavoring ingredient, aroma/taste of "Lobster"

Dried *Calanus finmarchicus*

So, why focus on copepods?

"Because it's there."
George Leigh Mallory
(March 1923)

"Because that's what's there."
Hal Batchelder
(October 2008)