

# **Role of zooplankton in marine ecosystems and modelling perspectives**

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UNIVERSITY OF SOUTHAMPTON AND  
NATIONAL ENVIRONMENT RESEARCH COUNCIL

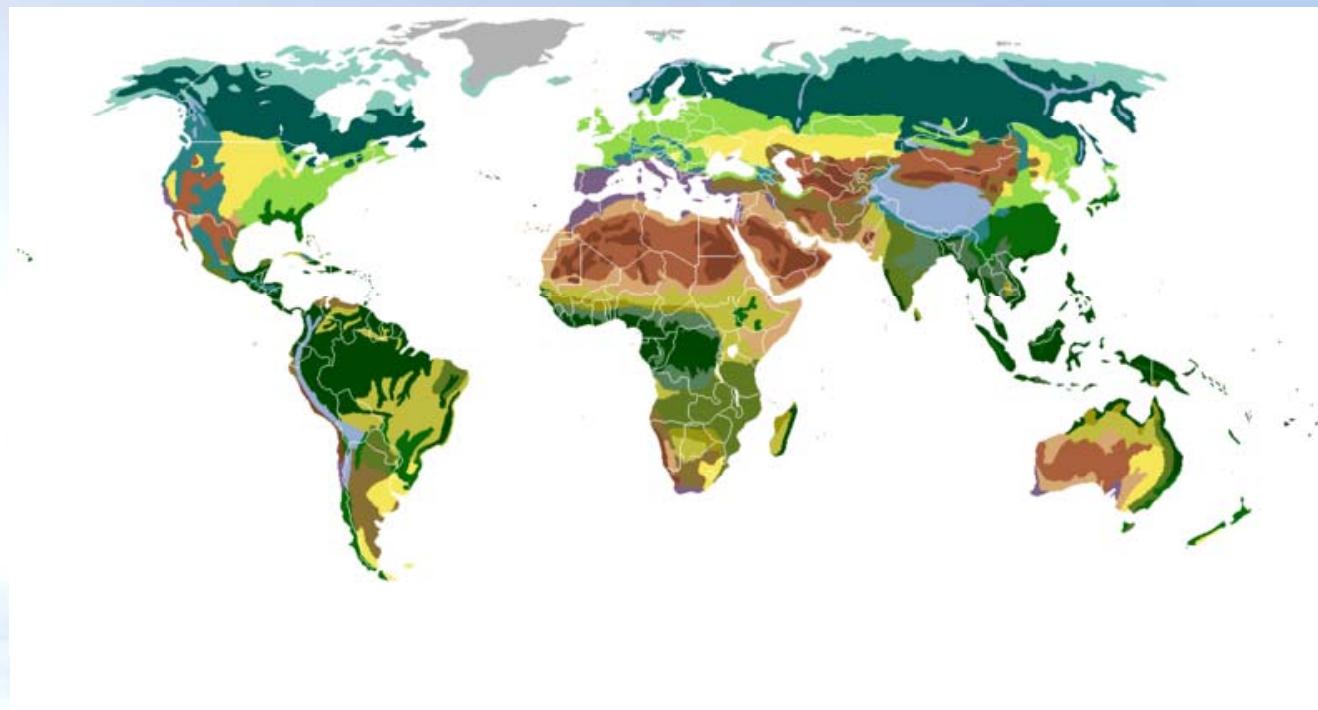
*ASP Researcher Workshop, NCAR  
Aug 6-10th 2013*

## Role of zooplankton in marine ecosystems and modelling perspectives

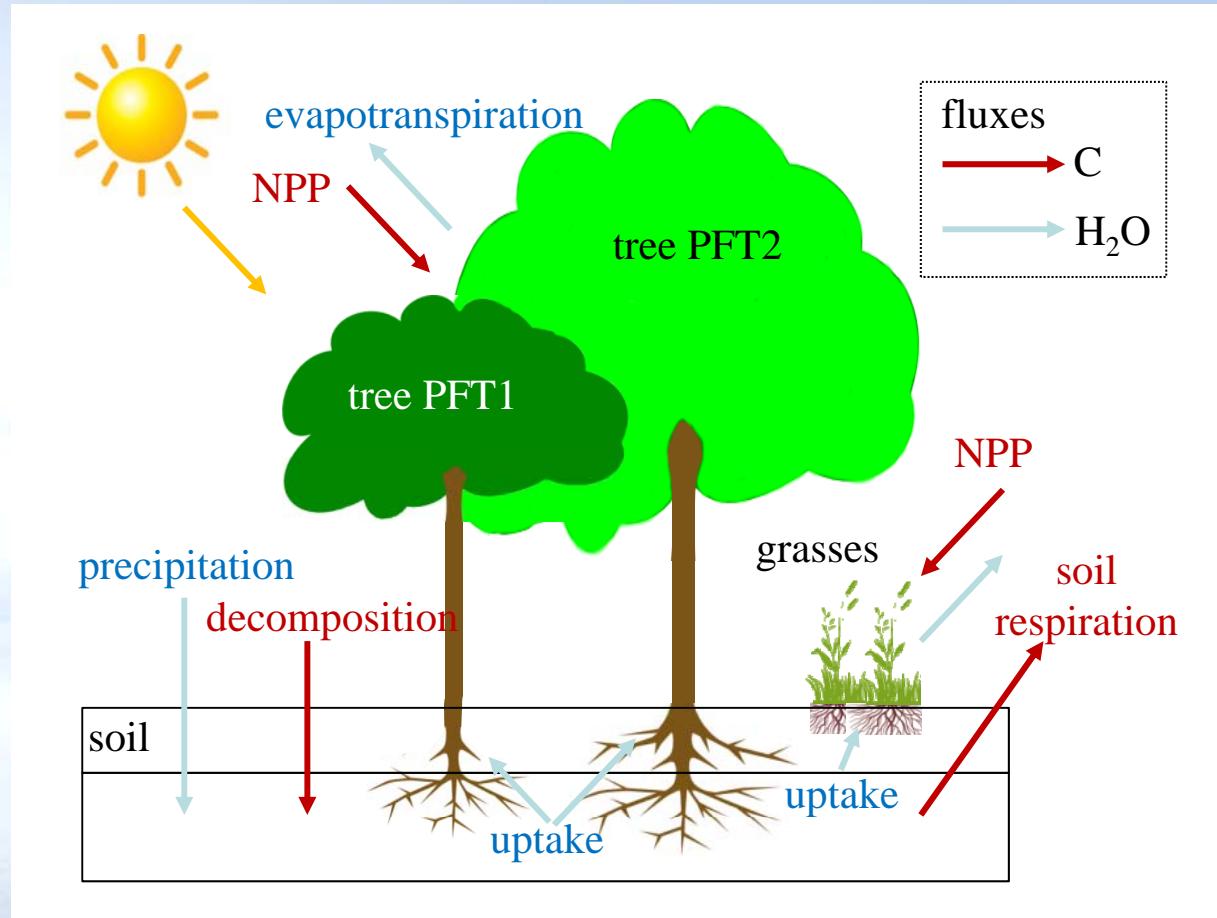
- ❖ Introduction: bottom up (BU) vs top down (TD) control of marine ecosystems
- ❖ Zooplankton control of phytoplankton blooms
- ❖ Zooplankton control of plankton community structure
- ❖ Modelling zooplankton: state-of-the-art

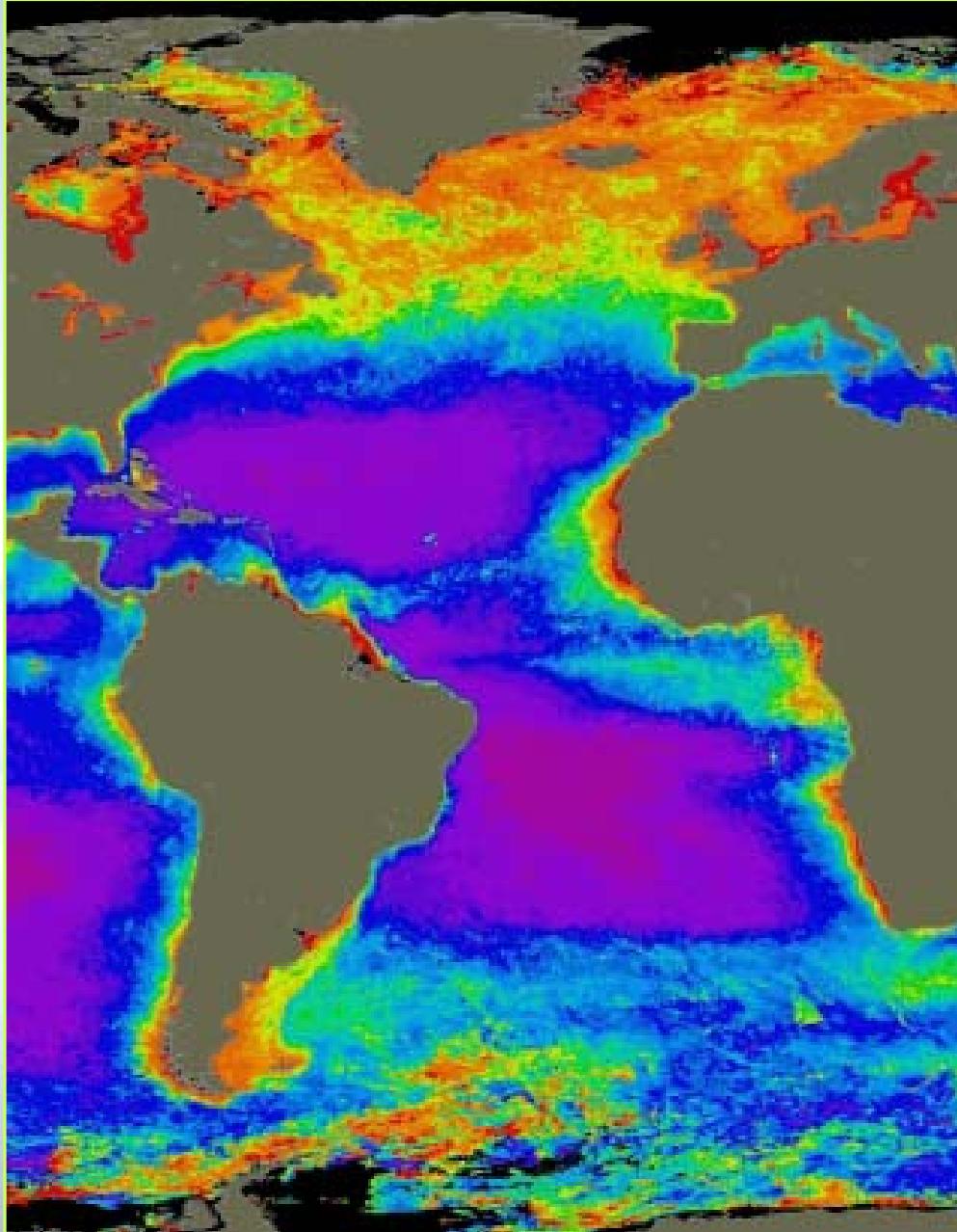
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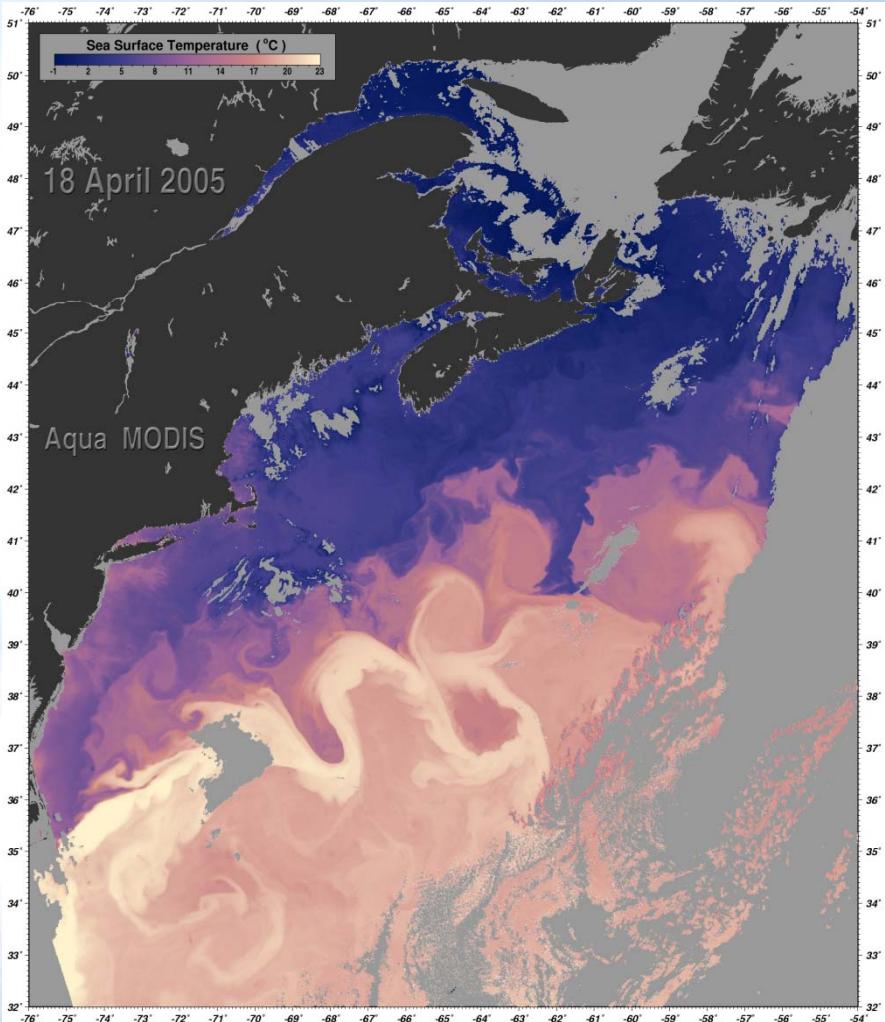
ice sheet and polar desert	temperate steppe	arid desert	grass savanna	alpine tundra
tundra	subtropical moist forest	xeric shrubland	tree savanna	mountain forest
taiga	Mediterranean vegetation	dry steppe	subtropical dry forest	
temperate broadleaf forest	monsoon forest	semiarid desert	tropical rainforest	



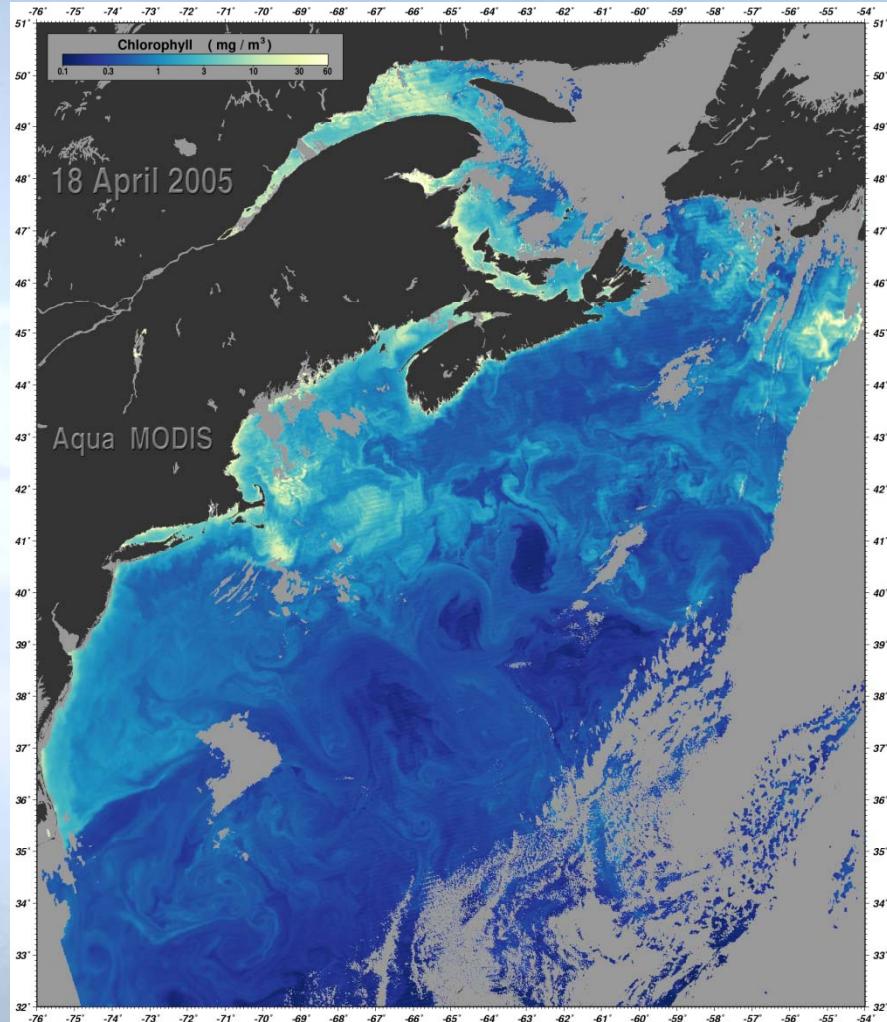




## Sea surface temperature

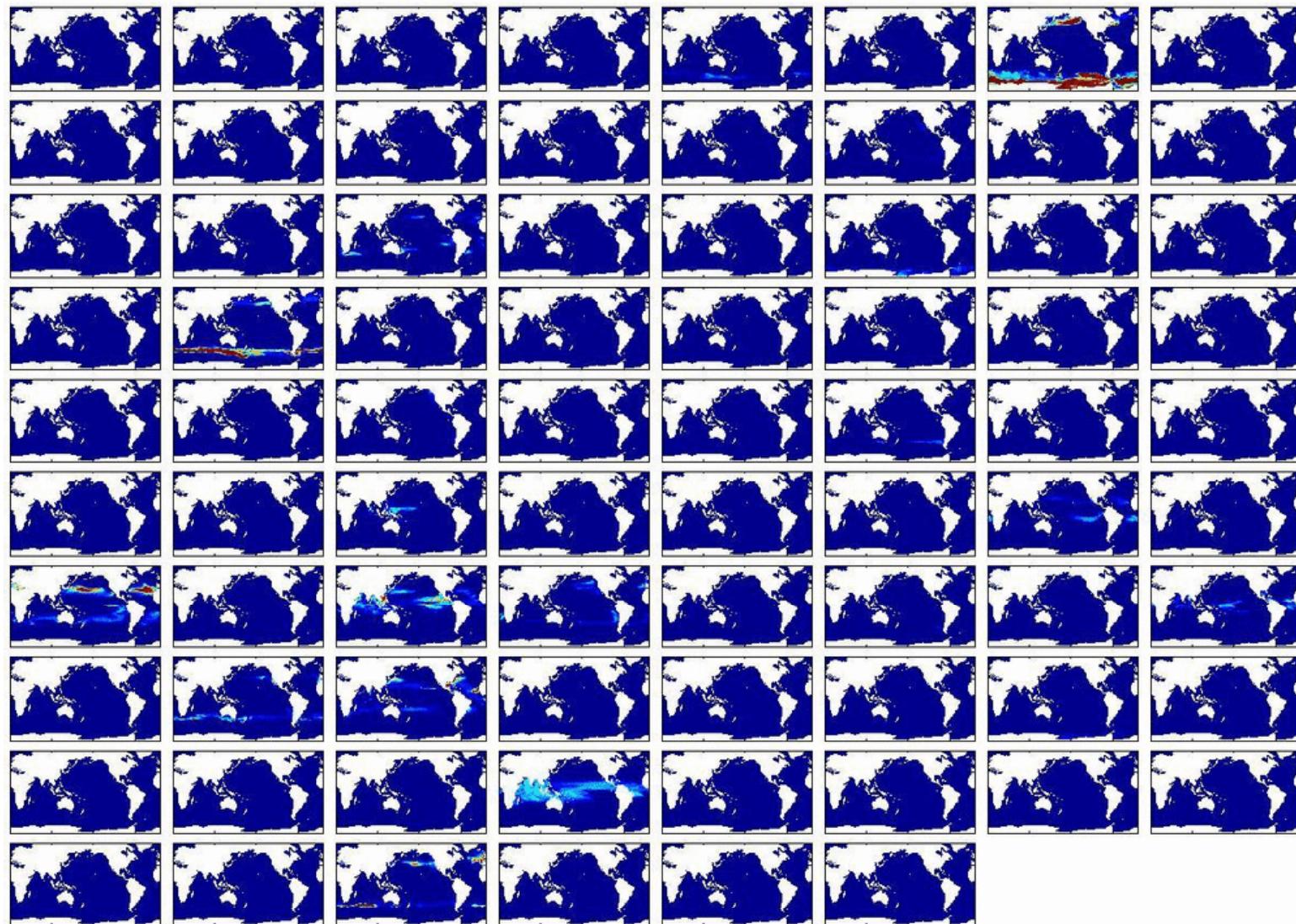


## Chlorophyll

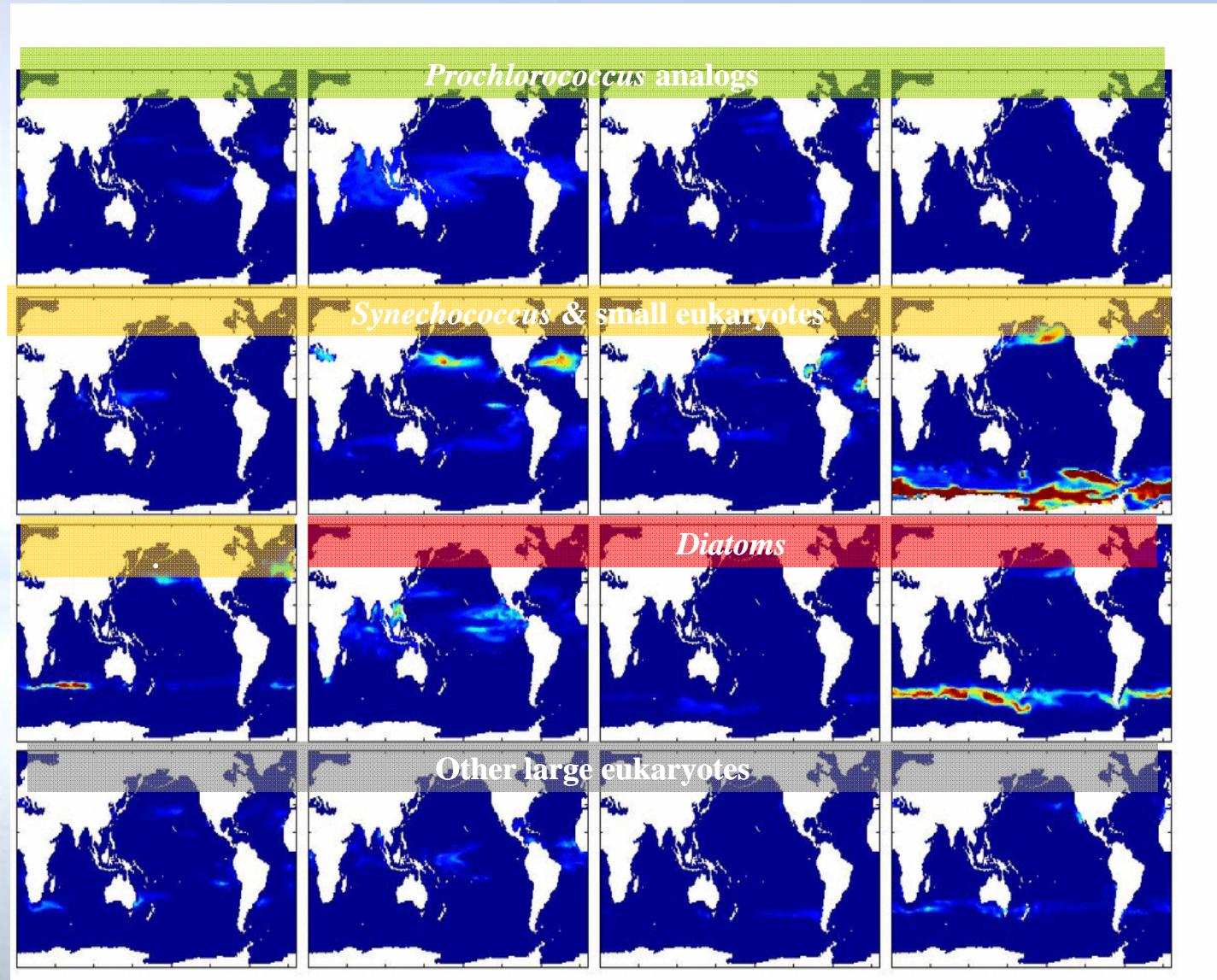


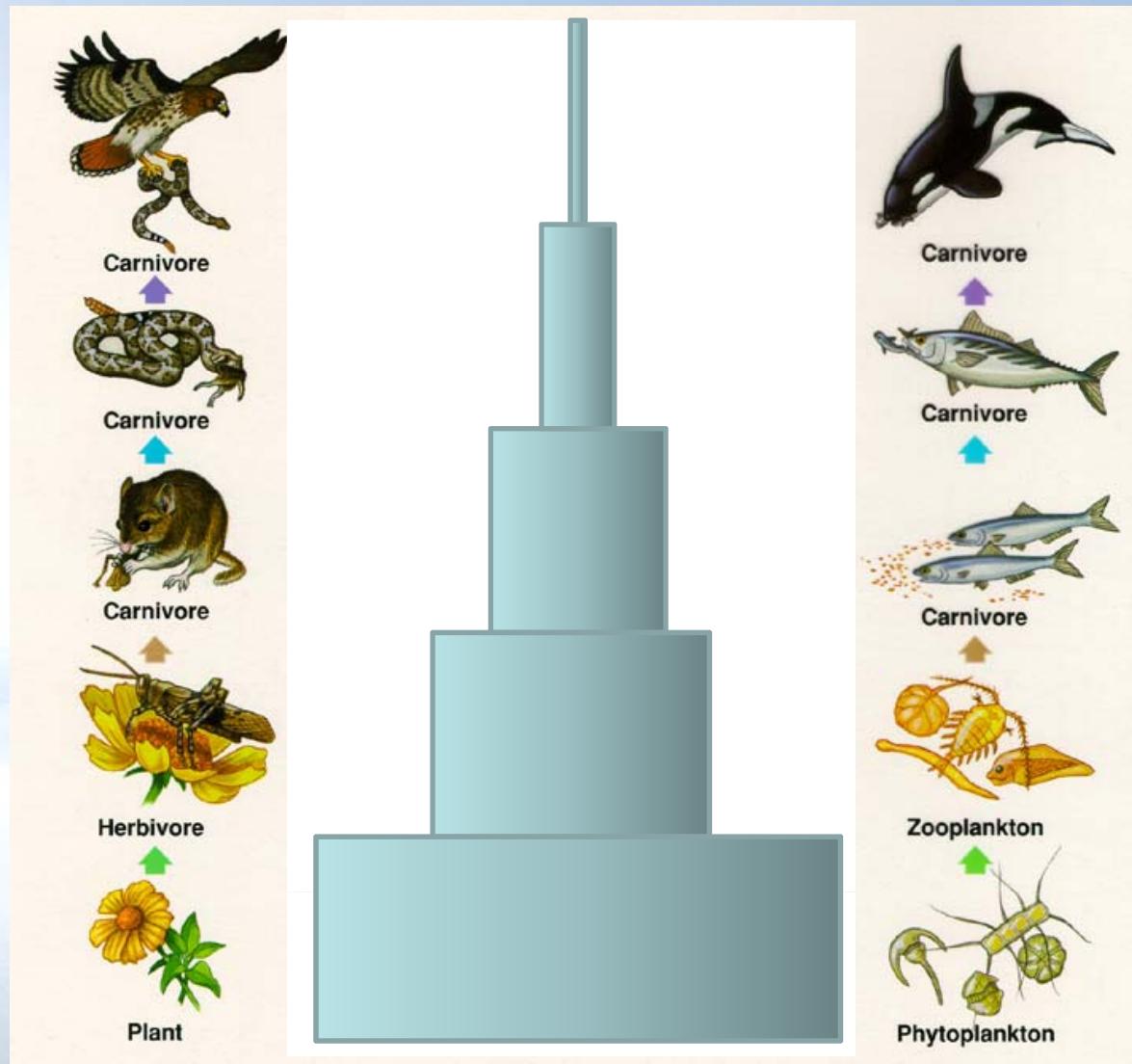
<http://earthobservatory.nasa.gov>



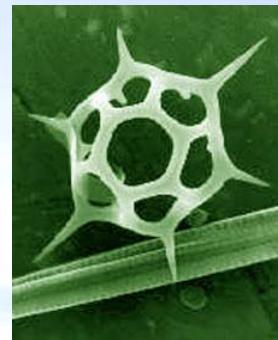


16 most abundant organized by “functional group”

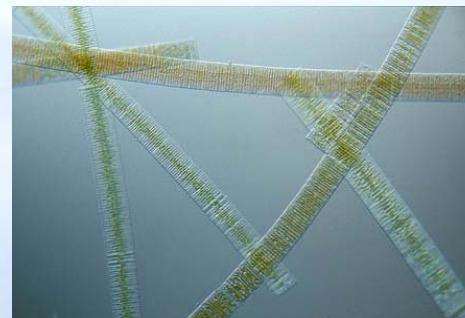




## Plant-animal wars

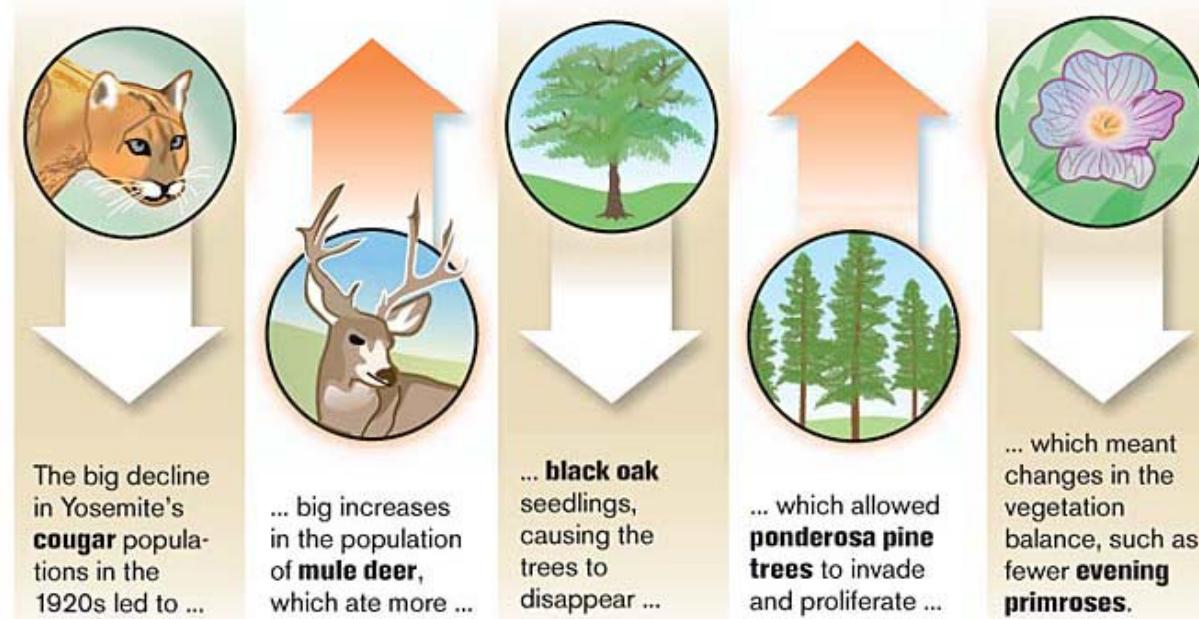


spines  
colonies  
toxins



## How the hunting of cougars altered Yosemite's ecology

Beginning in the 1920s, as more and more visitors crowded into Yosemite Valley, cougars were hunted to keep visitors safe. In a new study, scientists at Oregon State University offer evidence of how the decline in the cougar population affected other species in the valley.



Source: Chronicle research

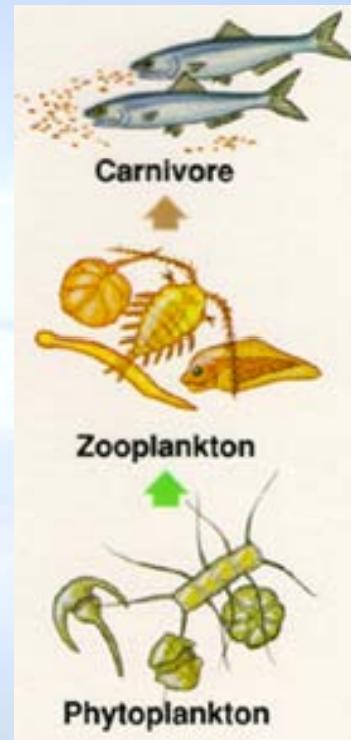
TODD TRUMBULL / The Chronicle

Daksalov (2002): “Overfishing drives a trophic cascade in the Black sea”

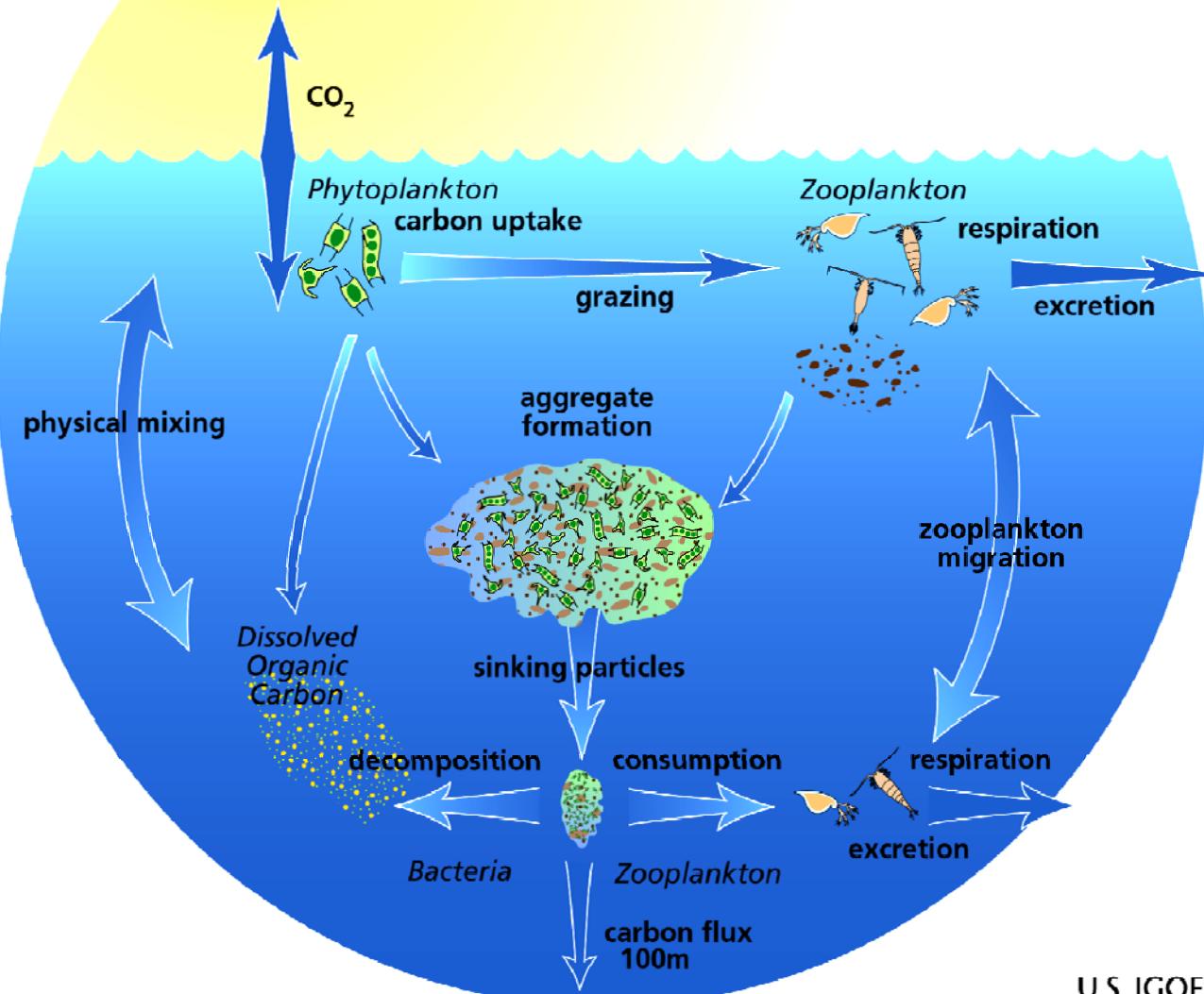
Change in dominance across the pelagic food chain since the depletion of top-predators after 1970: model results

<u>trophic level</u>	<u>before 1970</u>	<u>after 1970</u>
top predators	↑ resource limited	-
planktivores	↓ consumer controlled	↑ resource limited
zooplankton	↑ resource limited	↓ consumer controlled
phytoplankton	↓ consumer controlled	↑ resource limited

## Green world hypothesis



## The "Biological Pump"



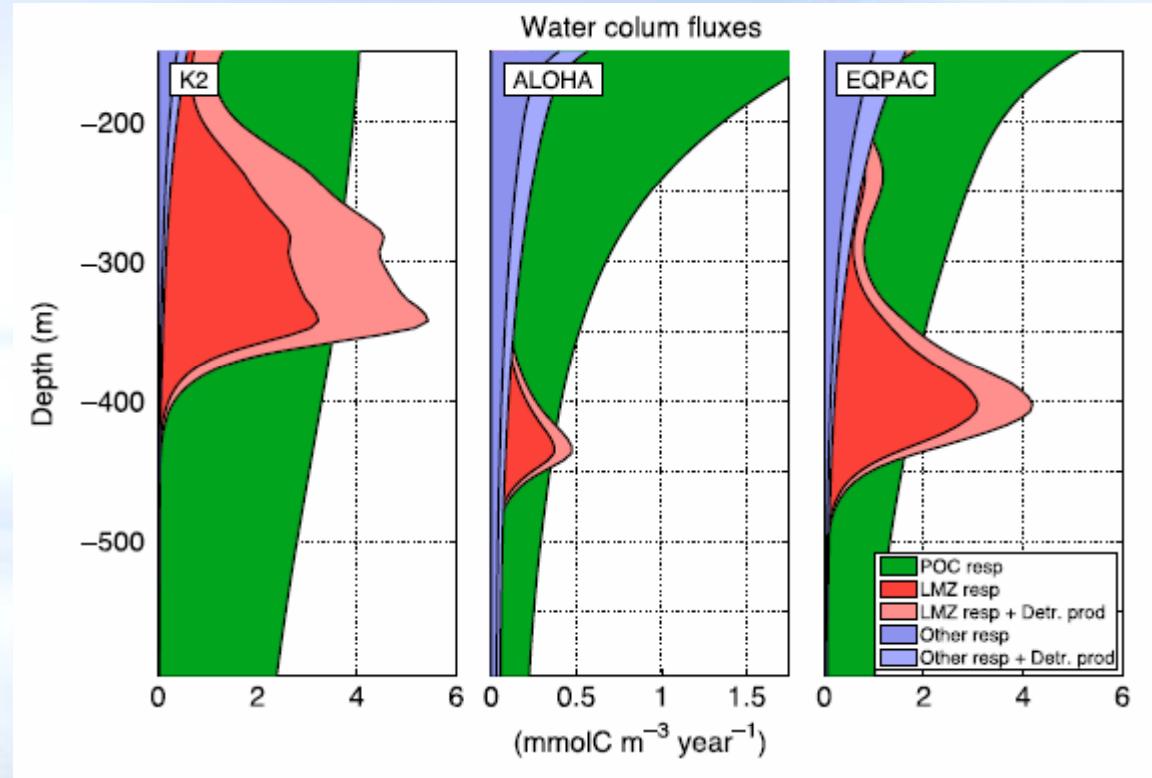
U.S. JGOFS



## Export

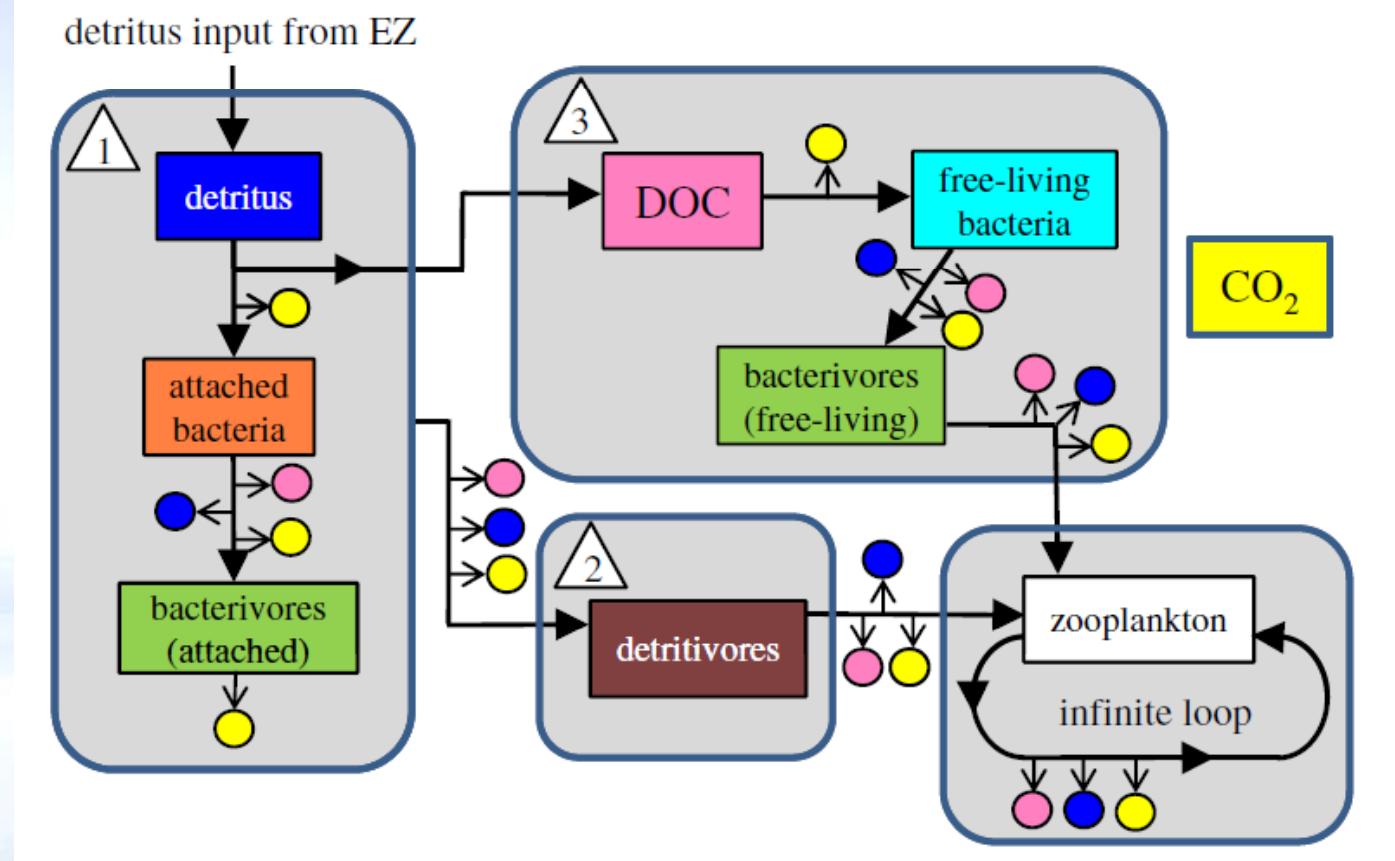
- ❖ No simple relationship with primary production
- ❖ Much export occurs during bloom events
- ❖ Is related to ecosystem structure

## Active flux



Bianchi et al. (2013)

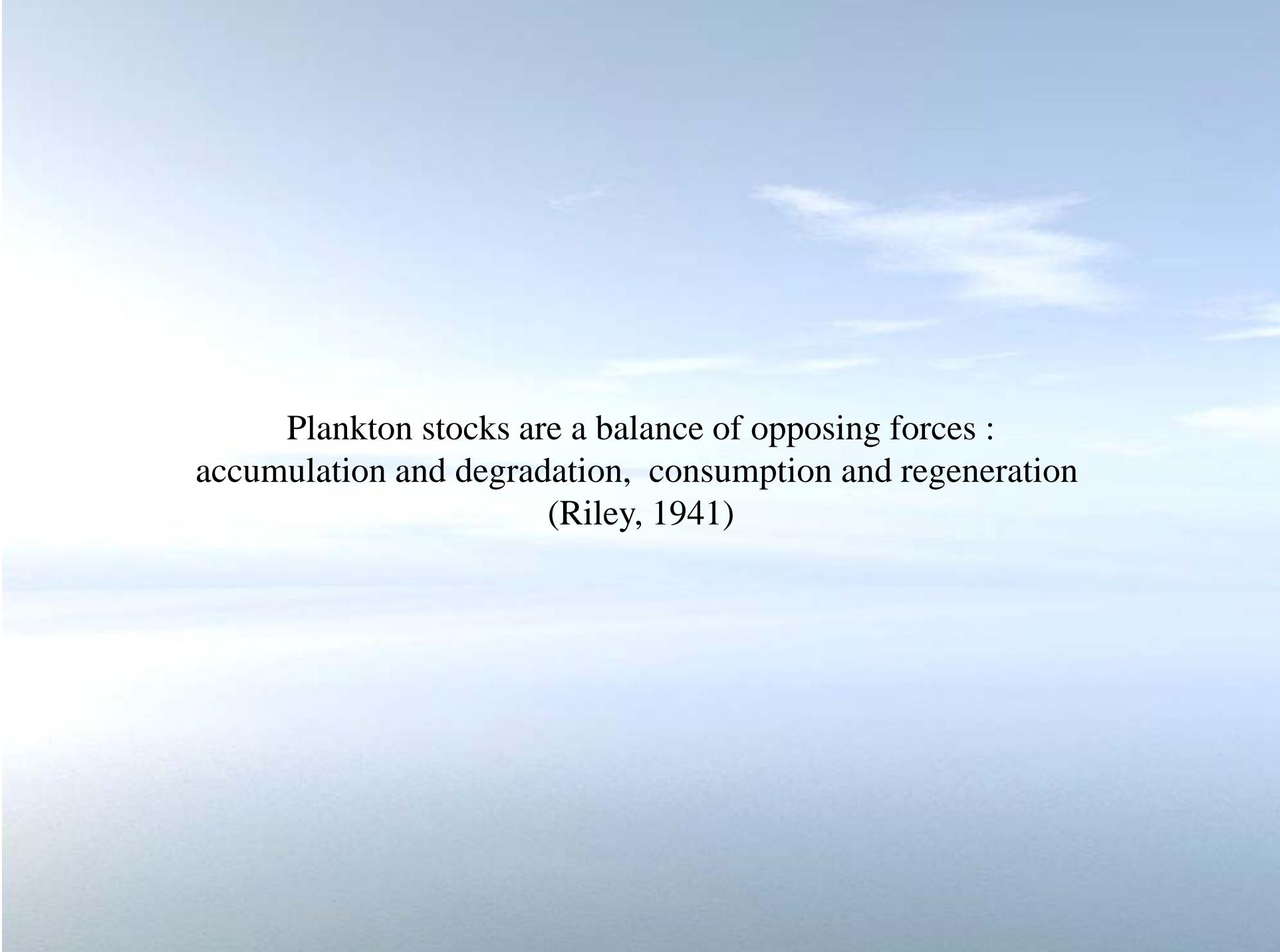
## Detritus turnover



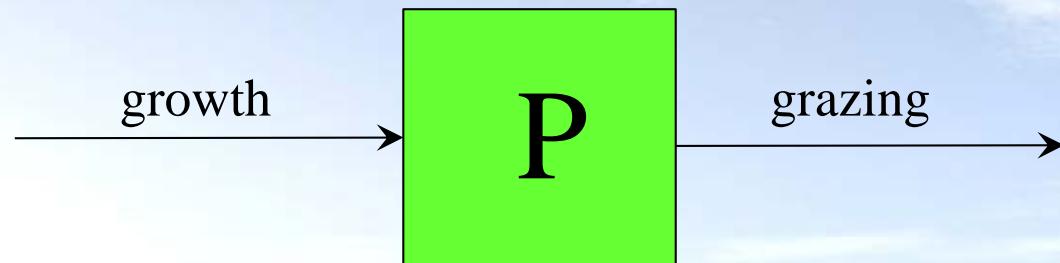
Anderson and Tang (2010)

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A wide-angle photograph of a calm sea meeting a clear blue sky at the horizon. The water is a light blue-grey, and the sky is a pale blue with very faint, wispy white clouds.

Plankton stocks are a balance of opposing forces :  
accumulation and degradation, consumption and regeneration  
(Riley, 1941)



Gordon Riley

$$\frac{dP}{dt} = (Ph - R - G)P$$

↑      ↑      ↑  
photosynthesis    respiration    grazing

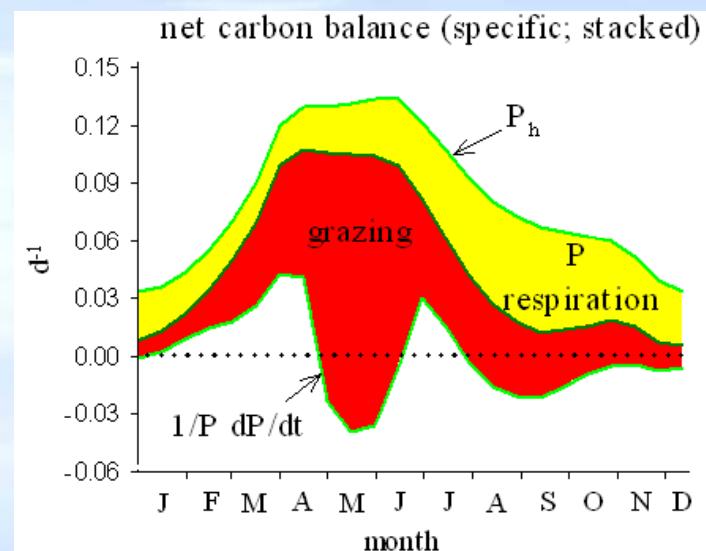
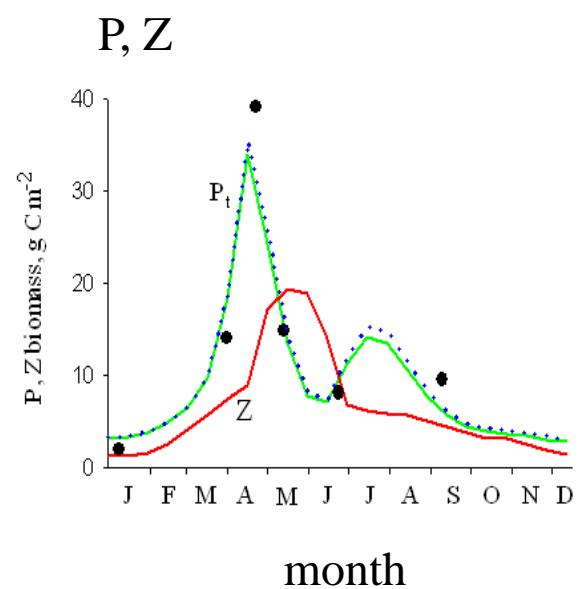
$$Ph = \frac{pI_0}{kz_{eu}}(1-e^{-k.z_{eu}})L_N L_V$$

$$R = R_0 e^{rT}$$

$$G = gZ$$

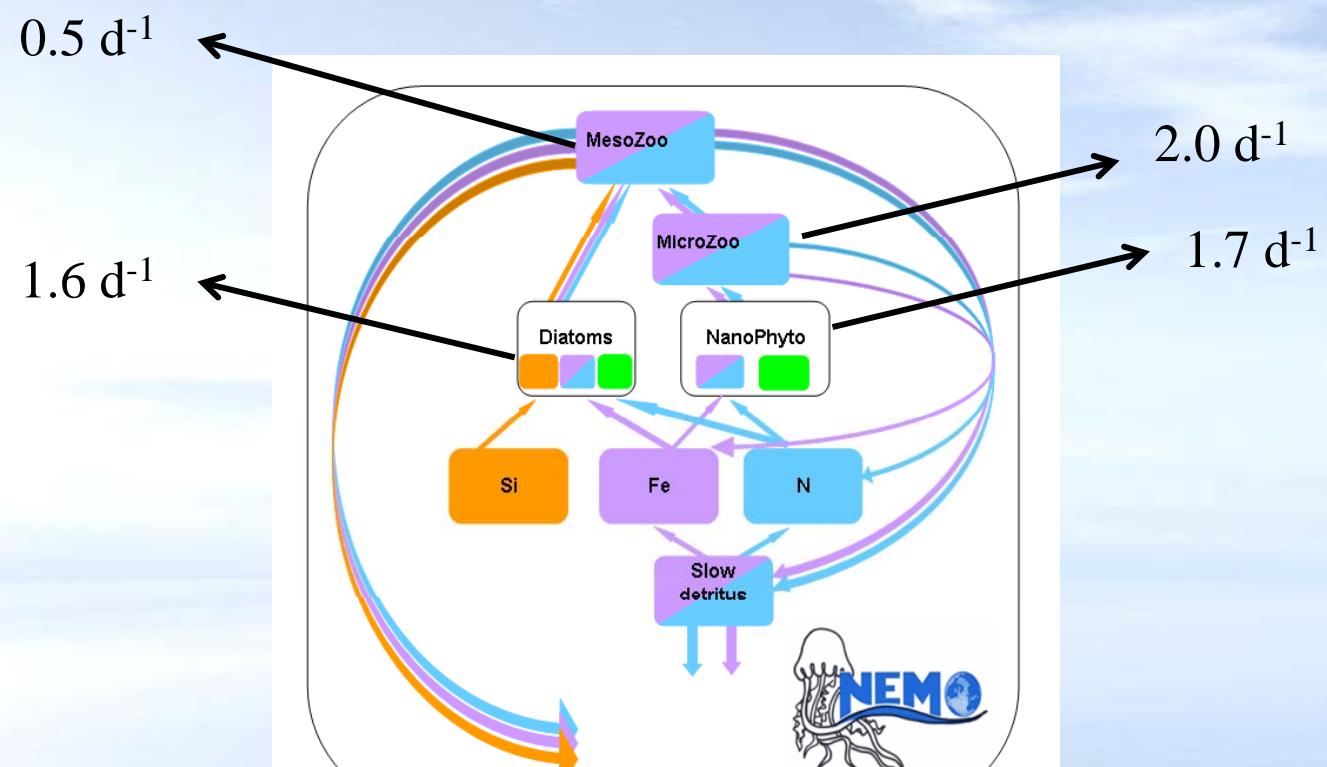
Riley (1946)

## Georges Bank simulation



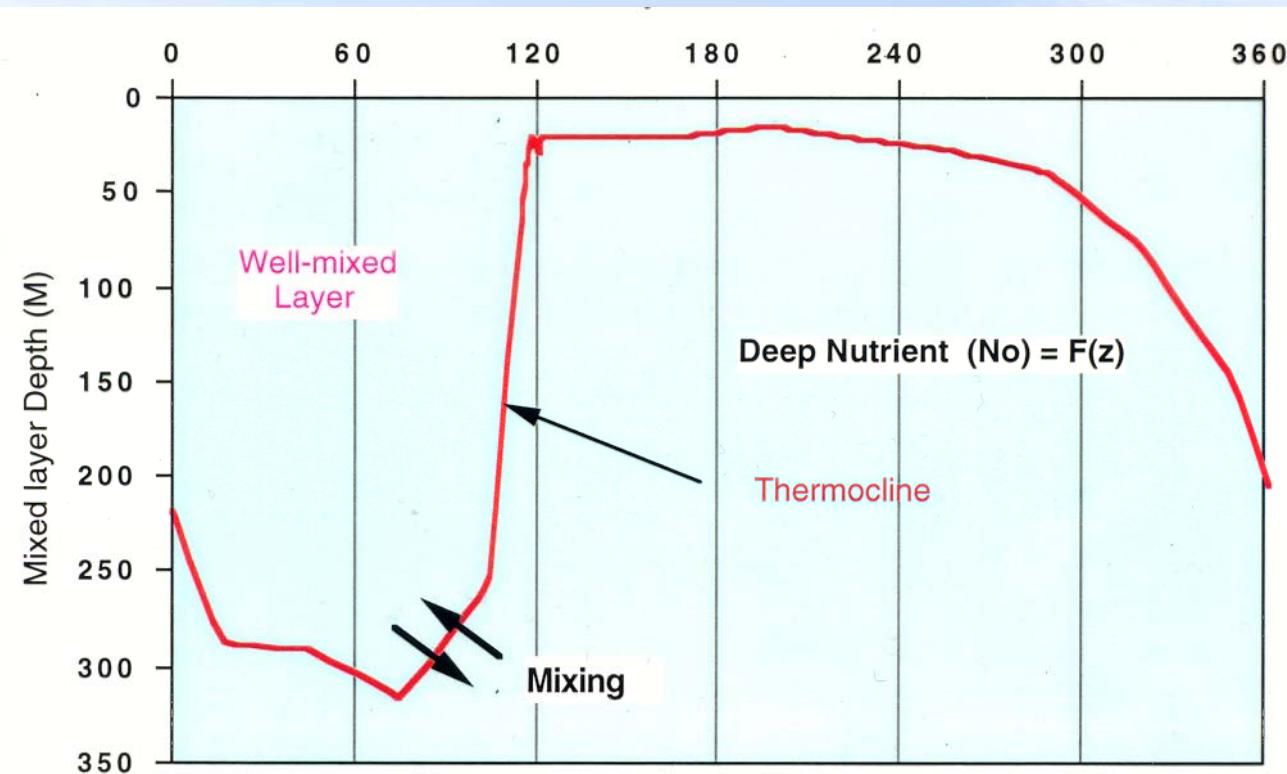
maximum growth and grazing rates

## MEDUSA

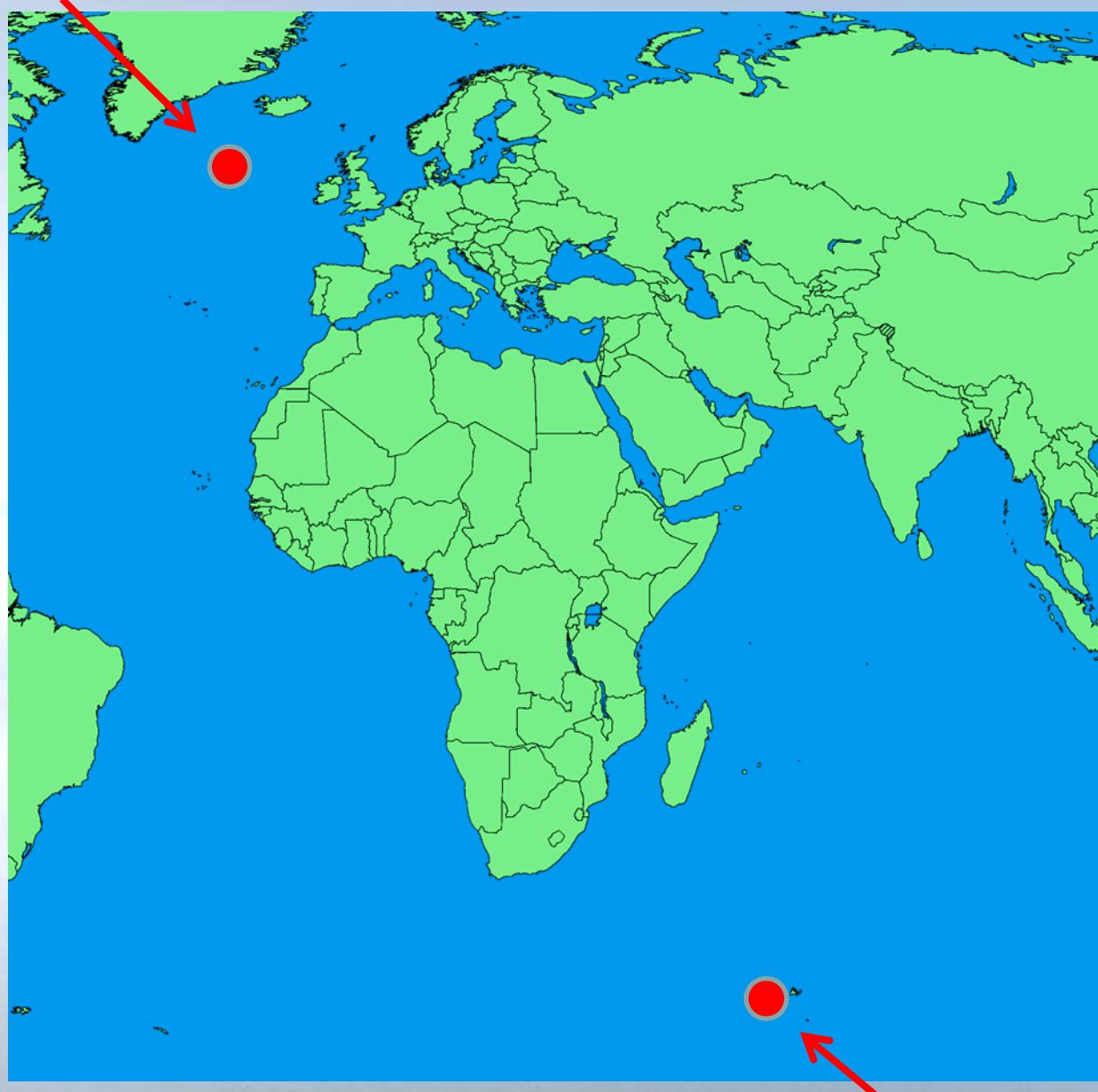


Yool et al. (2010, 2013)

## Annual cycle of mixed layer depth

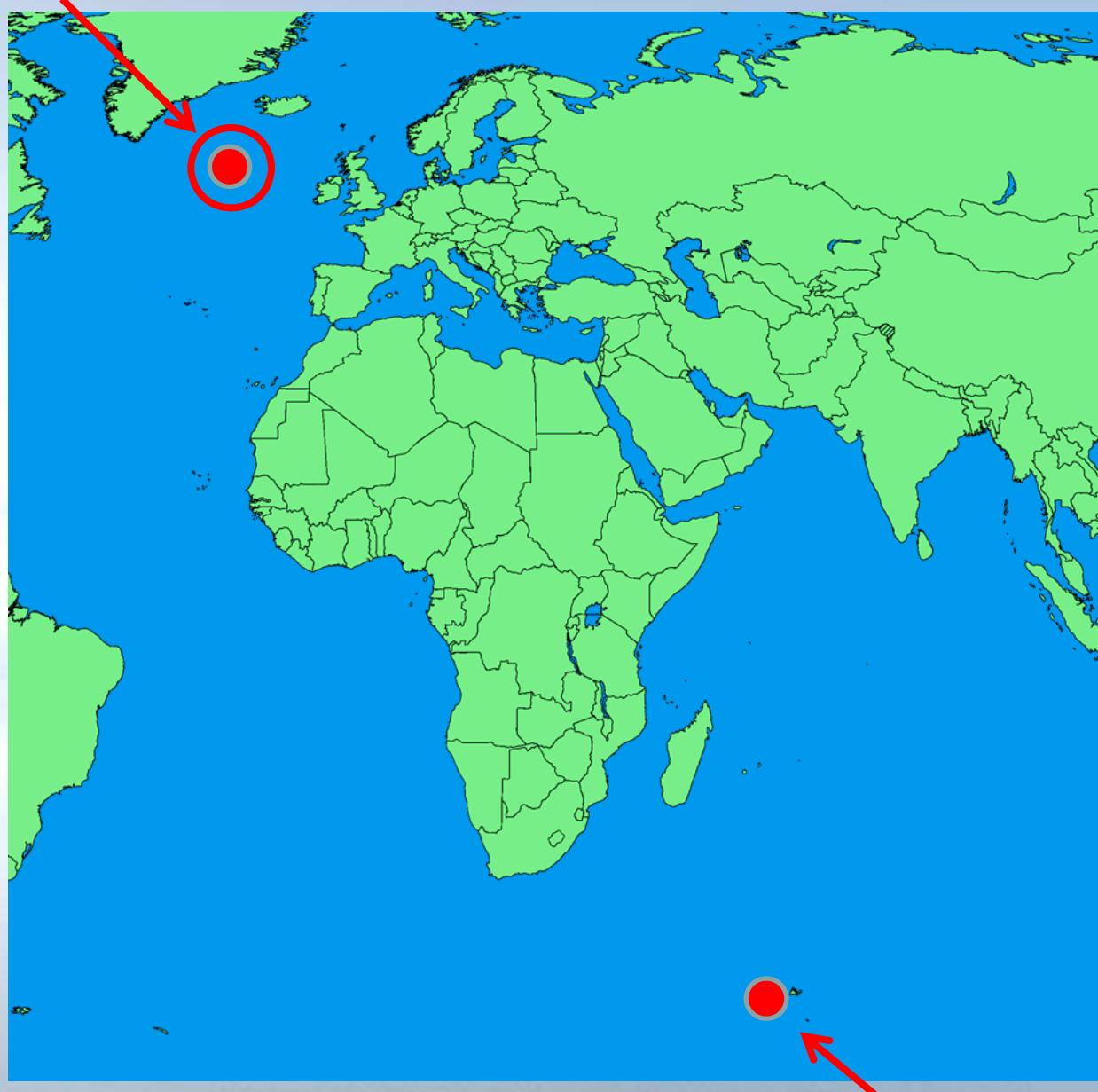


India 60N 20W



KERFIX 50S 68E

India 60N 20W

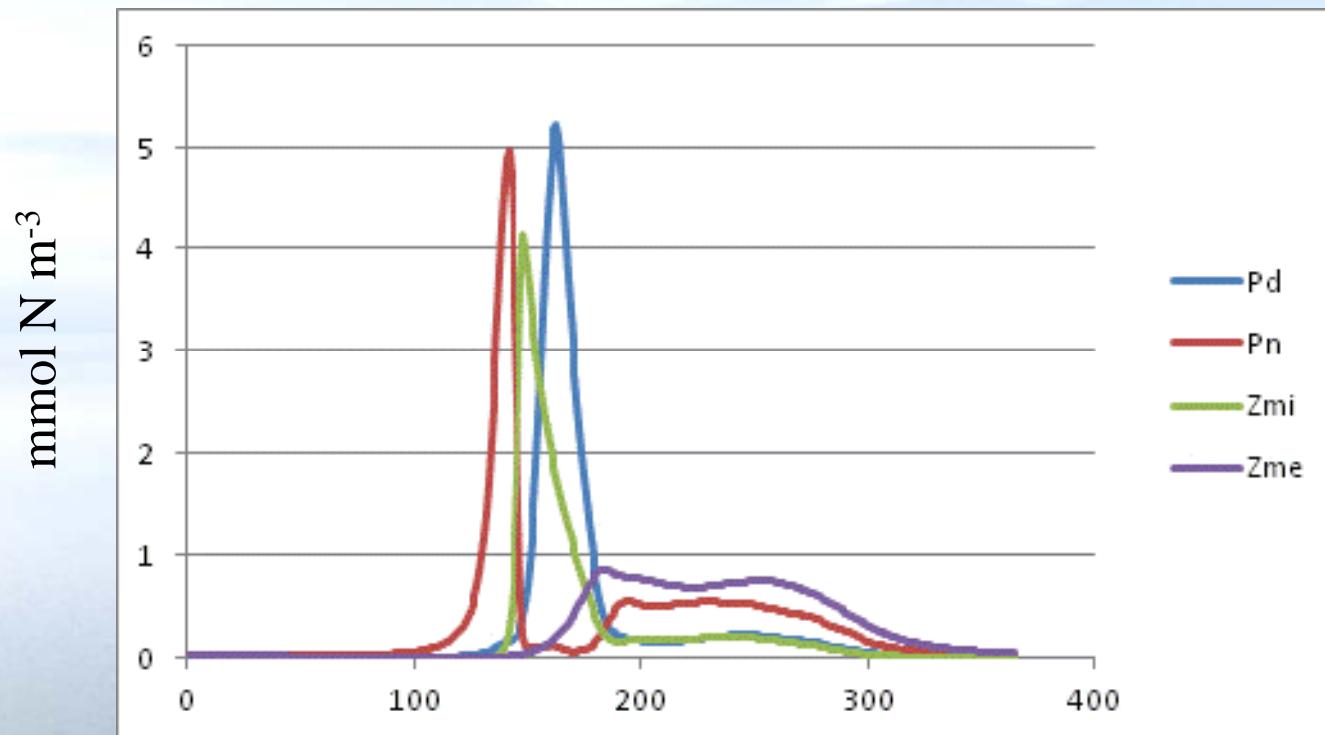


KERFIX 50S 68E

60N 20W

diatoms  
non-diatoms      mesozooplankton  
                      microzooplankton

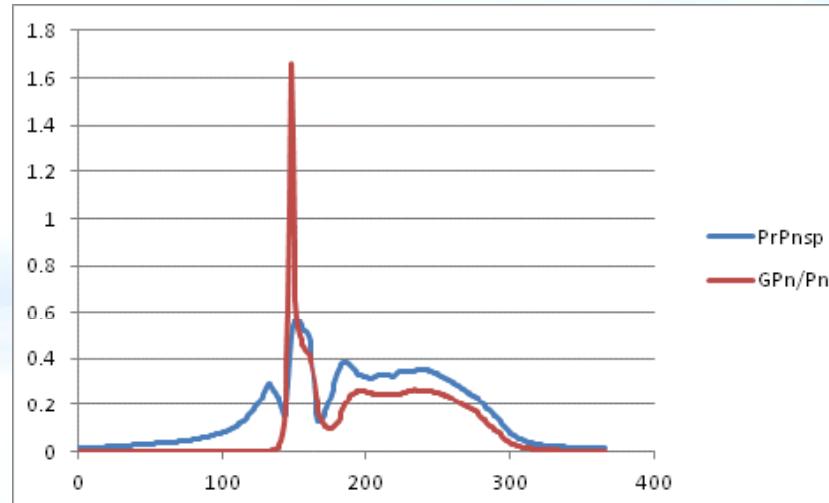
### plankton biomass



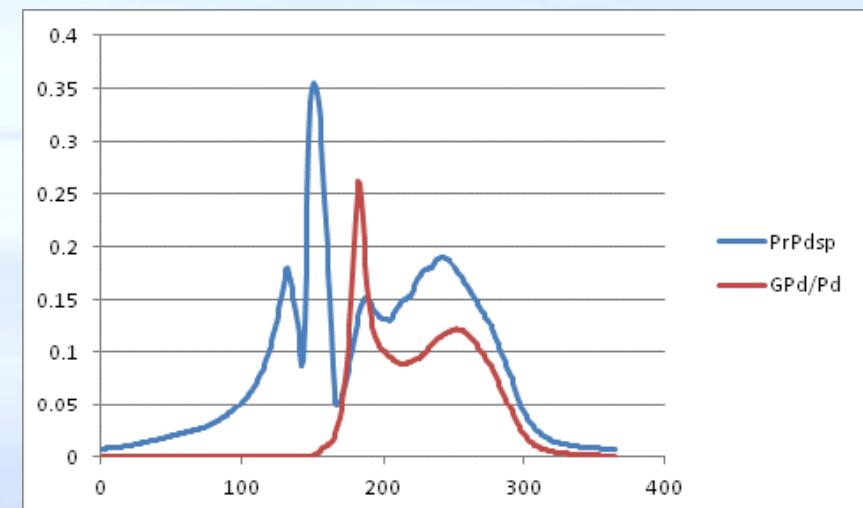
60N 20W

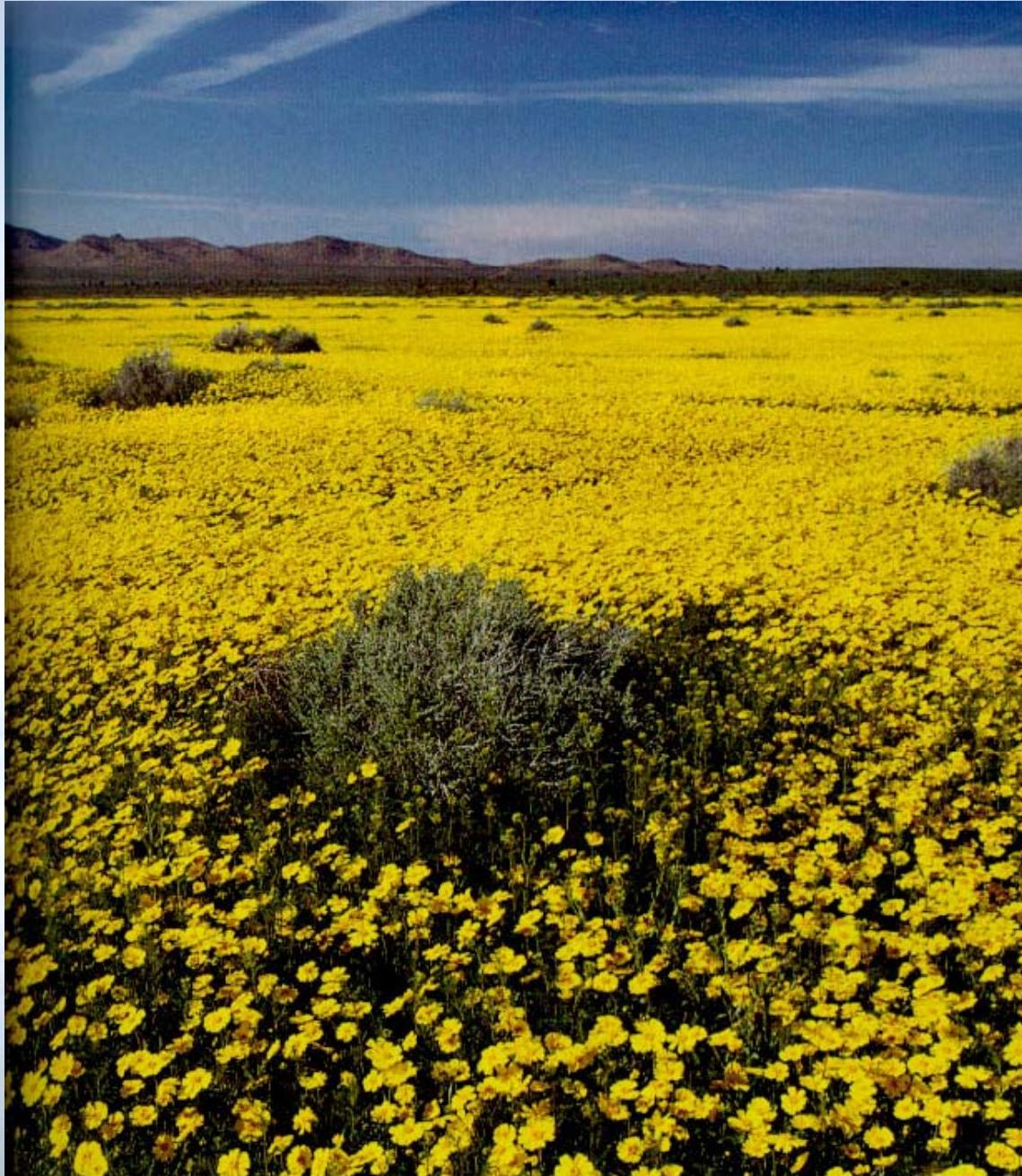
growth  $d^{-1}$   
grazing

non-diatoms



diatoms

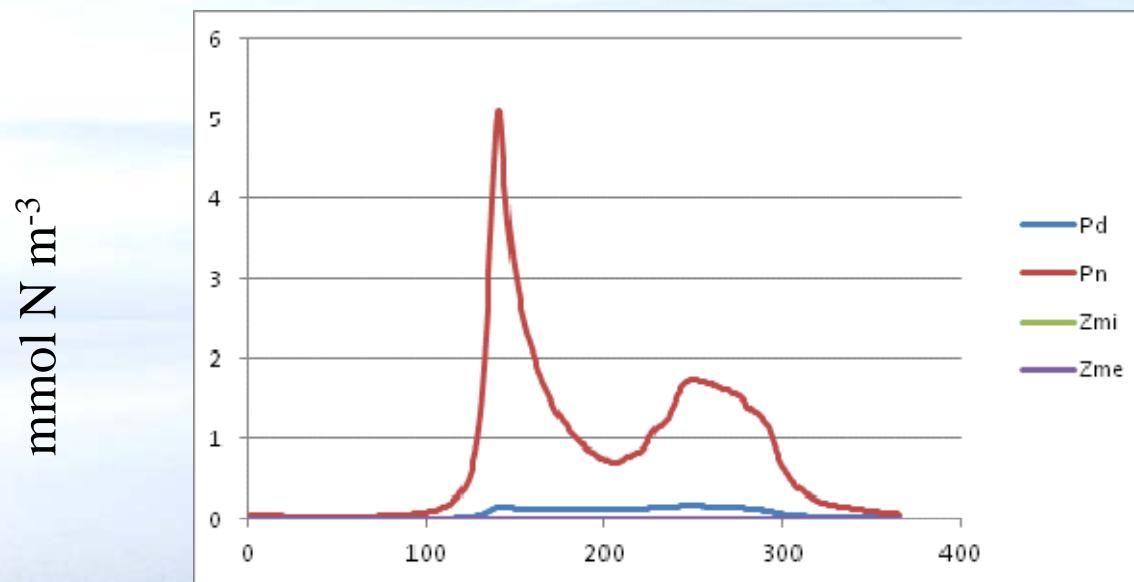




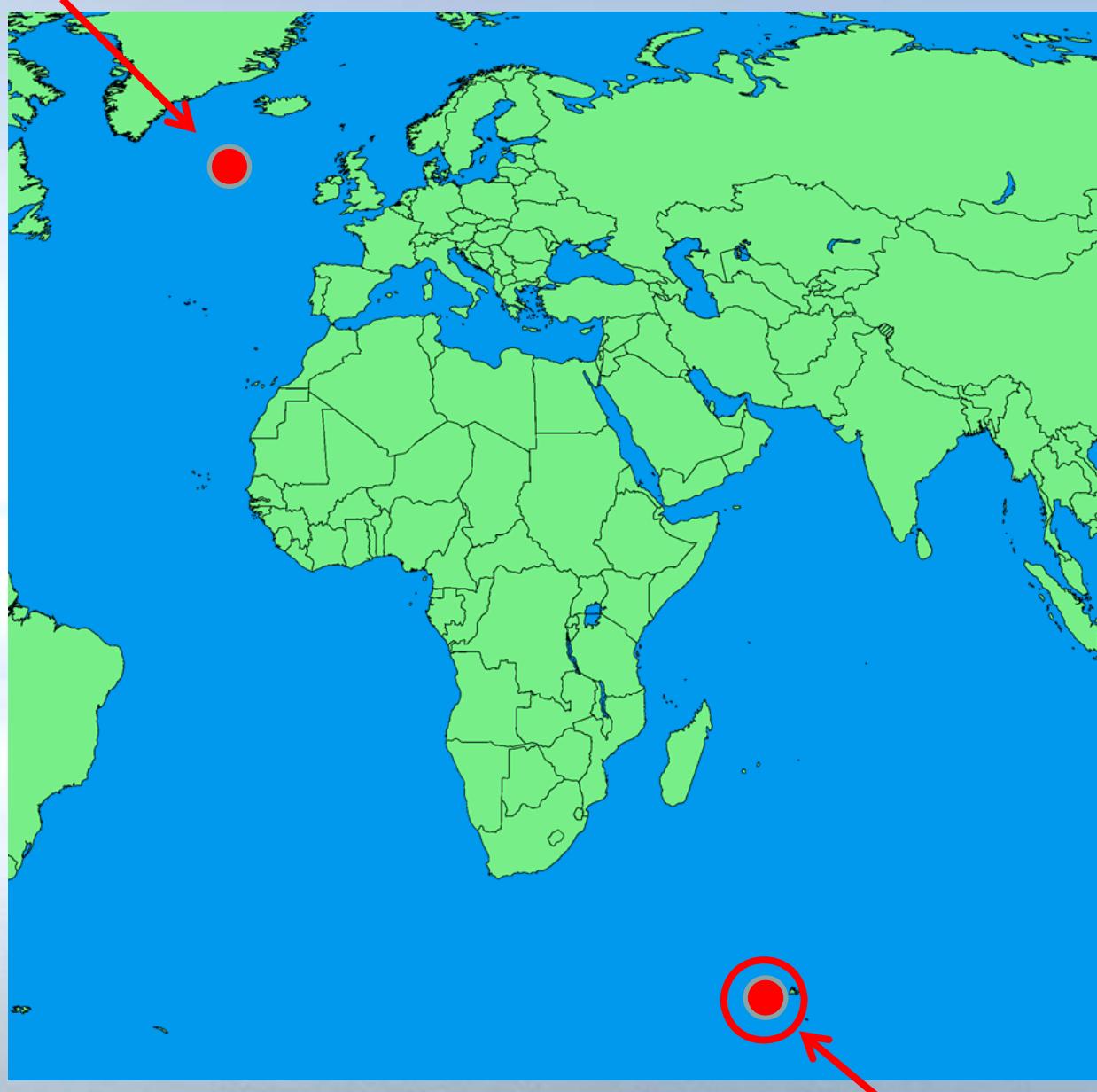
60N 20W  
no grazing

diatoms      mesozooplankton  
non-diatoms      microzooplankton

### plankton biomass



India 60N 20W

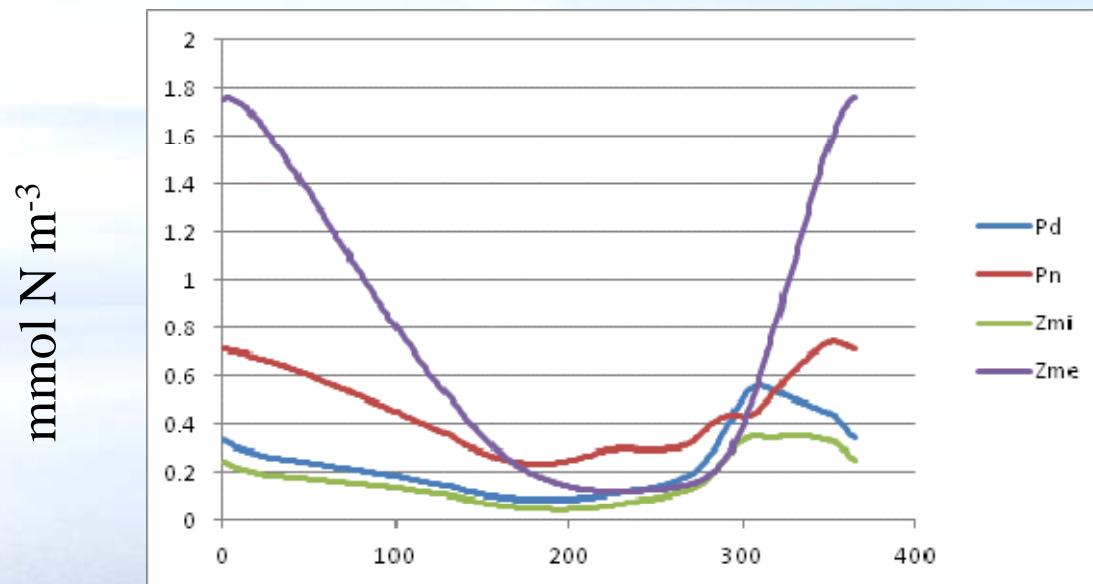


KERFIX 50S 68E

Kerfix

diatoms      mesozooplankton  
non-diatoms      microzooplankton

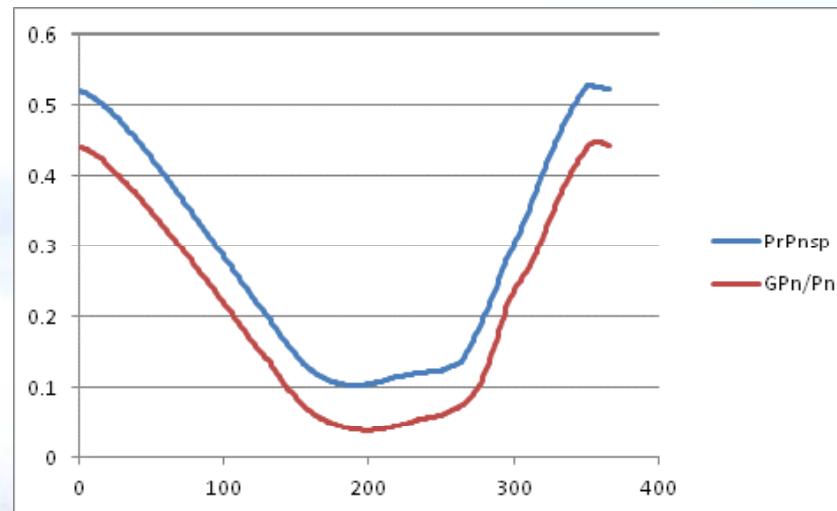
plankton biomass



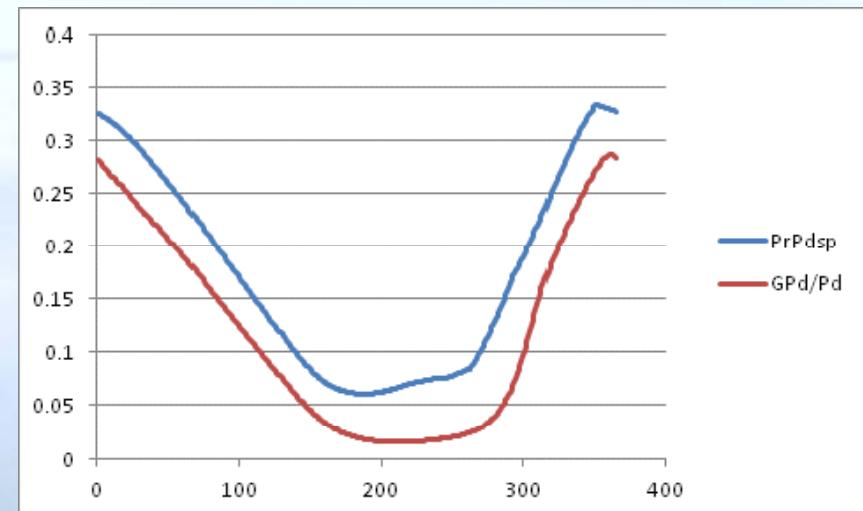
Kerfix

growth  $d^{-1}$   
grazing

non-diatoms



diatoms

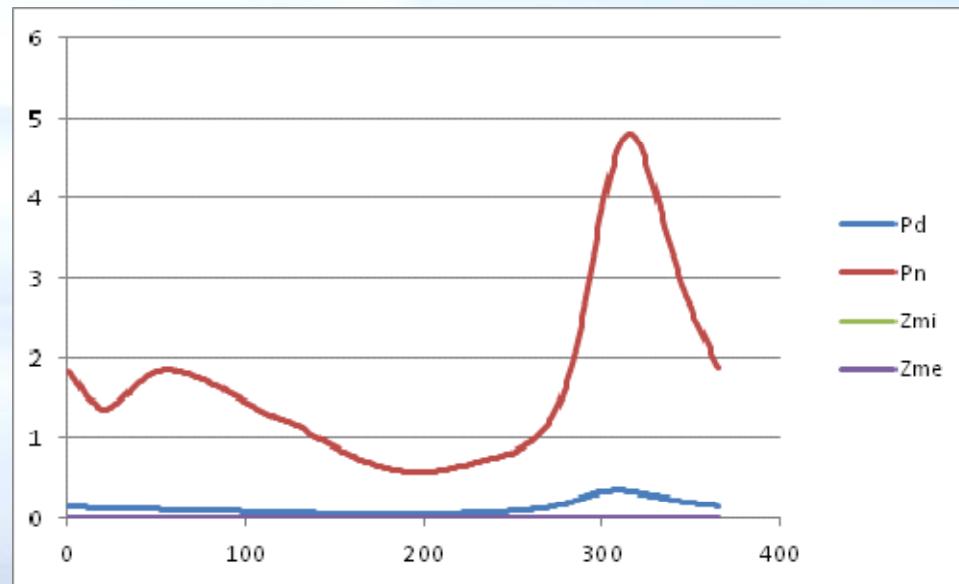


Kerfix,  
no grazing

diatoms  
non-diatoms      mesozooplankton  
                      microzooplankton

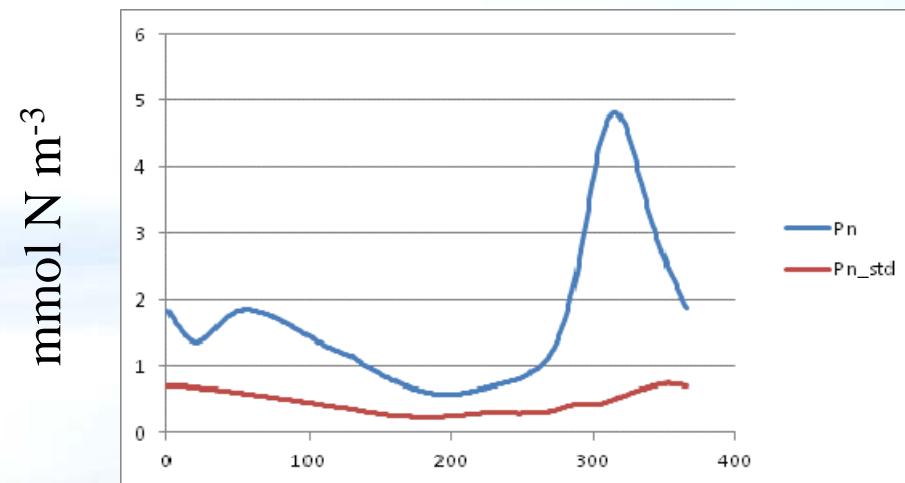
### plankton biomass

$\text{mmol N m}^{-3}$

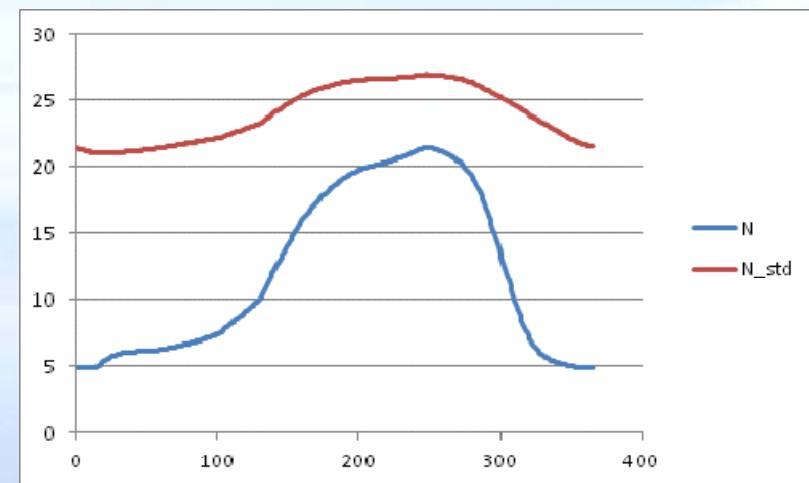


— grazing  
— no grazing

non-diatoms



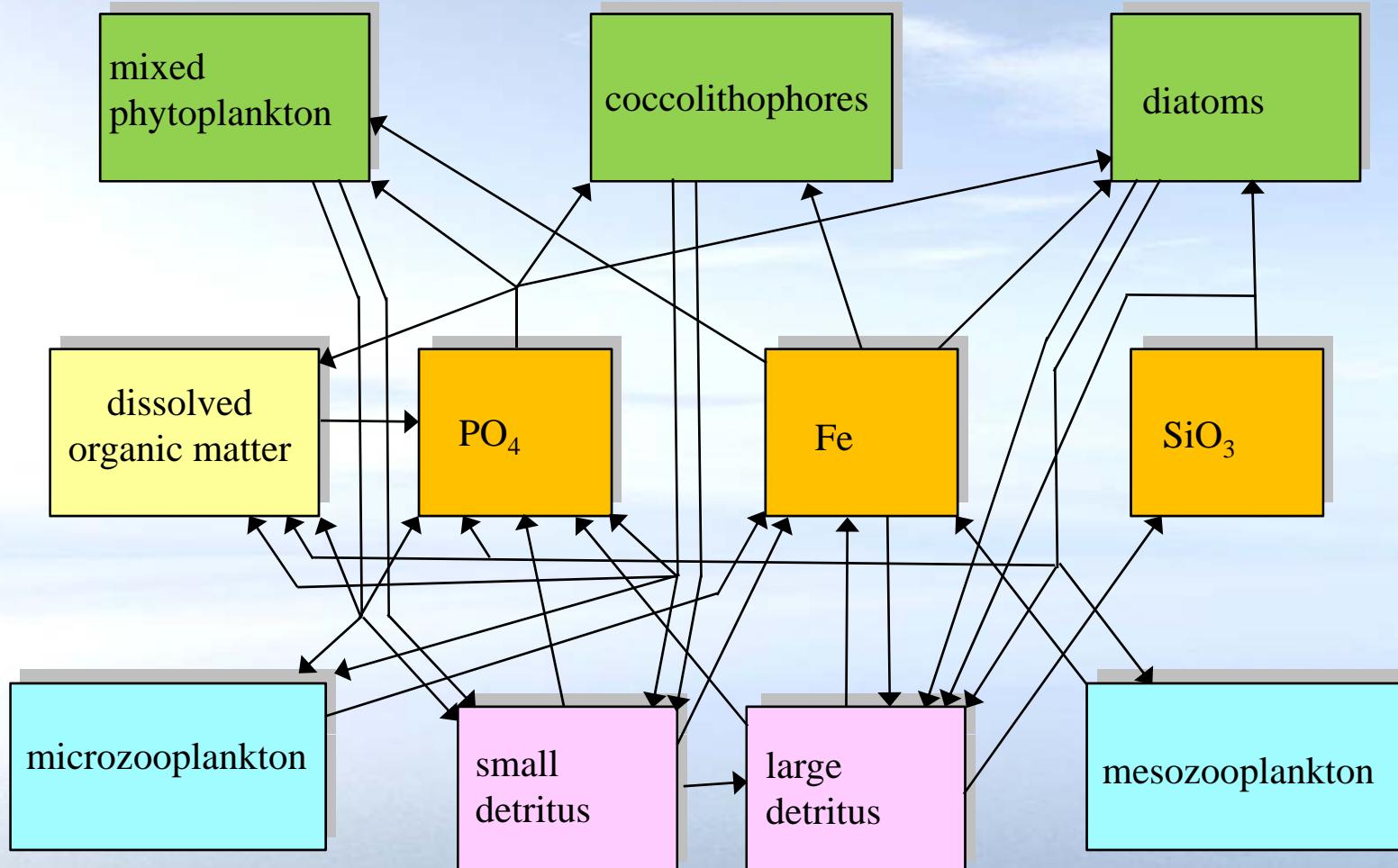
nitrate

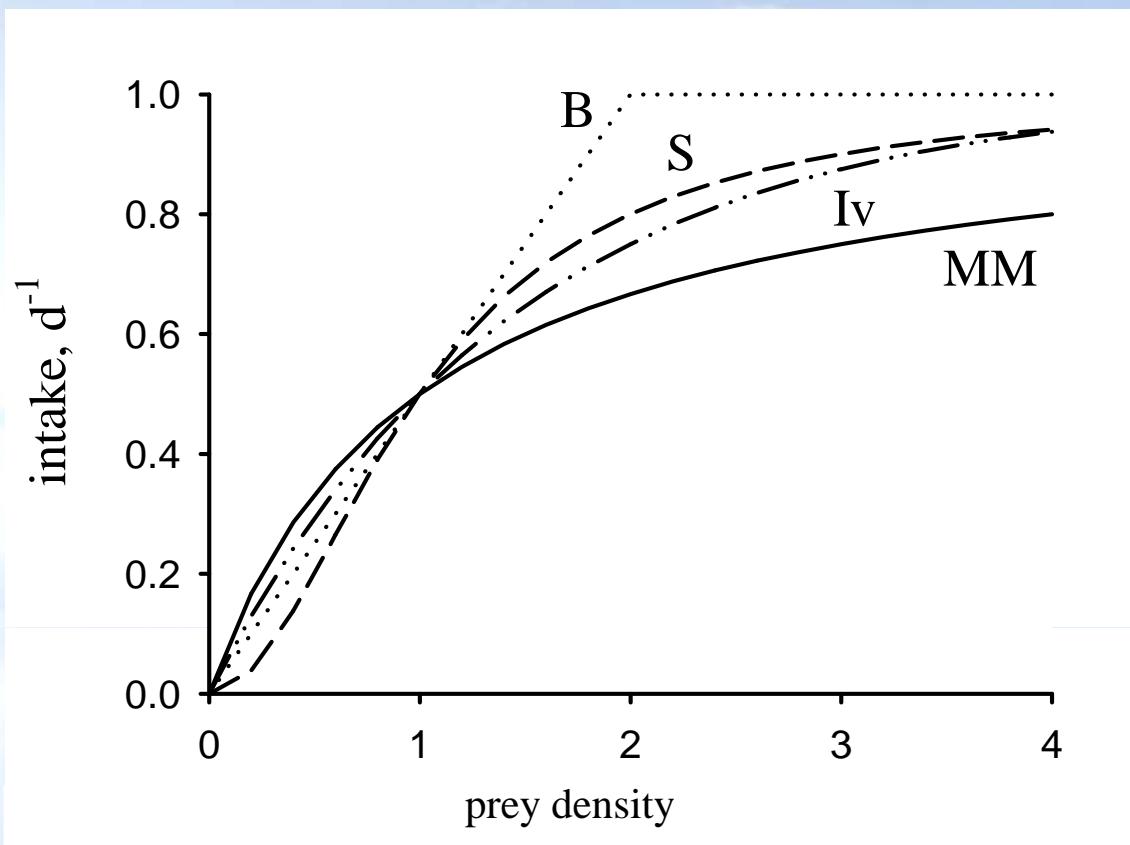


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# PlankTOM5



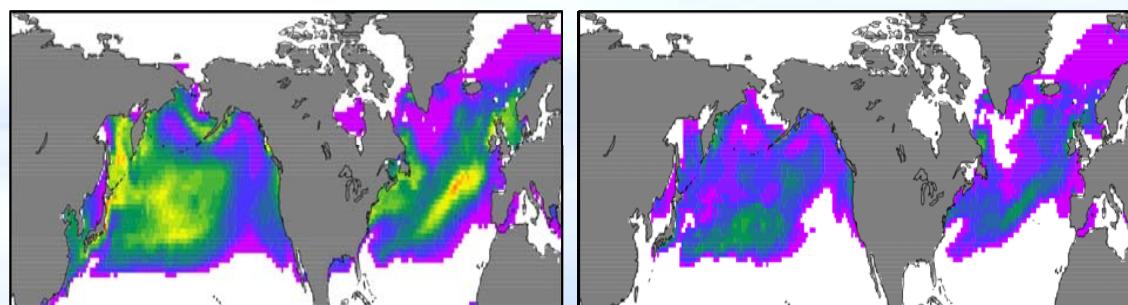
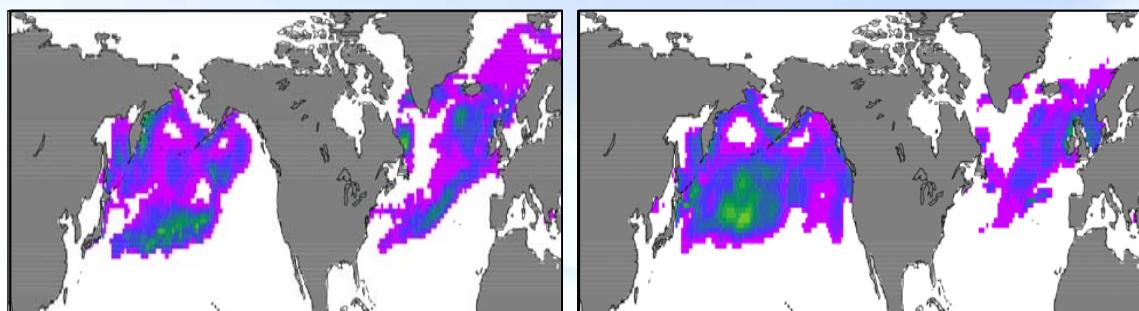


diatoms, mg chl m<sup>-3</sup>

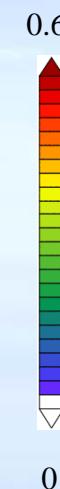
MM

March-May

B

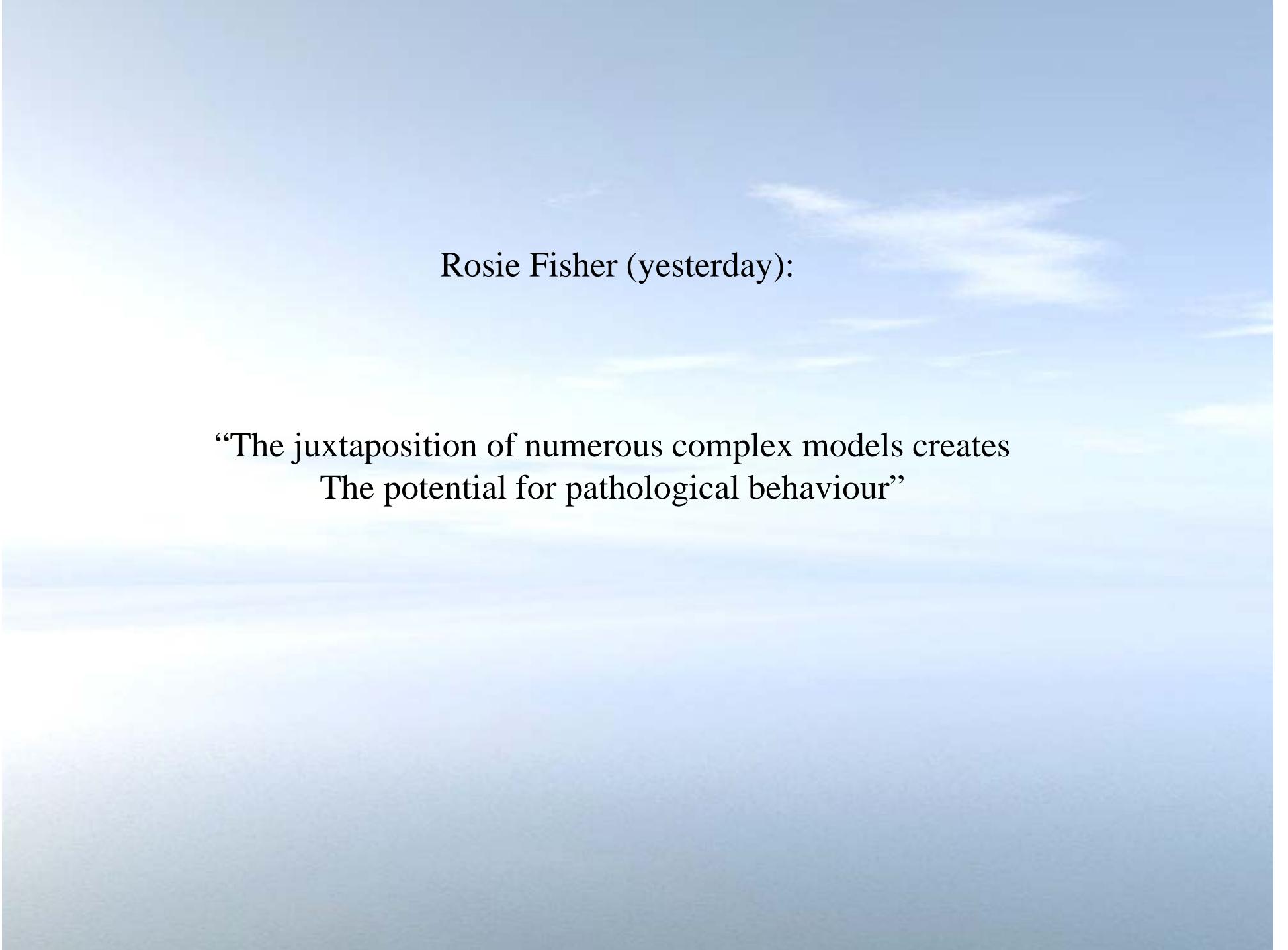


S



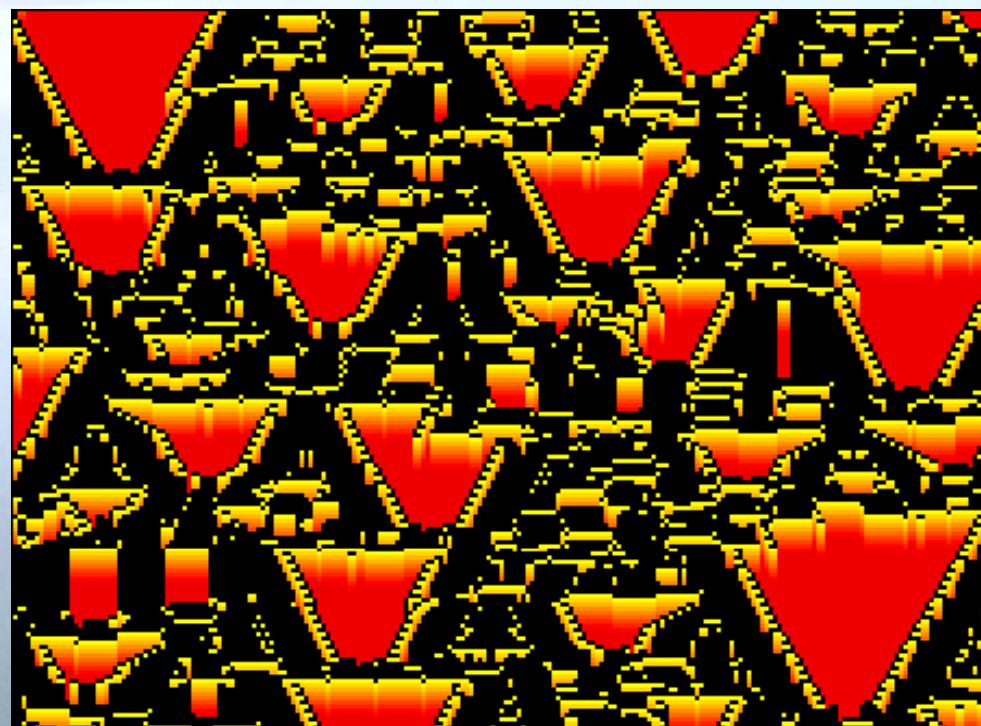
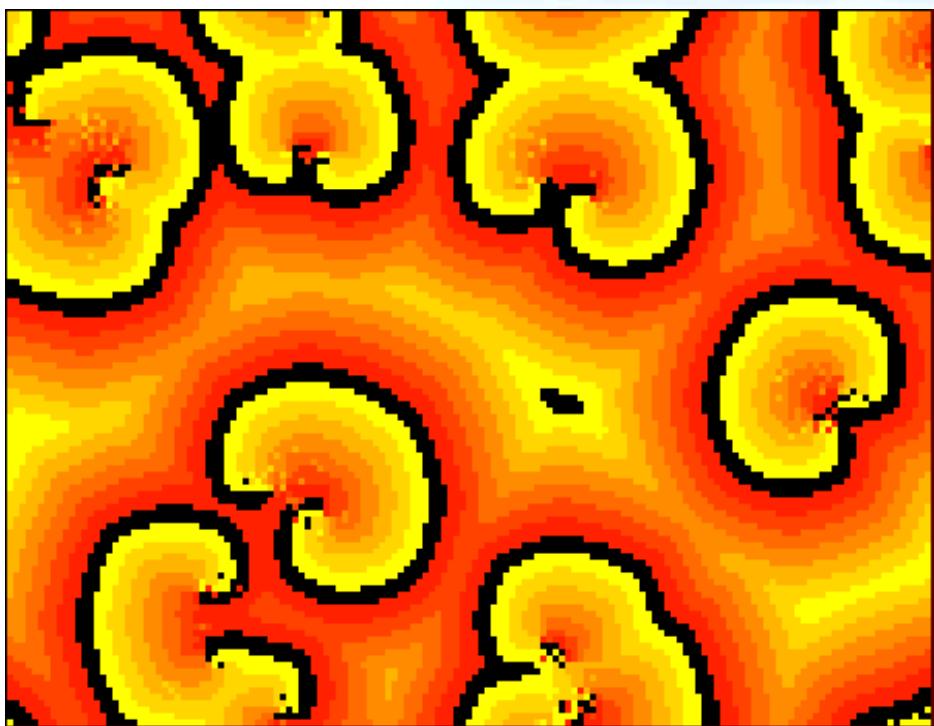
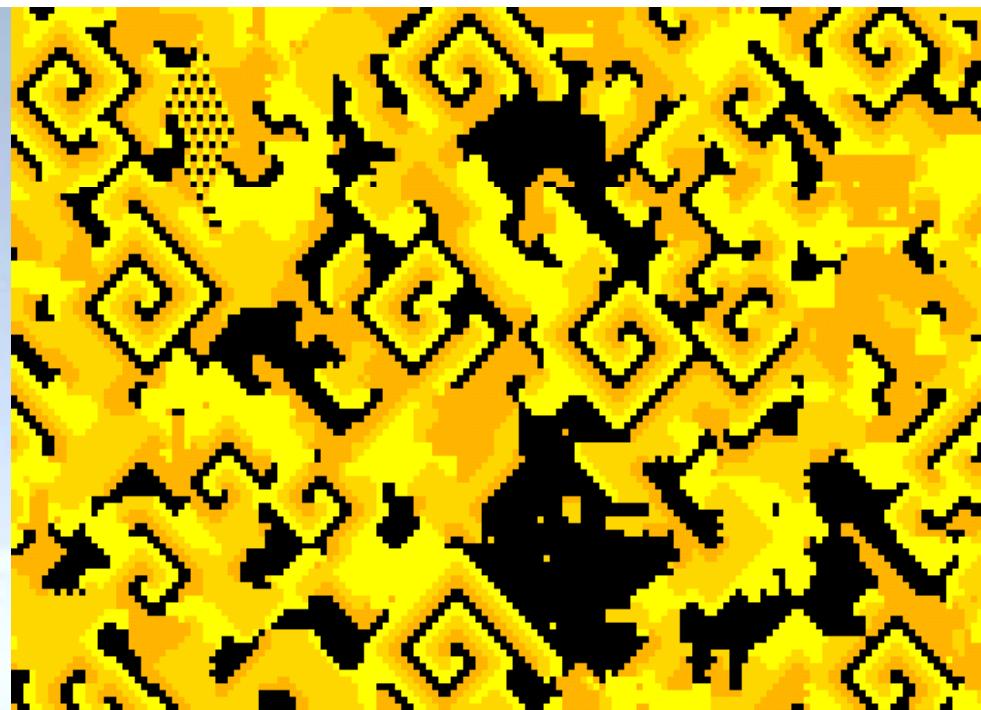
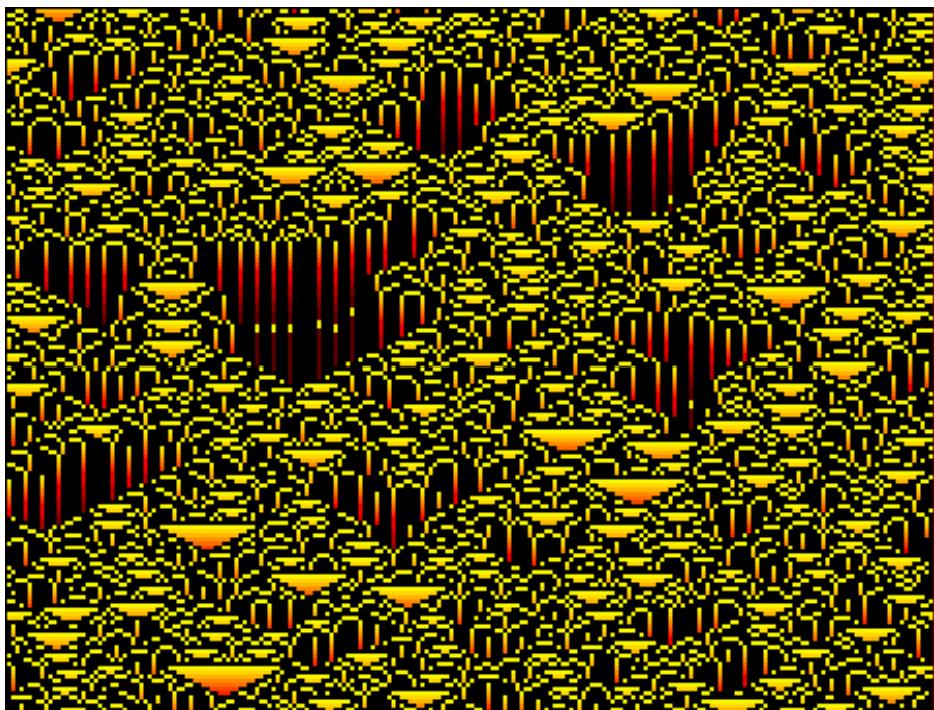
I<sub>V</sub>

(Anderson et al., 2010)

A photograph of a calm sea under a clear blue sky. The horizon is visible in the distance, and the water is a light blue-grey color.

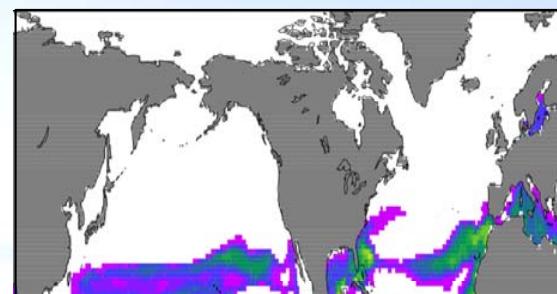
Rosie Fisher (yesterday):

“The juxtaposition of numerous complex models creates  
The potential for pathological behaviour”



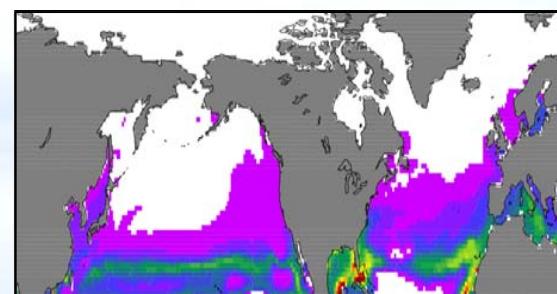
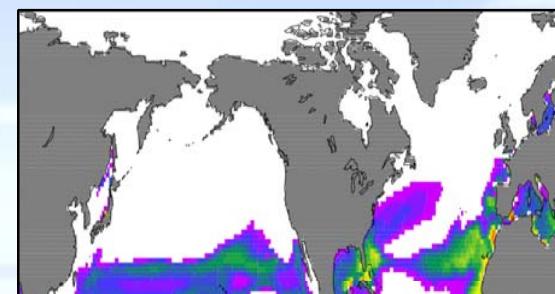
coccolithophores, mg chl m<sup>-3</sup>

MM

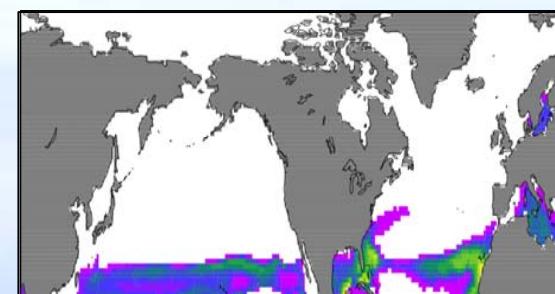


March-May

B



S

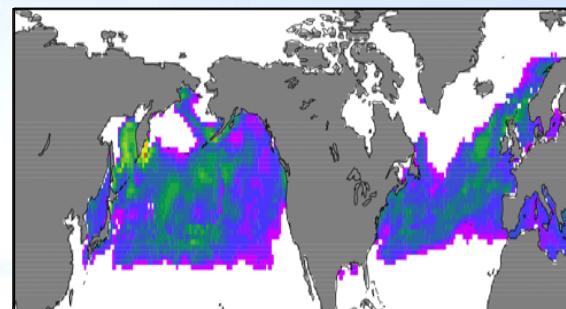


I<sub>V</sub>

(Anderson et al., 2010)

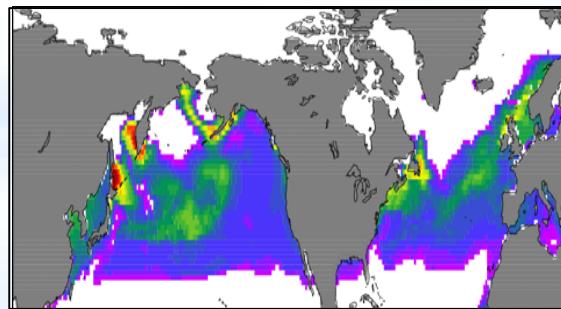
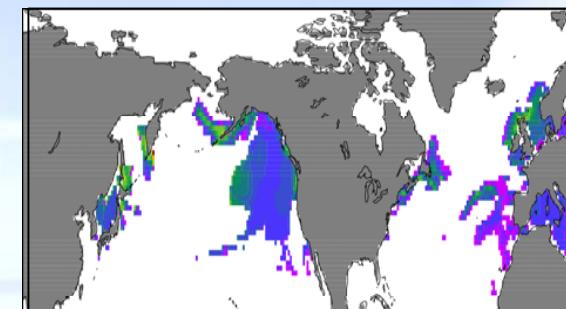
microzooplankton, mmol C m<sup>-3</sup>

MM

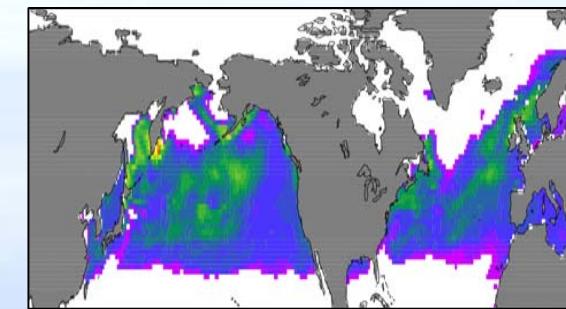


March-May

B



S



I<sub>V</sub>

0.8  
0

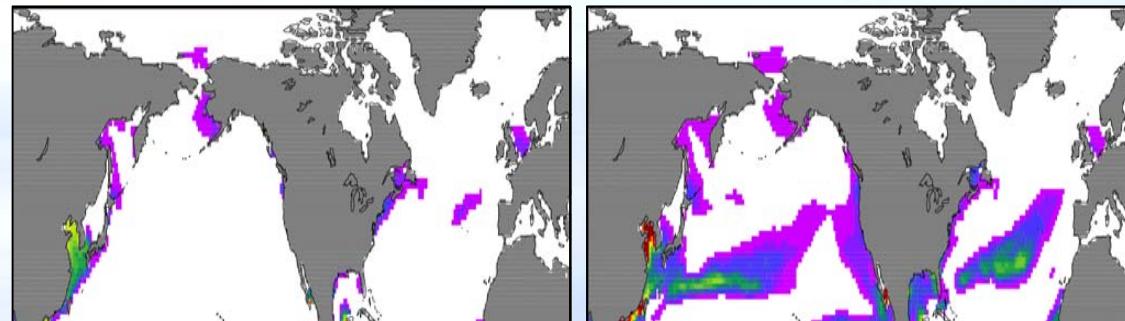
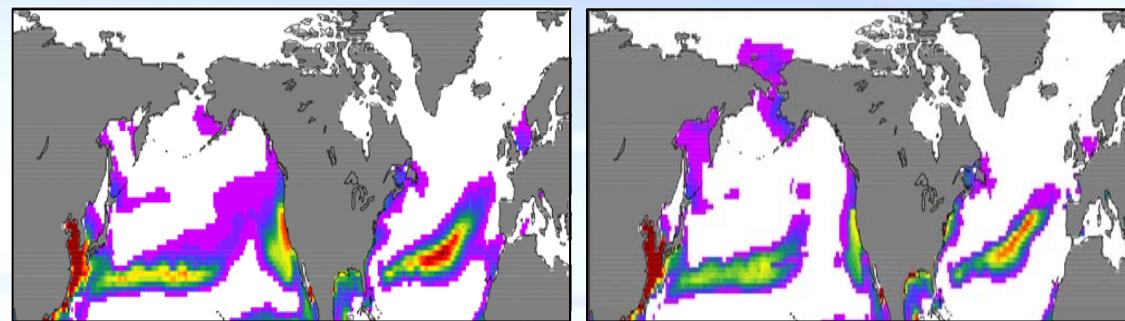
(Anderson et al., 2010)

mesozooplankton, mmol C m<sup>-3</sup>

MM

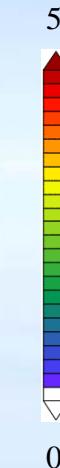
March-May

B



S

I<sub>V</sub>



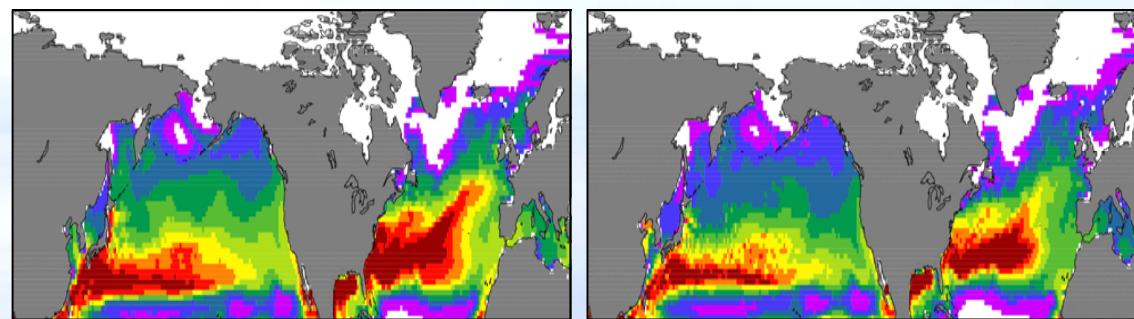
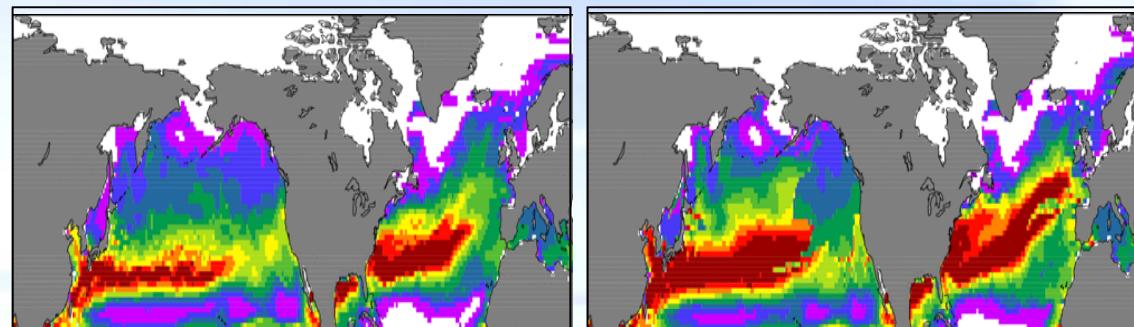
(Anderson et al., 2010)

Primary production, g C m<sup>-2</sup> d<sup>-1</sup>

MM

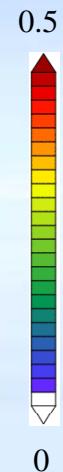
March-May

B



S

I<sub>V</sub>



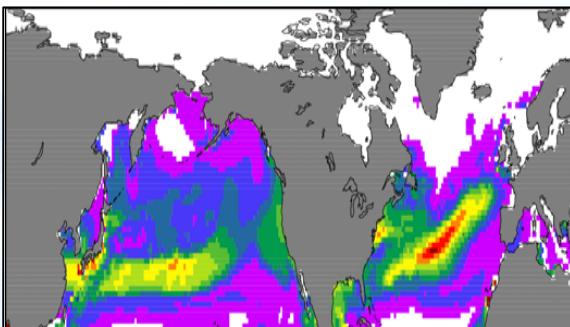
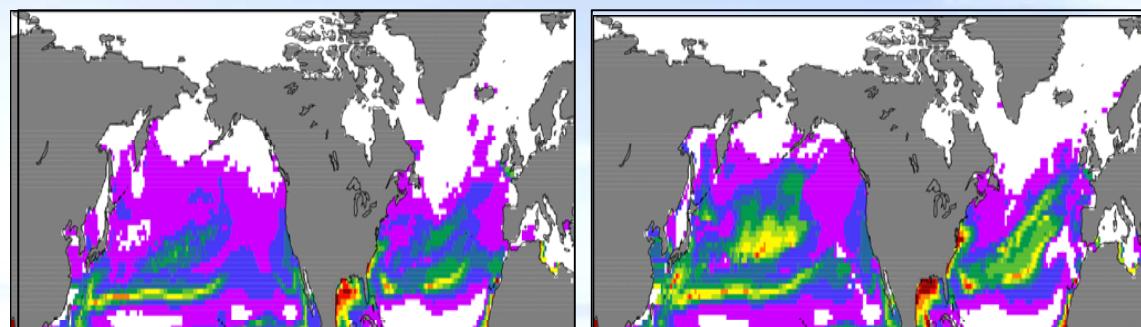
(Anderson et al., 2010)

export g C m<sup>-2</sup> d<sup>-1</sup>

MM

March-May

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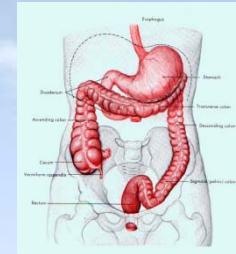
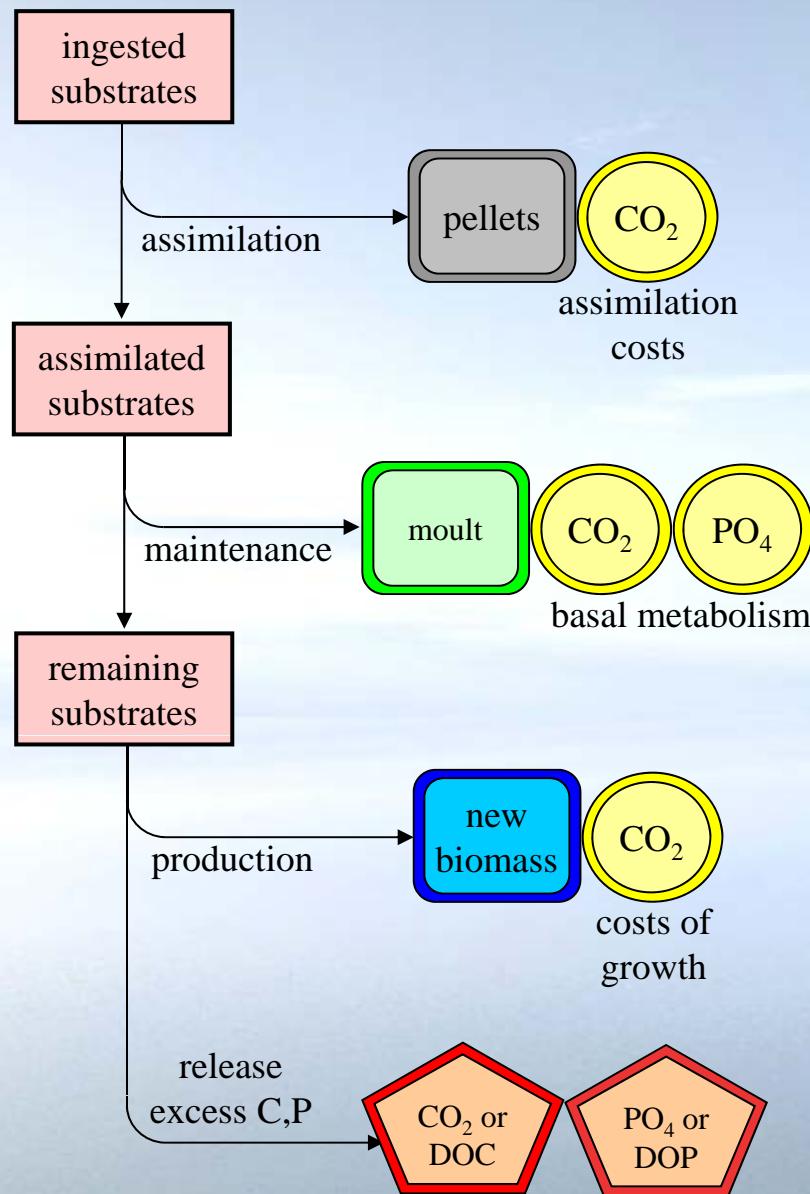
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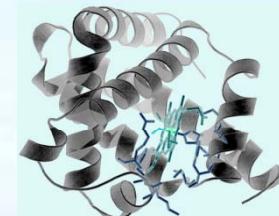
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## Trophic transfer



digestion



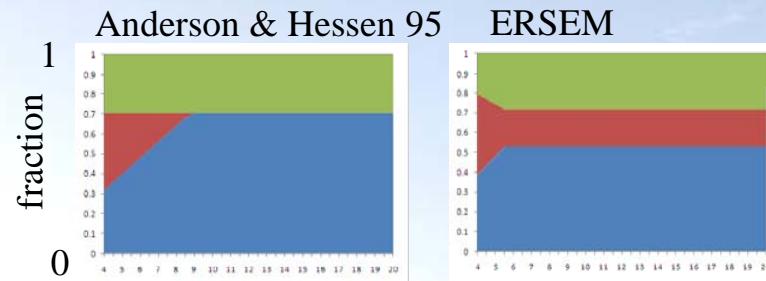
protein turnover



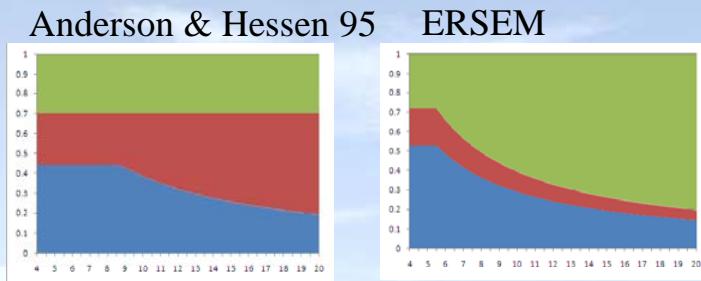
growth (incl. reproduction)

pellets  
 $\text{CO}_2, \text{NH}_4$   
 growth

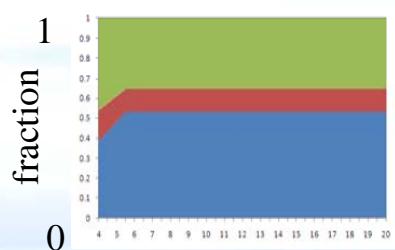
Nitrogen



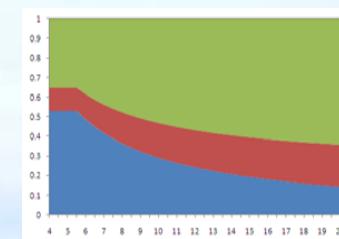
Carbon



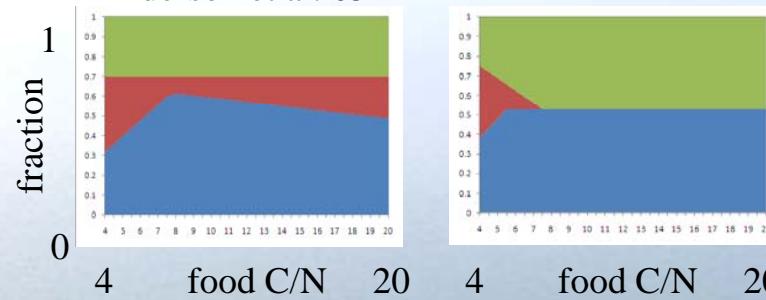
Pahlow 03



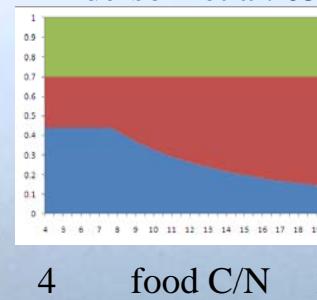
Pahlow 03



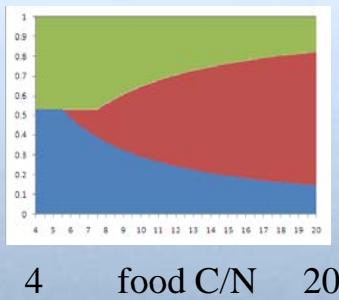
Anderson et al. 05



Anderson et al. 05



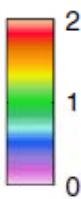
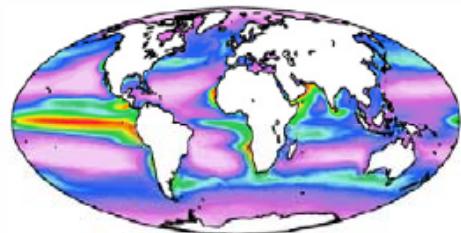
HadOCC



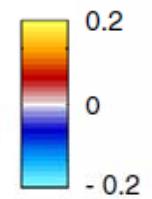
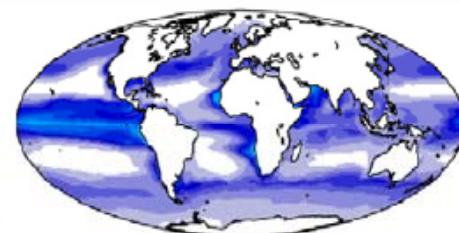
Anderson et al. (in press)

AH95

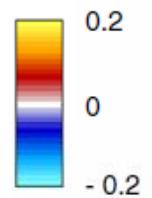
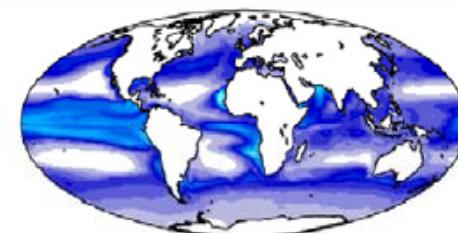
a) Primary production,  $\text{g C m}^{-2} \text{d}^{-1}$



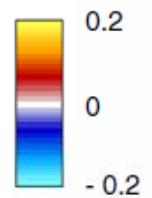
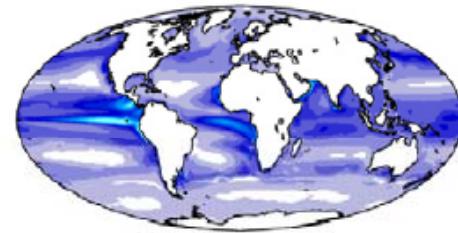
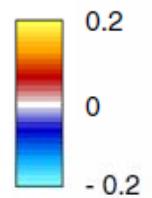
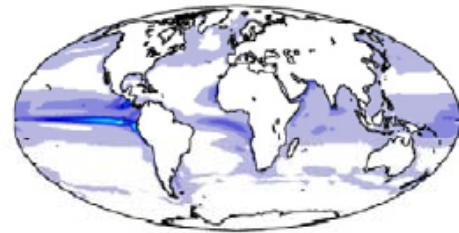
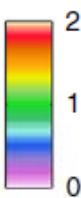
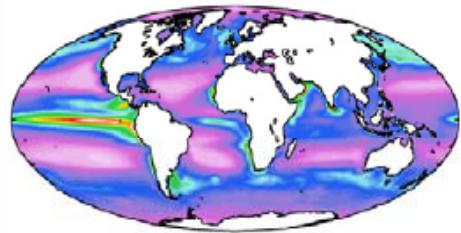
ERSEM/Pah08



HadOCC



b) Surface phytoplankton,  $\text{mmol N m}^{-3}$

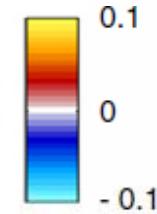
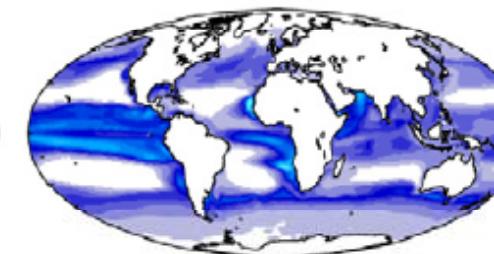
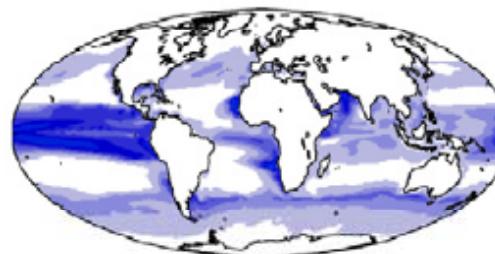
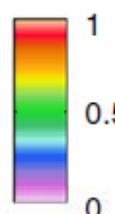
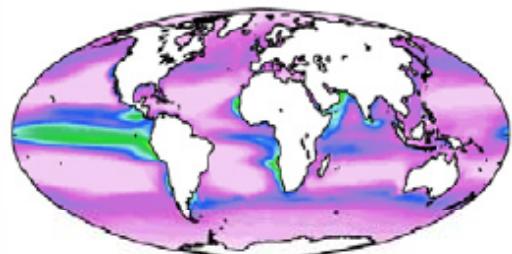


AH95

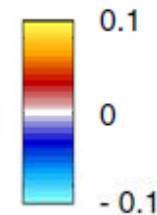
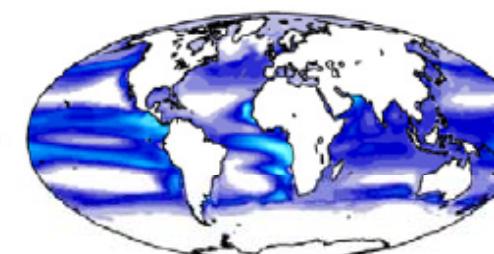
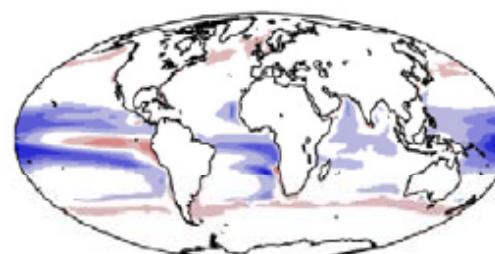
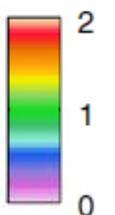
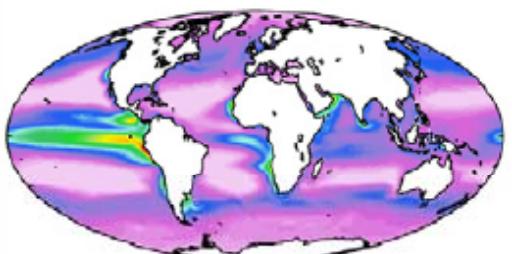
ERSEM/Pah08

HadOCC

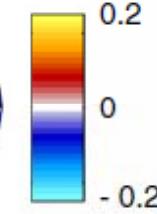
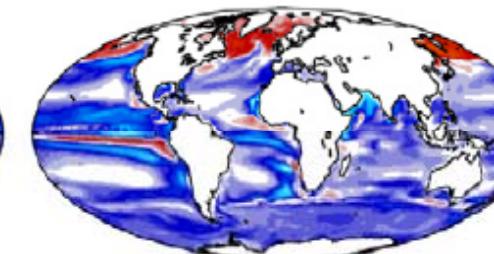
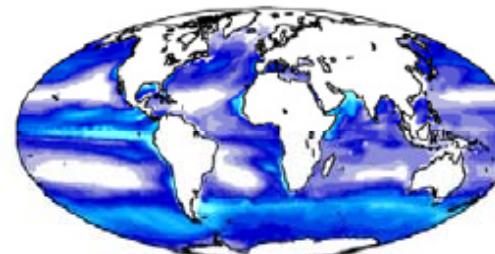
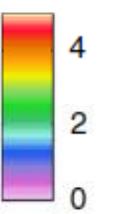
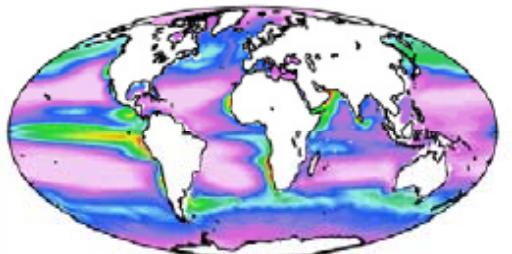
c) Zooplankton production,  $\text{g C m}^{-2} \text{ d}^{-1}$

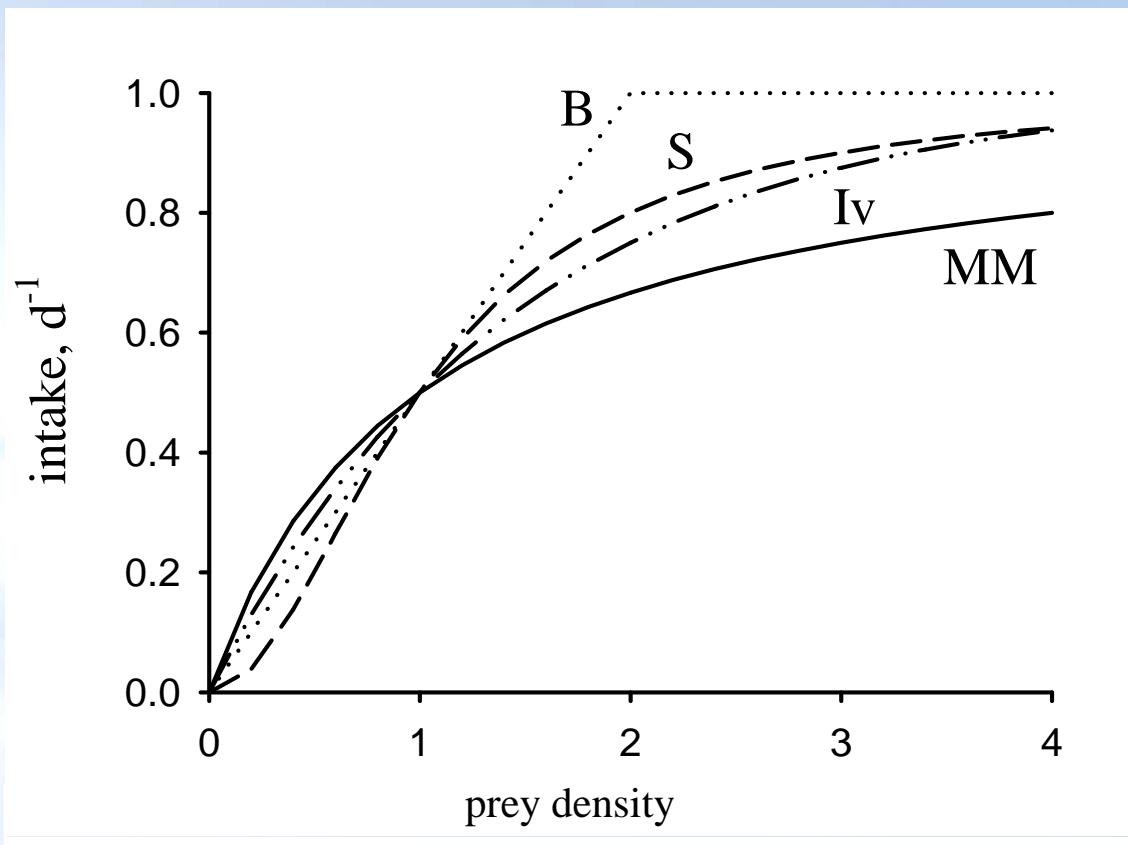


d) Surface zooplankton,  $\text{mmol N m}^{-3}$



e) Detritus flux at 100 m,  $\text{mmol N m}^{-2} \text{ d}^{-1}$

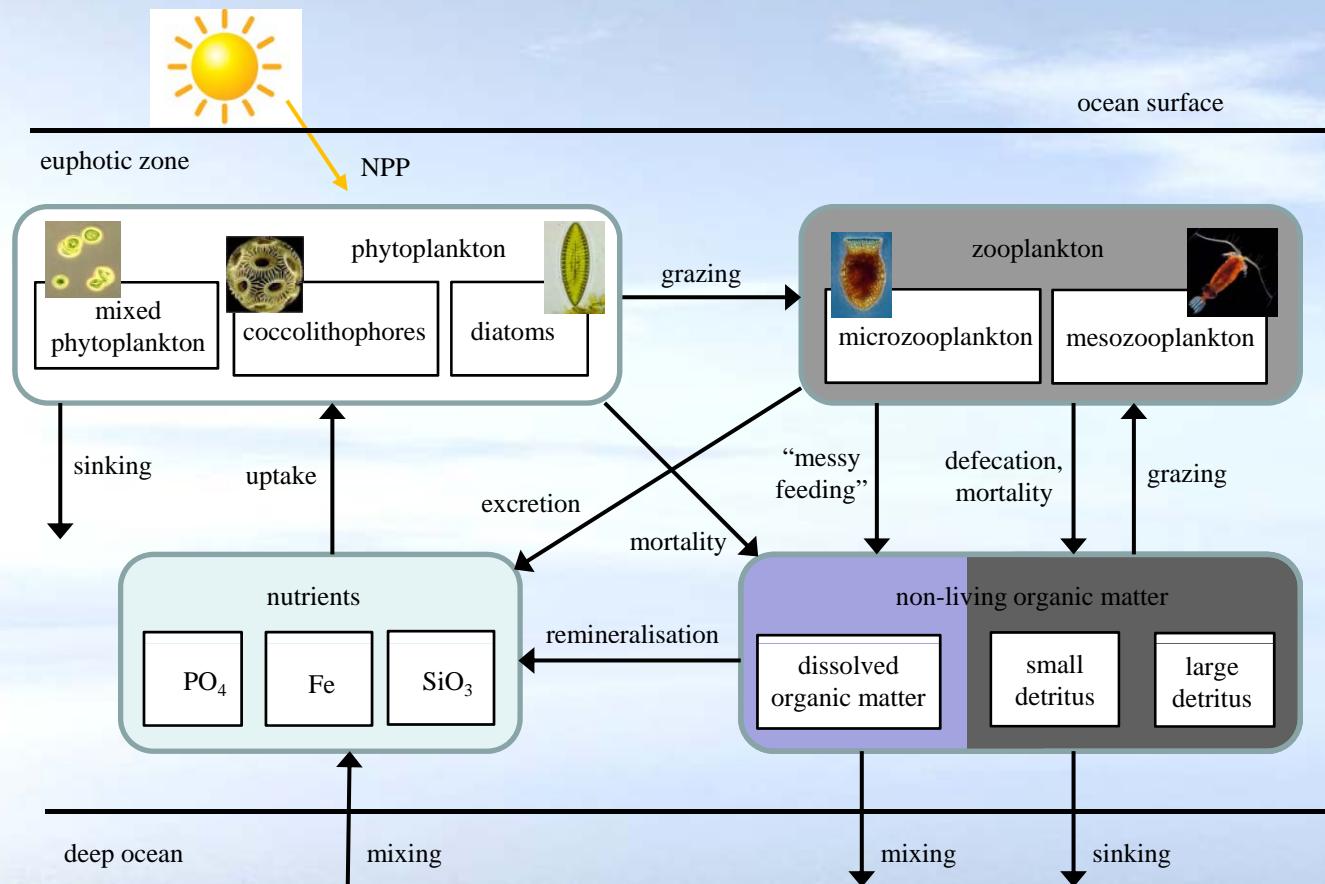






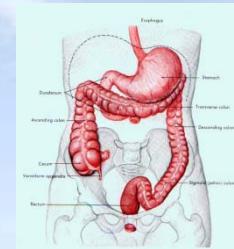
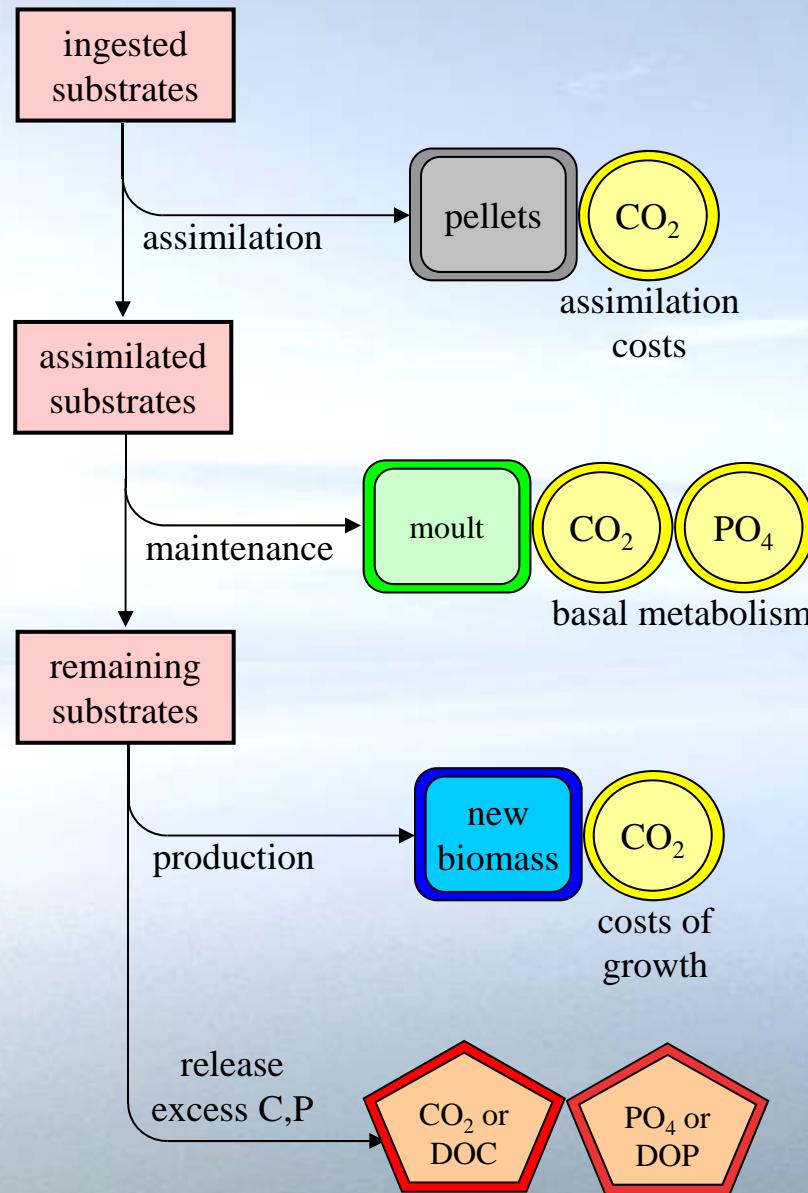
Loss terms and closure

## Complex models

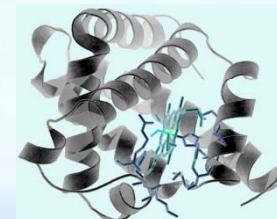




## Poorly understood ecology



digestion



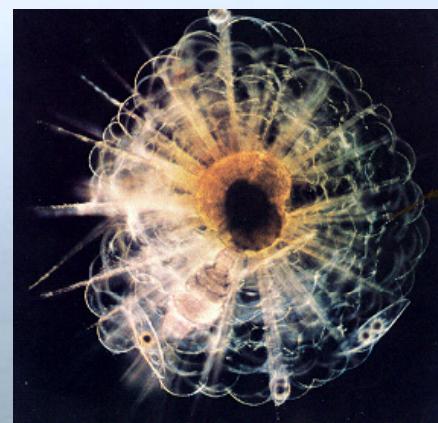
protein turnover



growth (incl. reproduction)



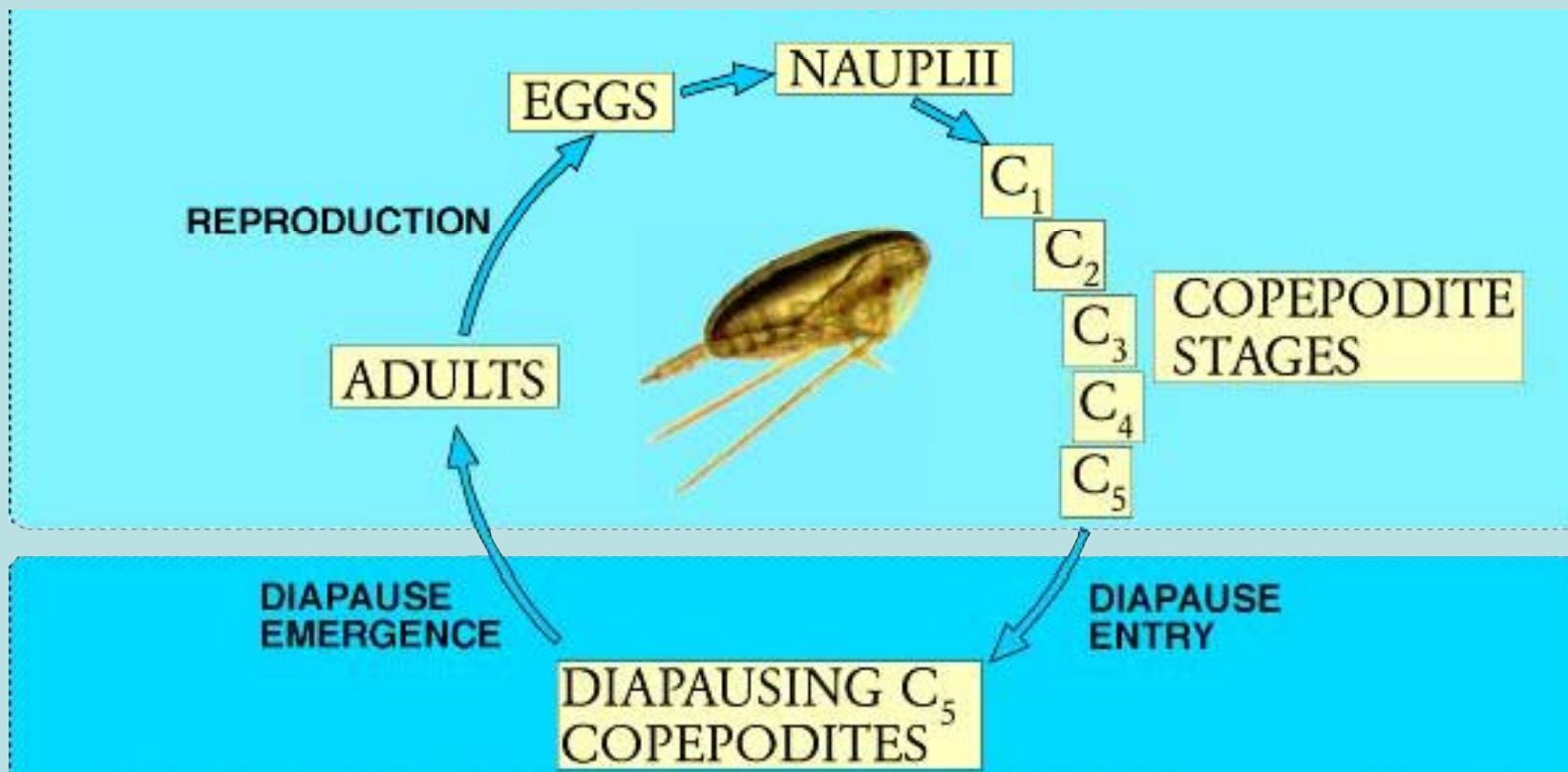
## Aggregation





## Simplification

### Calanus finmarchicus life history

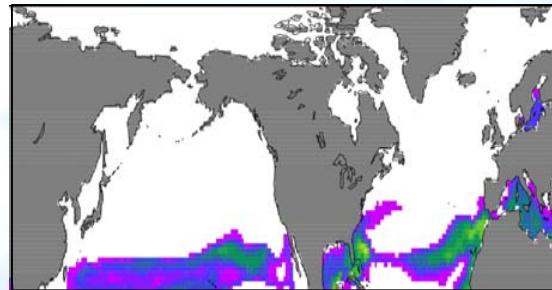




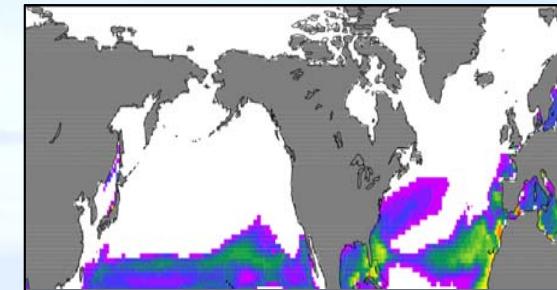
All in the interactions

coccolithophores, mg chl m<sup>-3</sup>

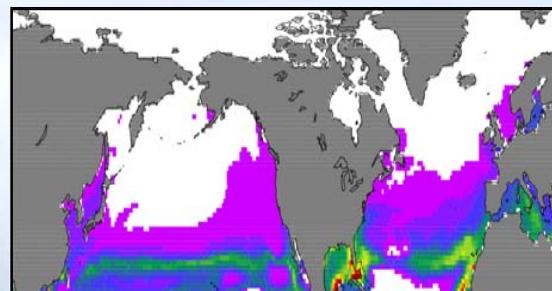
MM



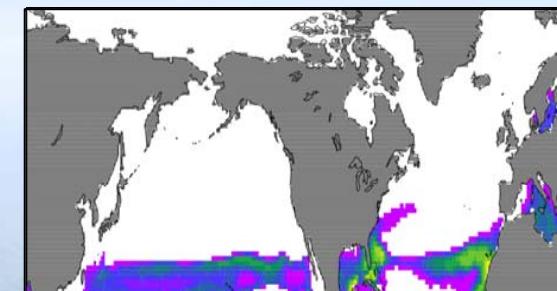
March-May



B



S



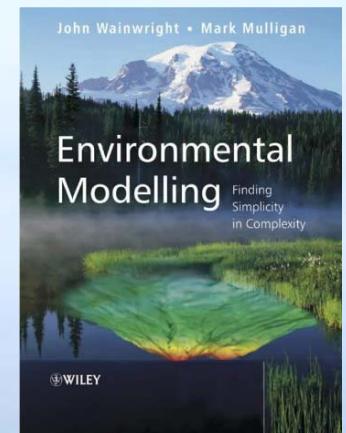
I<sub>V</sub>



### Lack of validation

- Insufficient data
- Too many free parameters

“What little validation is undertaken will always tend to overstate the case for belief in the model results”  
(Wainwright, 2003)



## Conclusions

- ❖ BU and TD combine to determine ecosystem structure and associated fluxes such as export
- ❖ The key is to understand the coupling of phytoplankton and zooplankton as mediated by physical environment
- ❖ Models are remarkably sensitive to the parameterisation of zooplankton
- ❖ The parameterisation of zooplankton in models is fraught with difficulty, especially in complex models