Small copepods channel missing carbon through metazoan predation

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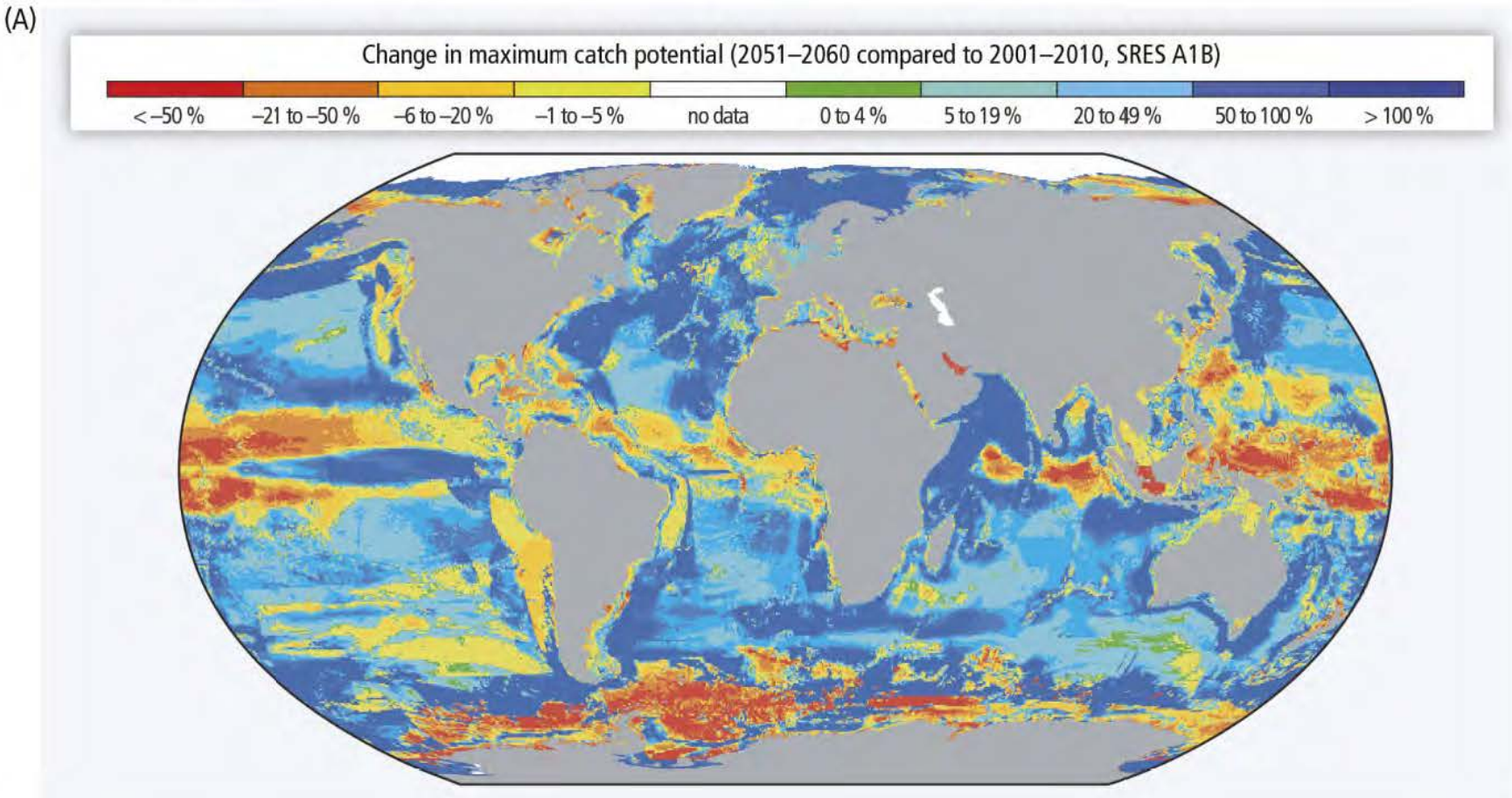
CLIMATE CHANGE
AHEAD

Climate change poses risks for food production

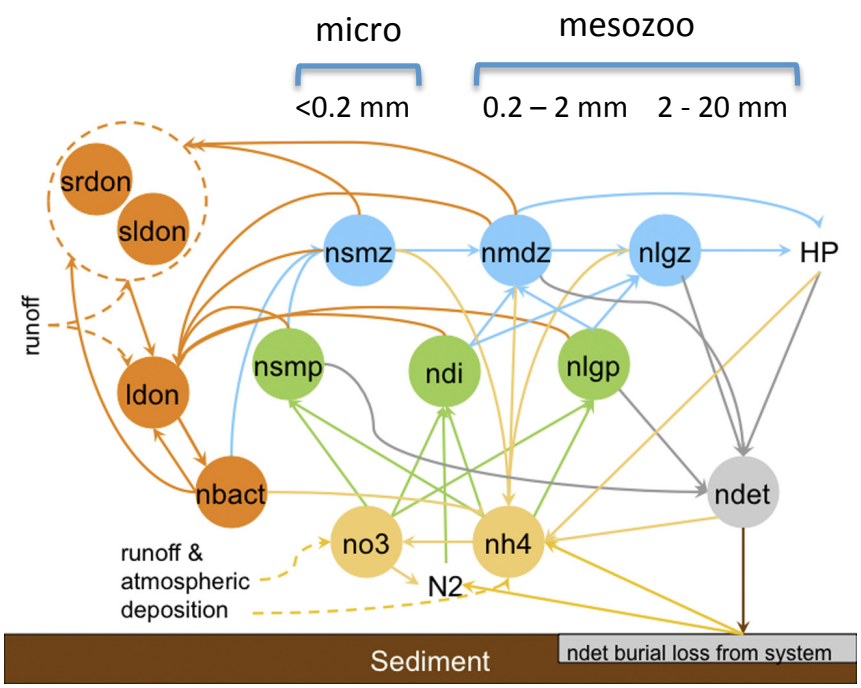
(IPCC 5, 2014)



TOPAZ biogeochemical model (Dunne et al. 2012, 2013)

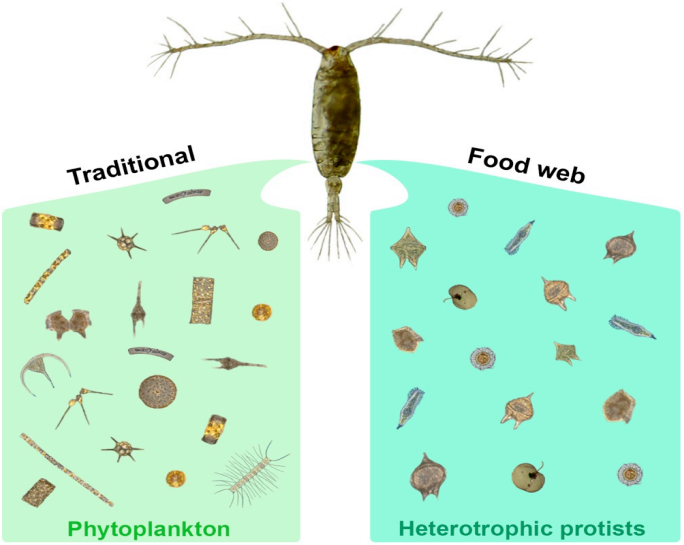
End-to-End ecosystem models

Carbon, Ocean Biogeochemistry and Lower Trophics (**COBALT**): Planktonic ecosystem Model



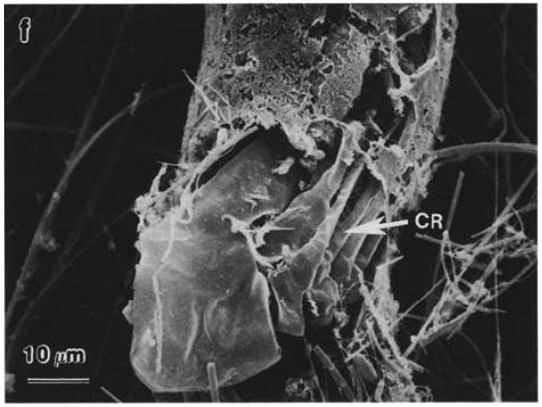
Stock et al. (2014)

Copepods <2 mm
"Unicellular feeders"

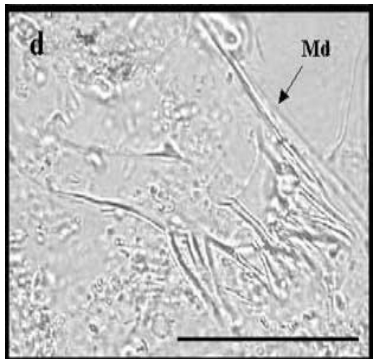


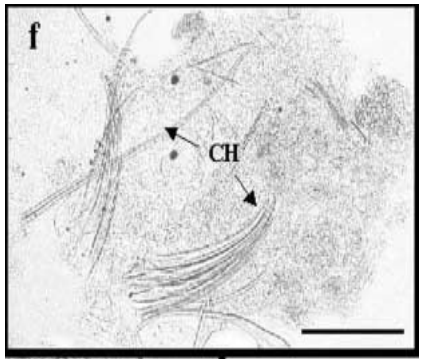
But…

Visual analyses



Turner (1984) *T. turbinata*



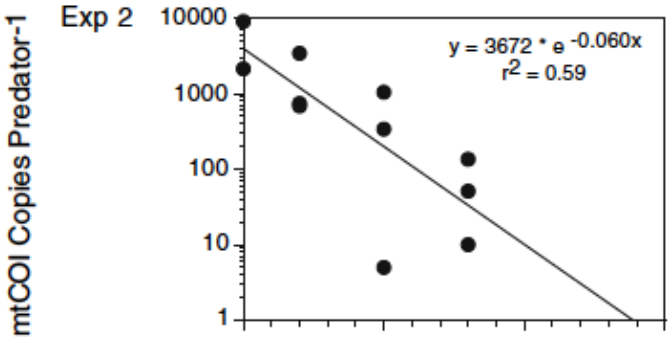


Schnettzer & Steinberg (2002) *P. xiphias*, *E. messinensis*

Go et al. (1998) *Oncaea*

Genetic analyses

Vestheim et al (2005) *C. helgolandicus* in *P. norvegica*



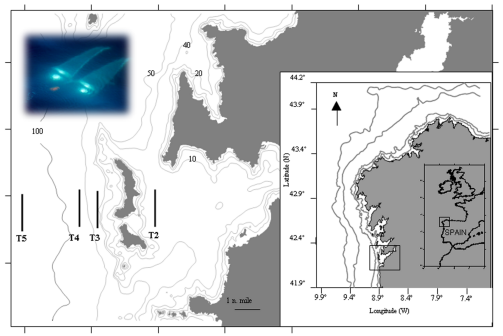
Durbin et al. (2008) *A. tonsa* in *C. typicus*

Just keep walking

And maybe it will go away

Aims of the study and methodological approach

1. Test "metazoan" predation in the dominant copepods of NW upwelling system



Ría de Vigo, NW Spain

17 copepod species

10 upwelling

7 downwelling

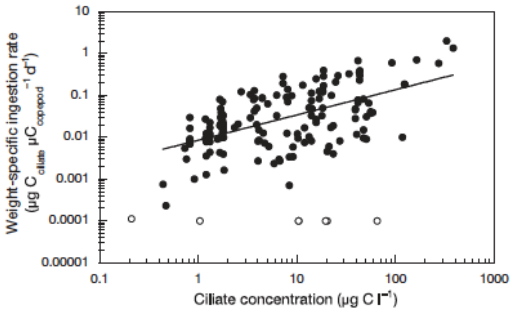
16S rRNA gene for "metazoans"

PREY identification

2. Estimate the "metazoan-copepod link" at a global scale

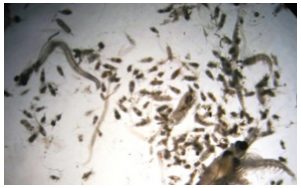
Calbet & Saiz (2005)

Weight specific Ingestion rate (WSIR)



X

Copepod standing stock

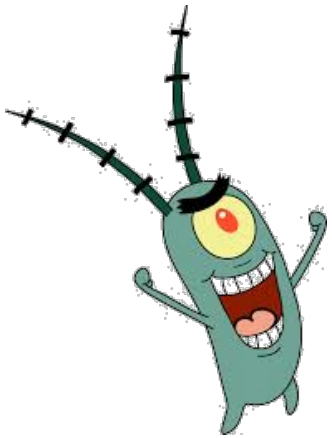


X 365 days =

Amount of C ingested

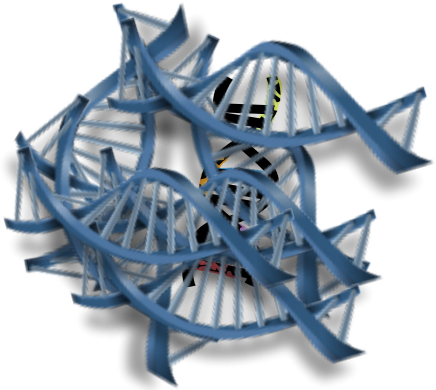
GtC prey / year

1. Metazoan predation: molecular approach



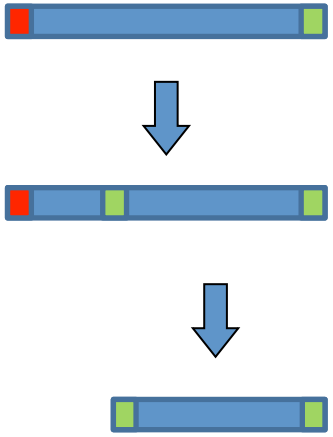
17 species

DNA extraction



Copepod + **prey**

16S



Prey DNA

Nested PCR

metazoan primers

Roura et al. (2012)

Prey DNA

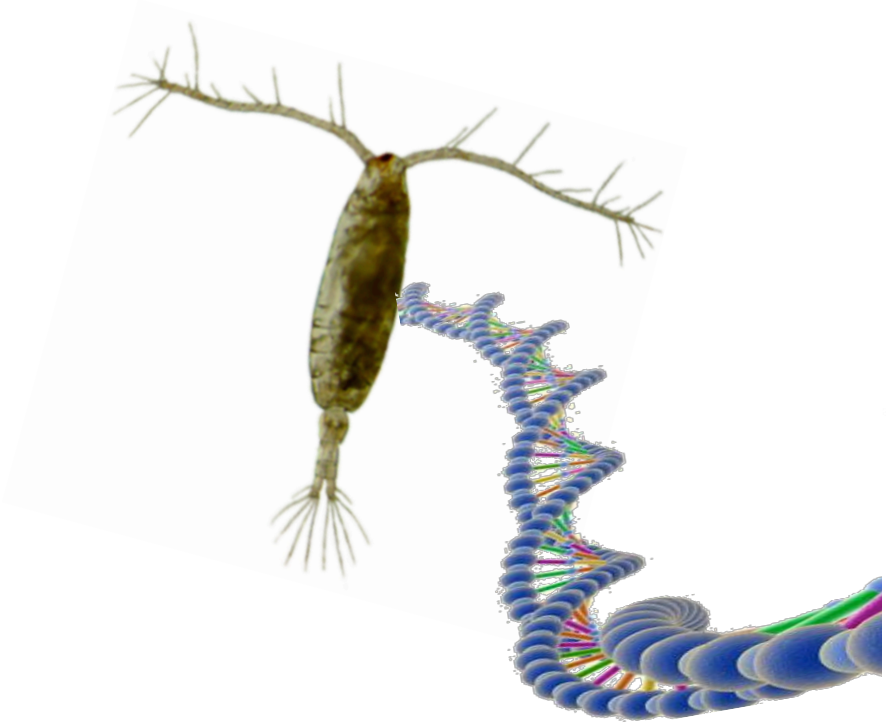
Cloning

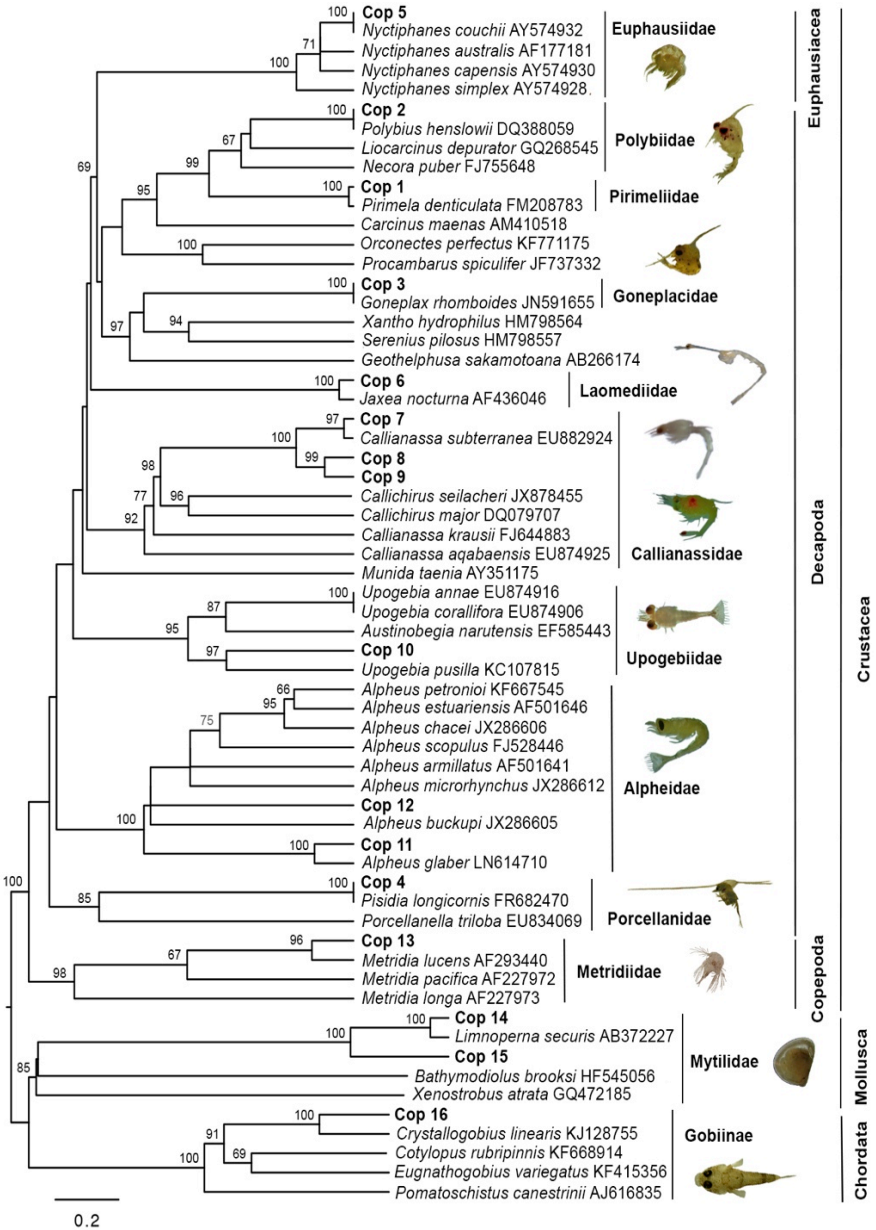
Sequencing

1. Metazoan predation: molecular approach

16 different zooplankton prey in 17 copepods

8 decapod families, krill, copepod, bivalves and fish



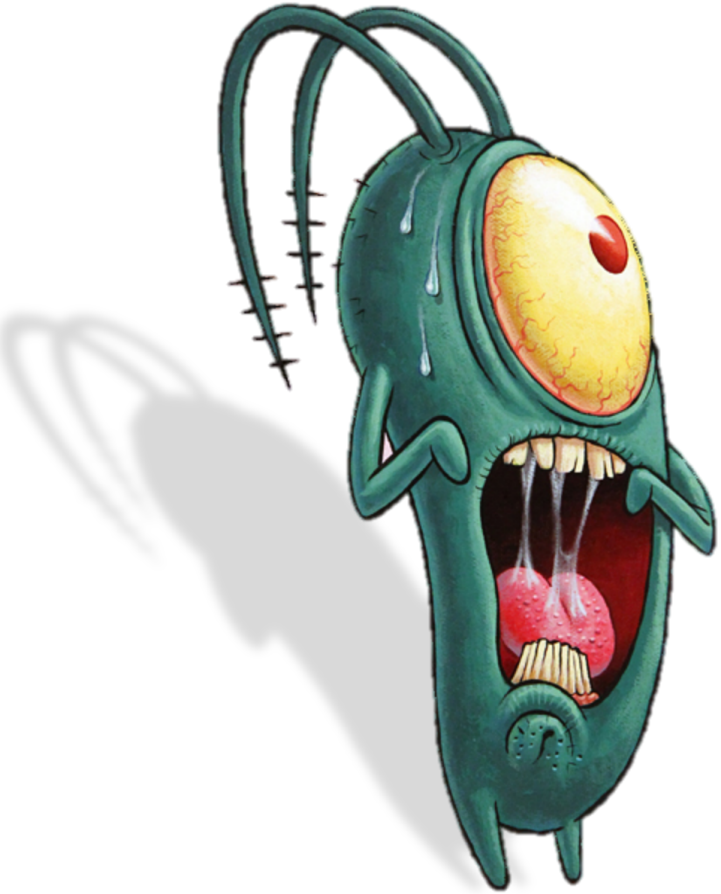


1 – 4 prey per copepod : Independent of the productivity of the system ($p < 0.05$)

Prey detected						Downwelling							Upwelling									
						l	s	s	s	s	s	s	s	s	s	s	l	s	l	s	s	s
OTUs Accesion number	OTUs	Taxon	Top BLAST hit	Accession number	(%)	**C 1**	**C 2**	**C 3**	**C 4**	**C 5**	**C 6**	**C 7**	**C 8**	**C 9**	**C 10**	**C 11**	**C 12**	**C 13**	**C 14**	**C 15**	**C 16**	**C 17**
FR851241	Cop 1	Brachyura	*Pirimela denticulata*	FM208783	99	4		2		3	4		4	1	5	2	2	1	2	3	4	
LN614707	Cop 2	Brachyura	*Polybius henslowii*	FM208765	100											1						
LN614708	Cop 3	Brachyura	*Goneplax rhomboides*	JN591655	100											2						
FR851242	Cop 4	Anomura	*Pisidia longicornis*	FR682470	100	1	3	2			1								2			
FR851243	Cop 5	Euphausiacea	*Nyctiphanes couchii*	AY574933	97				1													
FR851244	Cop 6	Gebiidea	*Jaxea nocturna*	AF436046	98					1							2					
FR851245	Cop 7	Axiidea	*Callianassa subterranea*	EU882924	99													1				
FR851246	Cop 8	Axiidea	*Callianassa* sp.	EU882924	93													1				
FR851247	Cop 9	Axiidea	Callianassidae	EU882924	90													1				
FR851248	Cop 10	Gebiidea	Upogebiidae	EU874916	81												1					
FR851249	Cop 11	Caridea	*Alpheus glaber*	LN614710	96					1												
FR851250	Cop 12	Caridea	Alpheidae 5	FJ528445	78																	4
LN614709	Cop 13	Copepoda	*Metridia lucens*	AF293440	96		1															
FR851251	Cop 14	Bivalvia	*Limnoperna securis*	AB372227	98									2								
FR851252	Cop 15	Bivalvia	Mytilidae	AB372227	87									1								
FR851253	Cop 16	Teleostei	Gobiinae	EF218650	92							4										

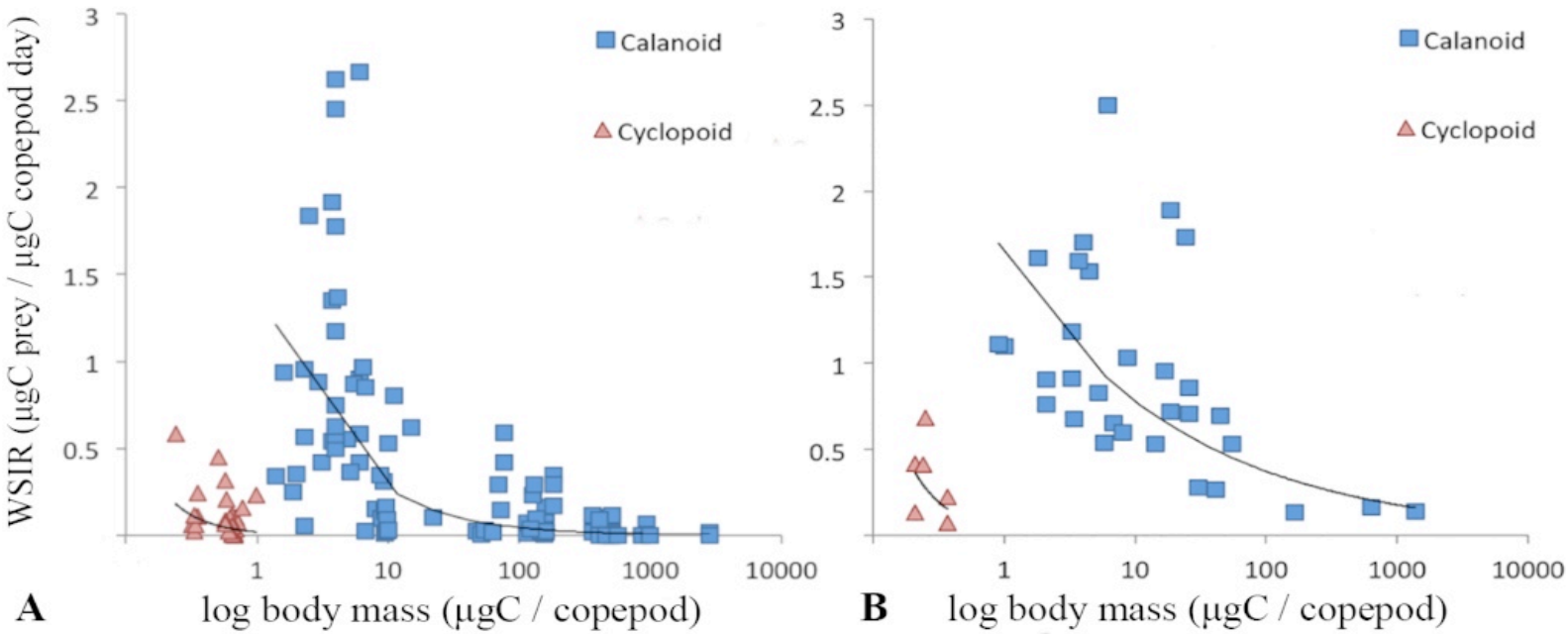
Copepod species analysed:
C1: Paraeuchaeta hebes; C2: Diaixis pygmaea; C3: Temora longicornis; C4: Centropages chierchiae; C5: Clausocalanus spp.; C6: Acartia clausii; C7: Isias clavipes; C8:Pseudocalanus elongatus; C9: Centropages typicus; C10: Pleuromamma gracilis; C11: Aetideus armatus; C12: Calanoides carinatus; C13: Ctenocalanus vanus; C14: Calanus helgolandicus; C15: Paracalanus parvus; C16: Oithona sp.; C17: Corycaeus spp.

C ?



“Carnivorous” weight specific ingestion rate

39 feeding studies, adults & late copepodites, carnivorous predation: protists and metazoans (Saiz & Calbet, 2007)



Calanoids 238.54 µg C → WSIR **0.023**

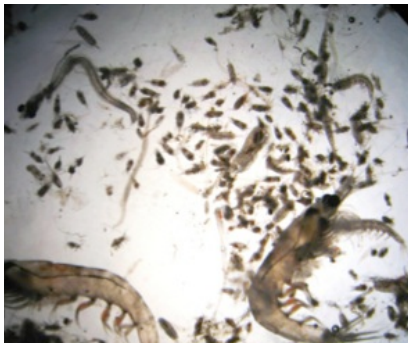
Cyclopoids 0.582 µg C → WSIR **0.044**

Calanoids 82.35 µg C → WSIR **0.396**

Cyclopoids 0.27 µg C → WSIR **0.241**

2. “Metazoan-copepod link”

Copepod standing stock >100m

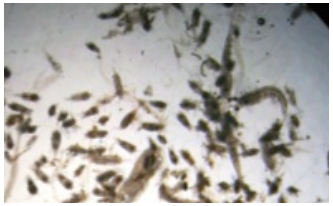


0.31 GtC Zooplankton
Bogorov et al. (1968)
Moiseev (1971)

1/3 underestimated
Gallienne & Robins (2001)

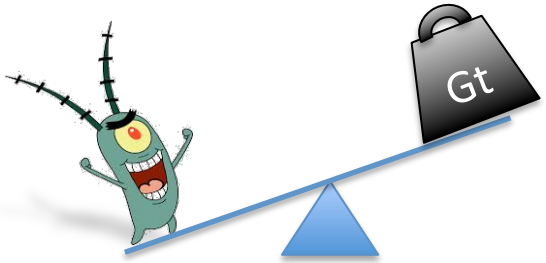
0.41 GtC Zooplankton

80% copepods
Kiørboe 1997

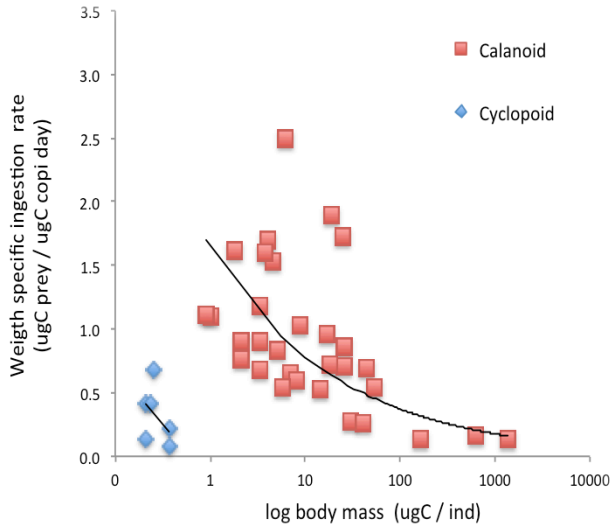


0.33 GtC copepods

60% adults and
Copepodites
Turner (2004)



0.198 GtC copepods



Coast (IMOS)

0.120 GtC Calanoids 60.5%

0.078 GtC cyclopoids 28.5%

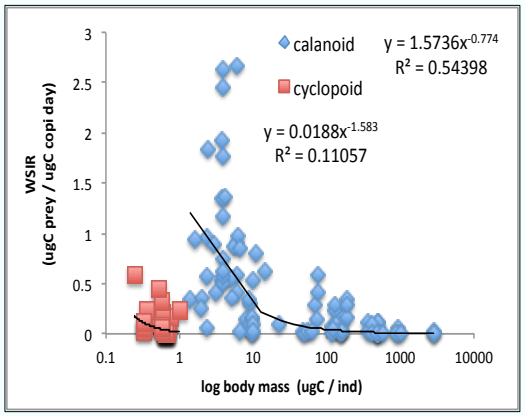
Ocean (COPEPOD)

0.181 GtC calanoids 91.3%

0.013 GtC cyclopoids 6%

2. “Metazoan-copepod link”

Field Studies (n = 125)

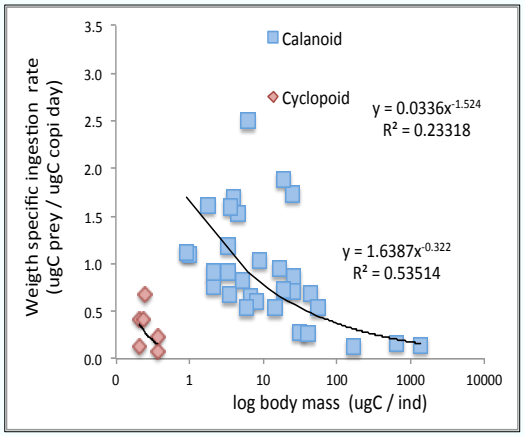


Av weight:
- Calanoids 238.54 µgC
- Cyclopoids 0.58 µgC

$WSIR_{cal}$ 0.023

$WSIR_{cyc}$ 0.063

Laboratory studies (n = 37)



Av weight:
- Calanoids 82.35 µgC
- Cyclopoids 0.27 µgC

$WSIR_{cal}$ 0.396

$WSIR_{cyc}$ 0.241

X

Copepod standing stock (>100 m)

Coast (IMOS) **0.198 GtC** Ocean (COPEPOD)

0.120 GtC calanoids

0.181 GtC calanoids

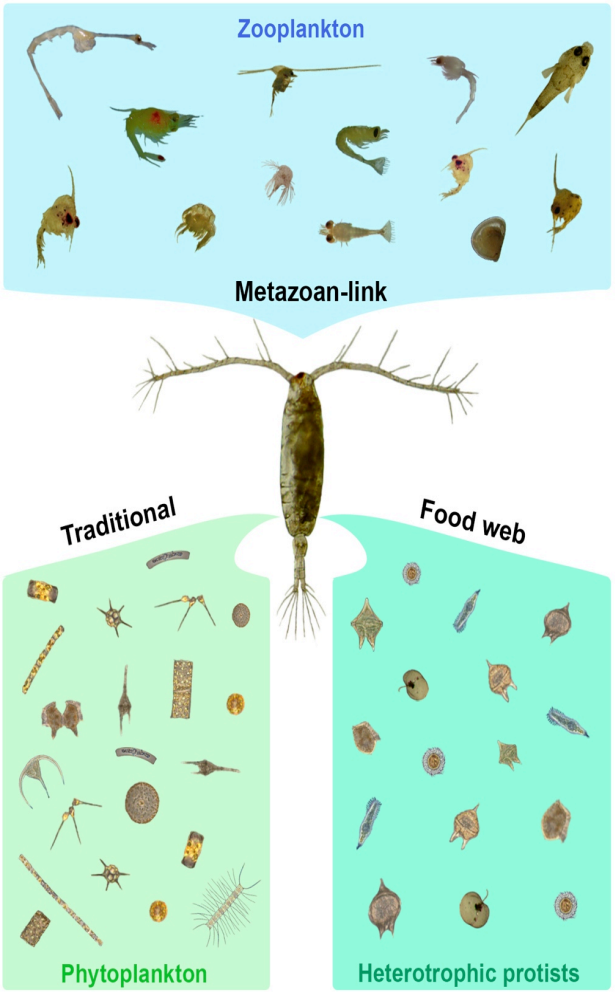
0.078 GtC cyclopoids

0.013 GtC cyclopoids

“Overlooked” carbon ingestion (GtC/y)			
Field	calanoids	0.99 - 1.5	**1.79 - 2.8**
	cyclopoids	0.29 - 1.81	
Lab	calanoids	17.3 - 26.1	**24.16 - 27.2**
	cyclopoids	1.1 - 6.87	

2. “Metazoan-copepod link”

Global scale (field estimates)



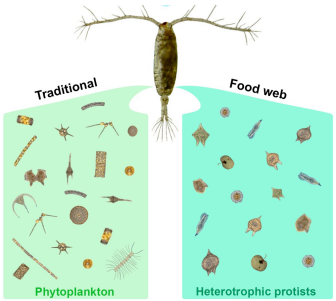
1.79
2.8
GtC

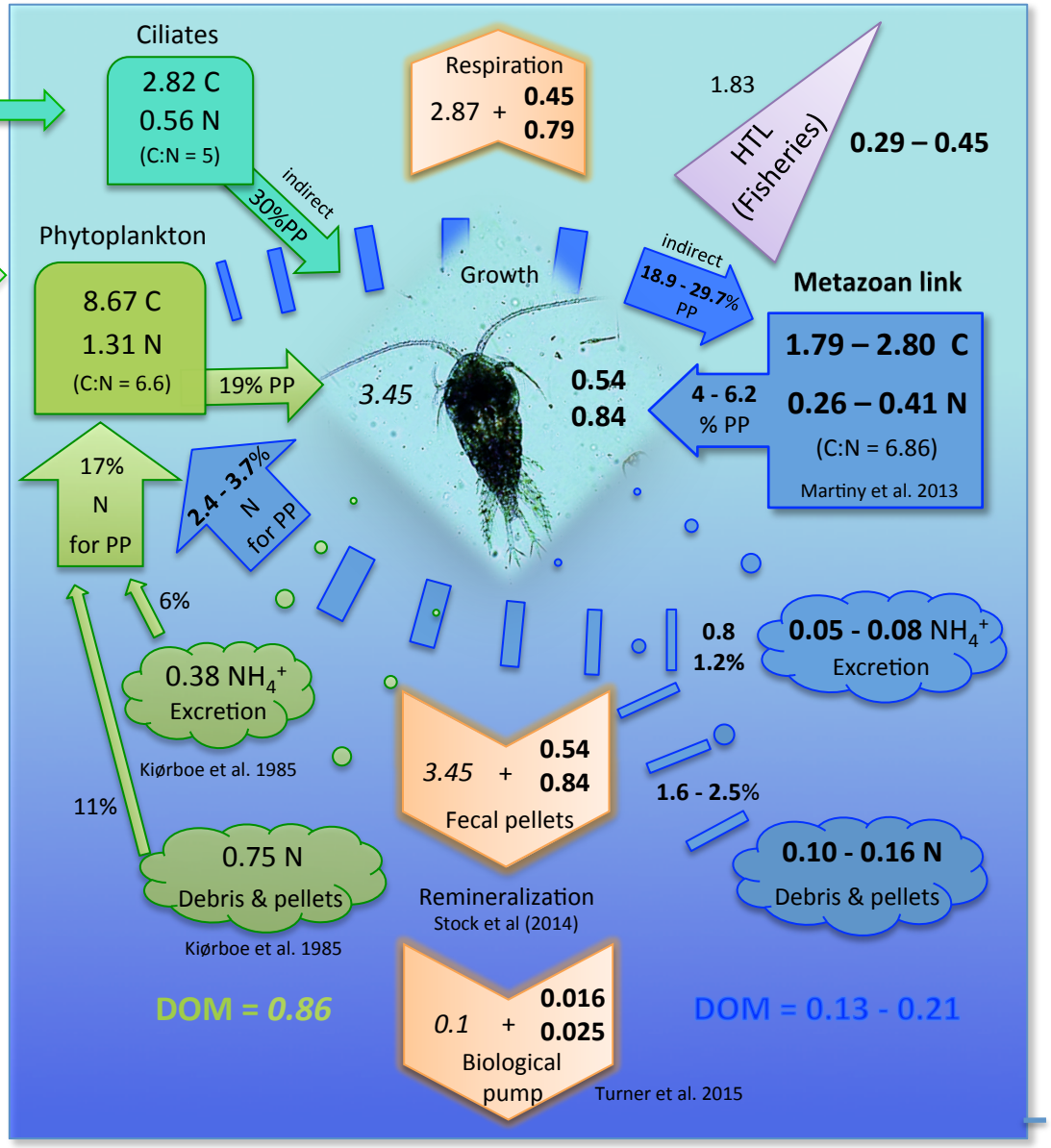
15.6 – 24.4 %

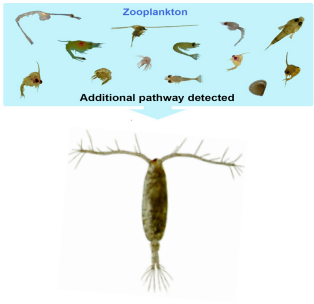
11.5
GtC

Calbet & Saiz (2005)

Global scale impact on pelagic fluxes of C & N (Gt y^{-1})







Data shown:

Phytoplankton-ciliate ingestion and metabolic fluxes modified from Calbet & Saiz (2005)

Assumptions:

Copepods 80% of total biomass (Kiørboe 1997)

Copepod biomass underestimated 30% (Gallienne and Robins 2001)

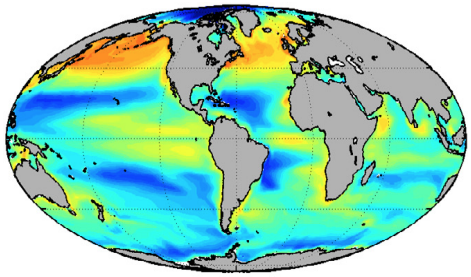
Metabolic rates (Ikeda & Motoda 1978):
Assimilation efficiency = 0.7
Growth efficiency = 0.3
Ingestion rate = 2.5 Resp
Growth rate = 0.75 Resp

PP = 45GtC (Falkowski et al 1998)

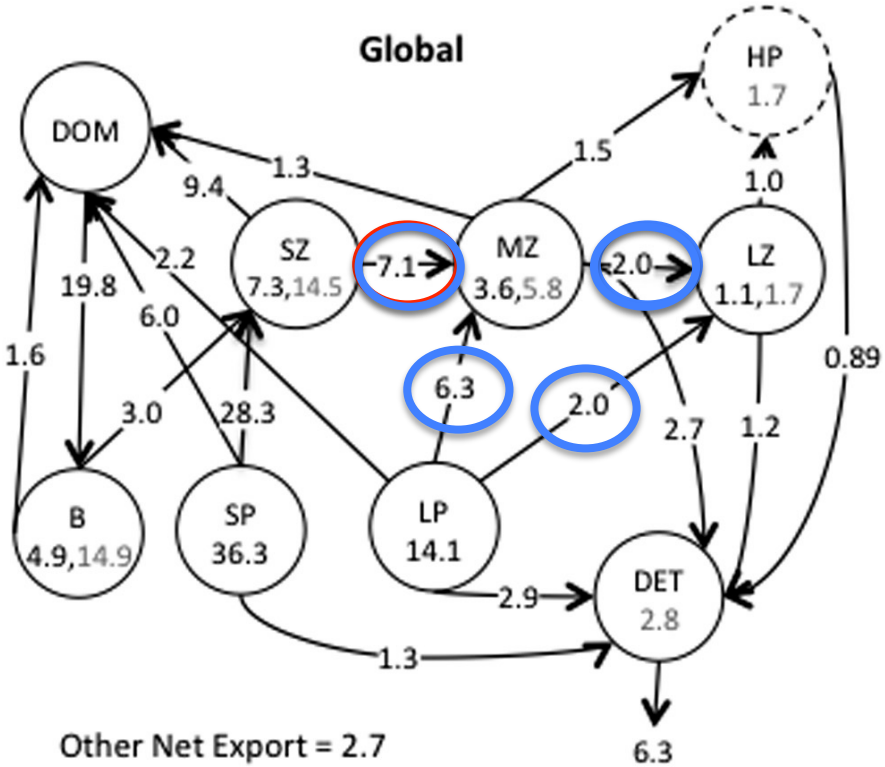
WSIR from field studies

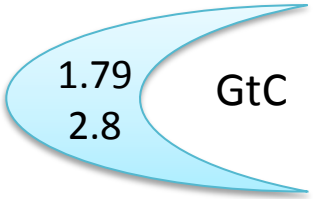
Calanoids / Cyclopoids
Coast (IMOS): 67.9 / 32.1
Ocean (NOAA): 91.29 / 5.95

But….all this effort make any sense?



COBALT Planktonic Ecosystem Model (Stock et al 2014)





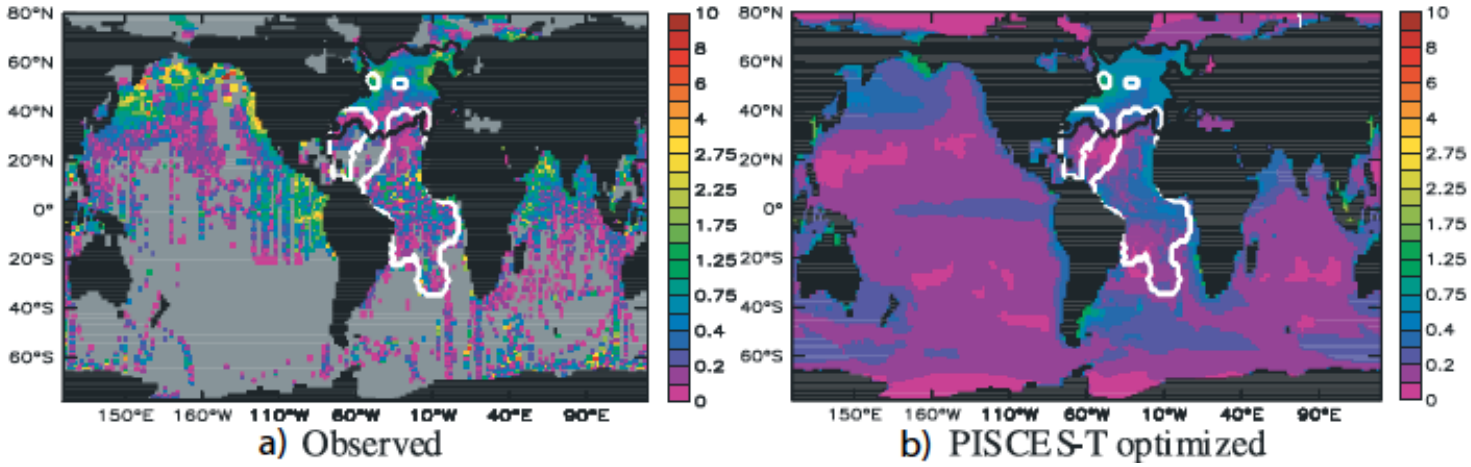
Artificial ingestion of 91% microzoo

Mesozooplankton ingestion = 17.4 GtC

26 GtC estimated using respiration
Hernández-León & Ikeda (2005)

Fluxes in Gt C / yr averaged over the top 100 m last 20 yr

What about laboratory estimations?



Buitenhuis et al. 2006*:* Global biogeochemical model with an explicit representation of mesozooplankton (PISCES-T) to estimate zooplankton grazing at a global scale using <u>laboratory data</u> compiled by Hirst and Bunker (2003).

Grazing by copepods: 42.8 Gt C/yr = 17 Gt phyto and microzoo + <u>25.8 Gt POC and bacteria</u>

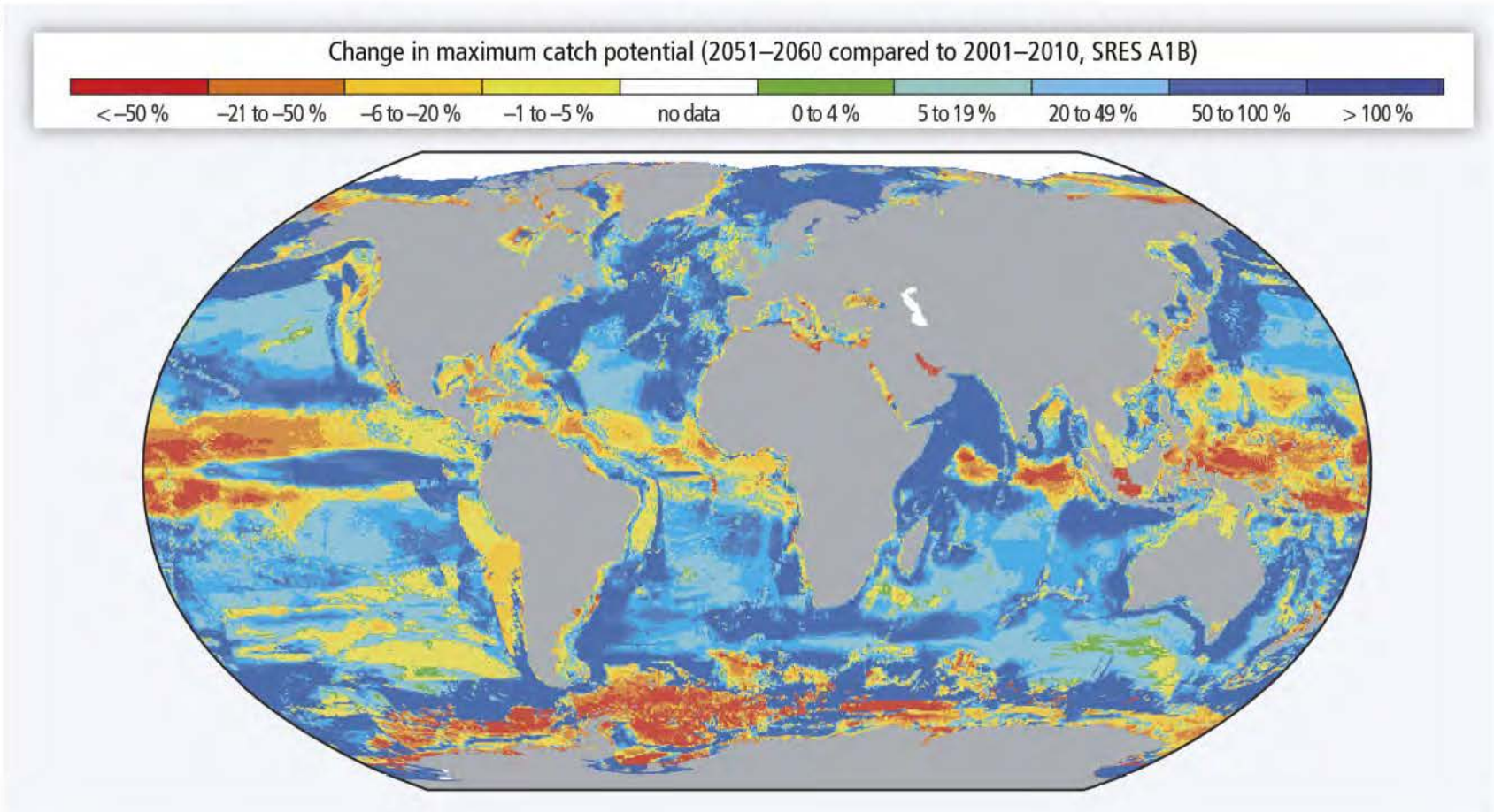
"To reconcile the grazing flux in our optimized model of 43 Pg C/yr … …direct and indirect grazing on <u>POC and bacteria</u> would have to make up the largest part of mesozooplankton grazing"

"Overlooked" carbon ingestion (GtC/y)			
Lab	calanoids	17.3 - 26.1	**24.16 - 27.2**
	cyclopoids	1.1 - 6.87	

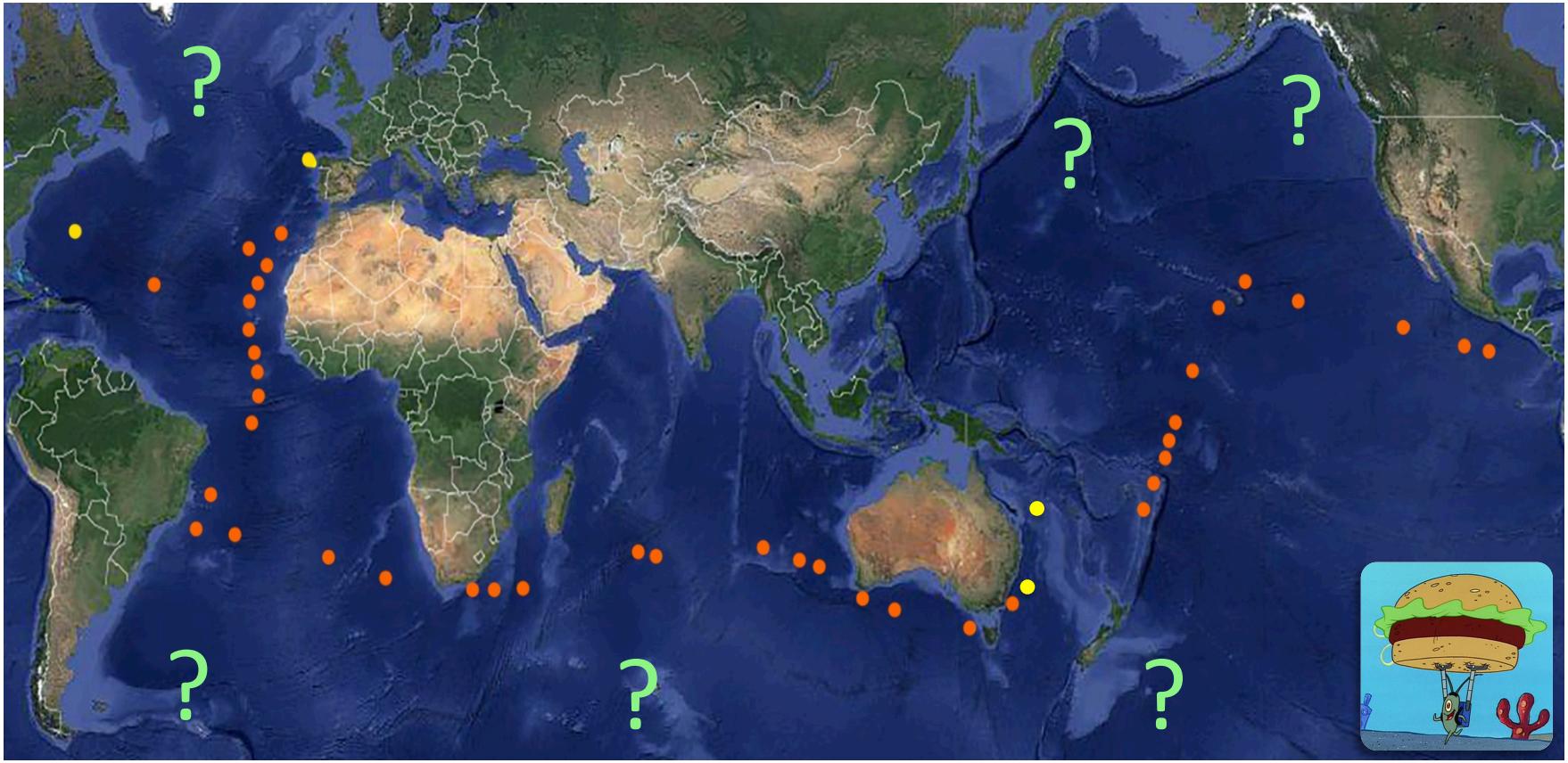
Consequences on climate change predictions models?

Climate change poses risks for food production

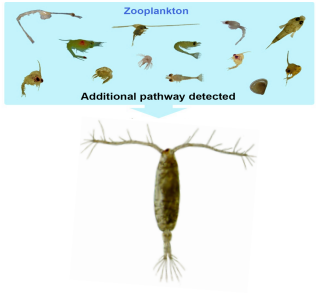
(A)



Future challenges



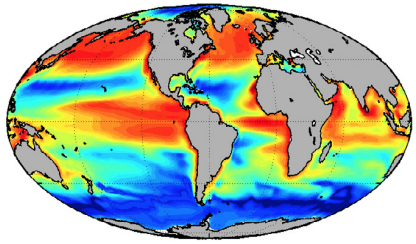
Molecular method



- 1 – 4 zooplankton prey detected in **all copepods**.
- 16 prey detected: decapods, krill, copepods, bivalves and fish

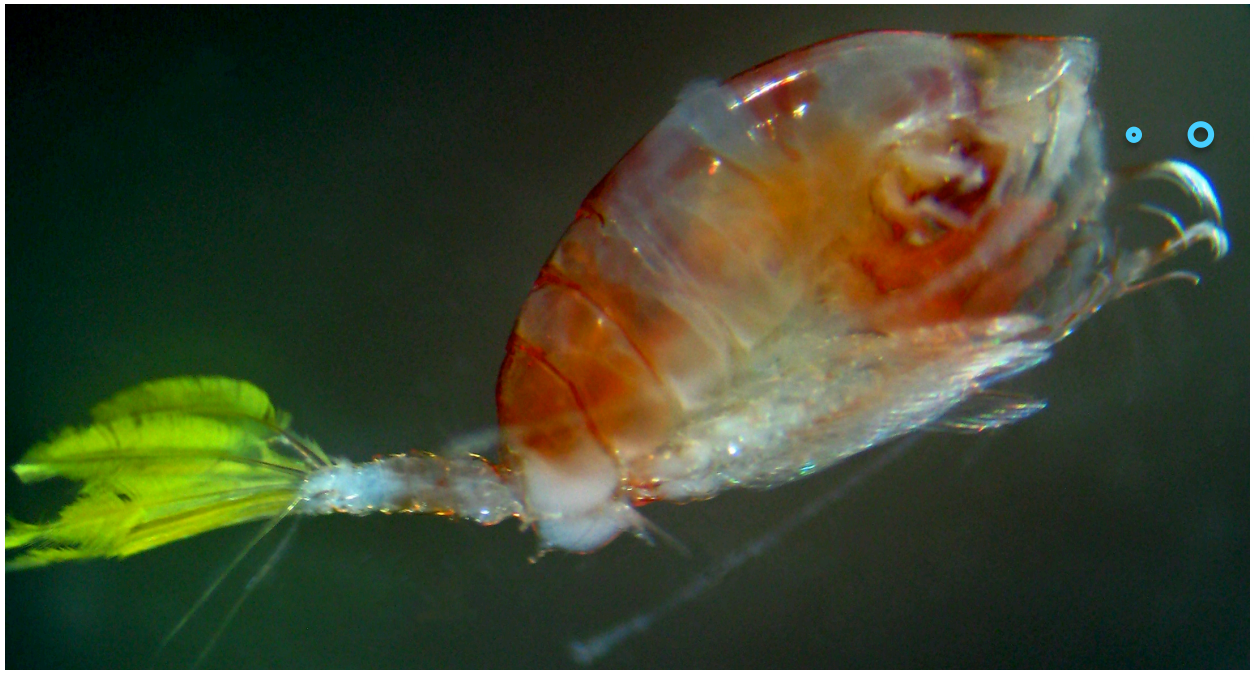
Global scale impacts of metazoan predation (upper 100 m)

- 15.6 - 24.4% increased amount of C through pelagic food webs (~1.8 – 2.8 GtC/yr)



- Reduce discrepancies between modeled and measured carbon in E2E

- Help to explain the unbalance between estimates of copepod ingestion/growth and metabolic demands



Any questions…?

Acknowledgements:

Mariana Cueto (IIM, CSIC)

RV “Mytilus” crew (IIM, CSIC)

ECOBIOMAR group (IIM,CSIC)

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