Grazer-mediated particle flux and the episodic nature of salp fecal pellet export

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UNIVERSITY

What do we know about grazer mediated flux?

What are we currently learning?

What do we still need to learn?

What do we know about grazer mediated flux?

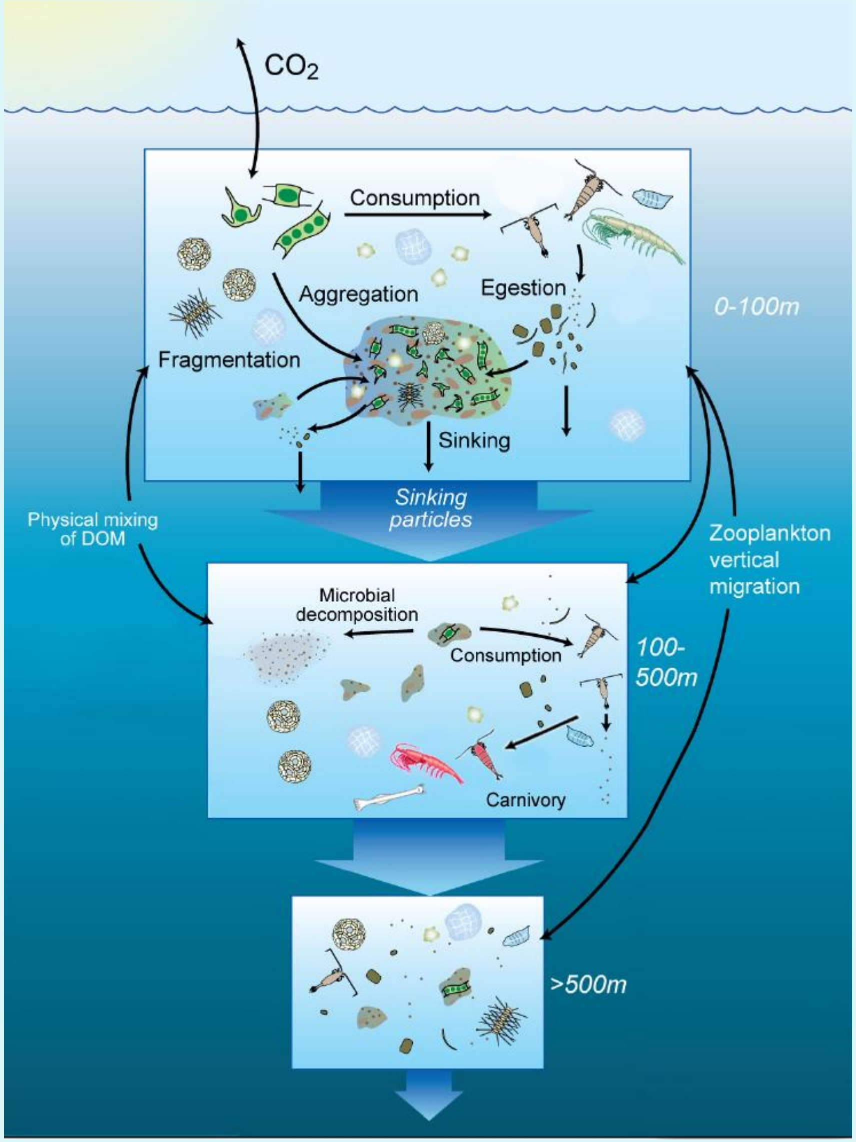
What are we currently learning?

What do we still need to learn?

Affect composition, rate and amount at which sinking particles reach the deep-sea

Zooplankton feeding ecology and trophic interactions are poorly understood

- diel vertical migration
- carnivory
- ingestion of particles
- egestion
- recycling



Modified from Buesseler et al. 2006

Zooplankton and the biological pump

Variations in zooplankton size and community structure can differentially alter the transfer efficiency of sinking POC flux

Zooplankton can:

- Consume – direct uptake
- Repackage – dense, quickly sinking fecal pellets
- Aggregate – produce sticky feeding webs and houses
- Break apart – sloppy feeding, swimming

Grazer-mediated particle flux

Zooplankton fecal pellets

Diagonostic of taxa and their diet

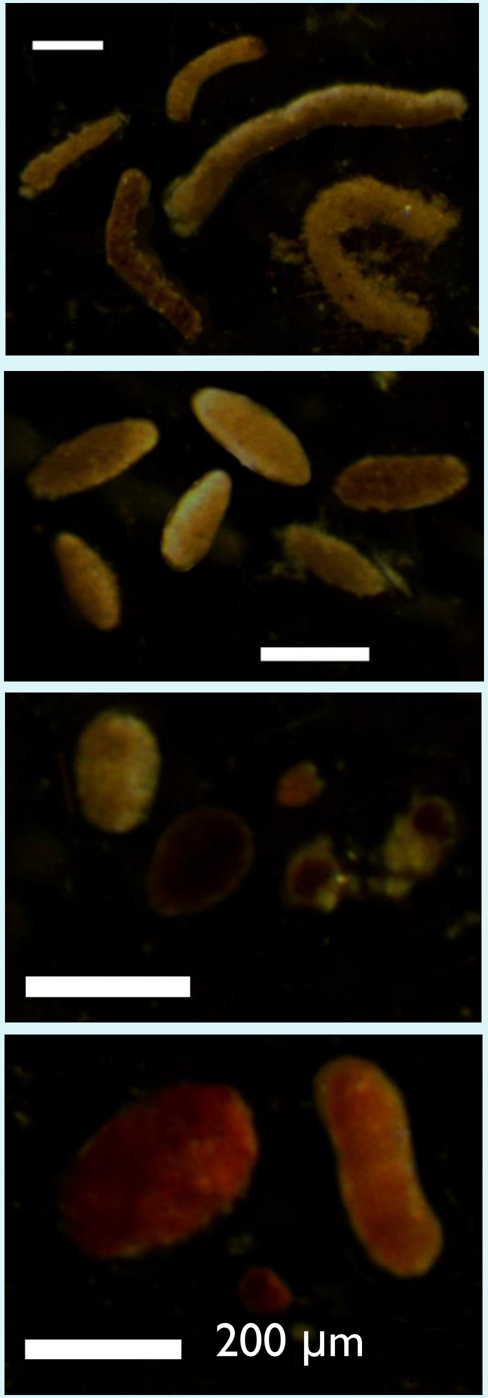
Shape – taxa

- cylindrical – crustaceans
- ellipsoid – larvaceans
- ovoid – copepods
- spherical – copepodites, protozoans
- Tabular – salps

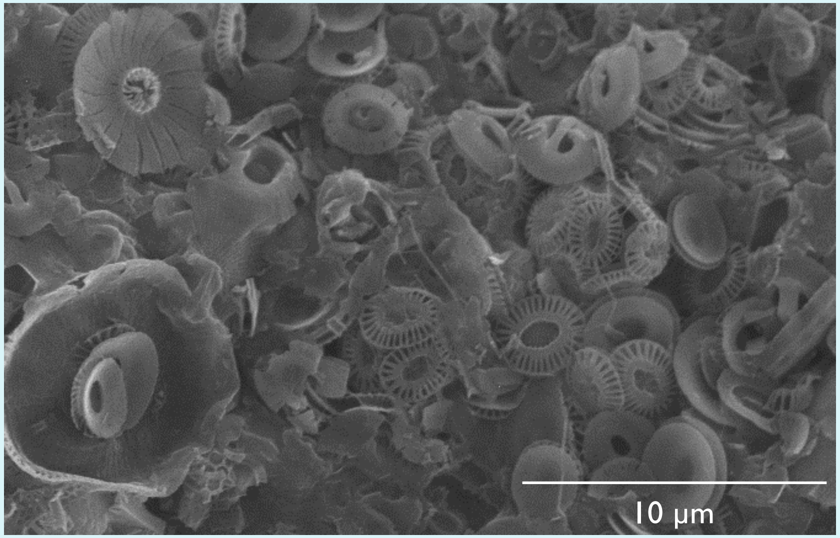
Color – diet

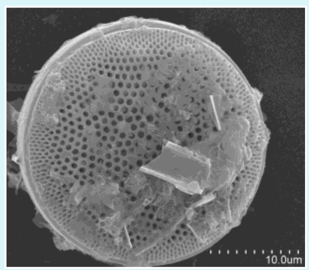
- reds – carnivores
- dark brown – herbivores?
- light brown – detritivores?

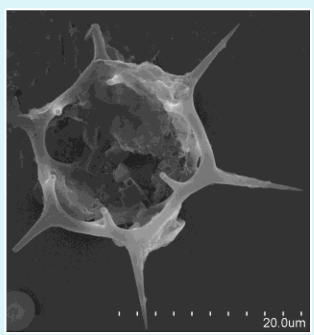
Potentially not so straight forward in the deep sea



Lighter brown pellets

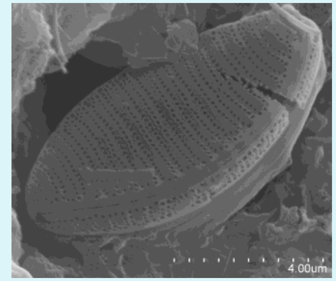


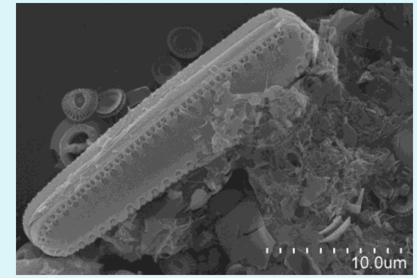


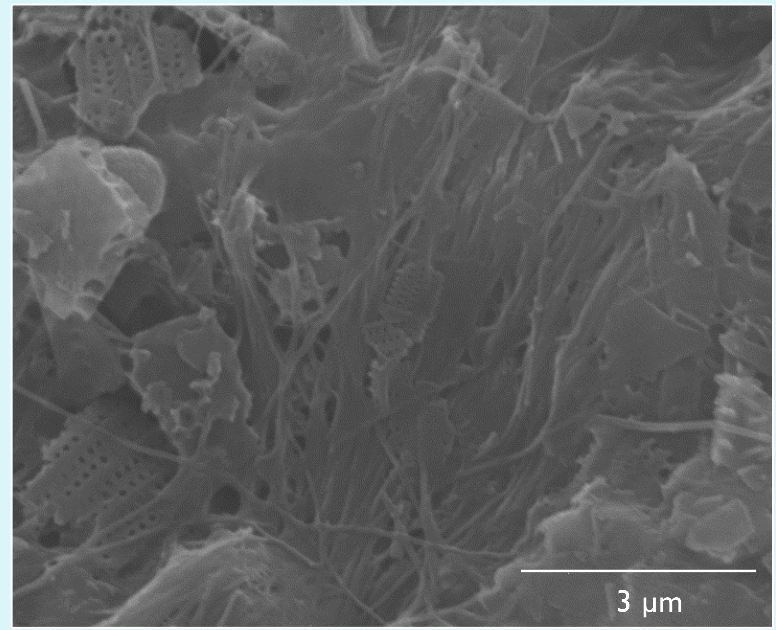


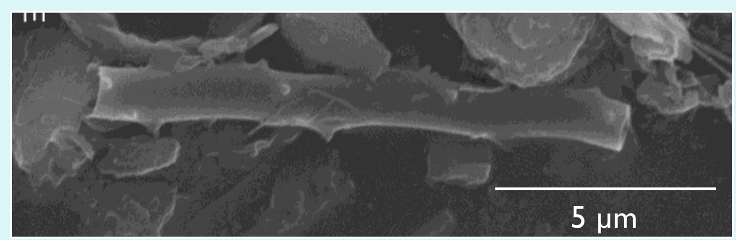
SEM images
Sediment traps @ 3500m
Station M - MBARI

Darker brown pellets

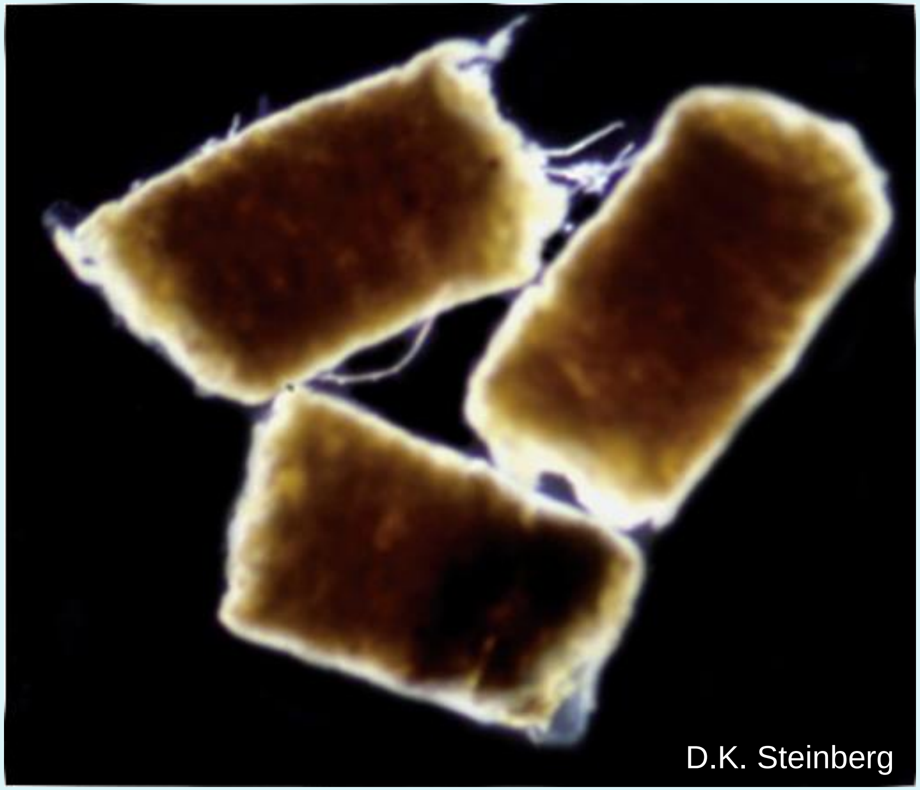






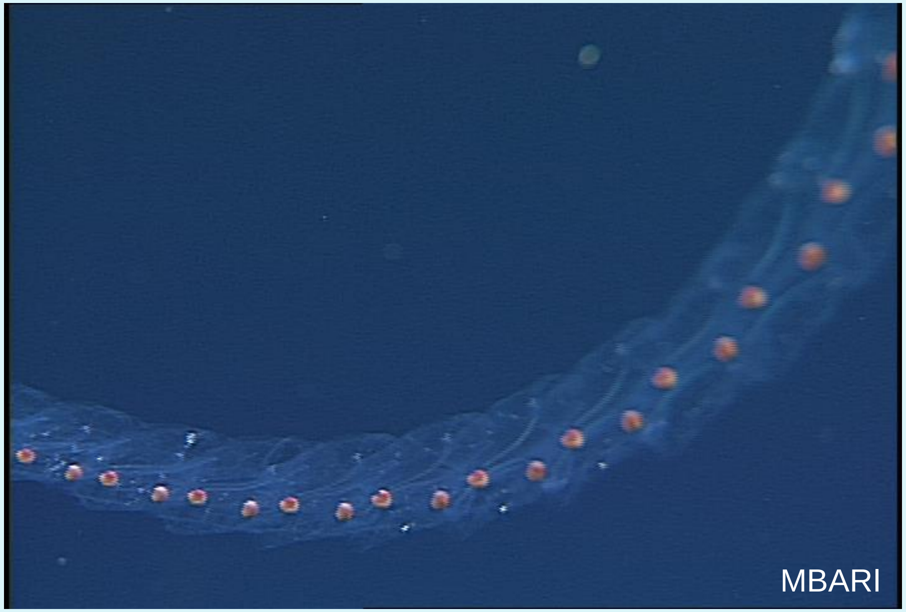


Wilson & Smith (in prep)

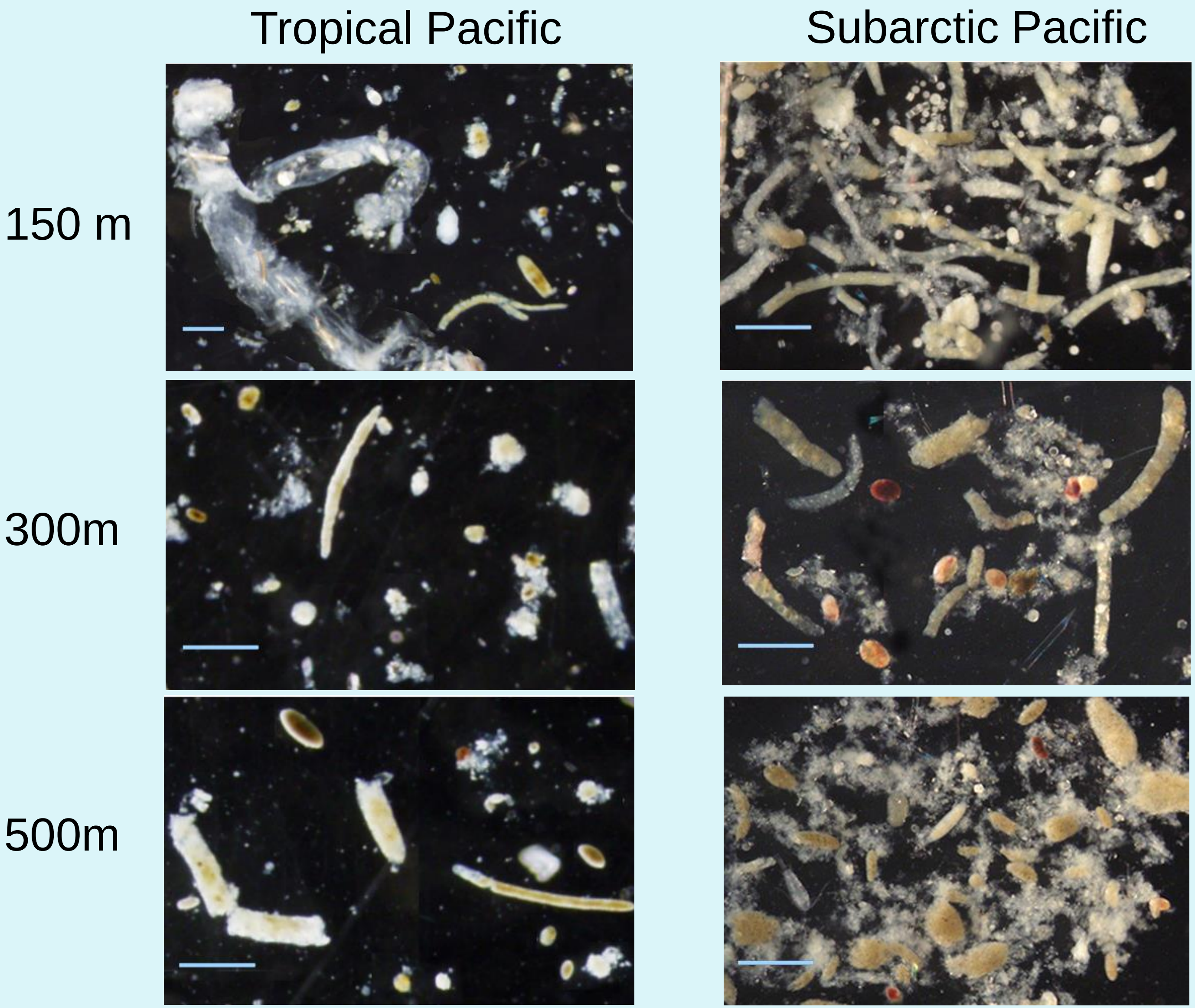


Salps are efficient filter feeders that produce large, rapidly sinking fecal pellets

Pellets can sink from epipelagic and mesopelagic zone to depth in 1-2 days



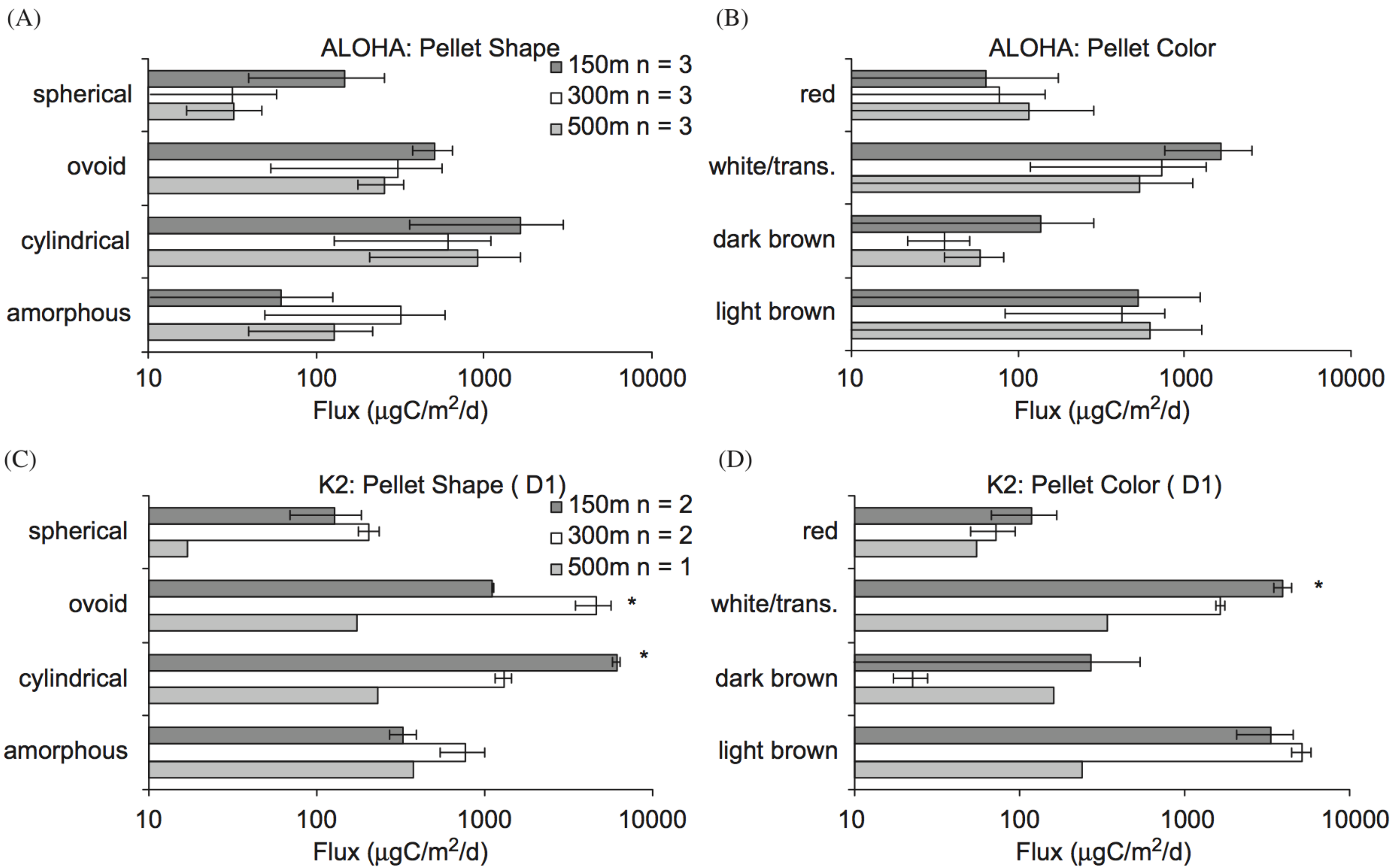
Rapid transport to the seafloor



scale bar = 500 µm

Wilson et al. (2008)

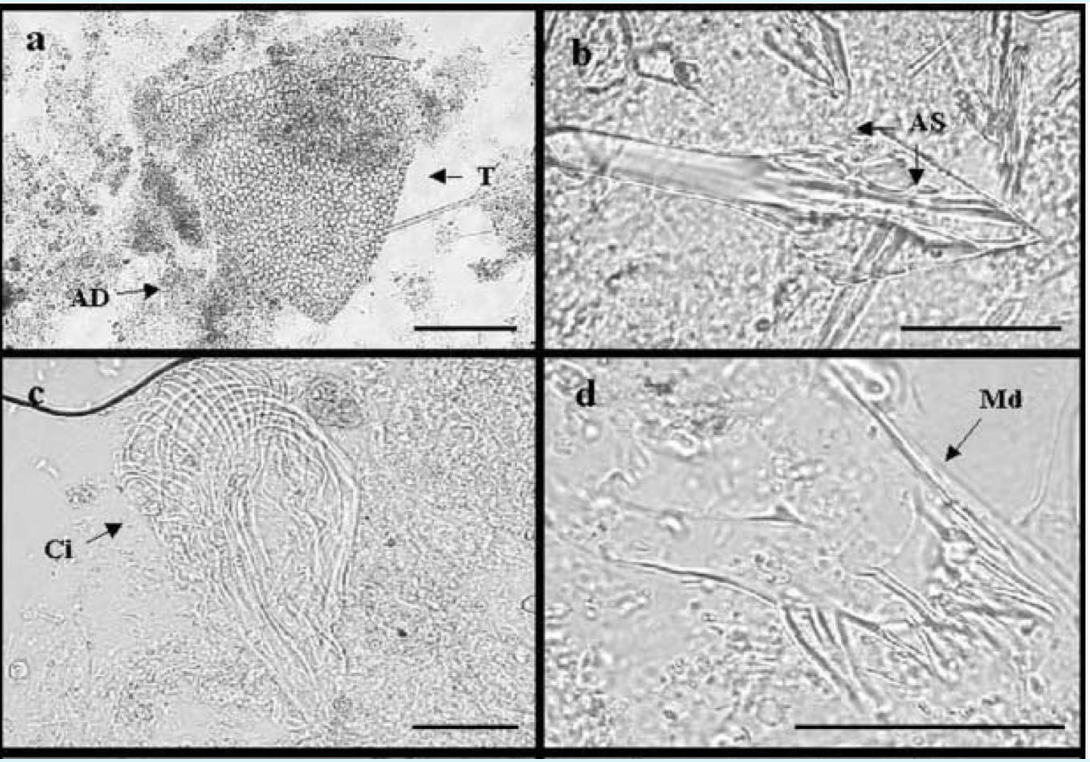
Community structure influences flux

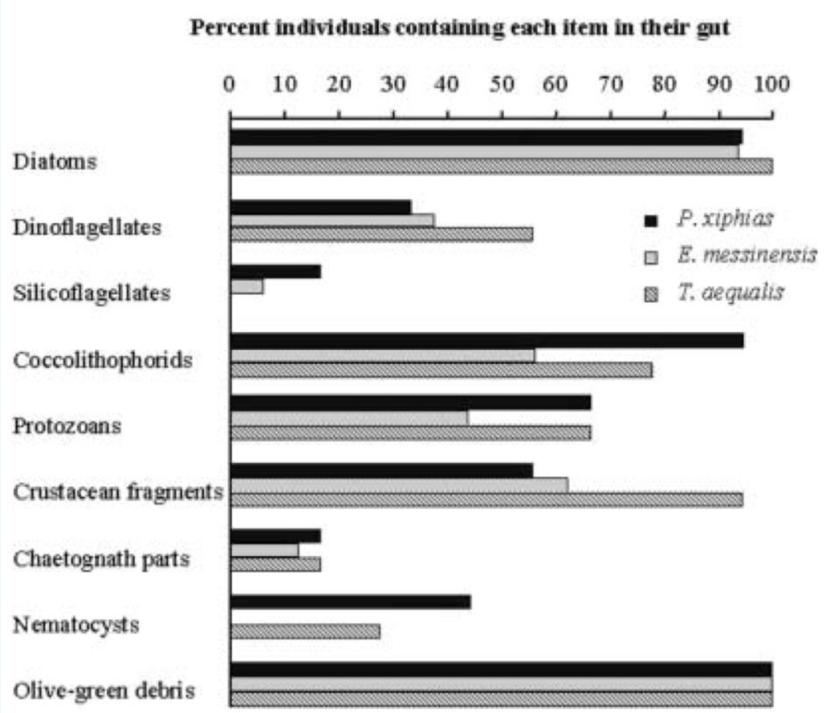


Wilson et al. (2008)

Community structure influences flux

- Stable isotopes – trophic level
- Fatty acid analyses – functional group
- Microscopy (SEM, epifuorescence, compound) – non digestible prey items
- DNA-based molecular techniques – species level





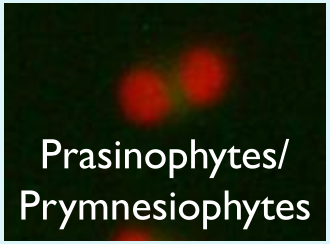
Schnetzer & Steinberg (2002)

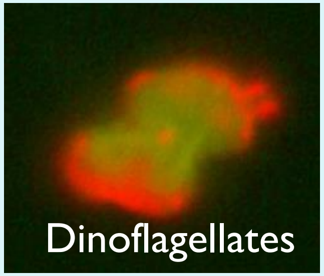
What is sinking out?

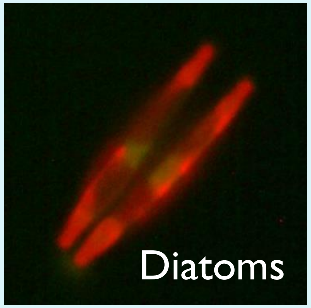
What do we know about grazer mediated flux?

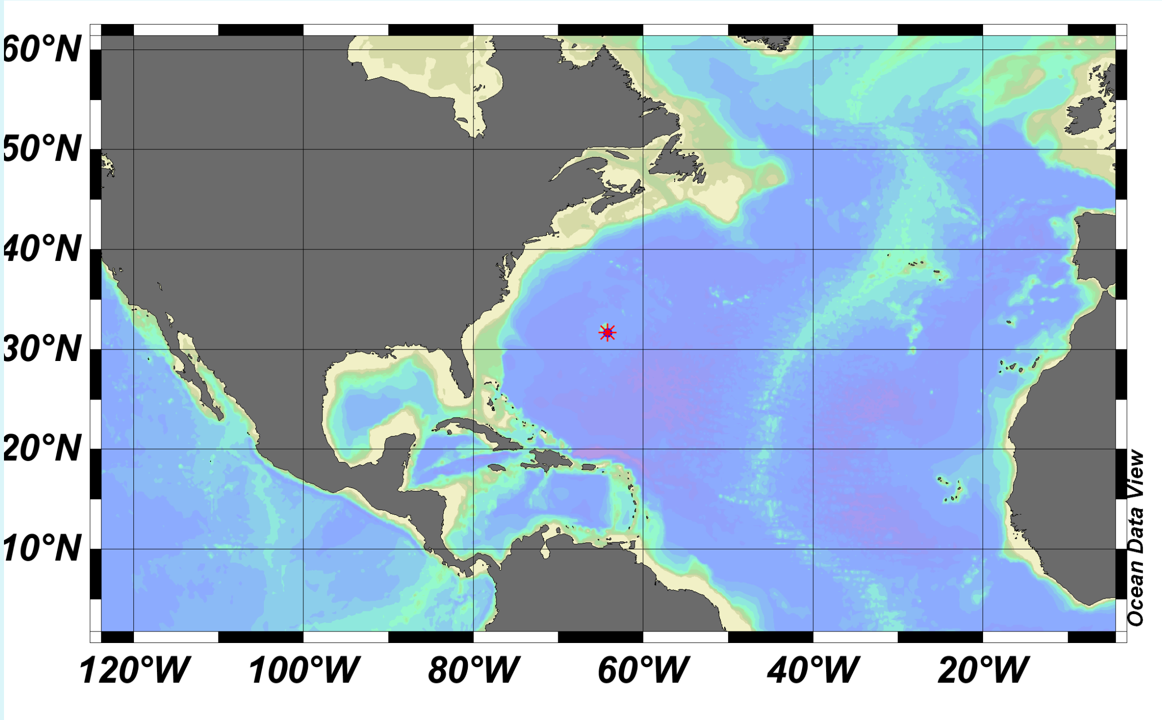
What are we currently learning?

What do we still need to learn?



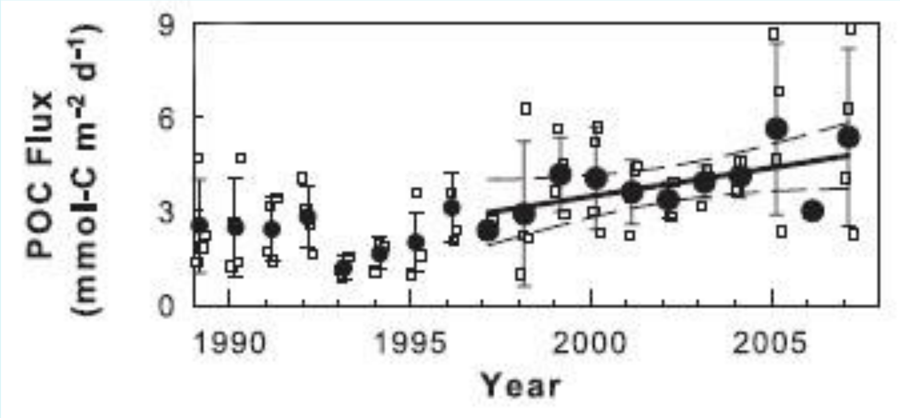




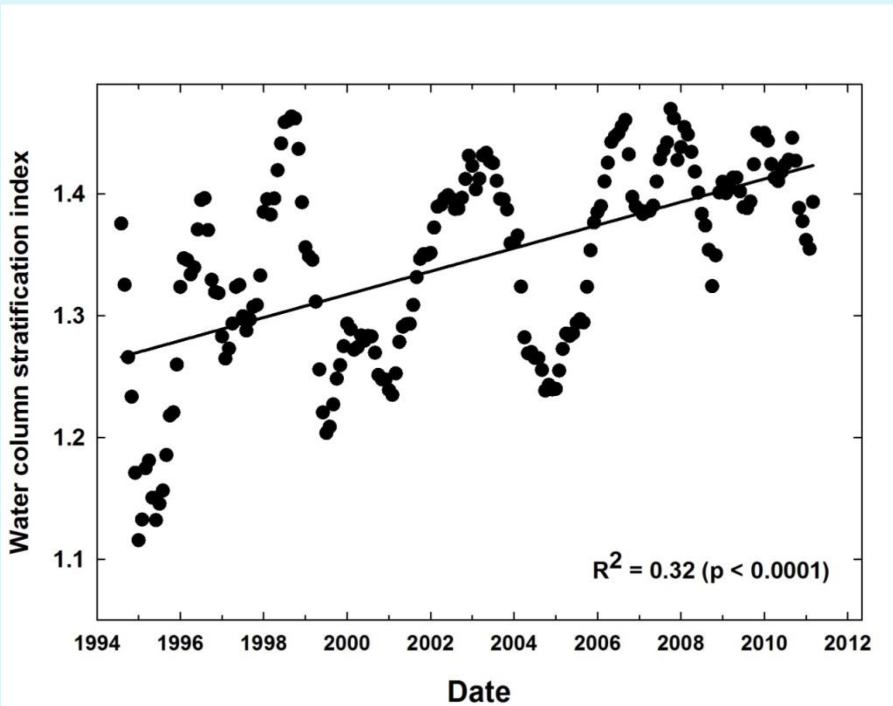


- The phytoplankton community exhibits seasonal variability
- Dominated by pico- and nanoplankton
- *Synechococcus* – winter/spring
- *Prochlorococcus* – summer/fall

Plankton of the Sargasso Sea - BATS



Lomas et al. 2010



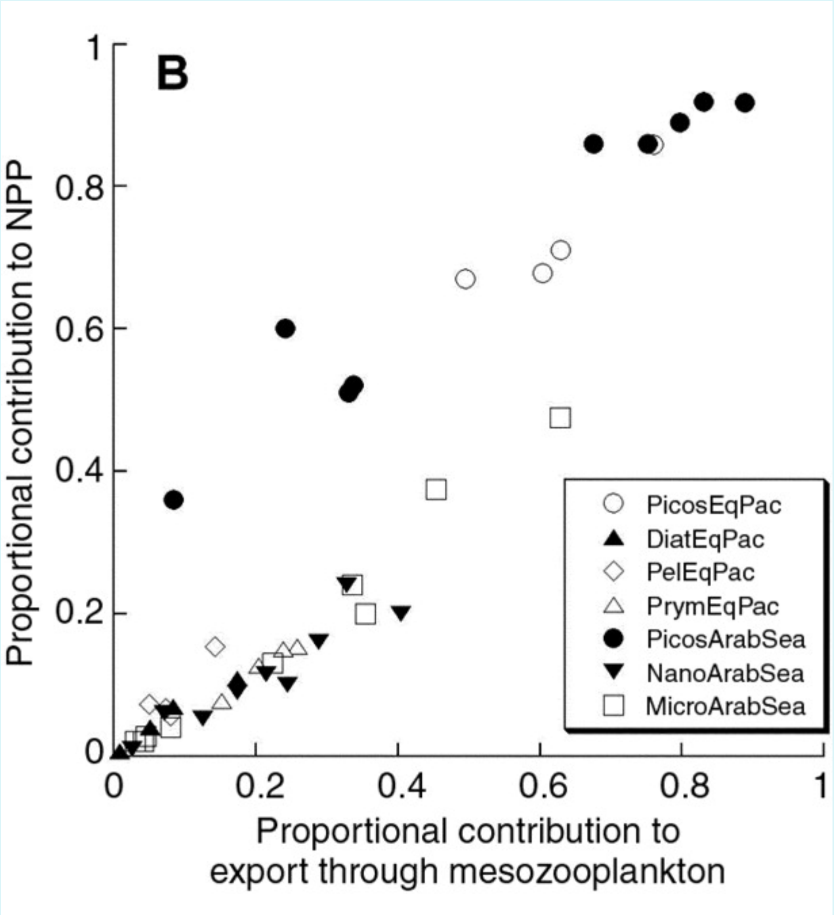
Stone & Steinberg (in press)

Time-series observations at BATS show an increase in:

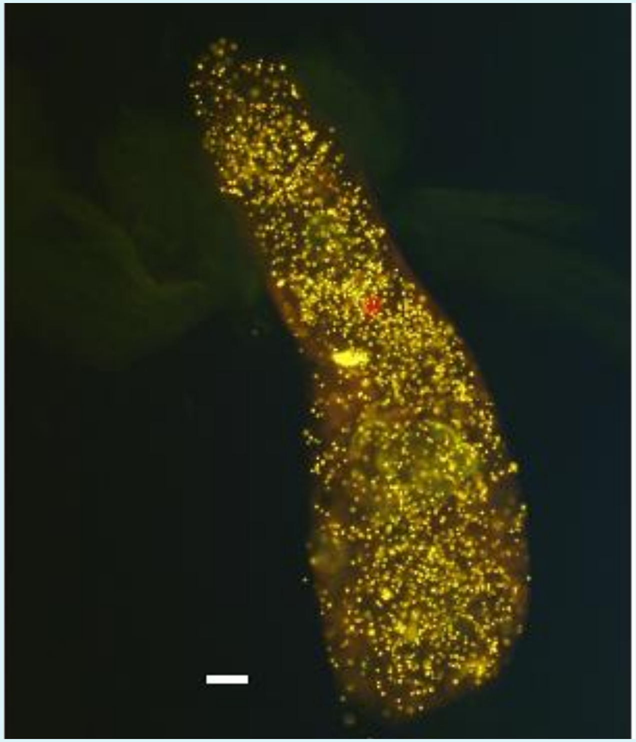
- POC export
- stratification index
- Total PP
- Zooplankton biomass

Pico- & nanoplankton export

Contribution by small plankton to export flux is greater than previously thought



Richardson & Jackson (2007)



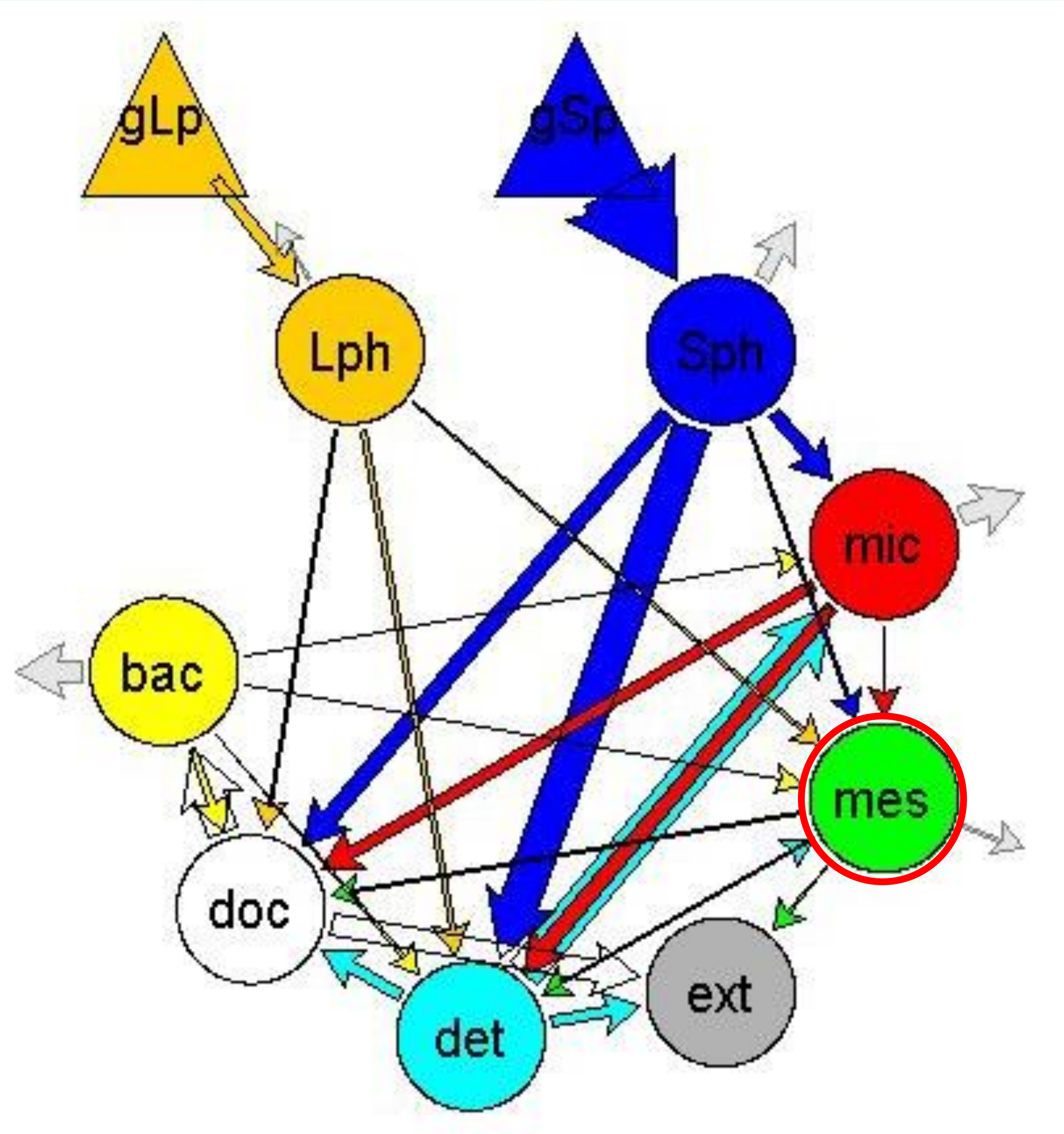
scale bar = 20 µm

Zooplankton grazing on picos and nanos:

- directly (e.g. salps)
- aggregate feeding
- microzooplankton

Pico & nanoplankton export

Knowledge of feeding preferences important for food web modeling



Bachmann & Richardson

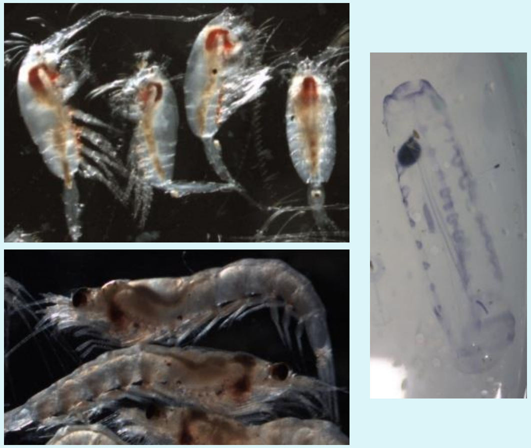
Questions arising:

- How does plankton community composition and trophic interactions modify carbon export from the euphotic zone?

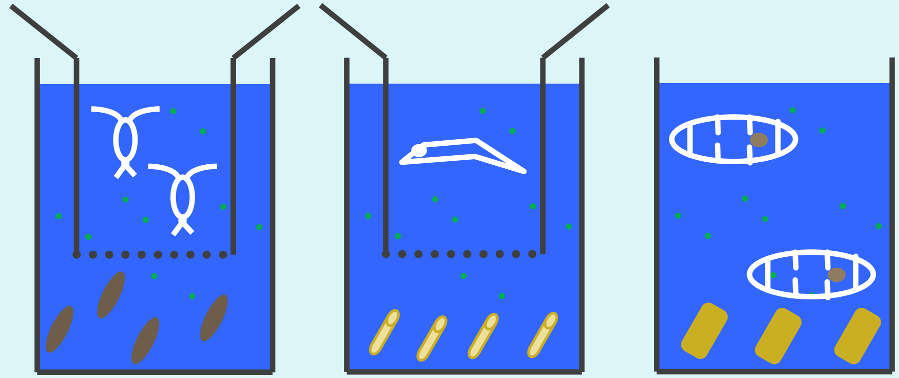
- Are zooplankton exporting specific types of eukaryotic and cyanobacterial phytoplankton out of the epipelagic?

- How does this change on an annual or seasonal basis?

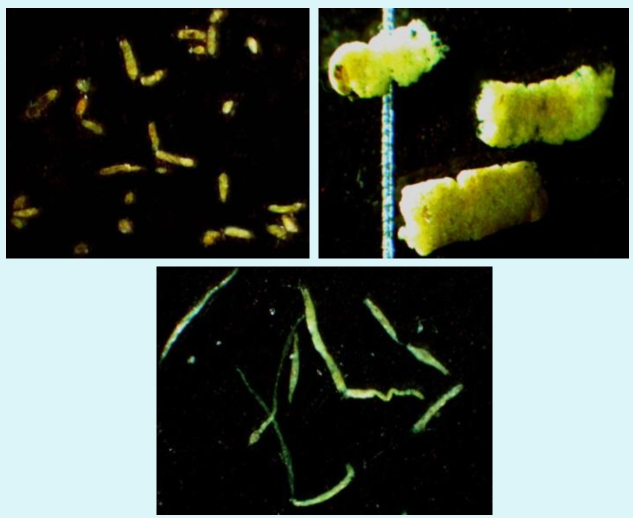
Zooplankton collection



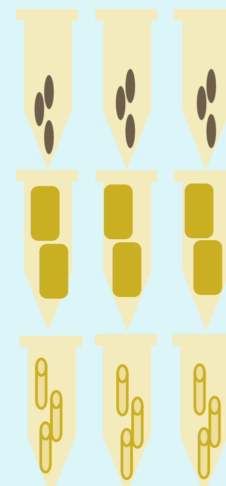
Incubations – 6-8hrs



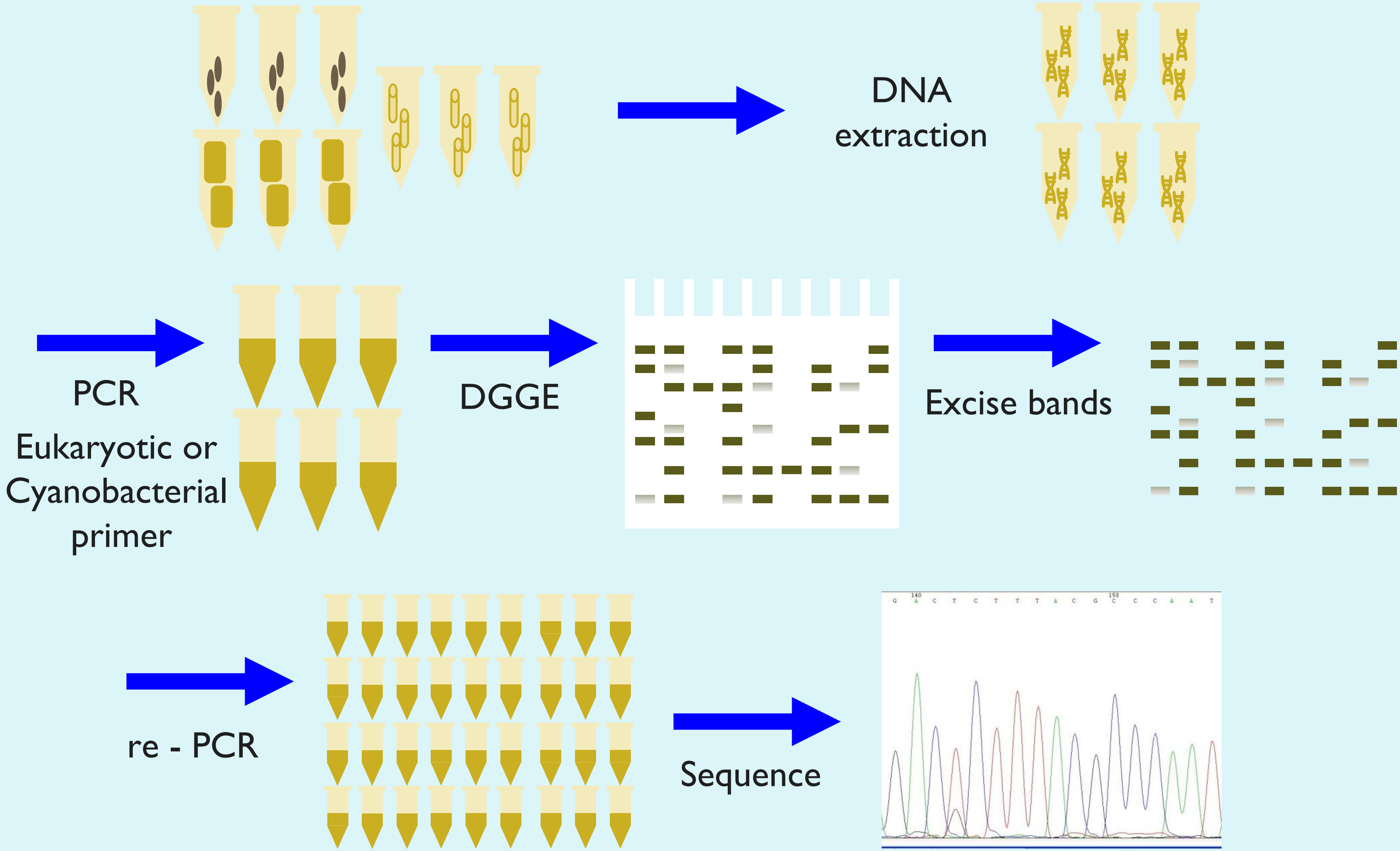
Count and measure faecal pellets



Freeze -80°C

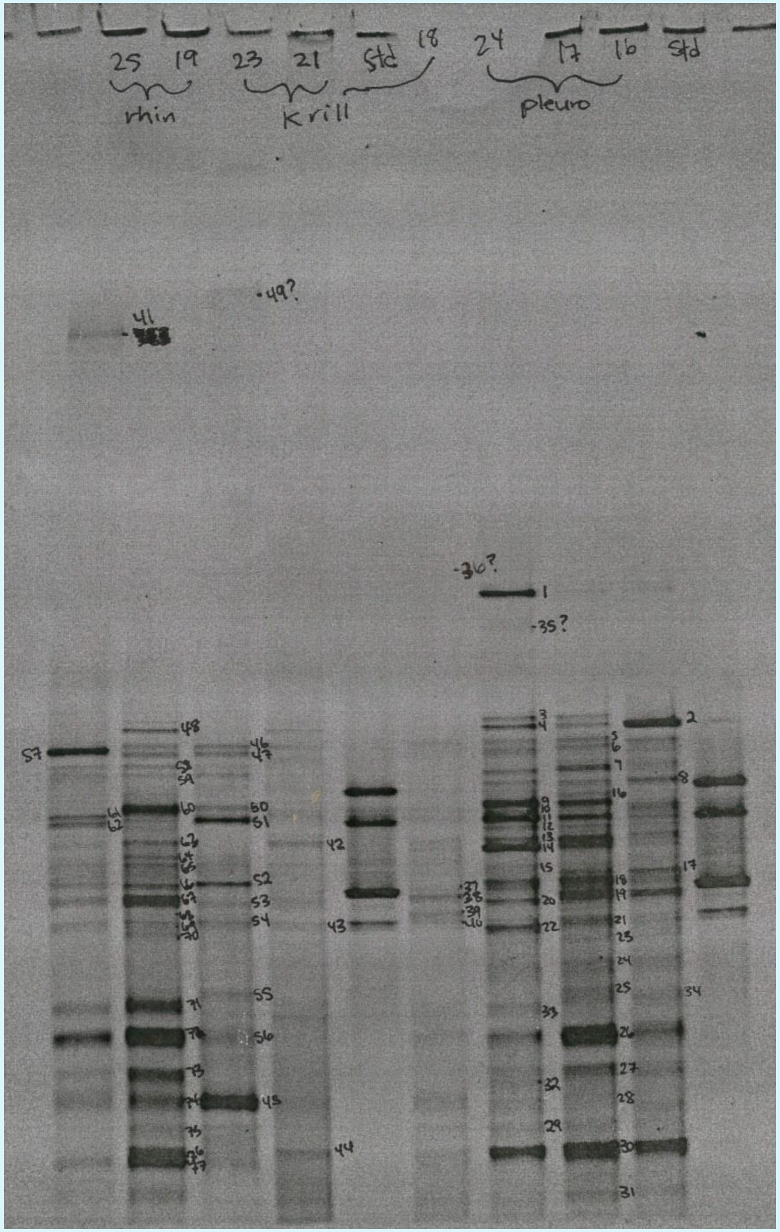


Fecal pellet production



Molecular analyses

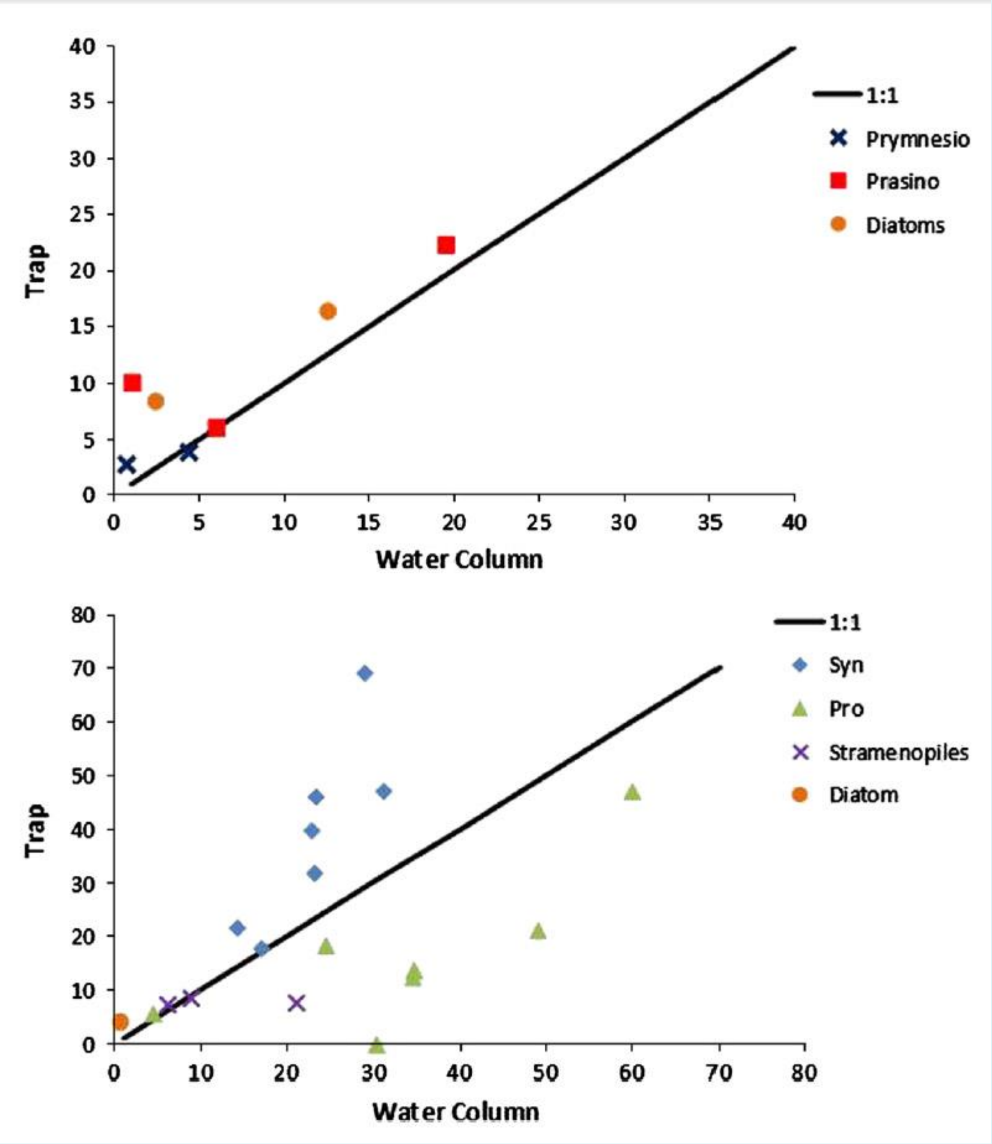
Caveats to DGGE



- Dominant bands only – fingerprint
- Some bands too faint to to be excised
- Band overlapping
- Relative abundances only – band density
- PCR bias – some organisms may be over represented
- Some DNA degradation in guts and pellets

DGGE analysis of sediment traps and water column plankton at BATS

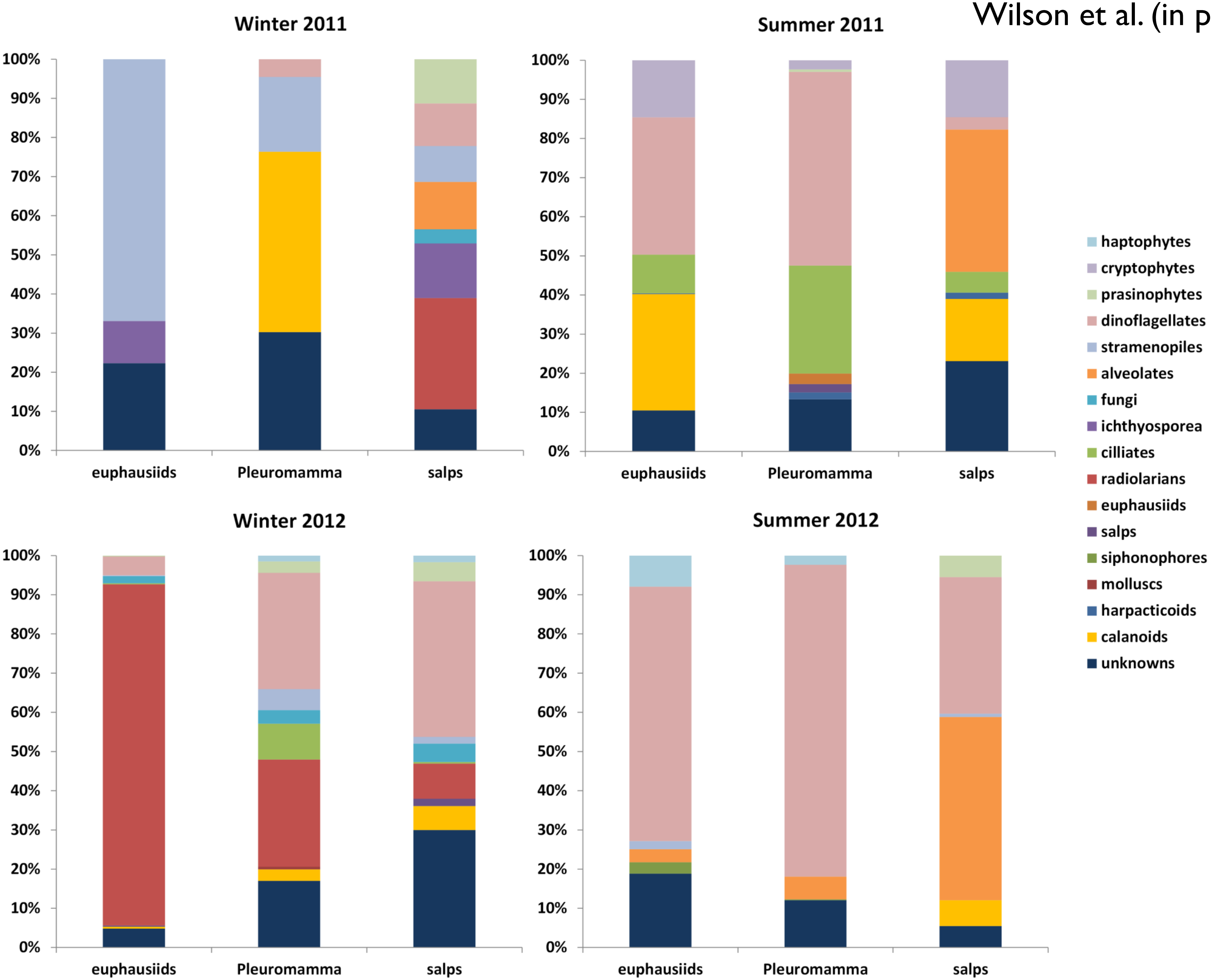
- *Prochlorococcus* lower in traps vs. water column
- Diatoms & prasinophytes higher in traps vs. water column
- Zooplankton as the link between water column and sinking flux?

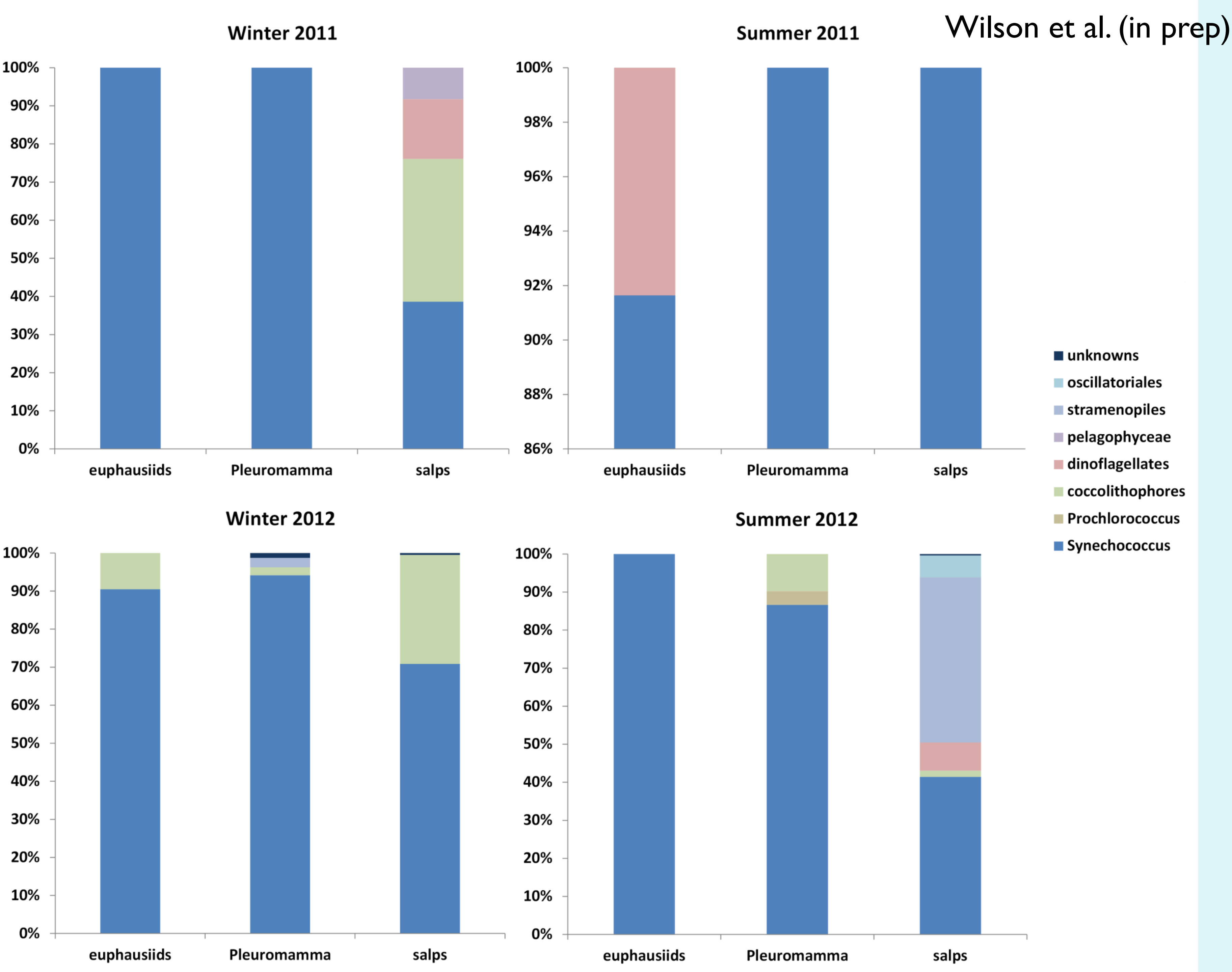


Amacher et al. (2013)

Trap vs. water column

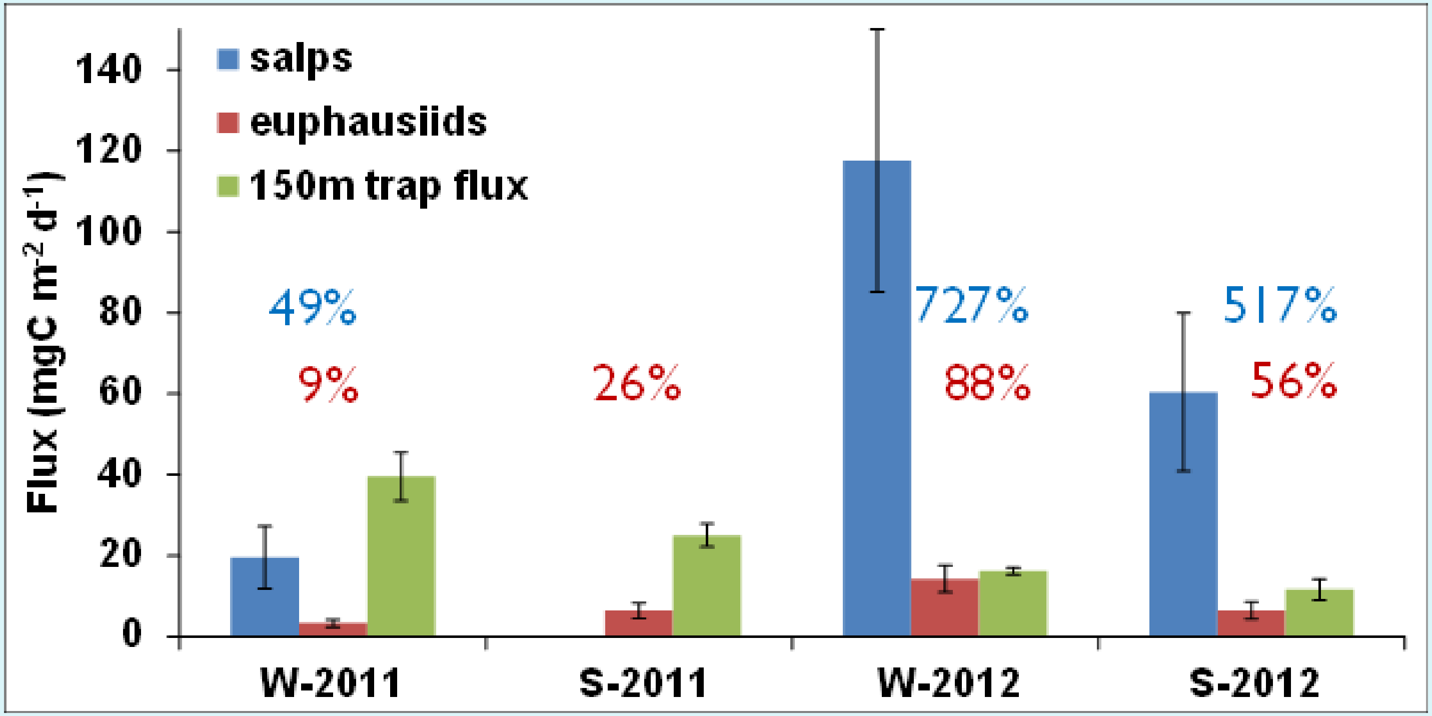
Wilson et al. (in prep)




Wilson et al. (in prep)
Winter 2011
Summer 2011
Winter 2012
Summer 2012
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
98%
96%
94%
92%
88%
86%
euphausiids
Pleuromamma
salps
unknowns
oscillatoriales
stramenopiles
pelagophyceae
dinoflagellates
coccolithophores
Prochlorococcus
Synechococcus

Potential export at BATS

(does not account for coprohexy or bacterial remineralisation)



Wilson et al. (in prep)

Zooplankton ARE potentially transporting specific small plankton out of the epipelagic – and in different proportions!

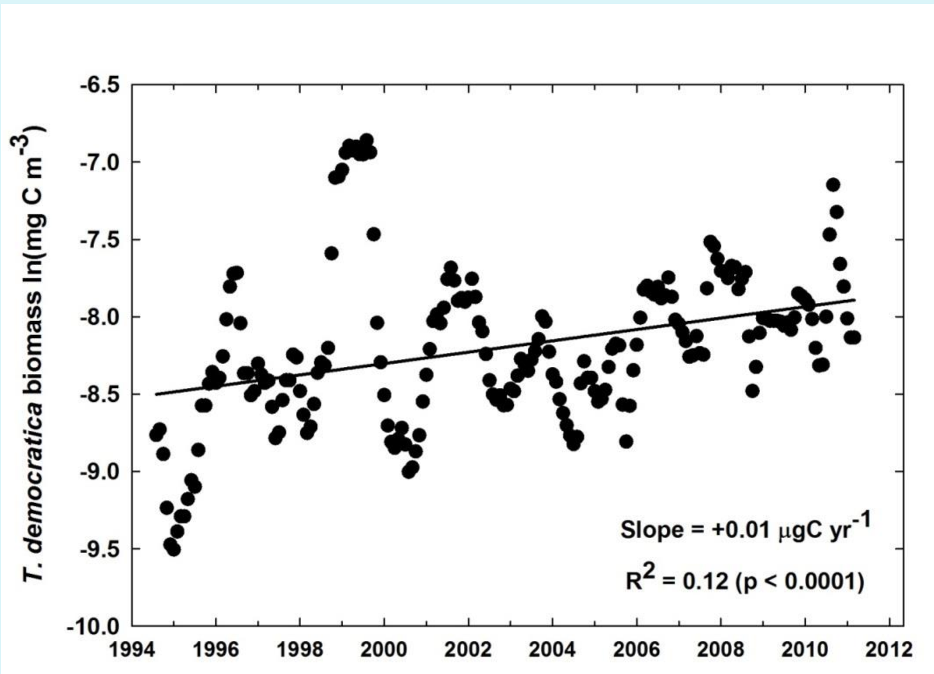
-Salps – efficient exporters – sediment traps missing some of this flux
-Euphausiids & *Pleuromamma* copepods – high but comparable to trap flux

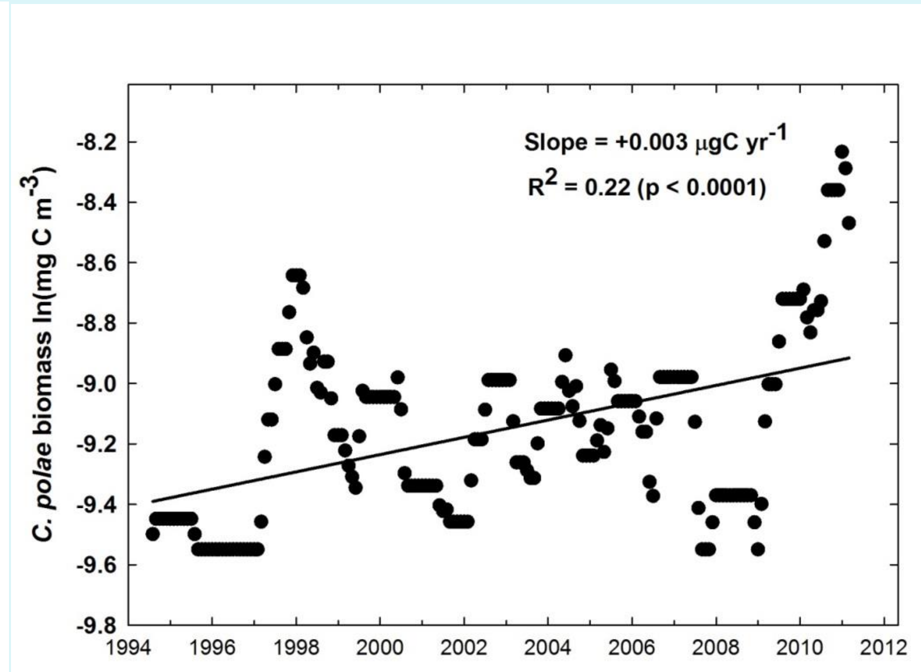
Table 6 *Salpa thompsoni* biomass and defecation compared with other oceanic salp species

Species	Location	Biomass (mg C m^{-2})	Defecation rate (mg C m^{-2} day^{-1})	Methods	Reference
S. thompsoni	W. Antarctic Peninsula	1.3–863	0.01–42.3	Defecation measurements	This study
S. thompsoni	Lazarev Sea		32.4	Defecation measurements	Pakhomov (2004)
S. thompsoni	W. Antarctic Peninsula	0.2–341	0.01–16.2	Calculated from biomass data (bongo nets only)	Pakhomov et al. (2006)
S. thompsoni	Weddell Sea		88	Calculations	Dubischar and Bathmann (2002)
S. thompsoni	W. Antarctic Peninsula, Elephant Is.	50–670	5–67	Defecation measurements	Huntley et al. (1989)
Species not defined	NE Pacific		6.7–23	Sediment traps	Matsueda et al. (1986)
Species not defined	Mediterranean Sea		43.2	Calculated from ecosystem model	Andersen and Nival (1988)
Salpa maxima, Pegea confederata	NW Atlantic	0.12	0.07	Defecation measurements	Caron et al. (1989)
Salpa fusiformis	Mediterranean Sea		18–576	Sediment traps	Morris et al. (1988)
Salpa sp.	Subarctic Pacific		6.7–10.5	Sediment traps	Iseki (1981)
Salpa aspera	NW Atlantic	909	8.5–137	Defecation measurements	Wiebe et al. (1979)
Cyclosalpa bakeri	Station P, NE Pacific	85–3,621	21–875	Defecation measurements	Madin et al. (1997)
Salpa aspera	NW Atlantic		5–91	Defecation measurements	Madin et al. (2006)

Philips et al. (2009)

The episodic nature of salp export





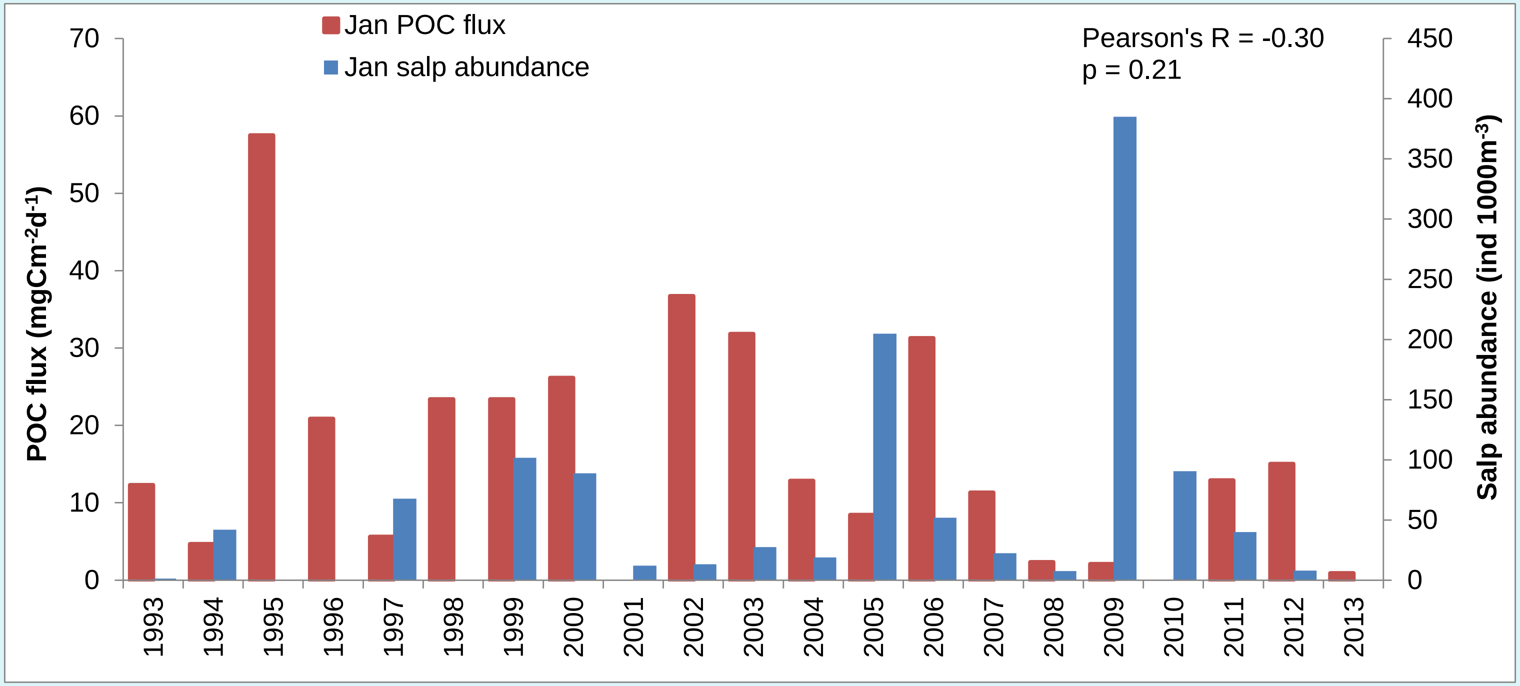
Stone & Steinberg (in press)

Salps at BATS

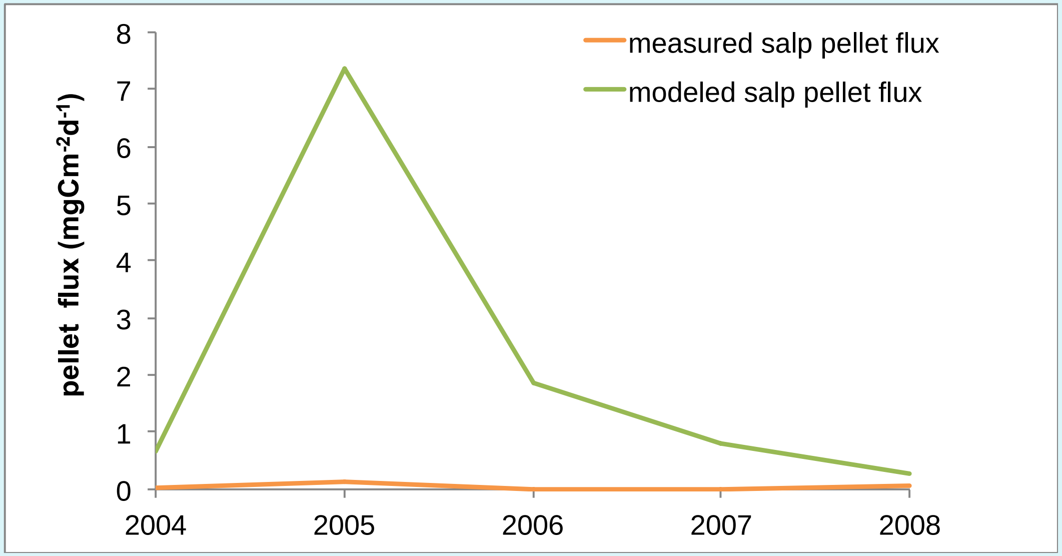
Unpublished data removed

Stone & Steinberg (in prep)

Salp abundance vs. POC flux (BATS)



Modified from Gleiber et al. 2012



Salp abundance vs. POC flux (PAL-LTER)

- Zooplankton community structure can influence flux
- Zooplankton have the potential to export pico- and nanoplankton in significant proportions out of the epipelagic zone
- Sediment trap samples may be underestimating export flux from migrator and salp faecal pellets (or salp pellet fluxes may be fueling the mesopelagic community)

Summary

What do we know about grazer mediated flux?

What are we currently learning?

What do we still need to learn?

Further Questions:

- Can next-generation DNA sequencing techniques help quantify proportions of zooplankton-mediated export flux?

- How can these proportional contributions be effectively added to models?

- How can we better incorporate episodic salp flux events into flux estimates?

Thank you for inviting me to speak

ASU

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