Ecosystem comparison of trends in zooplankton community structure and role in biogeochemical cycling

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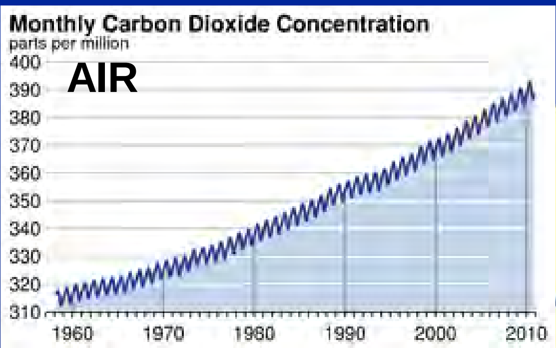
Context of PICES FUTURE program

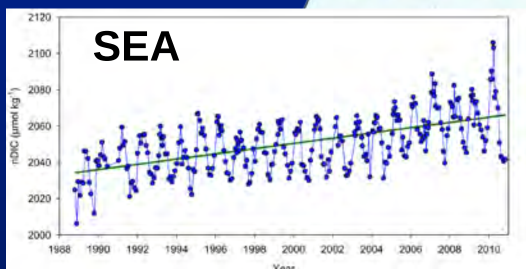
How do changing physical, chemical, and biological processes alter ecosystem structure and function?

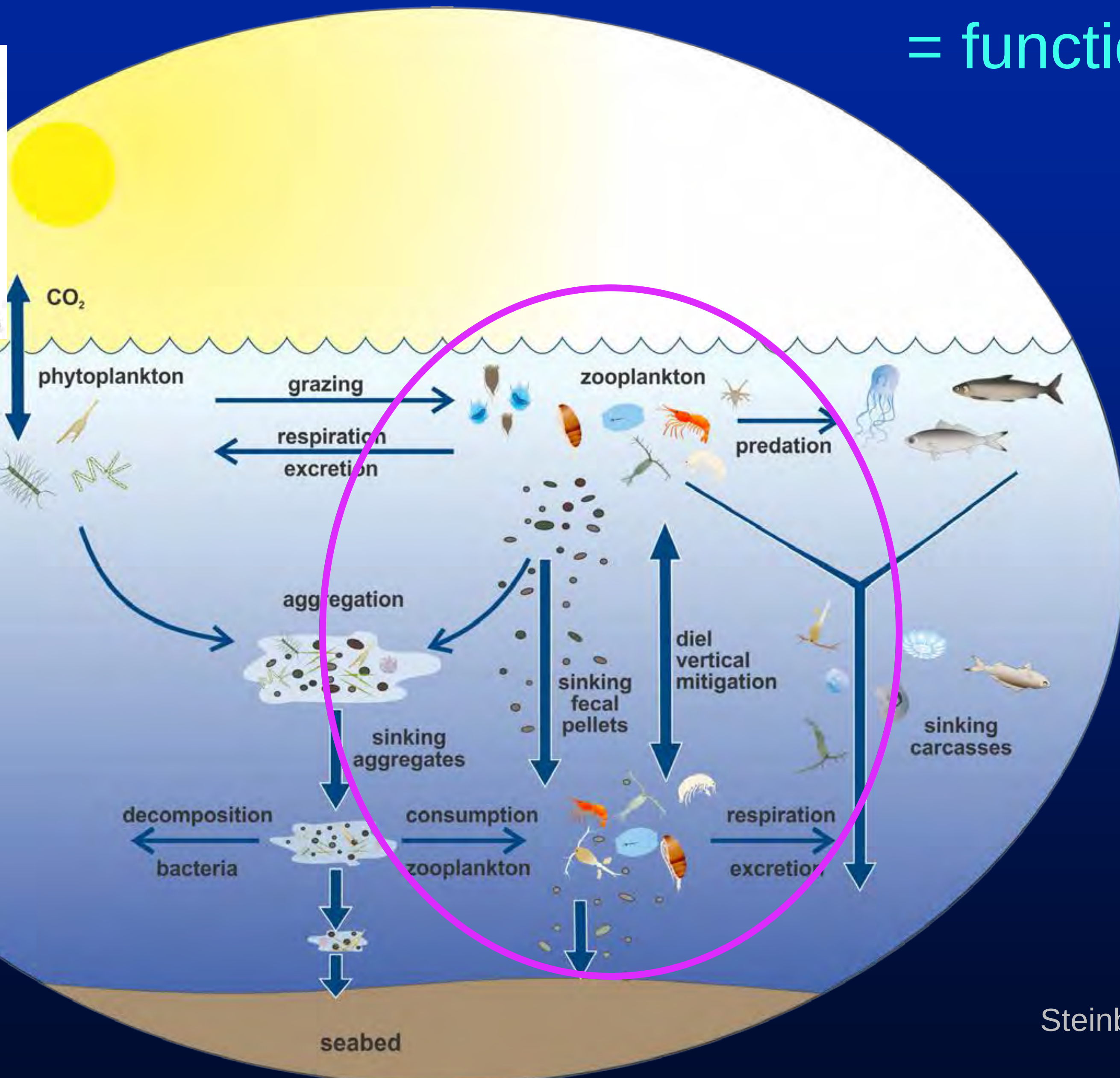
Ecosystem status, trends, & forecasts

Zooplankton and biogeochemical cycling

= function







Euphotic zone

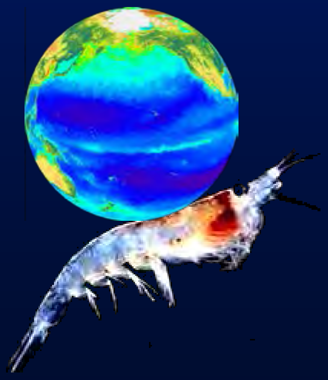
Mesopelagic zone

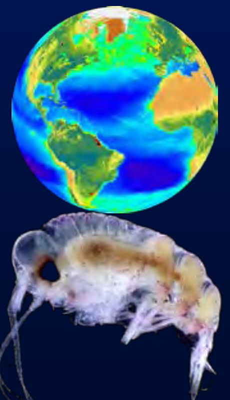
Organic C in particles

Steinberg (in press)

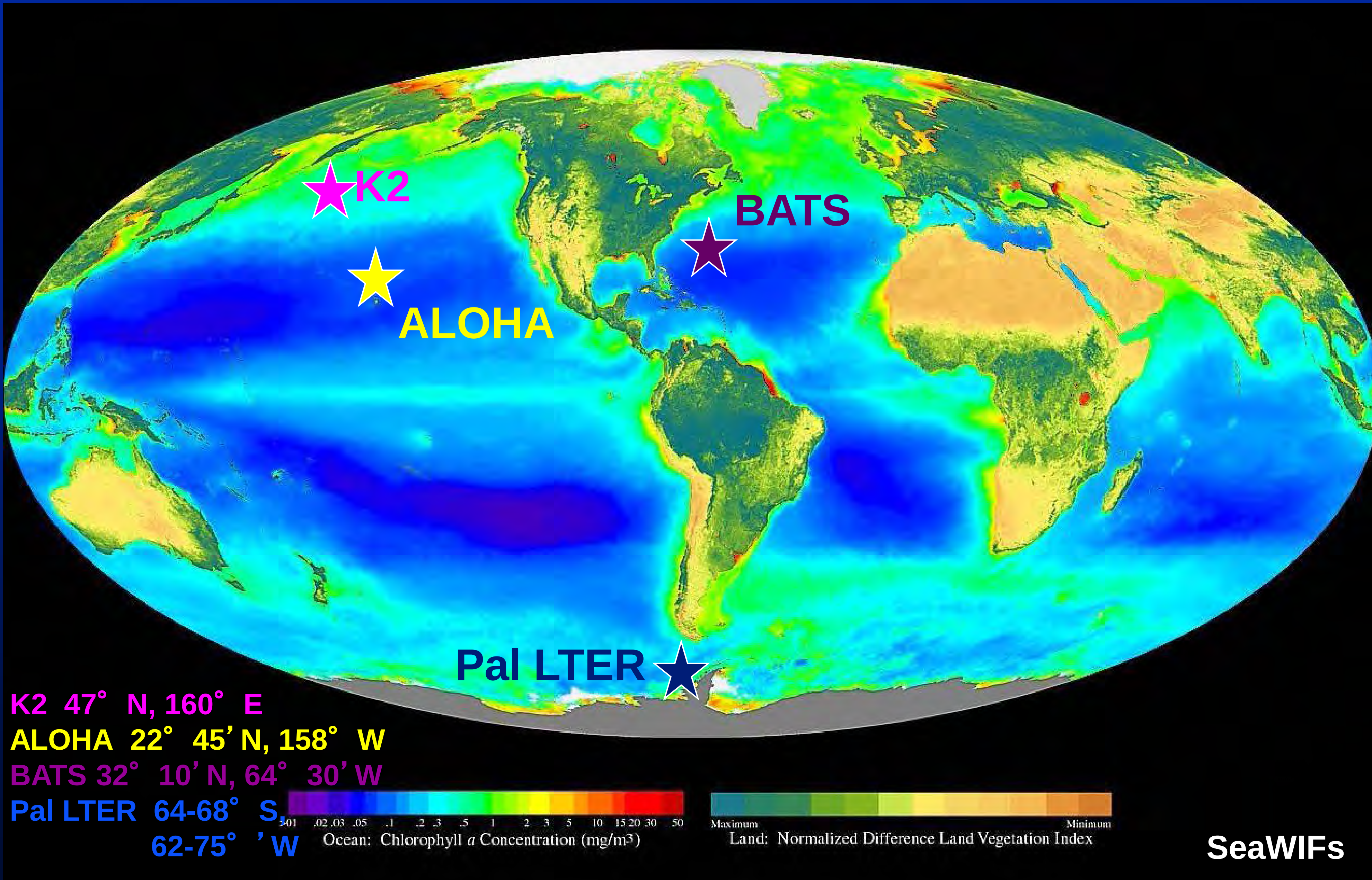
Outline

- Study sites & zooplankton community structure
- Long-term changes in zooplankton, zooplankton-mediated export, & comparisons between sites
- Summary & conclusions





Study sites



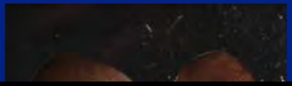
K2
BATS
ALOHA
Pal LTER
K2 47° N, 160° E
ALOHA 22° 45' N, 158° W
BATS 32° 10' N, 64° 30' W
Pal LTER 64-68° S,
62-75° ' W
.01 .02 .03 .05 .1 .2 .3 .5 1 2 3 5 10 15 20 30 50
Ocean: Chlorophyll a Concentration (mg/m3)
Maximum
Minimum
Land: Normalized Difference Land Vegetation Index
SeaWIFs

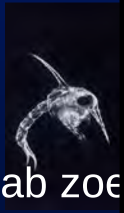
Zooplankton community comparison

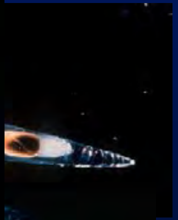
K2

Neocalanus

Pal LTER

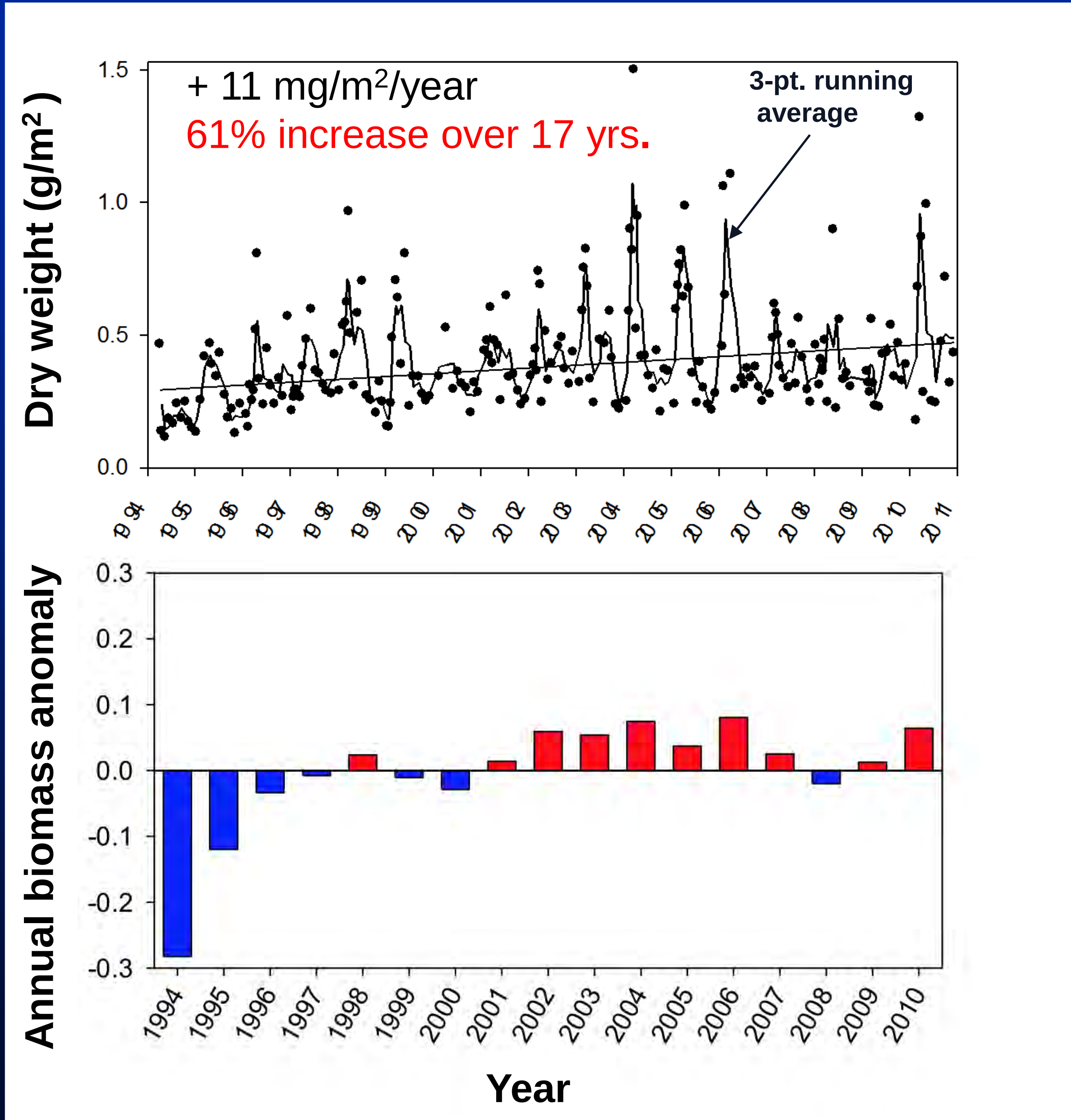






Additional photo credits:
A. McDonnell, L. Madin

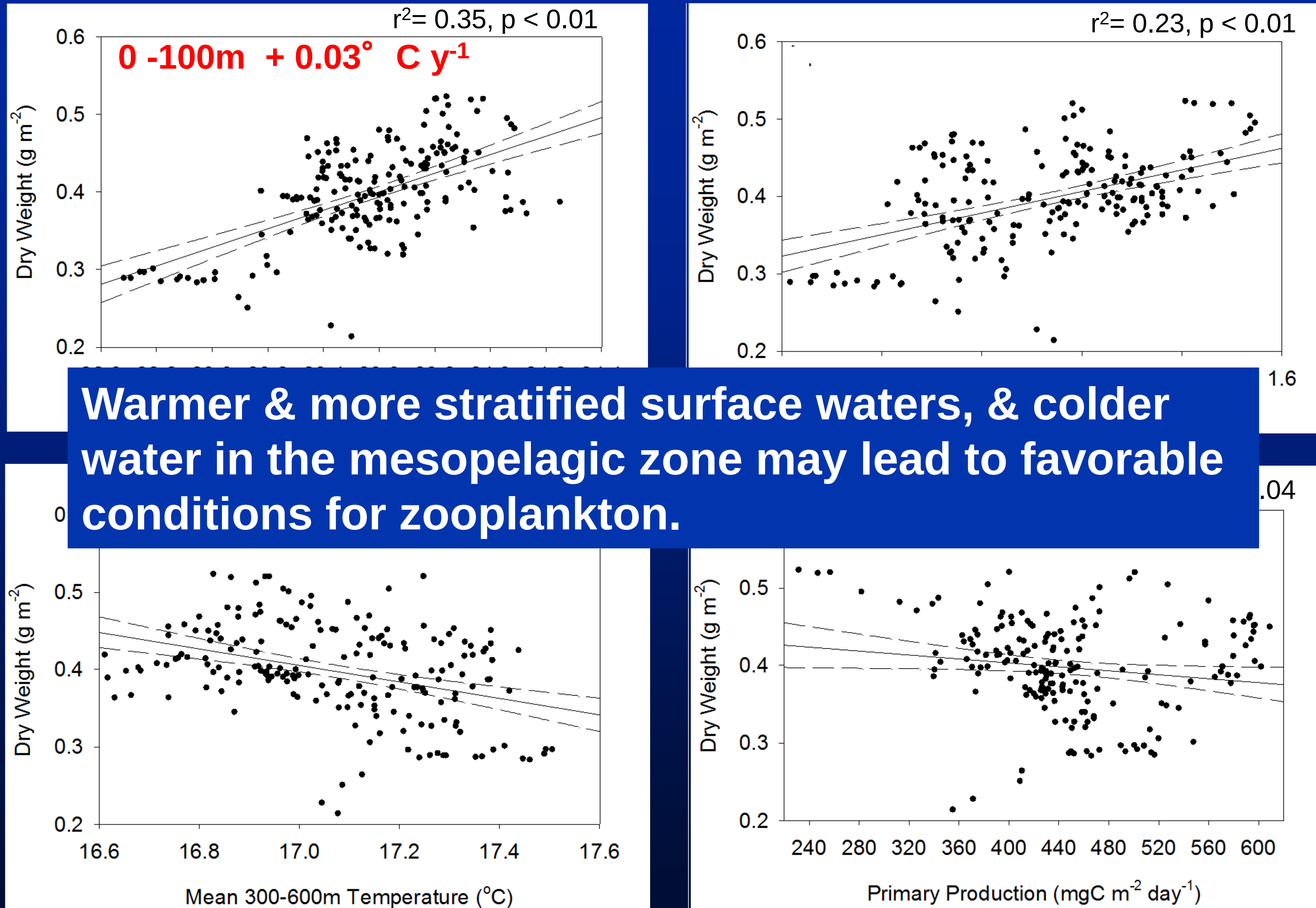
Increase in mesozooplankton biomass (top 150 m) at BATS



Day & night combined
n = 226
$r^2 = 0.09$
$p < 0.0001$

Steinberg, Lomas & Cope (2012)

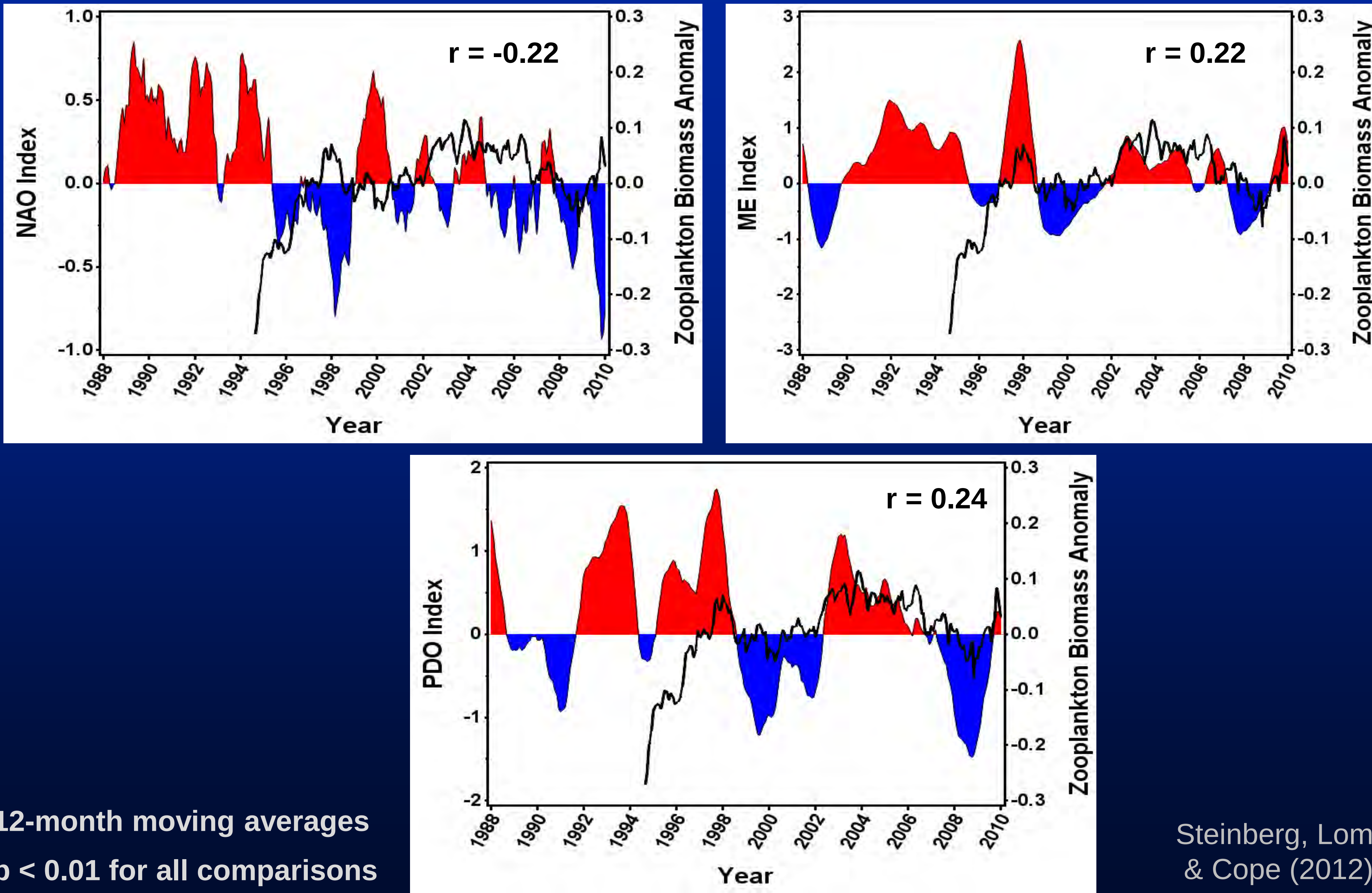
Why?



Warmer & more stratified surface waters, & colder water in the mesopelagic zone may lead to favorable conditions for zooplankton.

Data points are 12-month moving averages to dampen seasonal signal

Climate connections

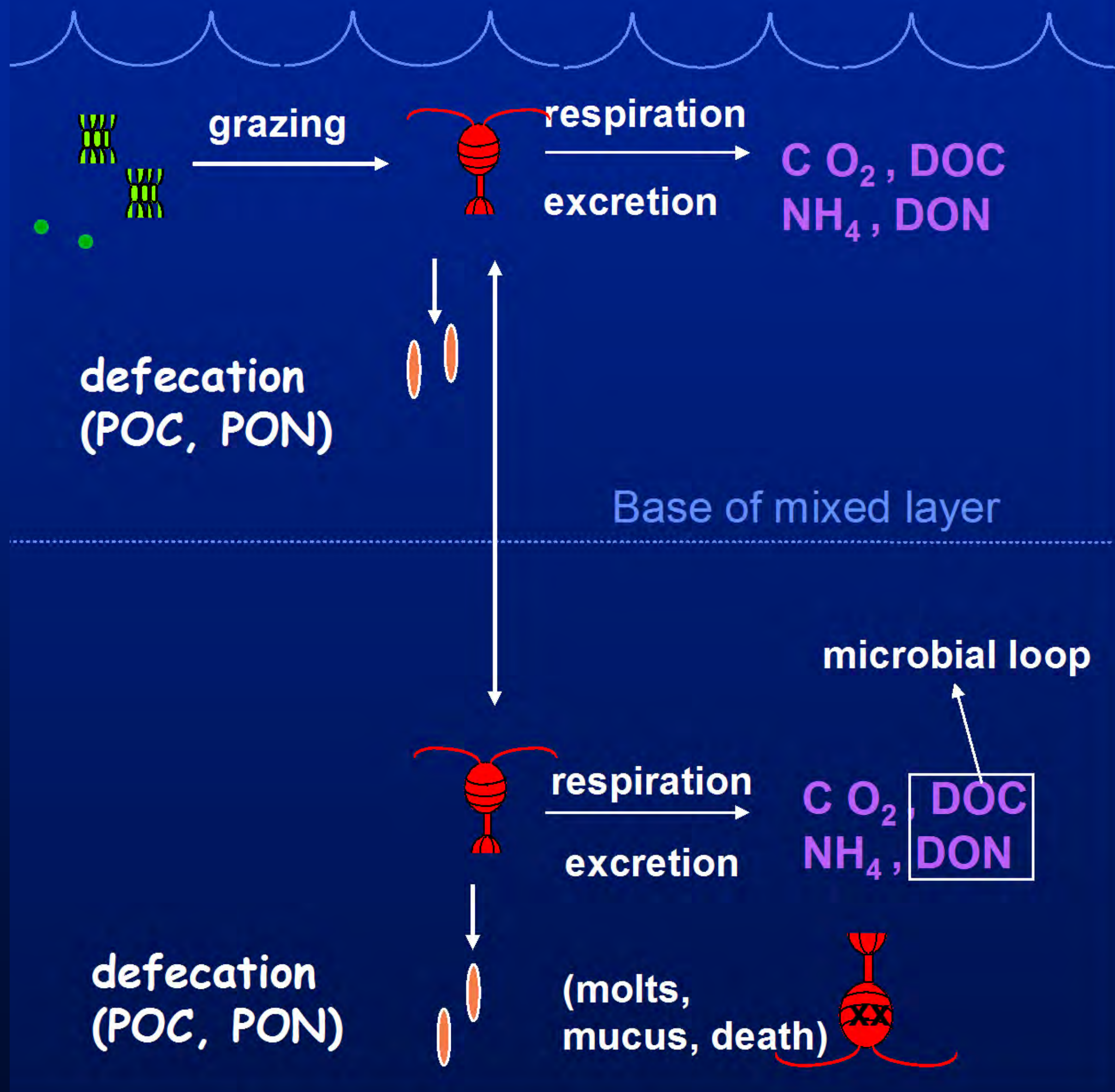


12-month moving averages

p < 0.01 for all comparisons

Steinberg, Lomas, & Cope (2012)

Vertical Migration and active transport and fecal pellet flux

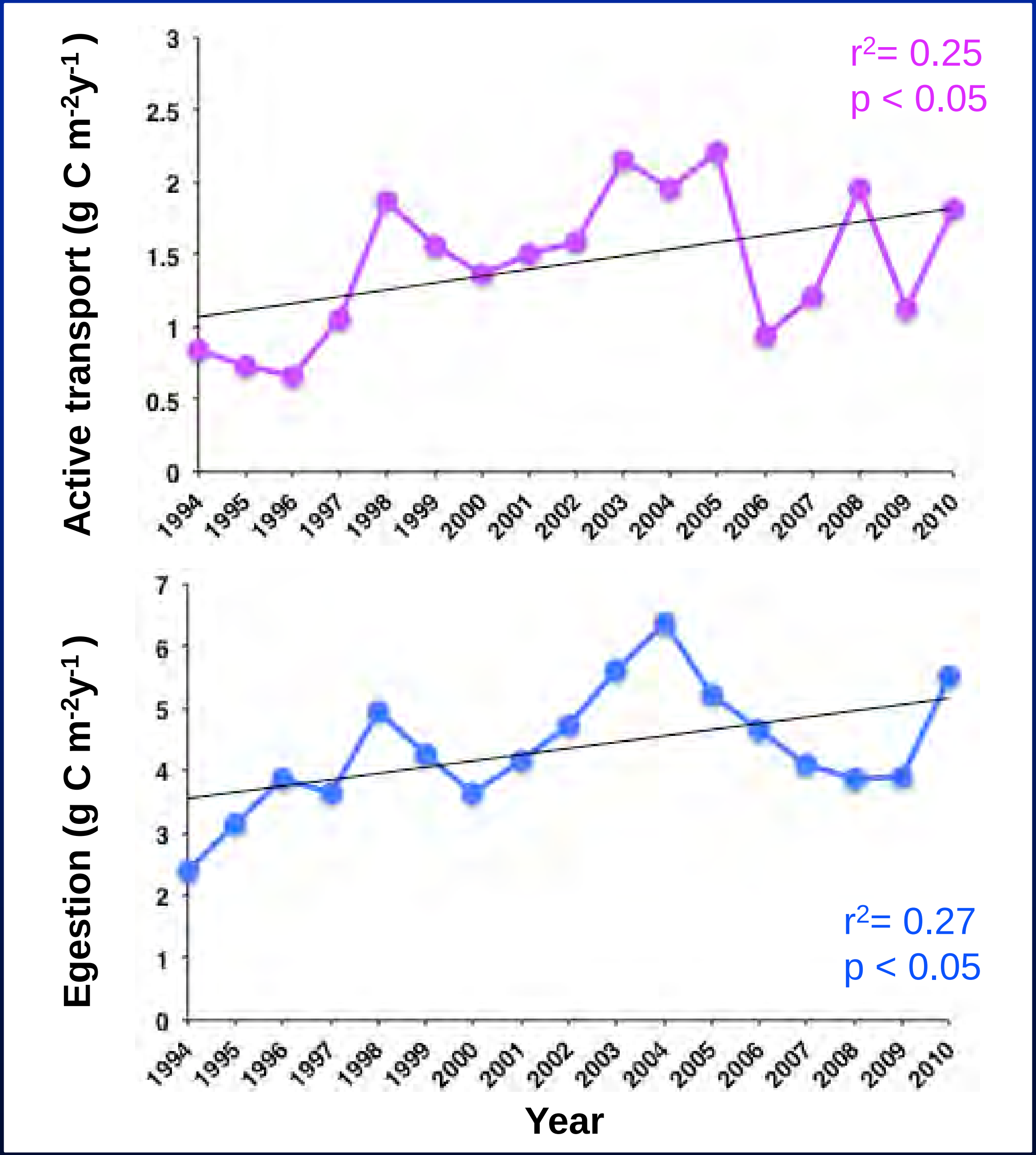


Vertical migrators

Increase in active transport & fecal pellet production at BATS

Annual migratory CO_2 + DOC + POC flux across 150 m

Annual fecal pellet production (egestion) in top 150 m

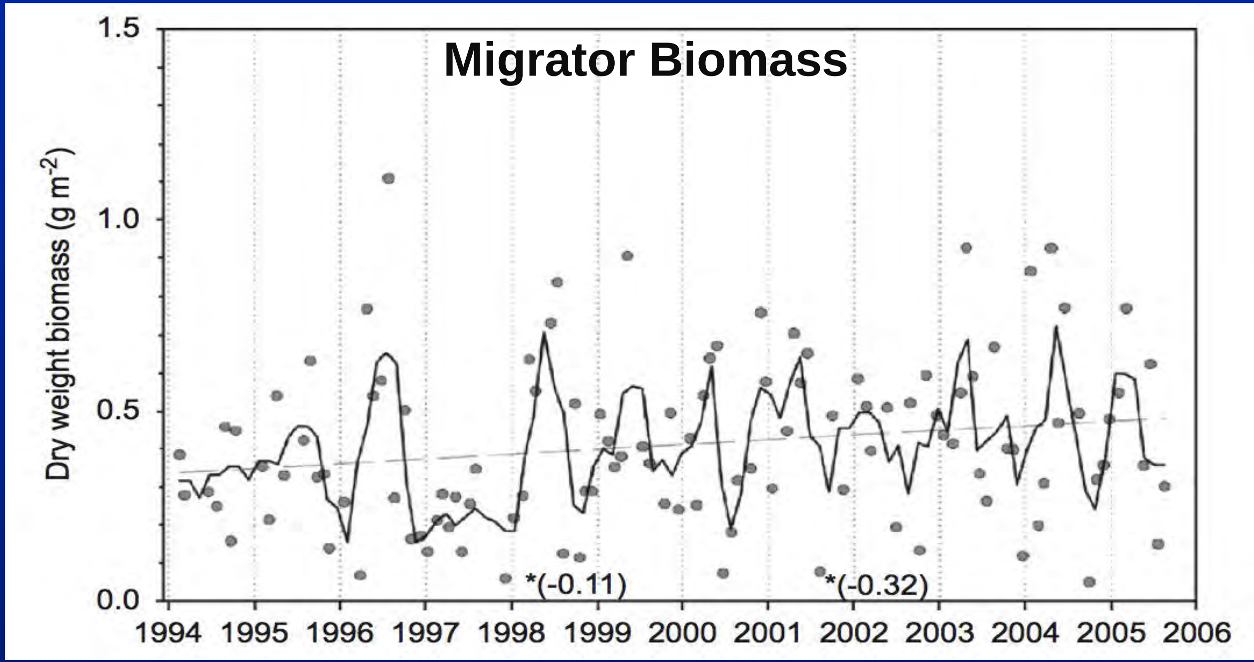


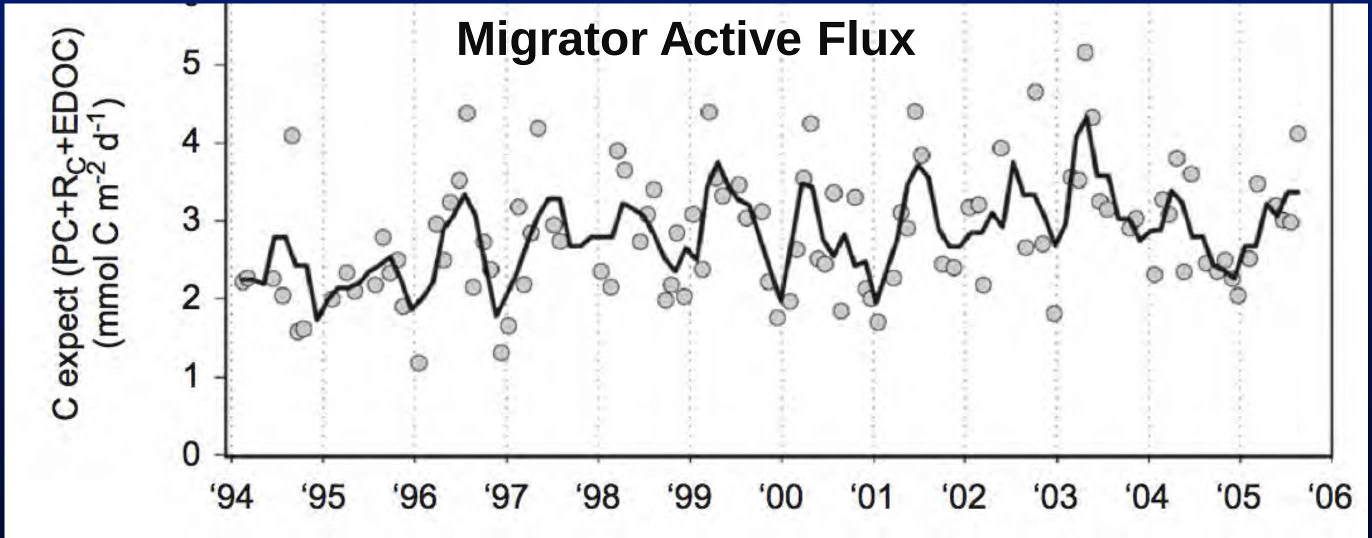
= 5-33% of POC flux

= 28-89% of POC flux

Steinberg, Lomas & Cope (2012)

Increase in active transport at ALOHA

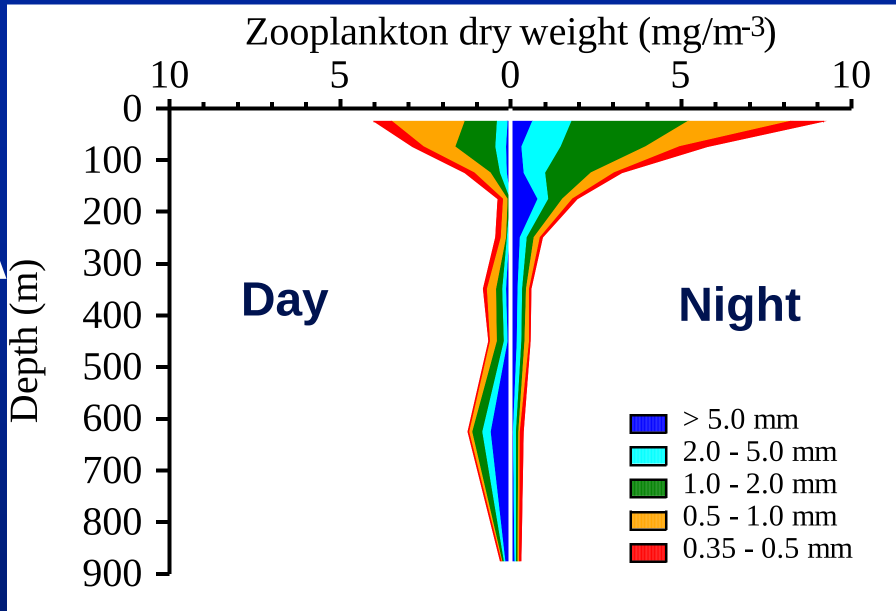




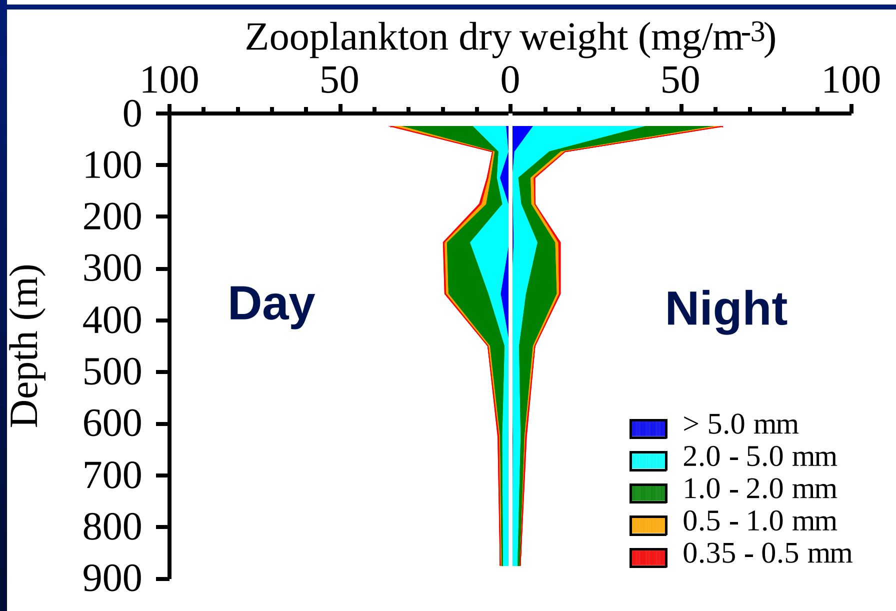
Hannides et al. (2009)

Mesozooplankton vertical biomass profiles

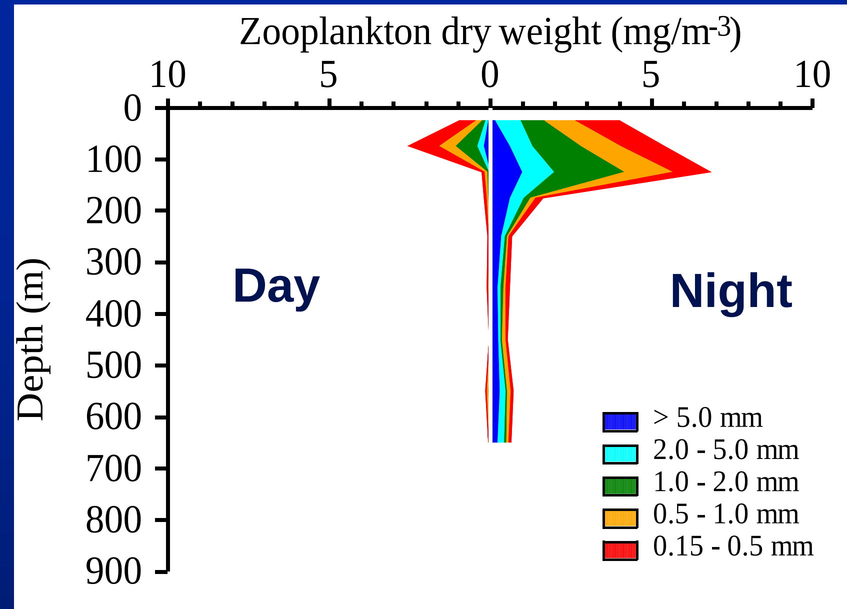
ALOHA



K2



mean, n=2

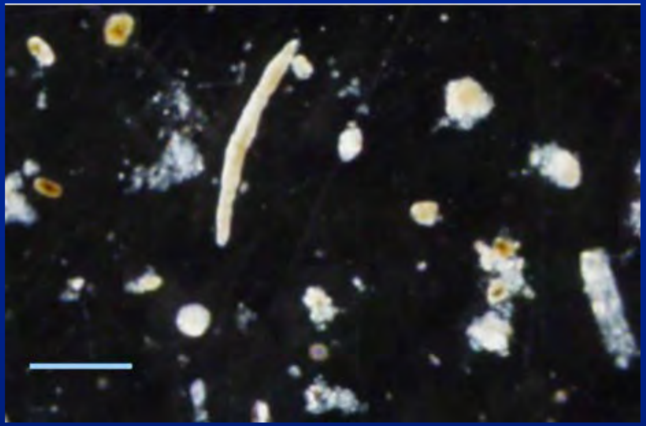


BATS/ Sargasso Sea

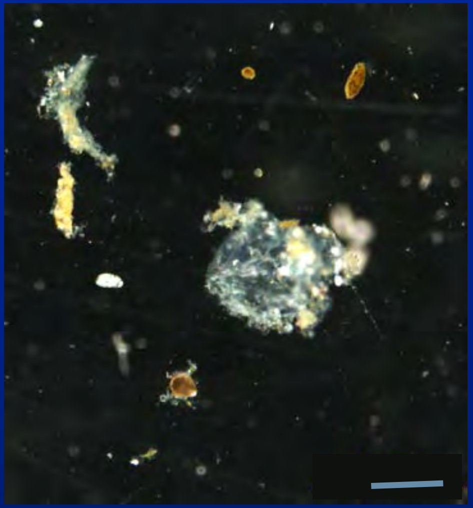
Steinberg et al. (2008),
Goldthwait & Steinberg (2008)

Fecal pellets and other sinking particles

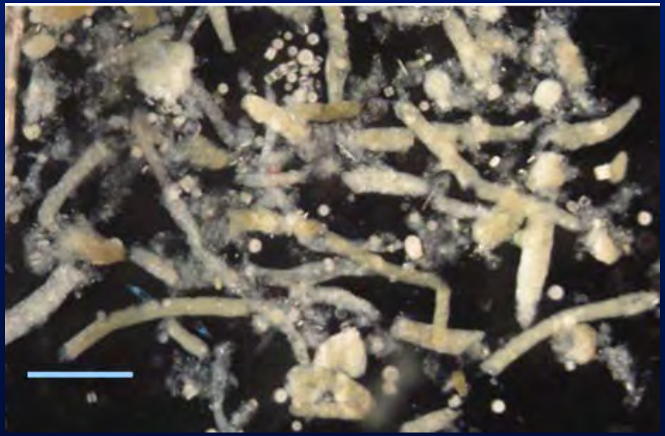
ALOHA



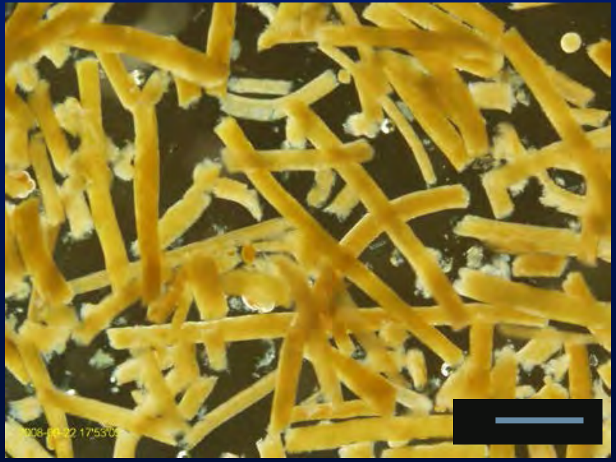
BATS



K2



Pal LTER



Scale bars= 0.5 mm

(Fecal pellet indicators!)

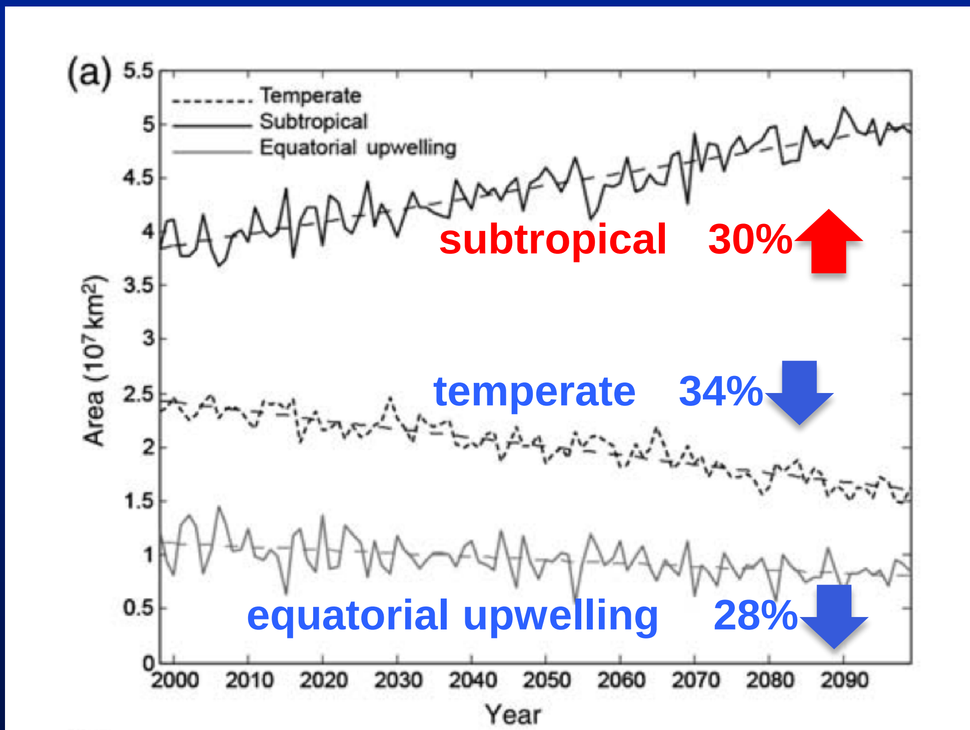
Overall comparison between sites

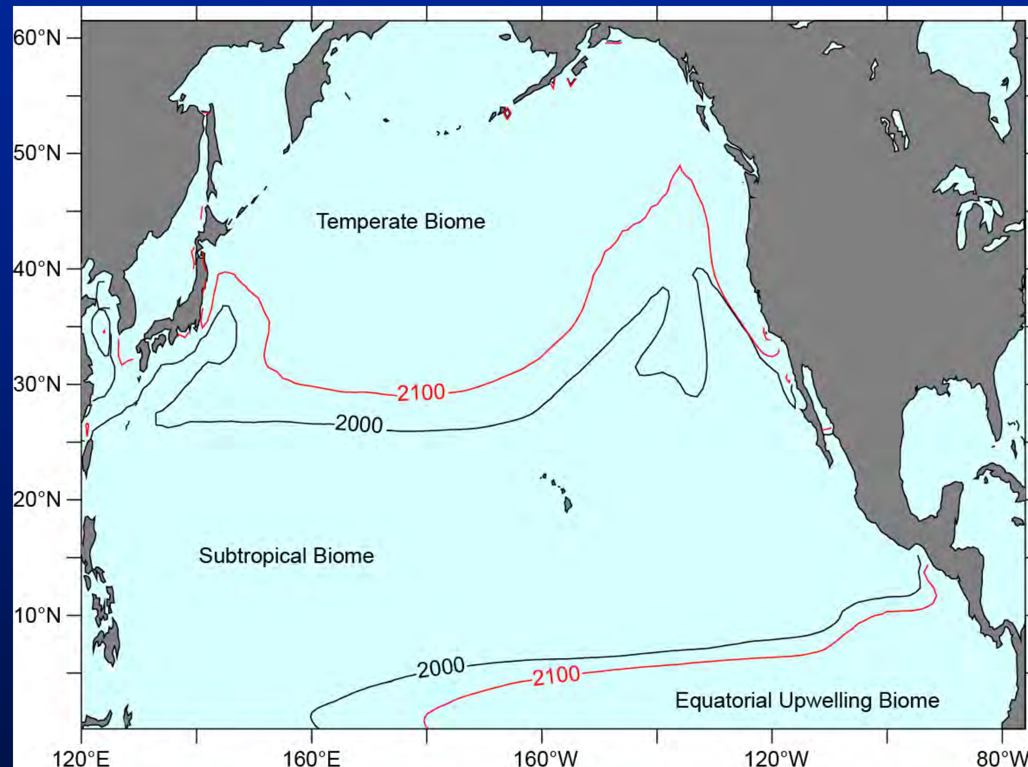
Site- Summer (annual)	**Total POC flux -sediment trap (mg C/m²/d)**	**Mean active flux by DVM (mg C/m²/d)**	**Pellet Flux across 150 m (mg C/m²/d)**
BATS (annual)	13 (29)	(4)	3 (6.5)
ALOHA (annual)	18 (29)	2-8 (5*)	2.5
K2	23 - 62	16-46	6.5 - 7.4
PAL LTER (annual)	73 (6)		42 (31)

increasing

* Hannides, Landry, et al. 2009

Expansion of subtropical biome in the North Pacific

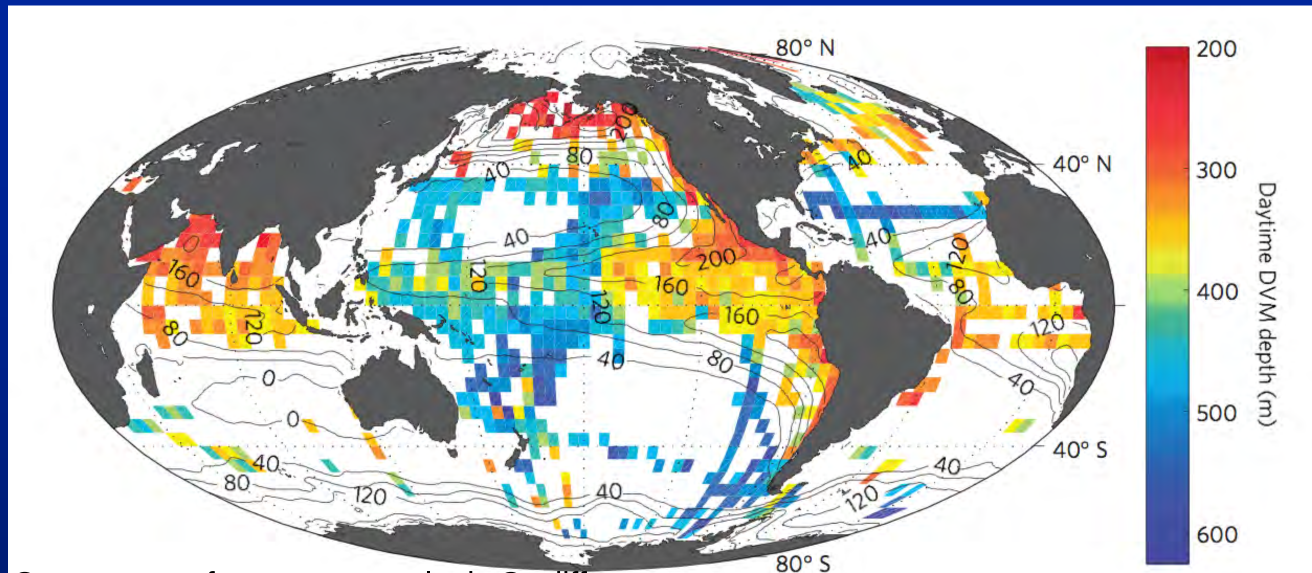




Polovina et al. (2011)

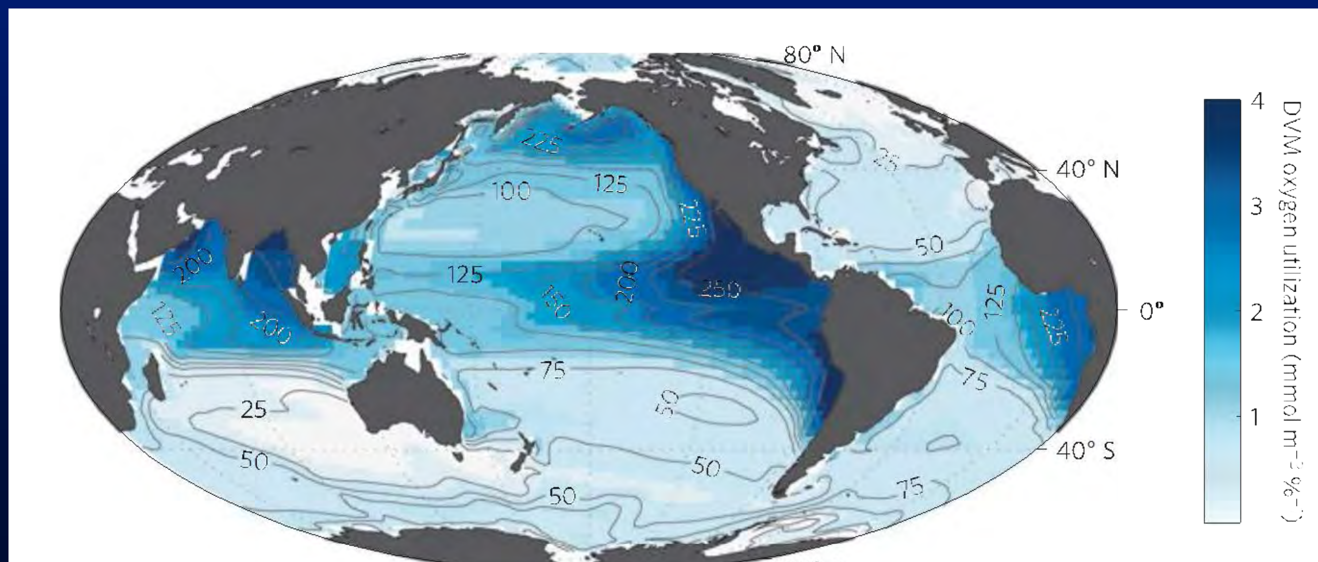
Intensification of O_2 depletion by diel vertical migrators

Migration depths are greater where subsurface O_2 concentrations are high



Contours- surface to mesopelagic O_2 difference

In O2 minimum zone areas, migrators descend as far as upper margins of low O_2 waters, focusing O_2 consumption there, and intensifying O_2 depletion

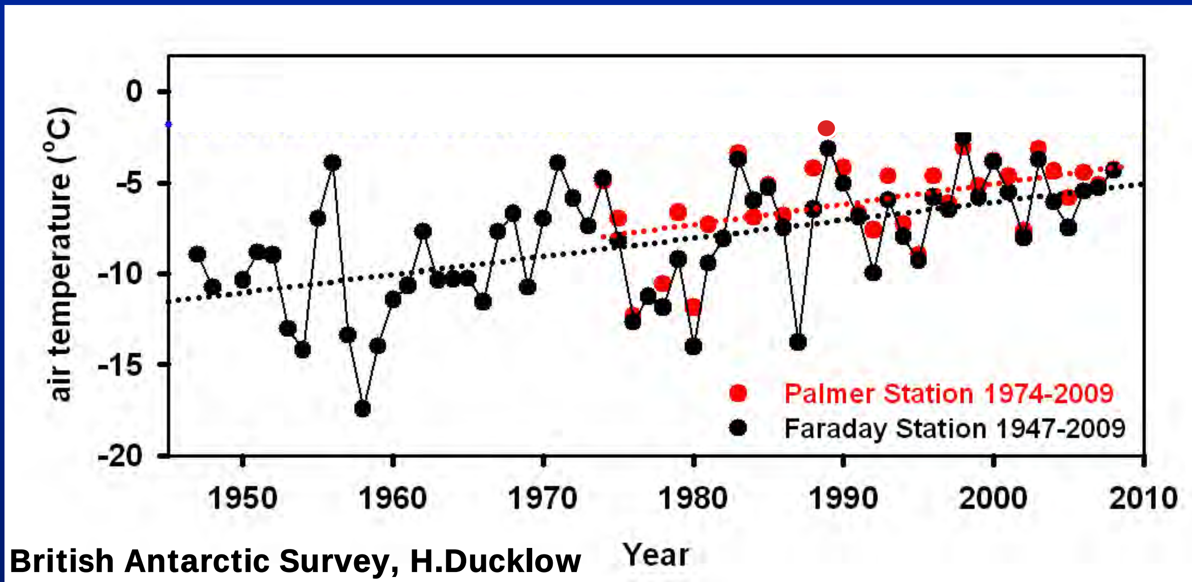


Contours- mesopelagic O_2 utilization

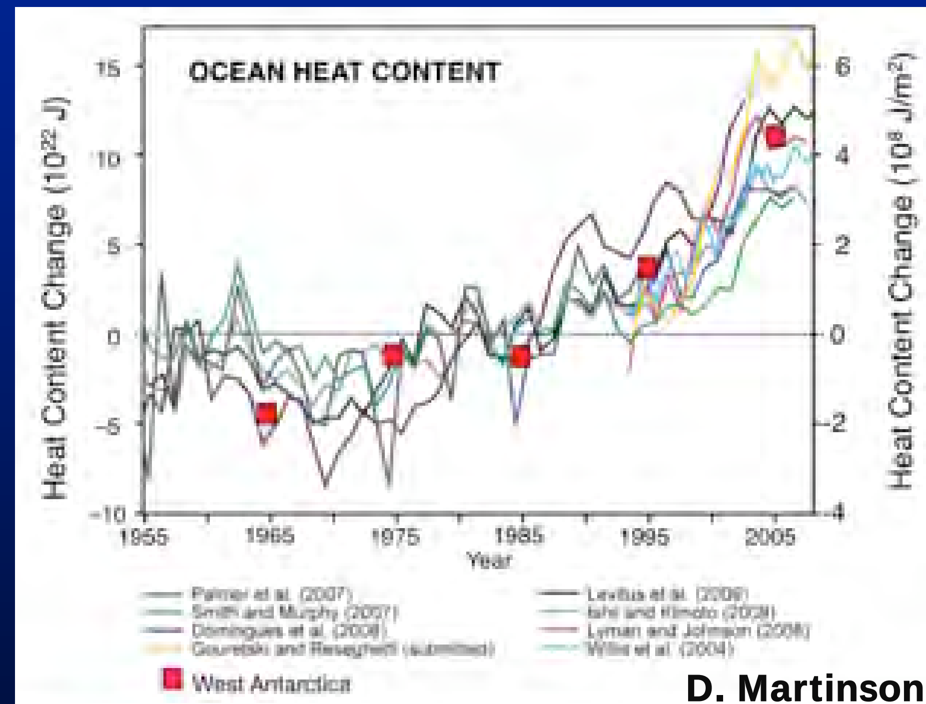
Bianchi et al. (2013)

Warming in the Western Antarctic Peninsula

Average winter (June-Aug.) temperature
+1.1ºC per decade: 6ºC since 1950: 5x global ave.

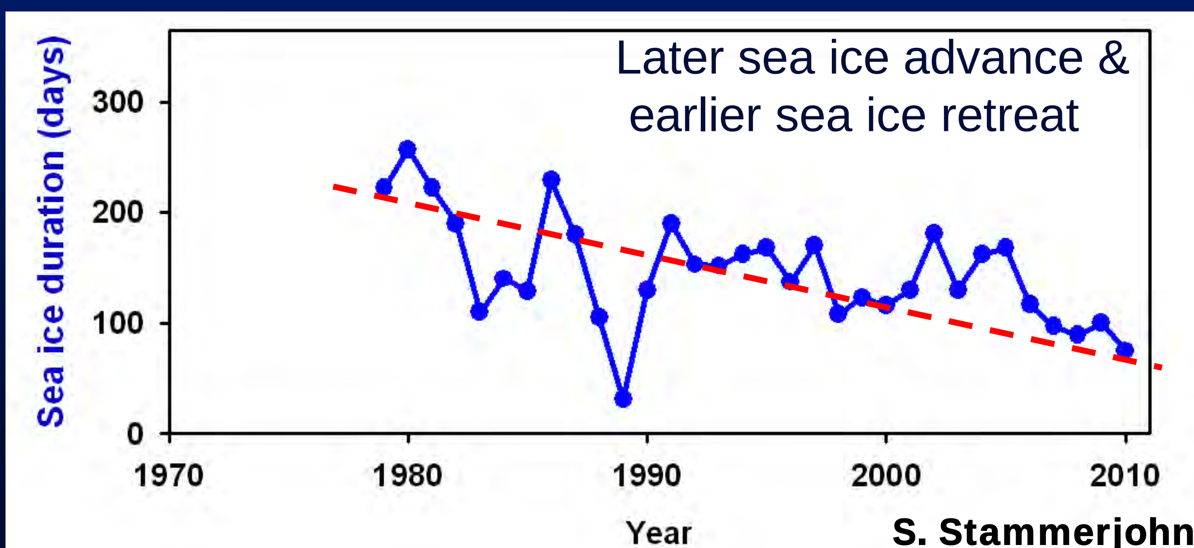


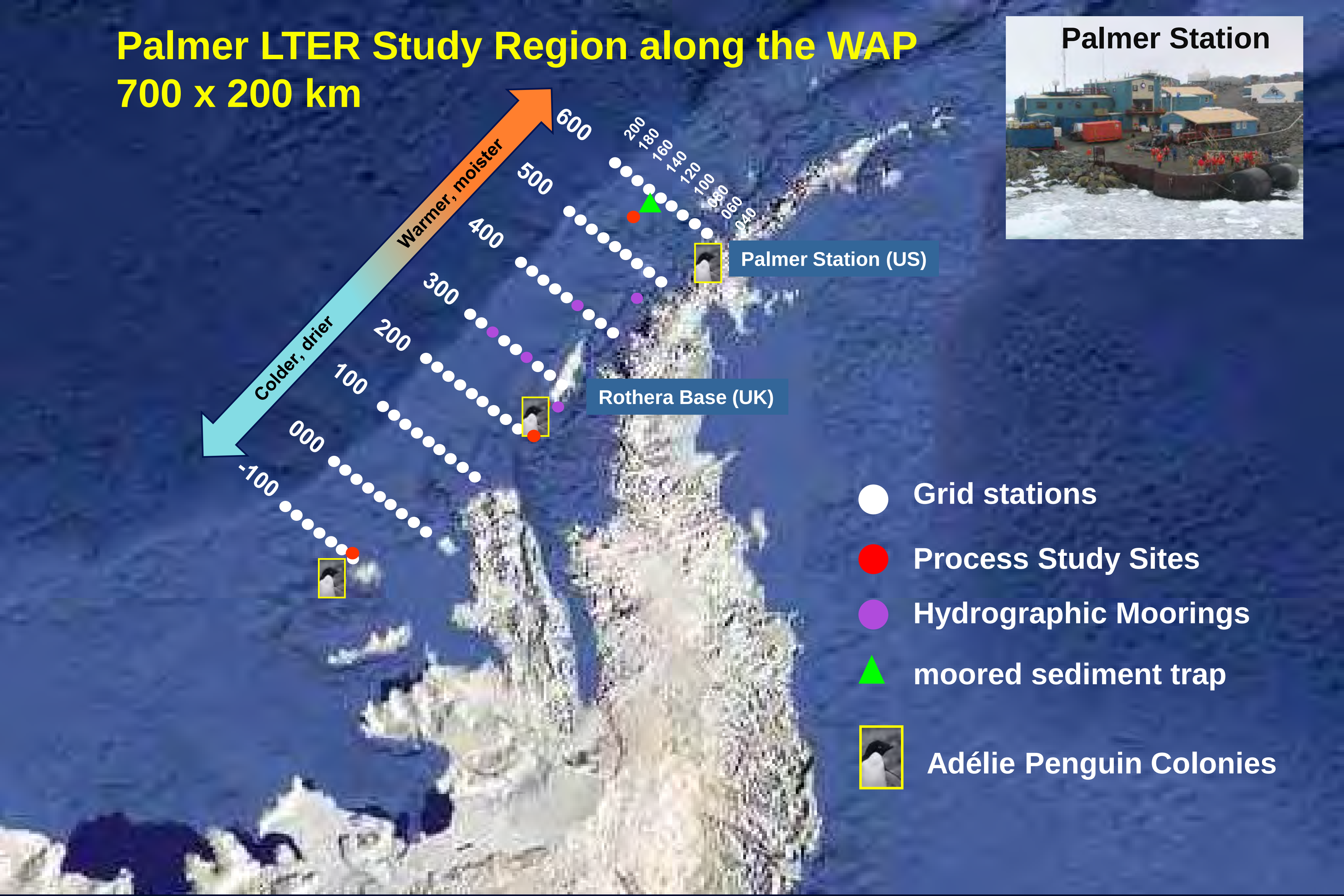
Increase in Heat Content of Water Over Shelf



Upper Circumpolar Deep Water (UCDW) heat content

Sea ice is declining



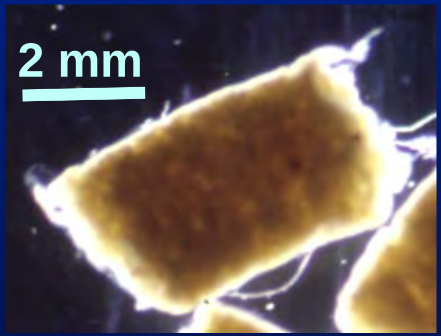

Palmer LTER Study Region along the WAP
700 x 200 km
Palmer Station
Warmer, moister
Colder, drier
600
500
400
300
200
100
000
-100
200
180
160
140
120
100
080
060
040
Palmer Station (US)
Rothera Base (UK)
Grid stations
Process Study Sites
Hydrographic Moorings
moored sediment trap
Adélie Penguin Colonies

Antarctic krill & salps

Zooplankton composition effects on particle export

krill fecal pellets

salp fecal pellet



Mean sinking rate = 197 m/ d

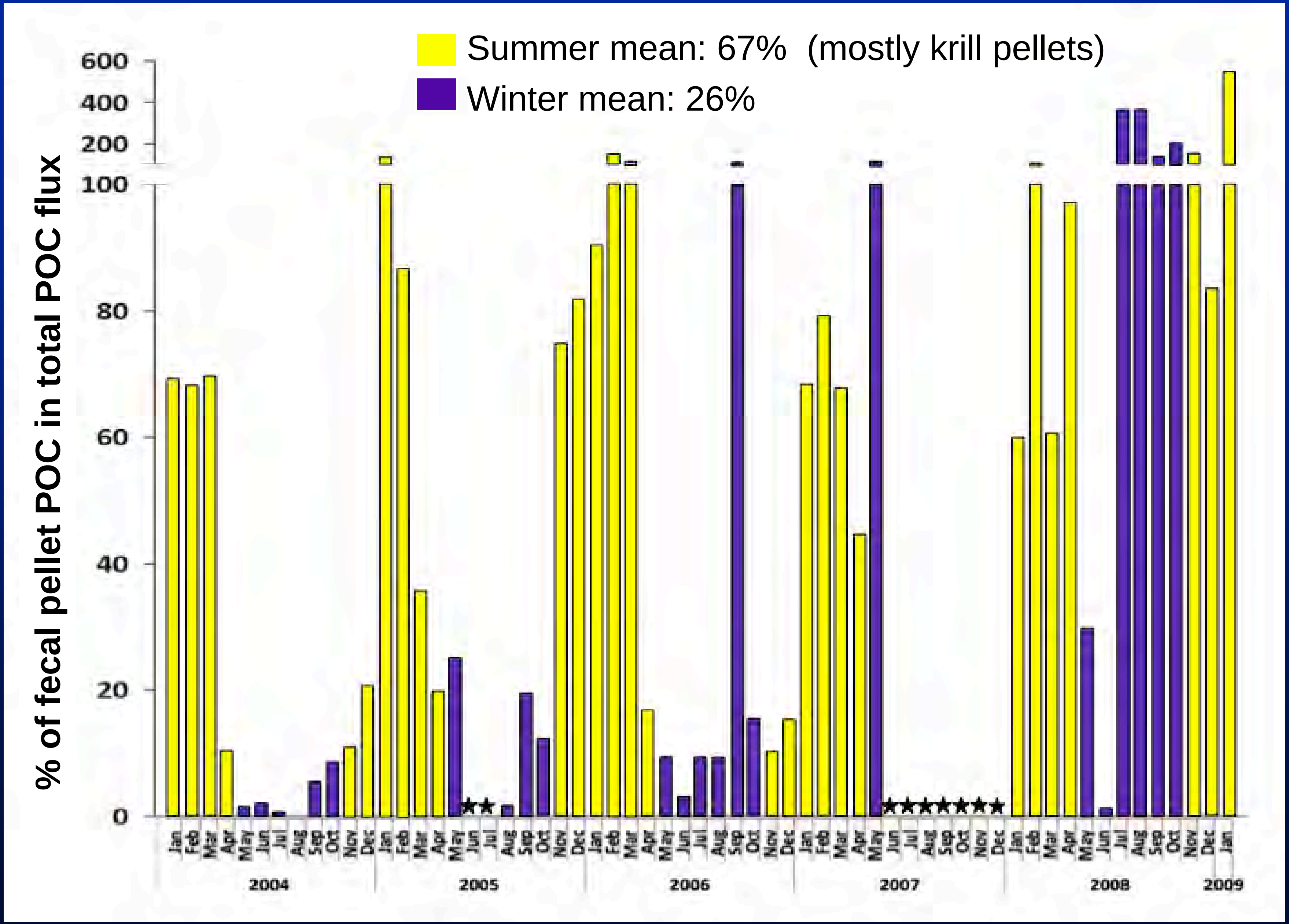
= 700 m/ d

Time series sediment trap
21 samples/ year

Fecal pellet production experiment

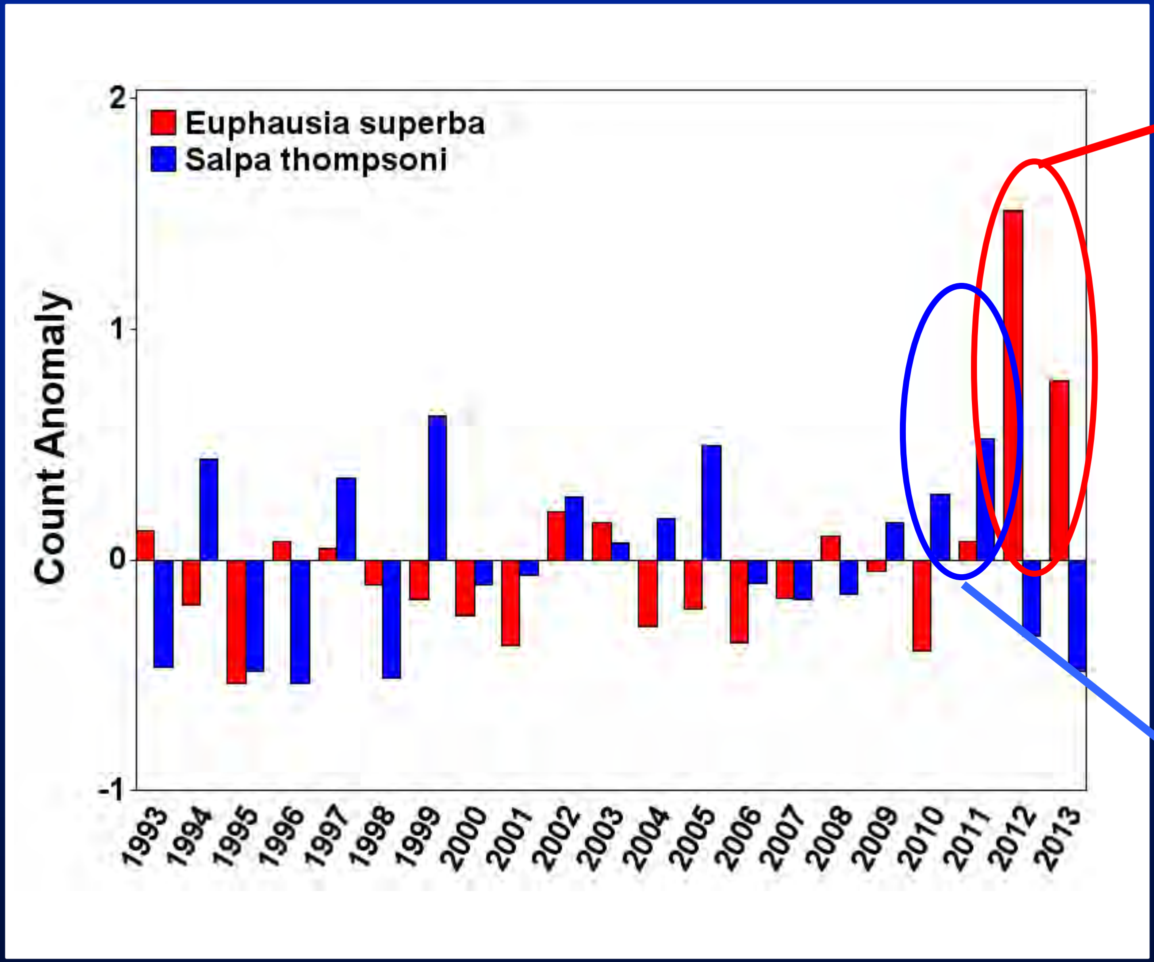
(Steinberg et al., in prep, Phillips et al. 2009)

Fecal pellets are major contributor to total POC flux



Gleiber, Steinberg, & Ducklow (2012)

Effect of changes in krill & salps on fecal pellet flux



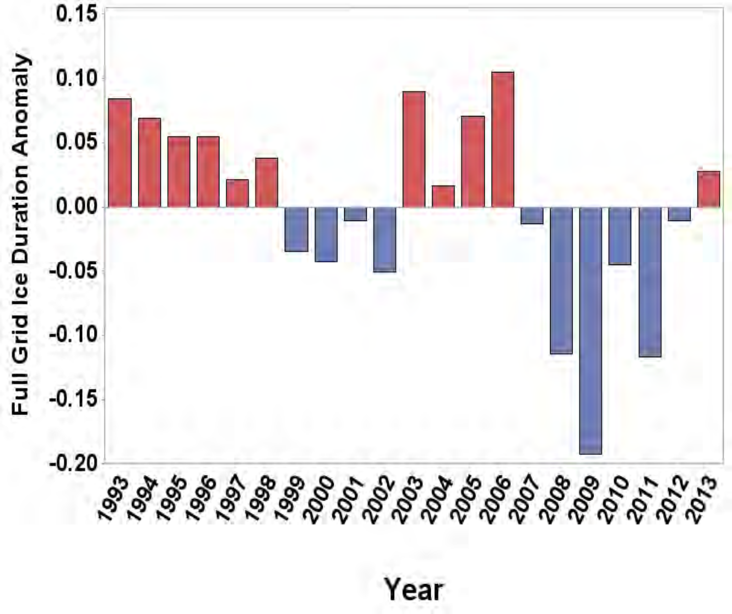
FP flux (mg C/ m^2/d)
Krill- 11.0
Salps- 0.2

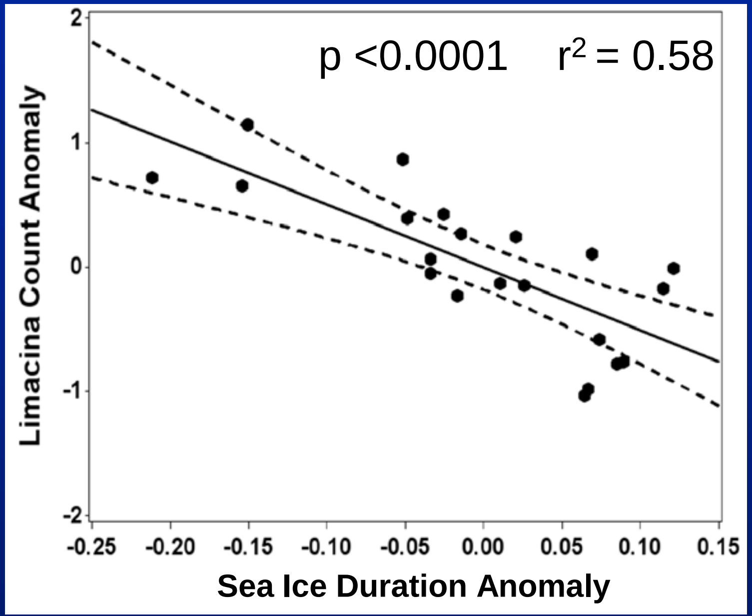
High ice

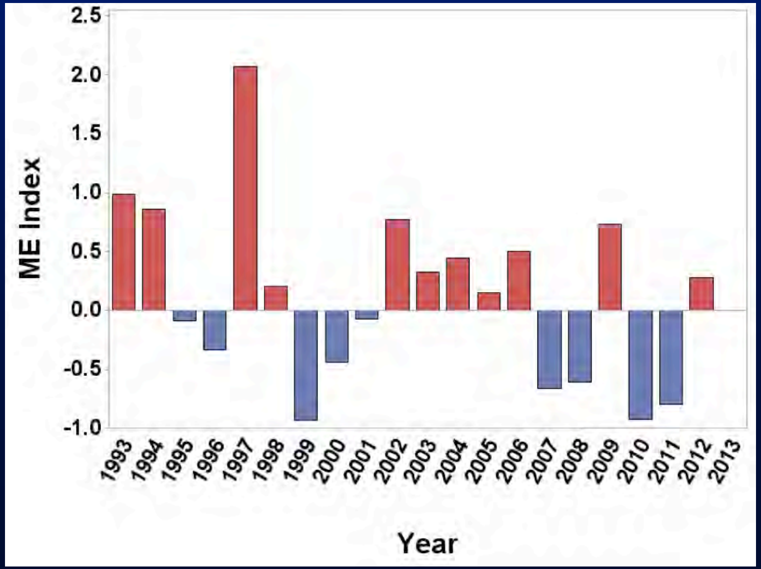
FP flux (mg C/ m^2/d)
Krill- 0.8
Salps- 2.8

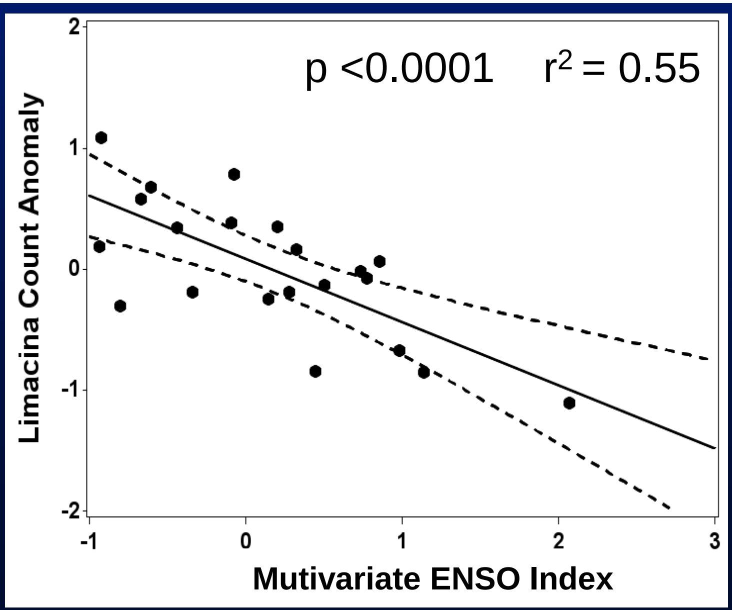
Low ice, warmer

Limacina pteropods, sea ice, and climate indices
(annual anomalies)

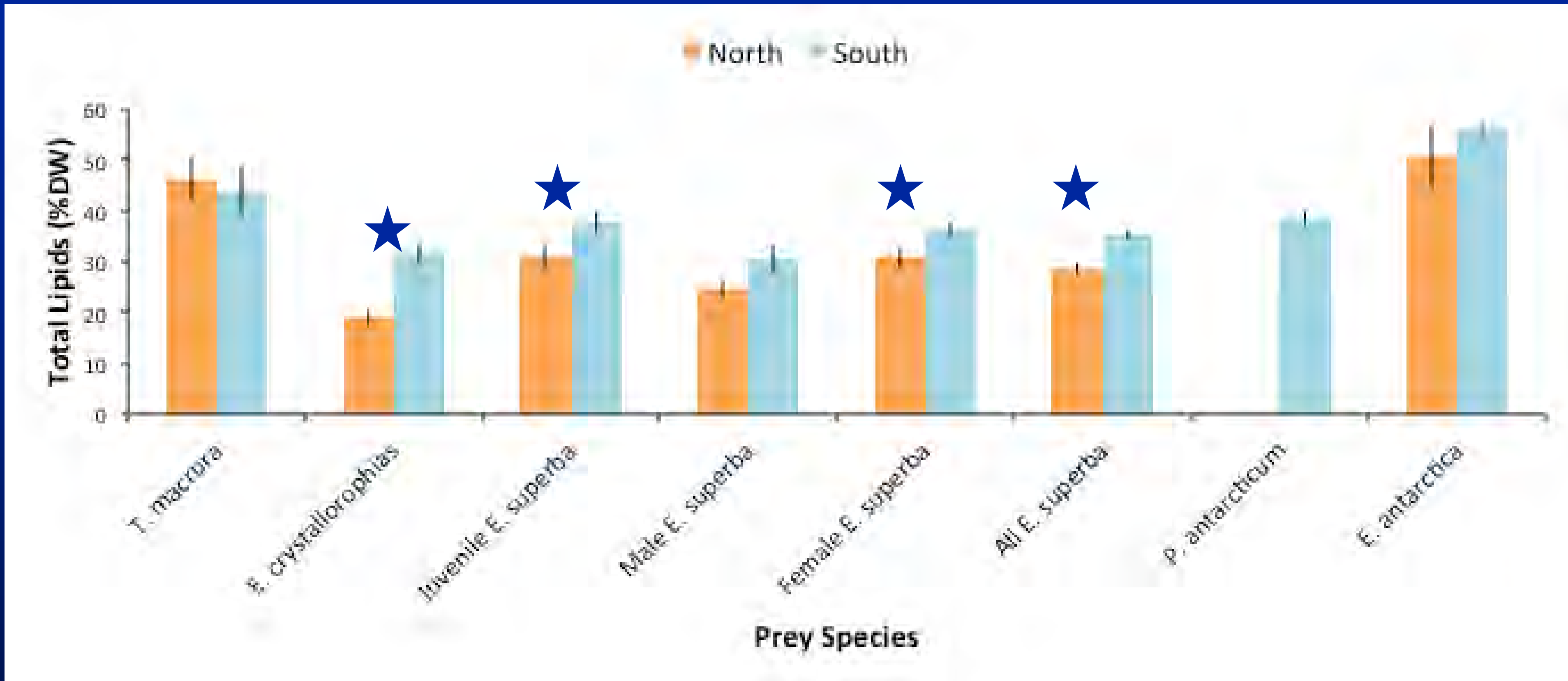








Potential indicators of environmental stress: Regional comparison in prey total lipid content

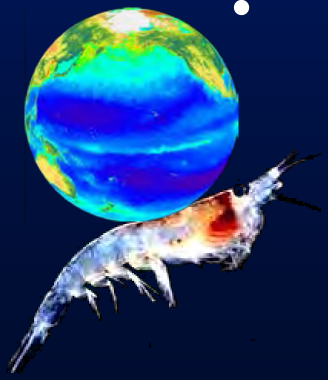


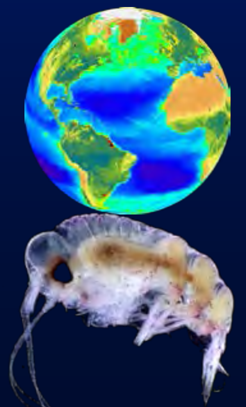
- **North– water temp , Chl a**
- **South– water temp , Chl a**

Ruck, Steinberg, & Canuel (in review)

Summary & Conclusions

- Changes in zooplankton community structure over time, or in space, differentially alters organic matter export. Implications for feeding the deep sea too.
- Patterns can (sometimes) be linked to climate oscillations and other physical dynamics (e.g., ice)
- Measurements of ‘function’ are needed to incorporate the role of zooplankton into predictive biogeochemical models.
- Time series are key!





THANK YOU (MAHALO) !

BATS, Pal LTER, VERTIGO coauthors, collaborators, technicians & students

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