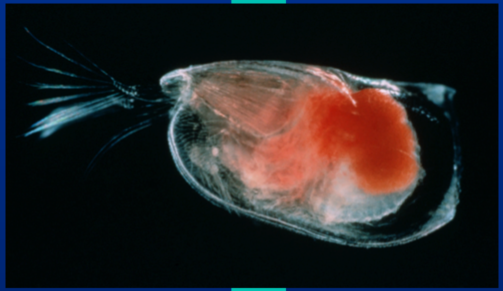
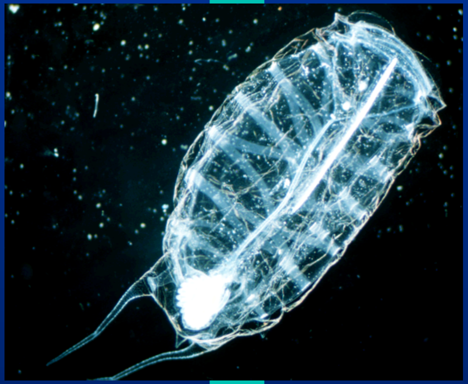
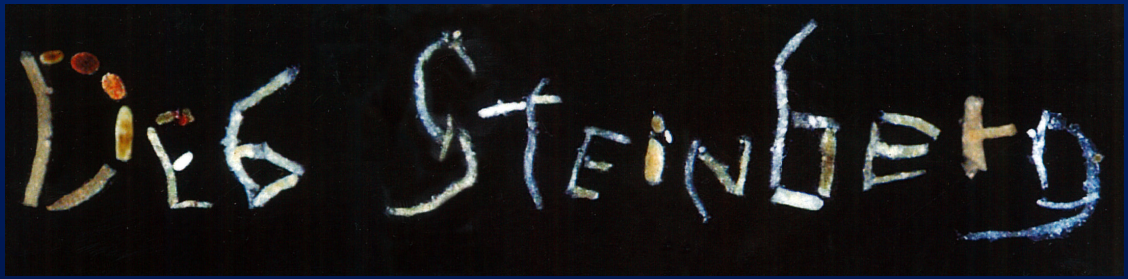
The biological pump: vertical migration

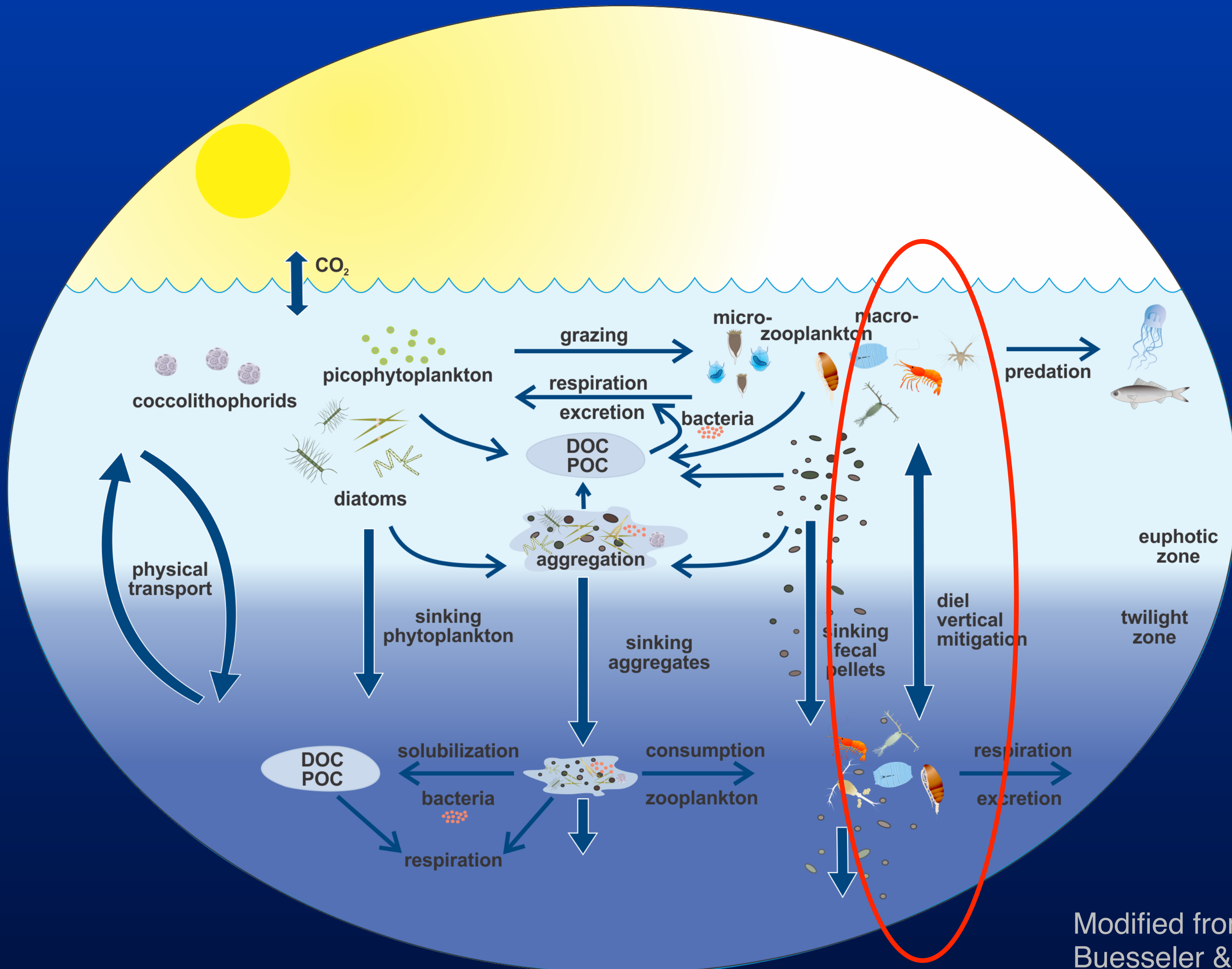






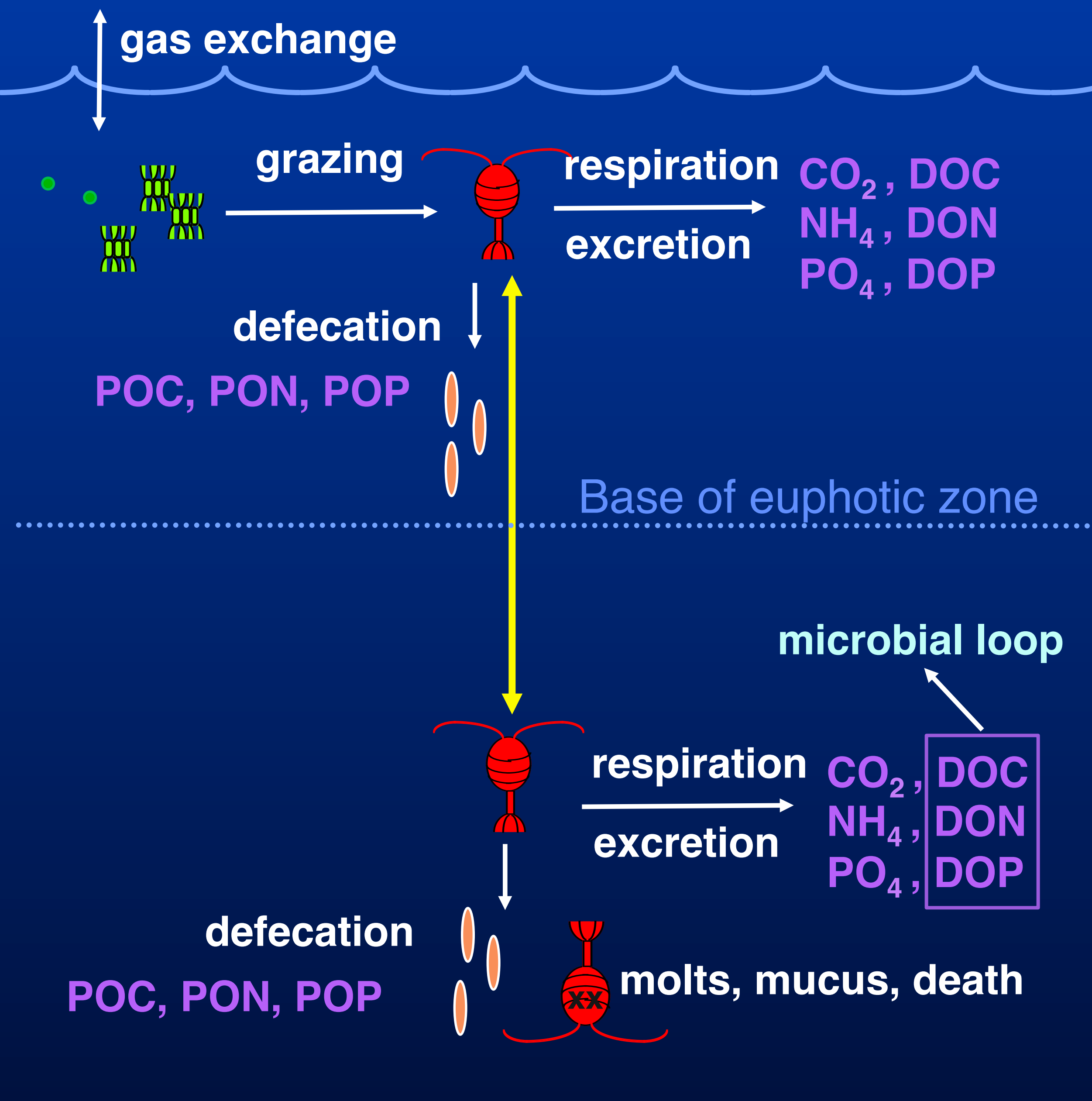
WILLIAM & MARY
VIMS
VIRGINIA INSTITUTE OF MARINE SCIENCE
SCHOOL OF MARINE SCIENCE

The biological pump



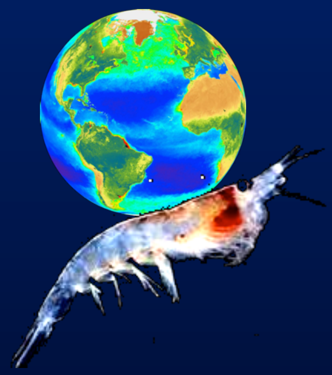
Modified from Steinberg, Buesseler & EXPORTS team

Active transport by vertical migration

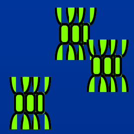


Outline

- Regional differences (community structure)
- Long-term changes
- Stoichiometry
- Modeling the biogeochemical impact
- Importance of different taxa
- Conclusions



Let's put this in perspective



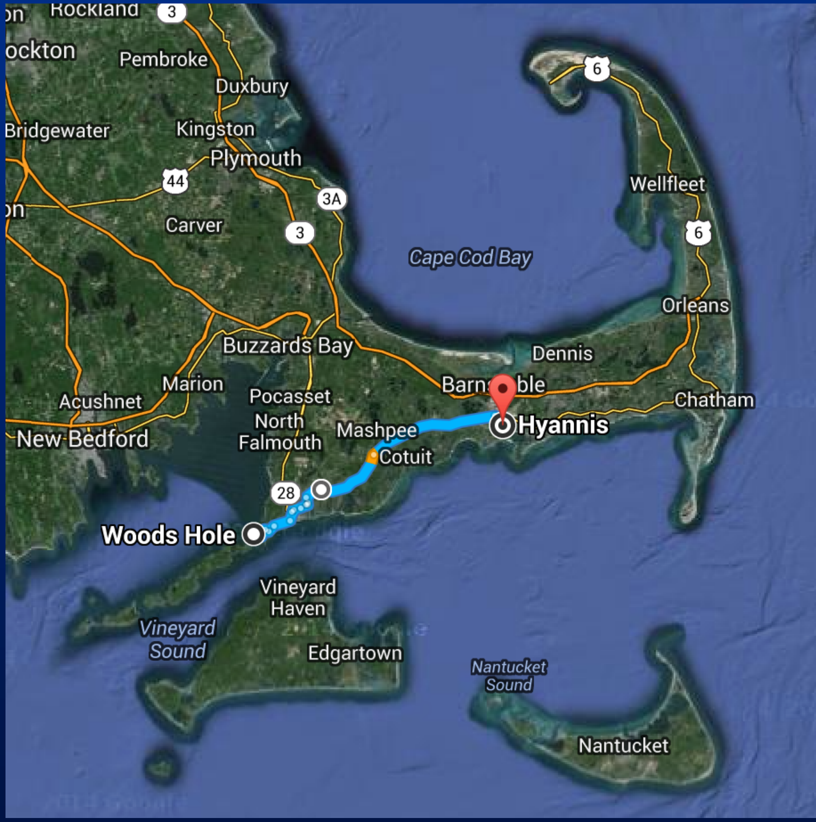
500 m = ⅓ mile

2 cm

= 25,000 body lengths

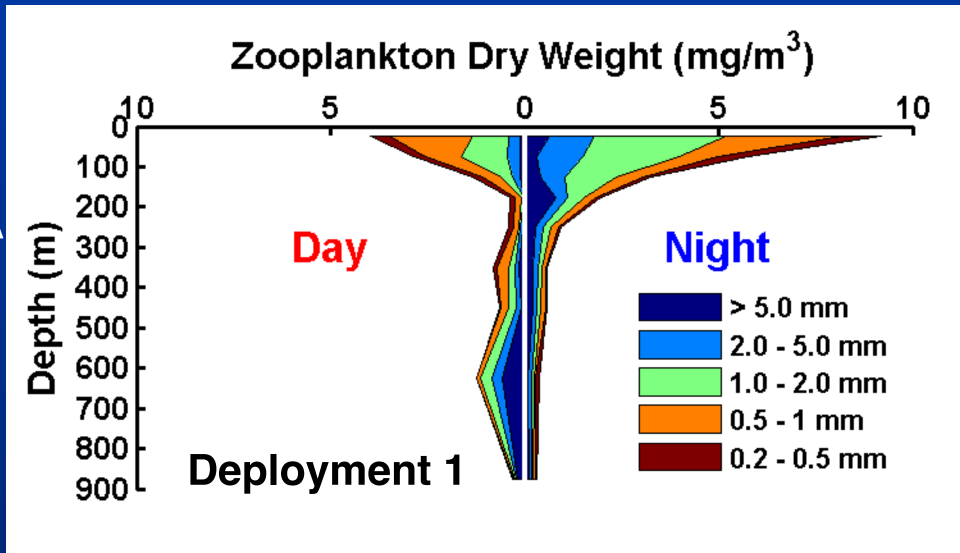
6 ft. = 1.8 m

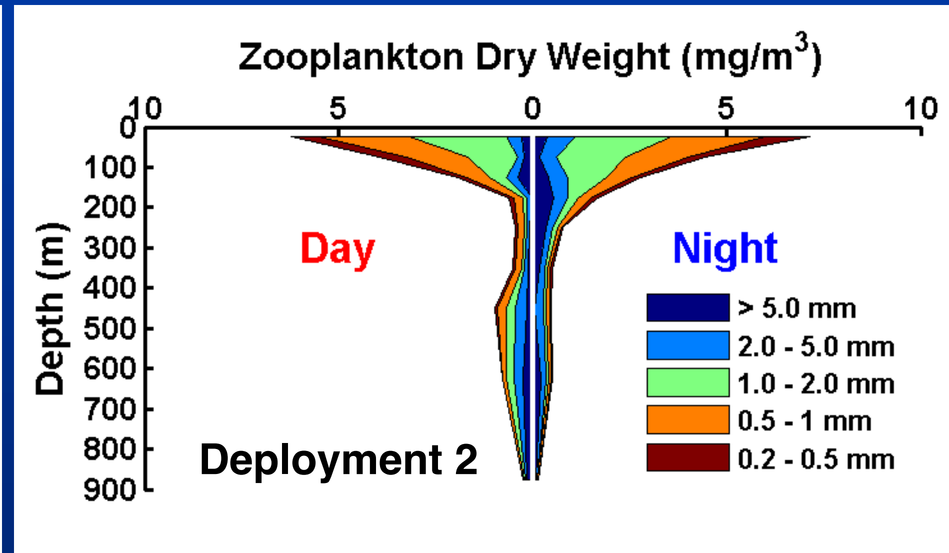
45,000 m = 28 miles !



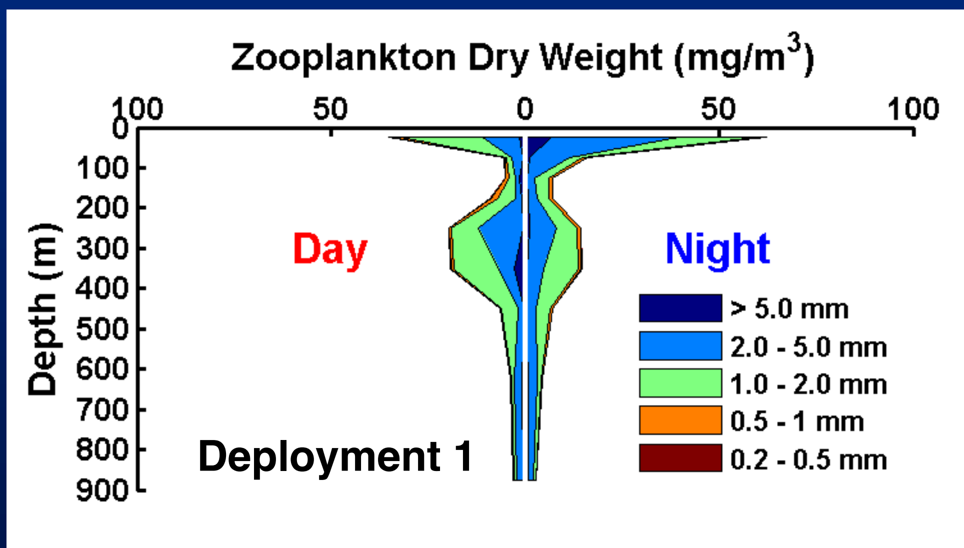
Zooplankton vertical biomass profiles in N. Pacific

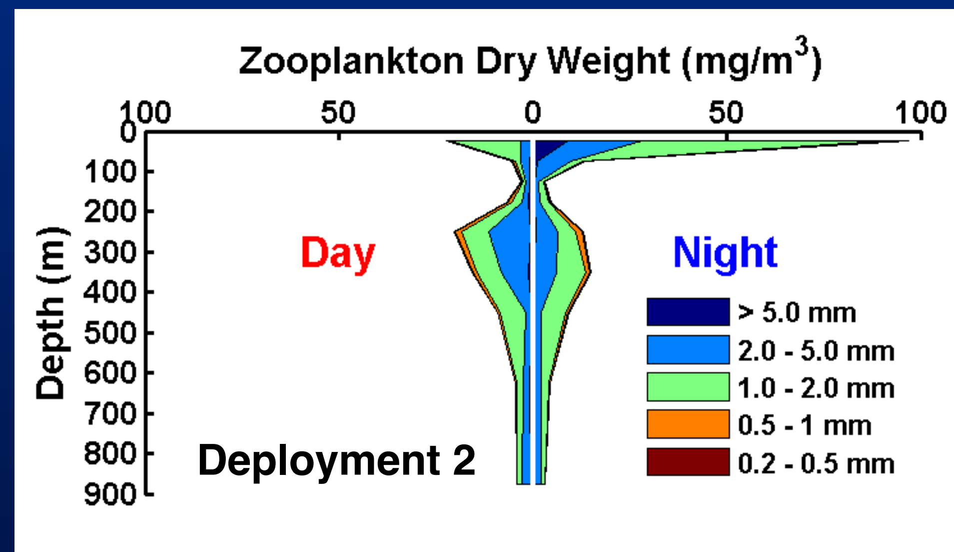
ALOHA





K2

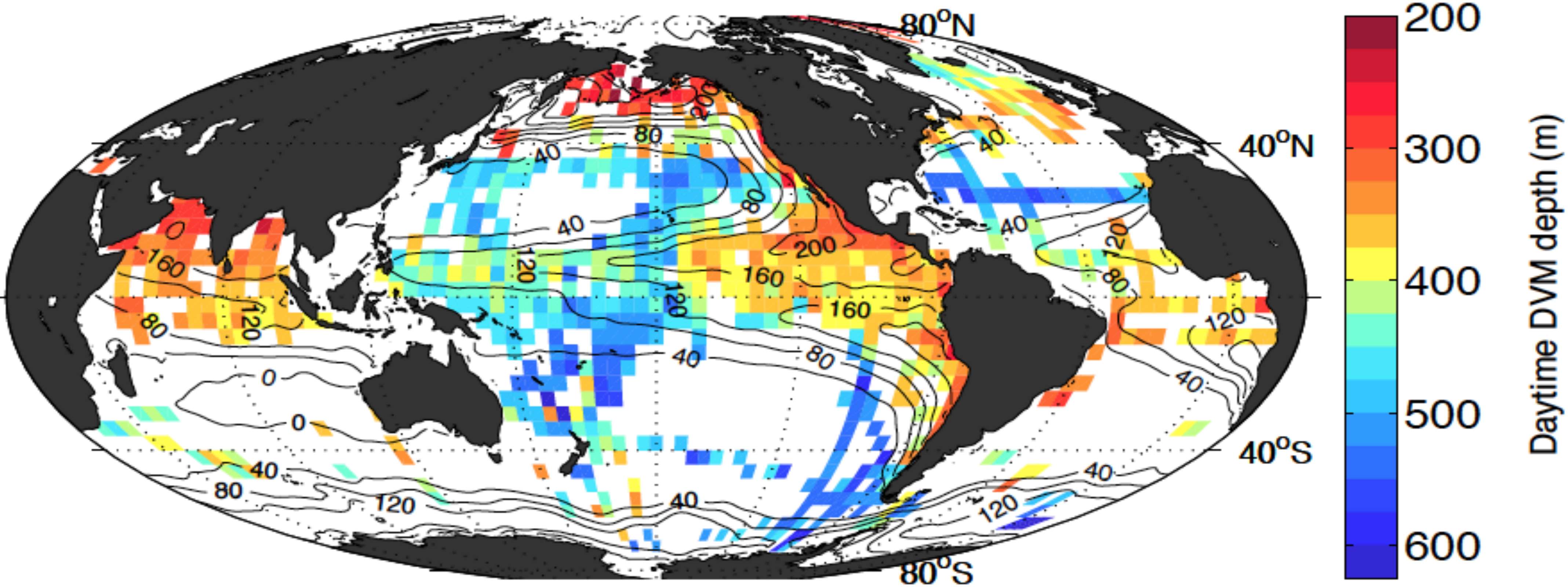




mean, n=2

Steinberg et al. (2008)

Daytime DVM depths & surface to mesopelagic O_2 gradients



Linear correlation with surface to mesopelagic O_2 gradients explains 45 % of the DVM depth variance

Bianchi, Galbraith, Carozza, Mislan, & Stock (2013)

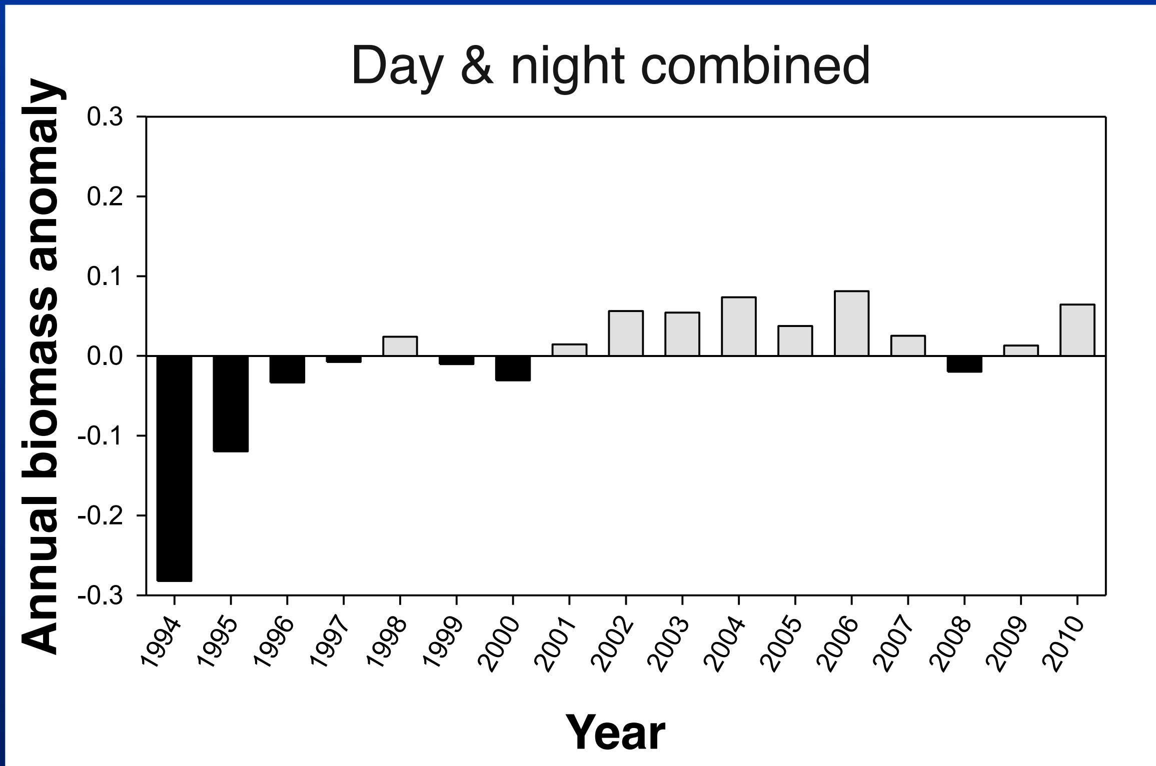
Regional comparison of active transport

(an example)

Site	Active flux (mg C/m2/d)	Trap POC flux @150m (mg C/m2/d)	Active transport/ Trap POC flux (%)
BATS (annual)	(4)	(29)	(14 %)
ALOHA HOT (annual)	2-8 (5)	18 (29)	11-44 % (19 %)
Canary Islands	4	10-12	~ 36%
Equatorial Pacific	4-8	23 - 29	4-25%
K2- Subarctic Pacific	16-46	23 - 62	26-200%

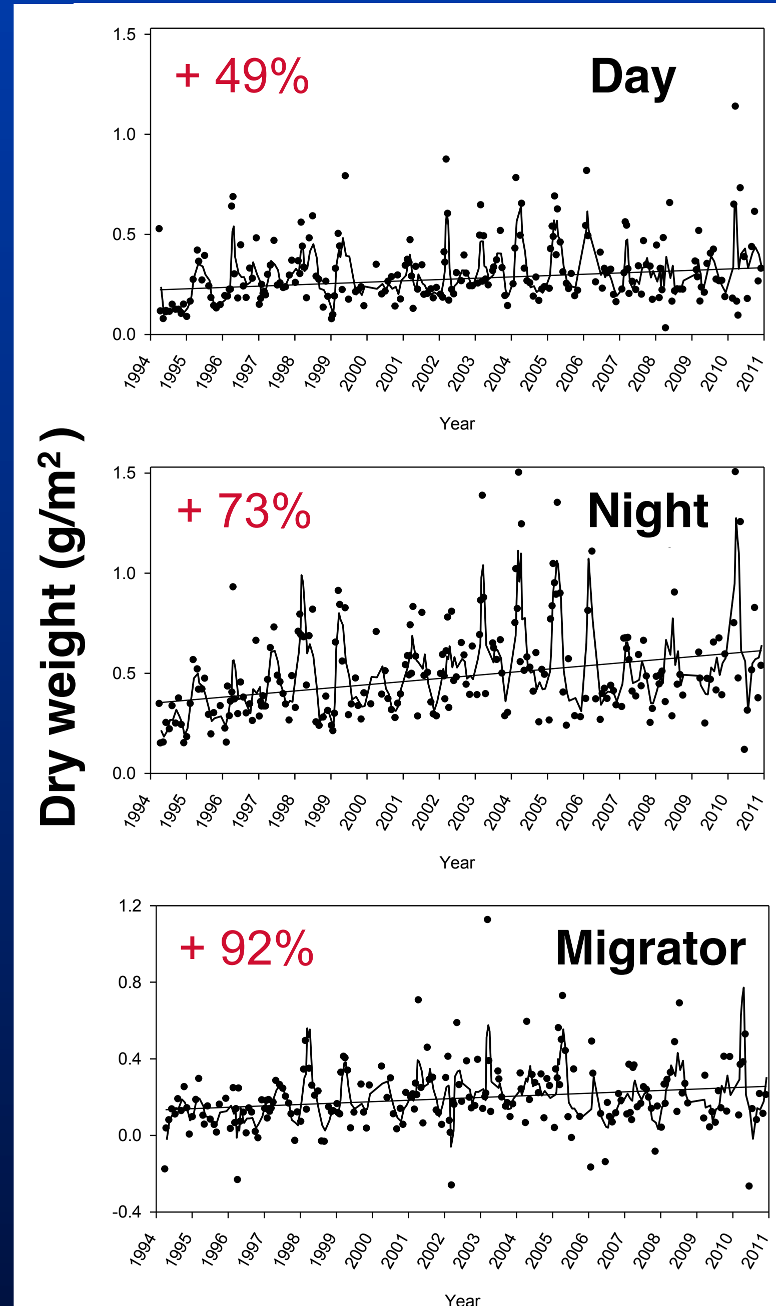
(Zhang and Dam 1997; Le Borgne & Rodier 1997, Hernández-León et al. 2001, Steinberg et al. 2008, 2012; Hannides et al. 2009)

Increase in mesozooplankton biomass (top 150 m) at BATS



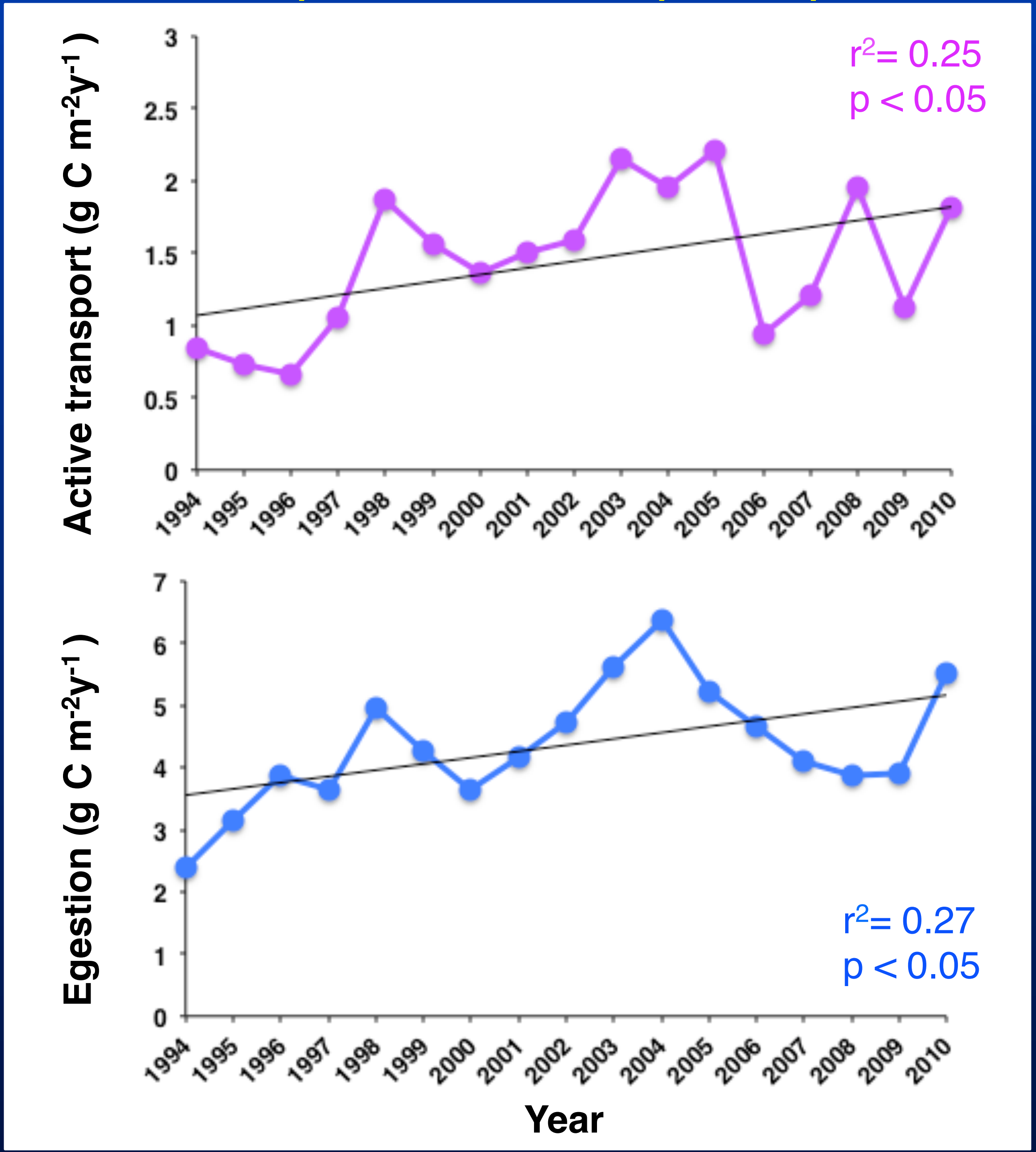
Steinberg, Lomas, & Cope (2012)

Increased more at night



Increase in active transport and fecal pellet production at BATS

Annual migratory CO_2 + DOC + POC flux across 150 m



= 5-33% of POC flux

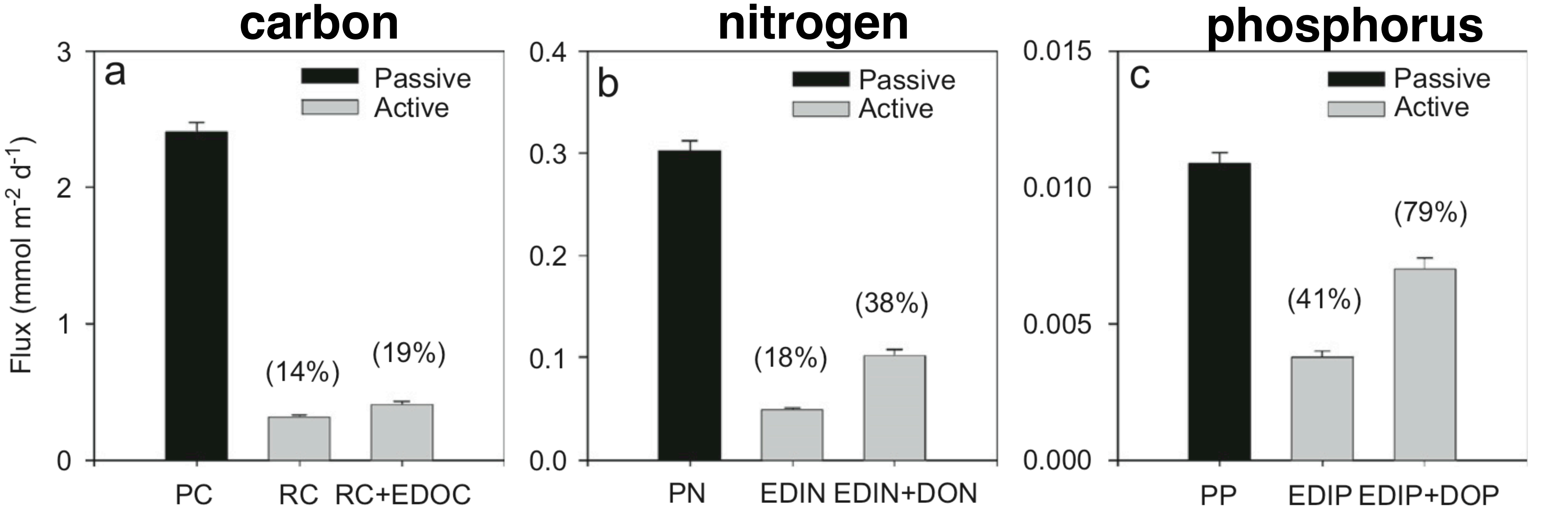
Annual fecal pellet production (egestion) in top 150 m

= 28-89% of POC flux

Steinberg, Lomas, & Cope (2012)

Stoichiometry of active transport

North Pacific subtropical gyre- HOT station ALOHA

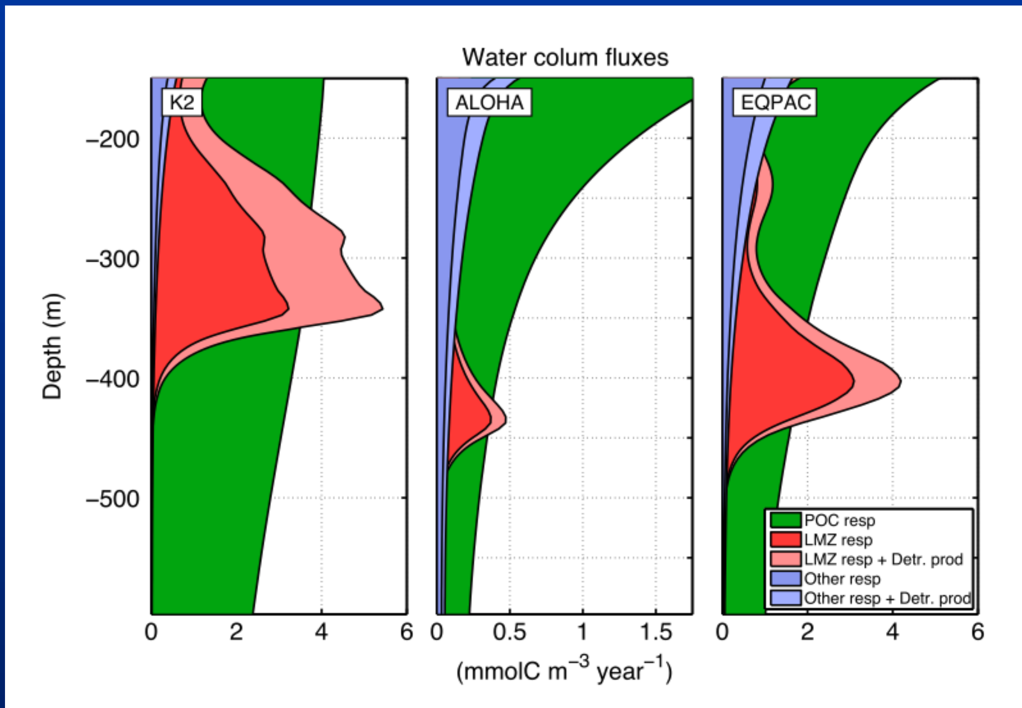


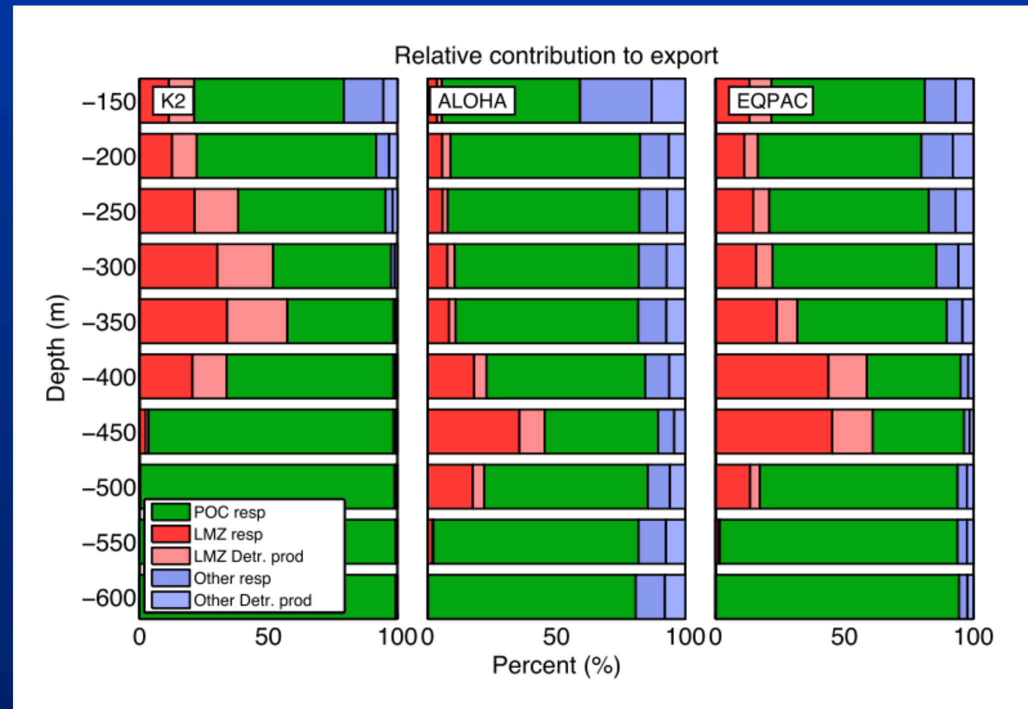
Active transport especially important mechanism for phosphorus (P) removal from the euphotic zone

Enhanced P-limitation of biological production in the N. Pacific subtropical gyre

Hannides, Landry, et al. (2009)

Modeling the biogeochemical impact of DVM



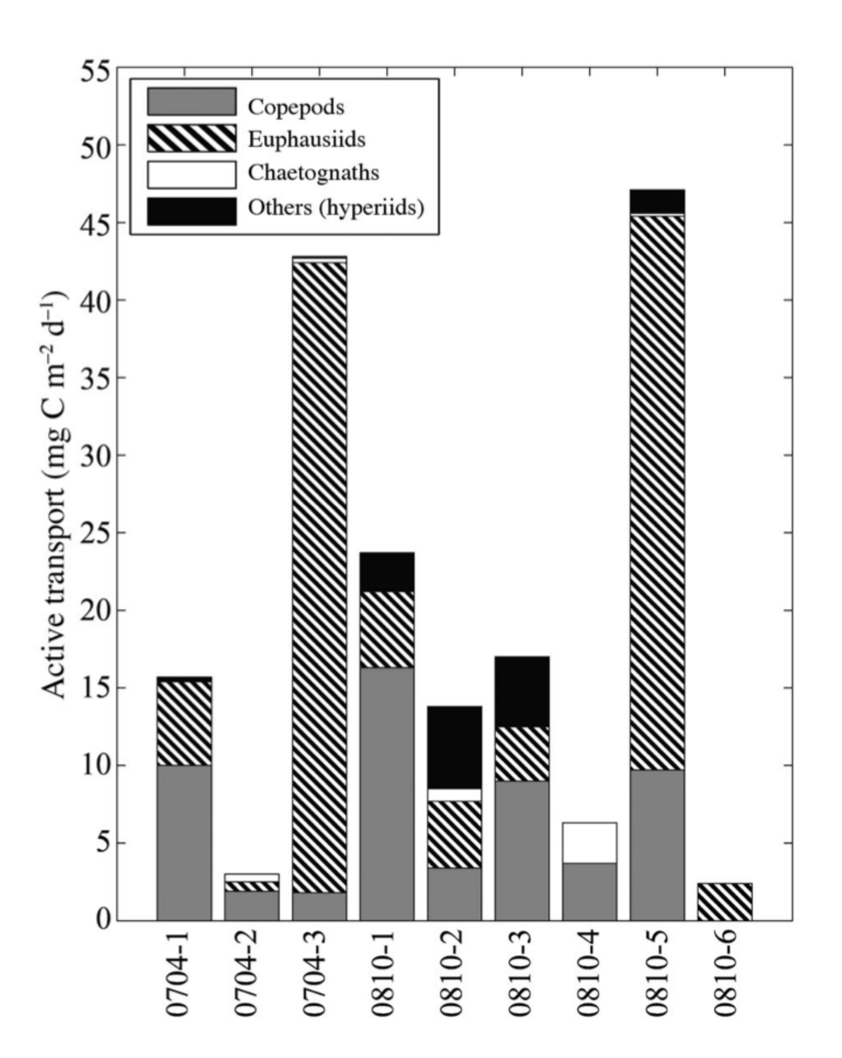


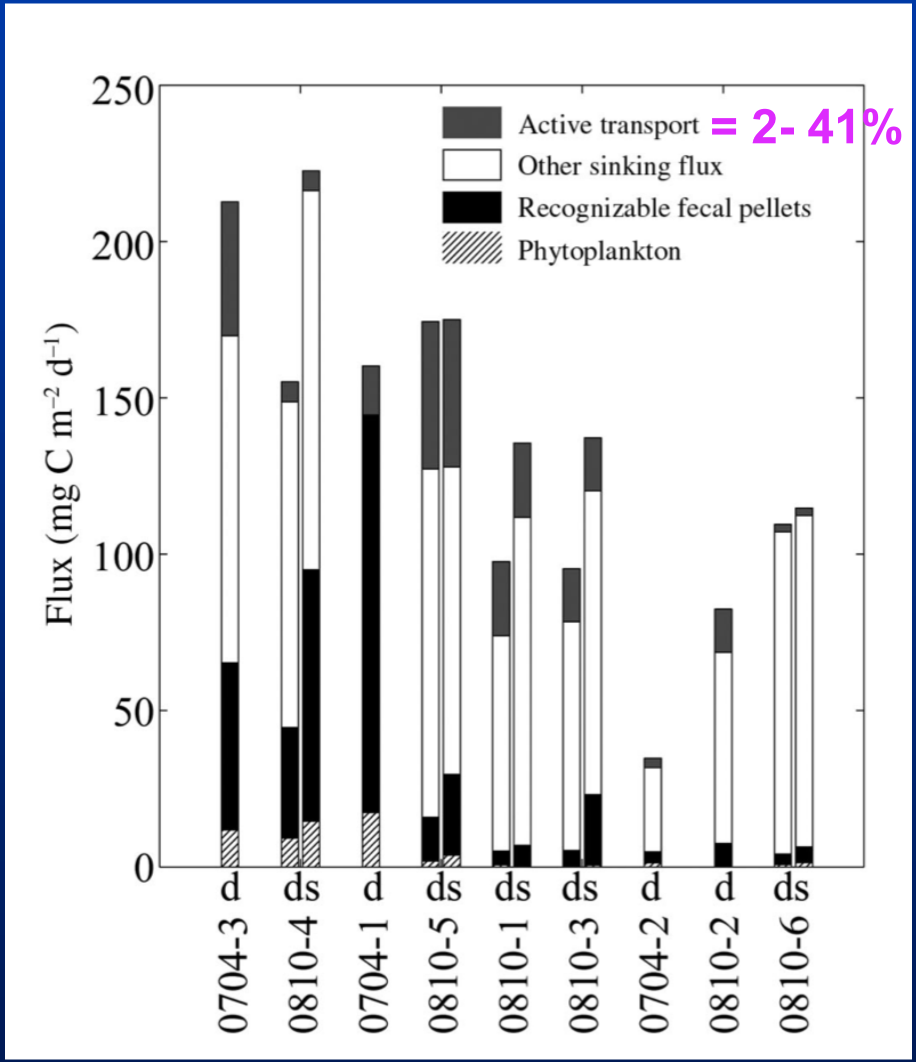
	K2	ALOHA	EQPAC
DVM flux : NPP	0.07	0.01	0.03
DVM flux : POC flux	0.3	0.14	0.38

(export calculated at euphotic zone boundary)

Bianchi, Stock, Galbraith, & Sarmiento (2013)

Importance of different taxa





= 2- 41% passive flux

Stations in the CA current

Stukel, Ohman, Benitez-Nelson, & Landry (2013)

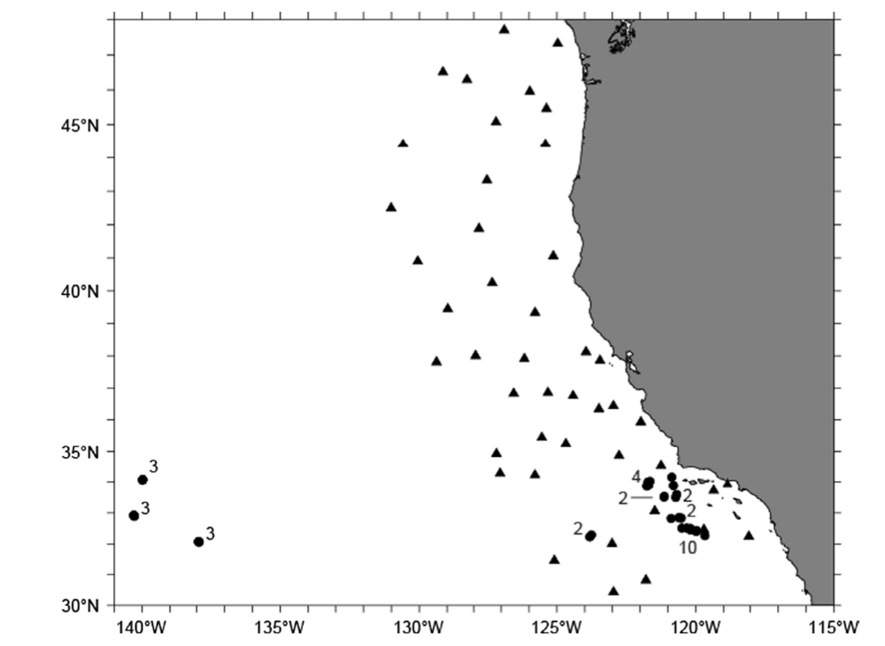
fishes, micronekton

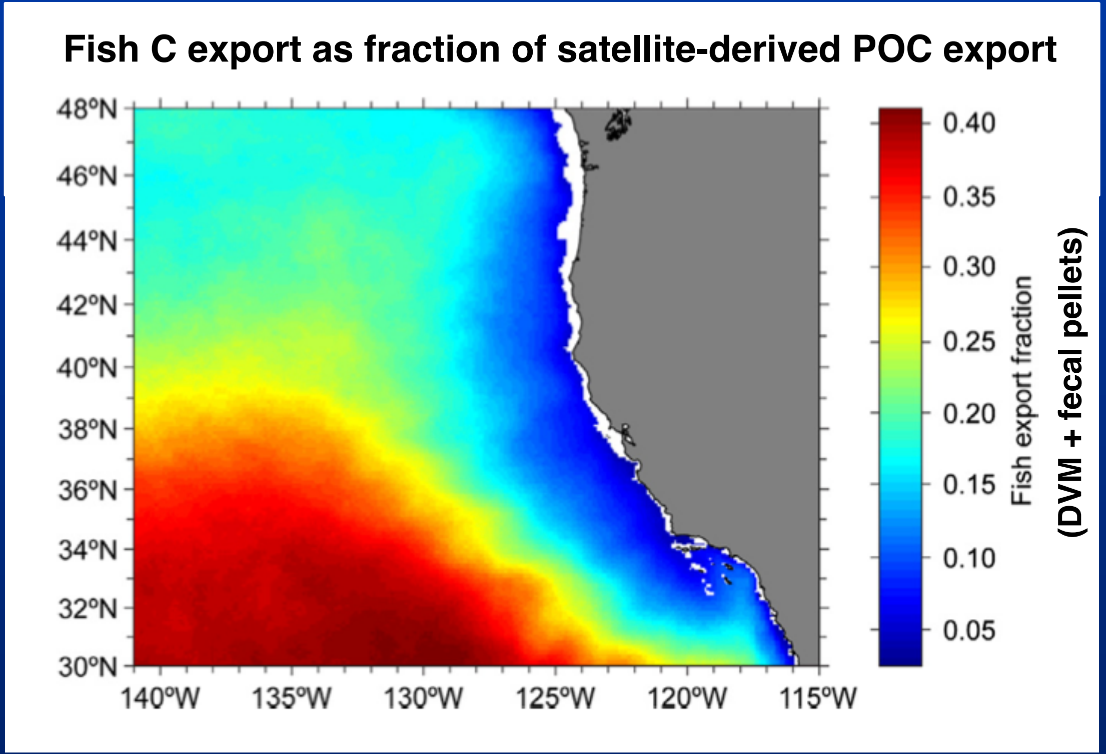
Deep scattering layer in Monterey Bay Canyon with aggregation of myctophids

38 kHz signal from sonic scattering layer

Bruce Robison, MBARI

Carbon export by mesopelagic fishes in NE Pacific





Individual-based metabolic modeling using the catch from 77 mesopelagic trawls

Fish (90% myctophids) DVM ~ 5-22% of passive C export

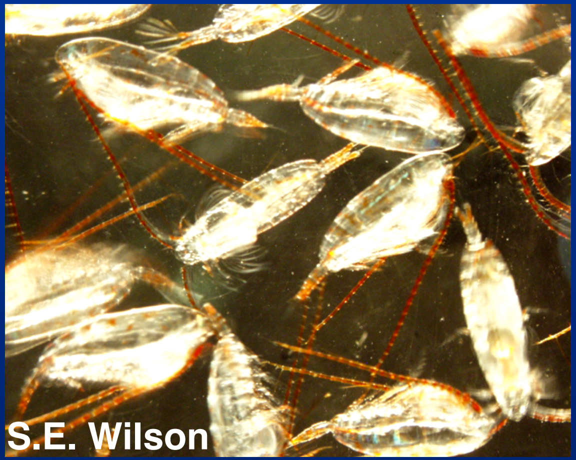
Davison, Checkley, Koslow, & Barlow (2013)

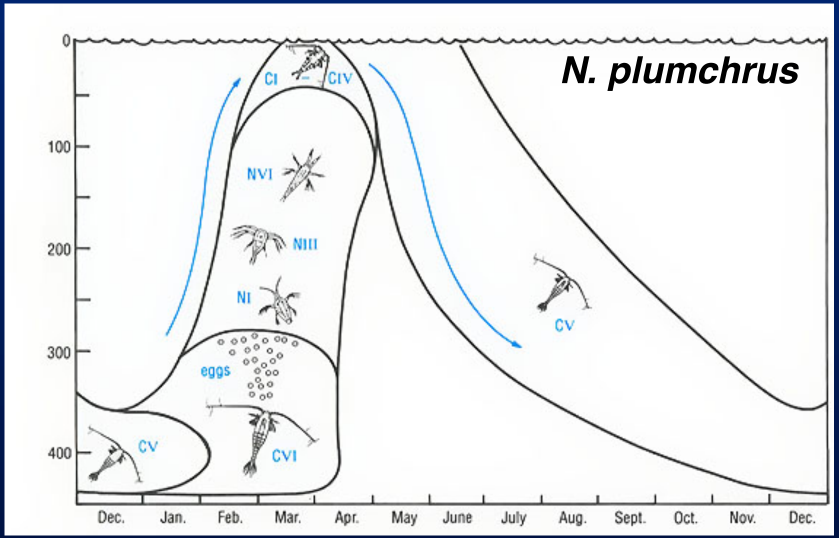
** undersampling of micronekton due to low capture efficiency of nets- mesopelagic fish biomass may be 1 order of magnitude higher than current estimate (Irigoien et al. 2014)

Ontogenetic (seasonal) vertical migration

Can be important at high latitudes

Neocalanus spp. copepods in subarctic Pacific





Site in Pacific	Ontogenetic migrant flux- (mg C/m²/y)	Active transport/ Trap POC flux @ 1000m (%)
Station P	5000	185 %
Oyashio	4300	91%
K2	246 + 1719	9% 64%

DVM @ K2 = 16-46 mg C/m²/d –summer @150 m

Bradford-Grieve et al. (2001), Kobari et al. (2003, 2008)

Summary/ parting thoughts

- Active transport on average ~15-20% of passive flux, but exceeds passive flux in seasons or regions of high migrating zooplankton biomass
- Changes in zooplankton biomass or community composition over time affects efficiency of bio pump
- Metabolism by migrators at depth not necessarily Redfield, and excretion of DOM significant. Supports mesopelagic metabolism!
- Active transport now being modeled, helps formulate and test hypotheses about global patterns, yay!
- Contribution of fish & invertebrate micronekton not well known
- Bring on observing systems, new technology

Thank you!