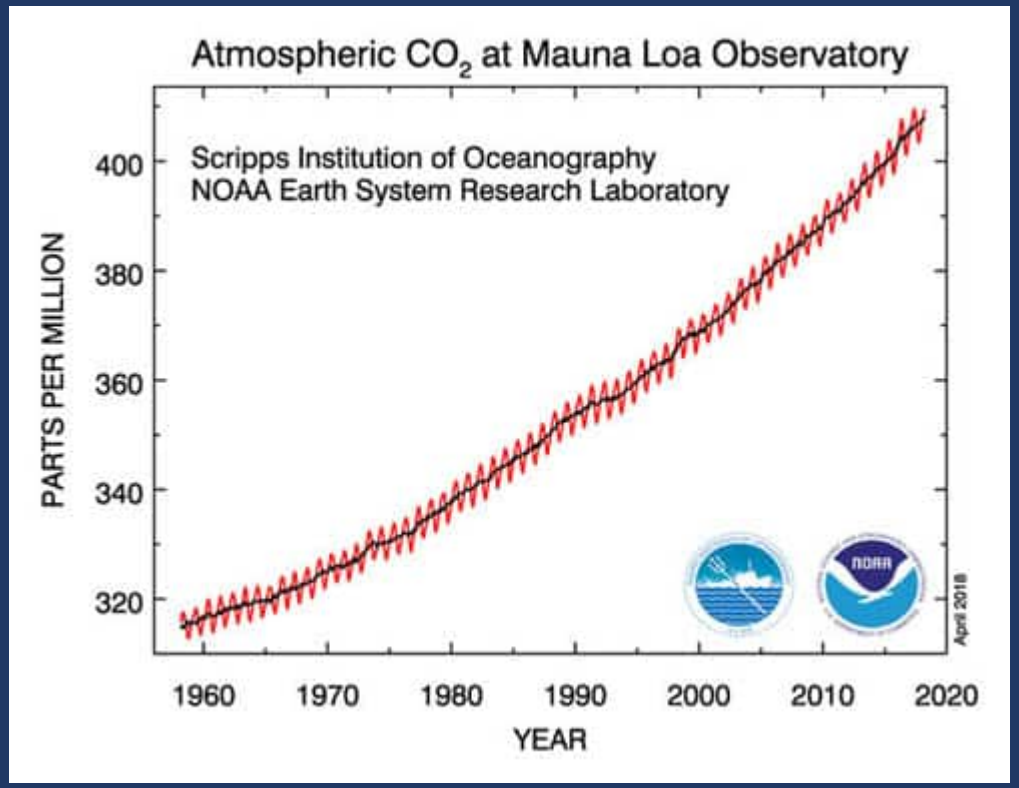
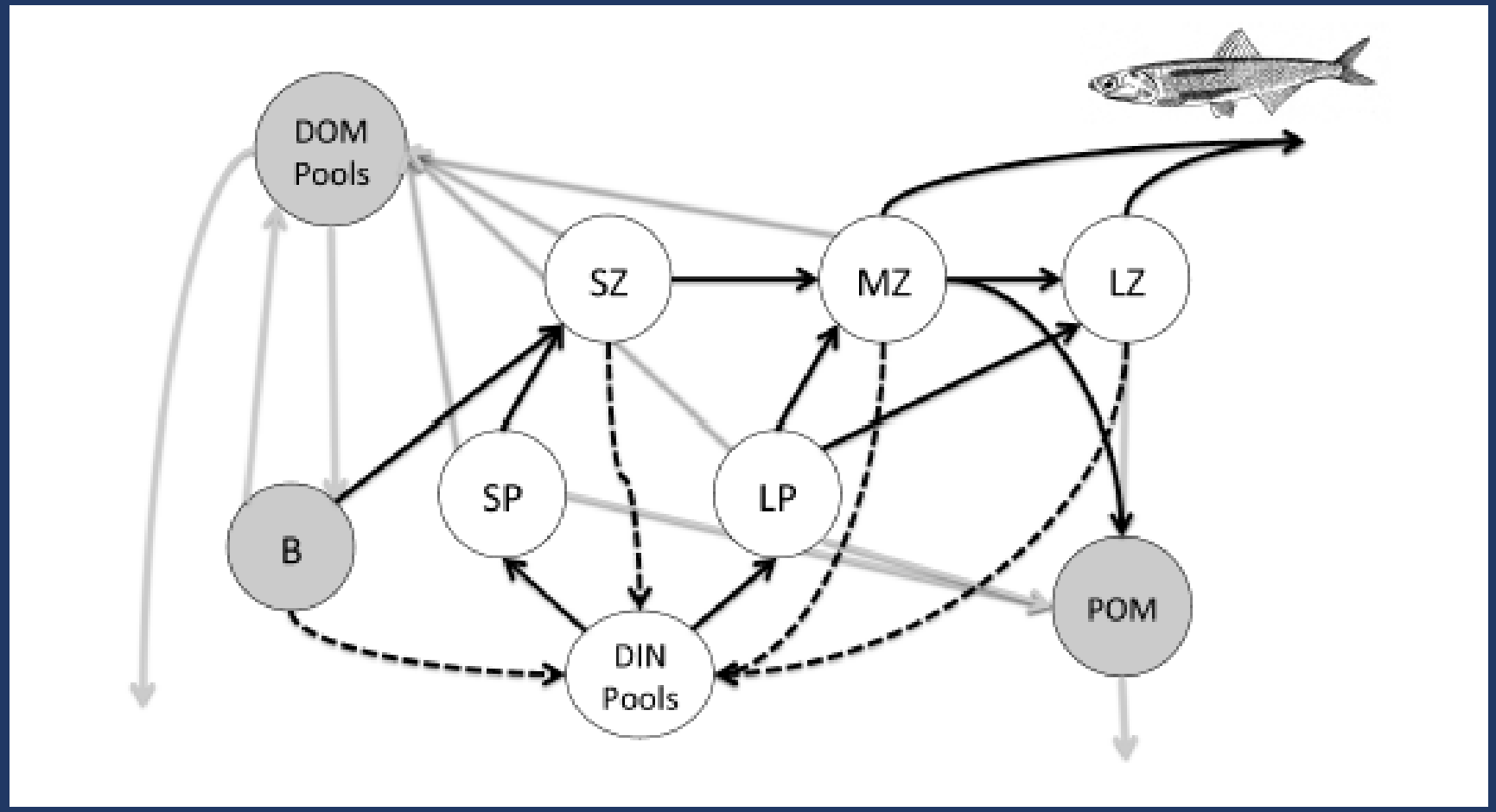
Simulating the Role of Fish in the Carbon Cycle: Some Perspectives from the Global Biogeochemical Modeling World



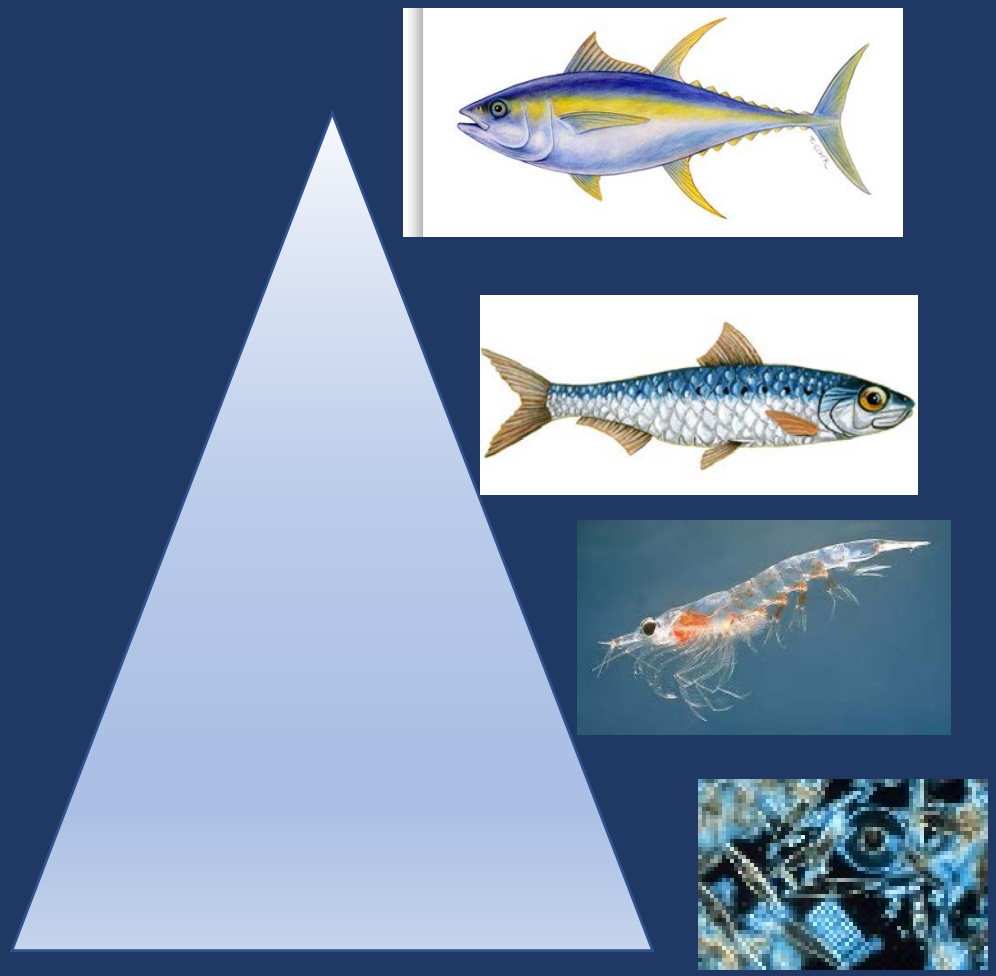
Debbie Meyer

Charlie Stock (NOAA/GFDL)

The higher predation kluge…err…closure….



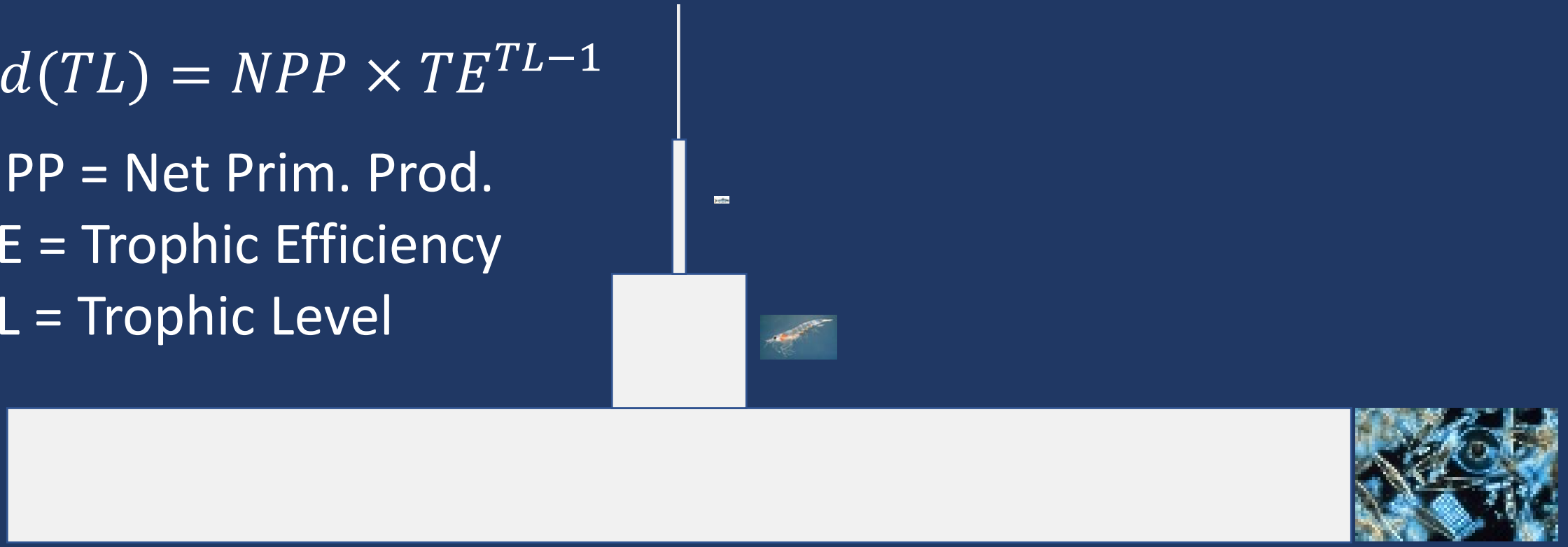
Why haven’t fish been included in carbon cycle models?



Why haven't fish been included in carbon cycle models?

$$Prod(TL) = NPP \times TE^{TL-1}$$

NPP = Net Prim. Prod.
TE = Trophic Efficiency
TL = Trophic Level



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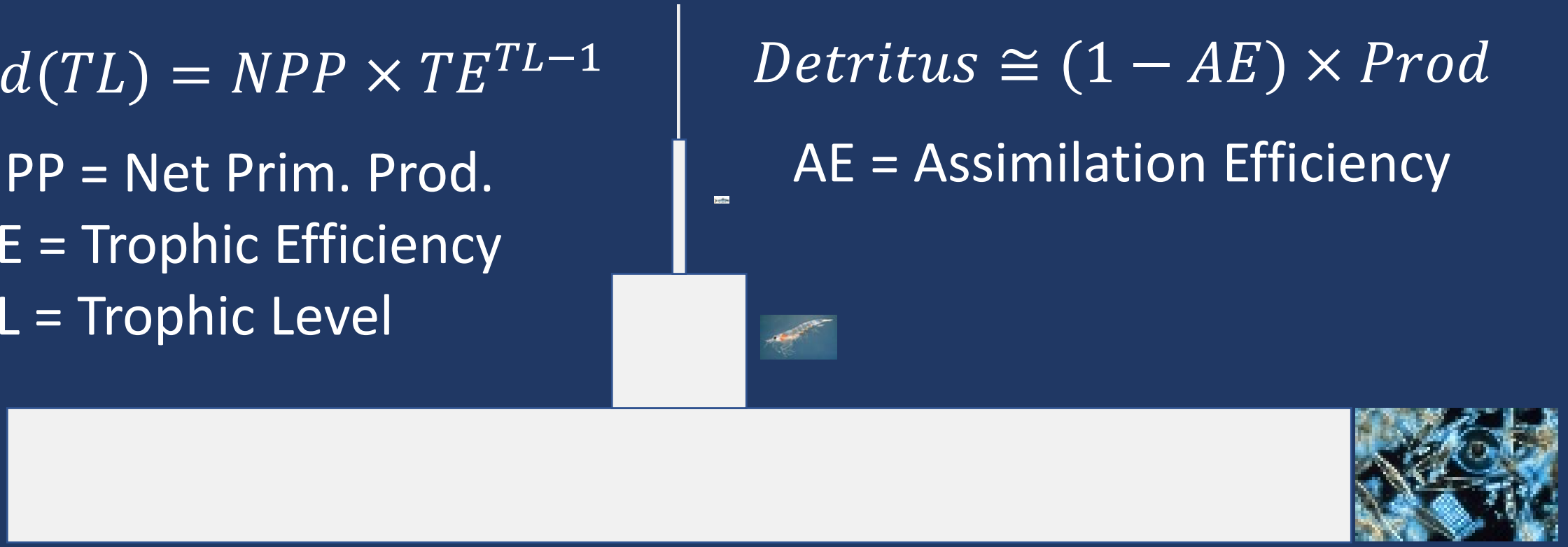
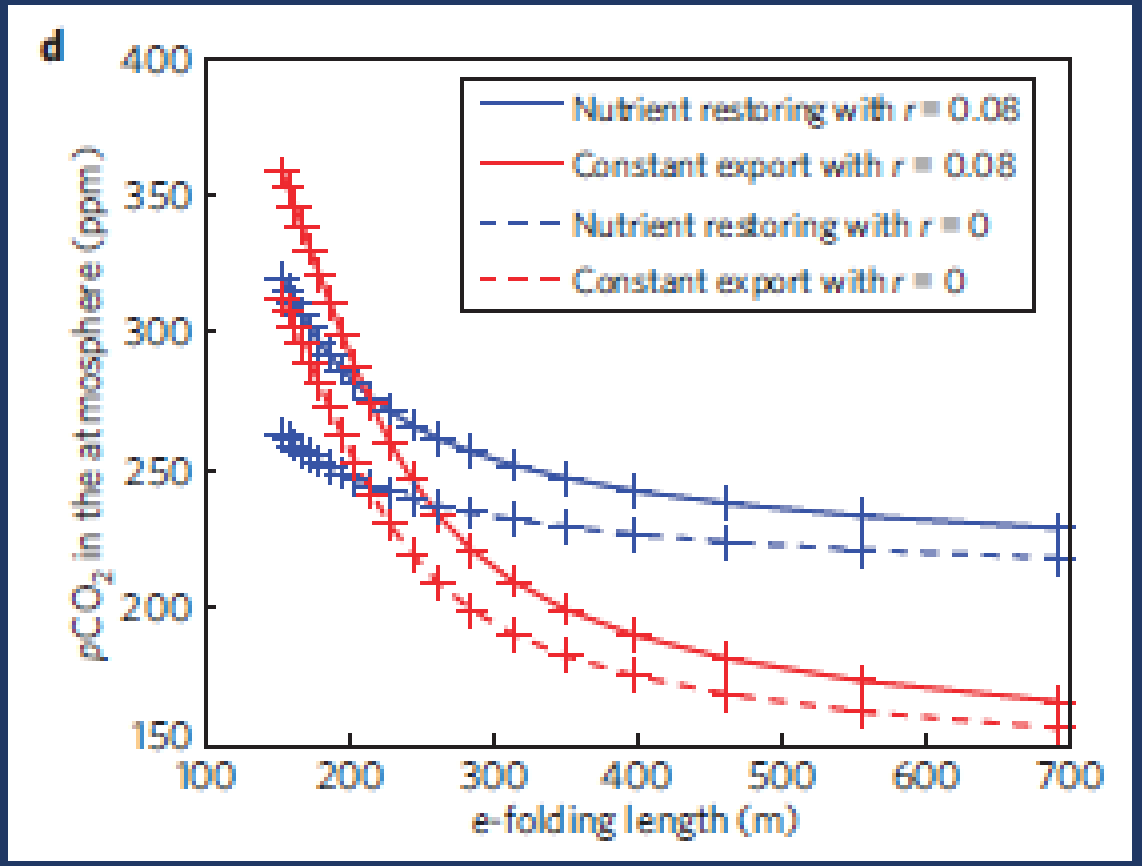
$$Detritus \cong (1 - AE) \times Prod$$

AE = Assimilation Efficiency



How big of an effect would they need to have to make a difference?



Kwon et al., 2009, Nature Geosciences

How well do we know the trophic transfer efficiency?

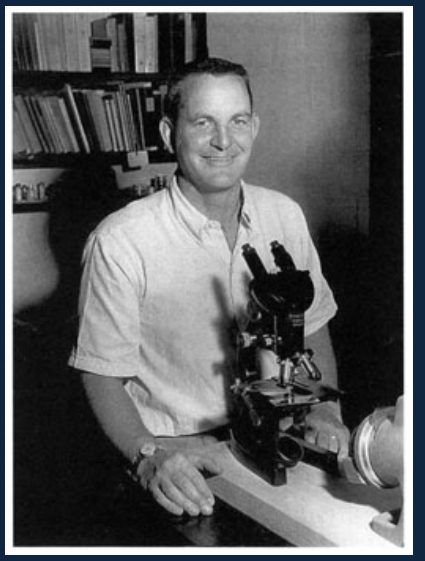
The uncertainty in global consumer Biomass is large and “primarily driven by uncertainty in the trophic transfer efficiency“

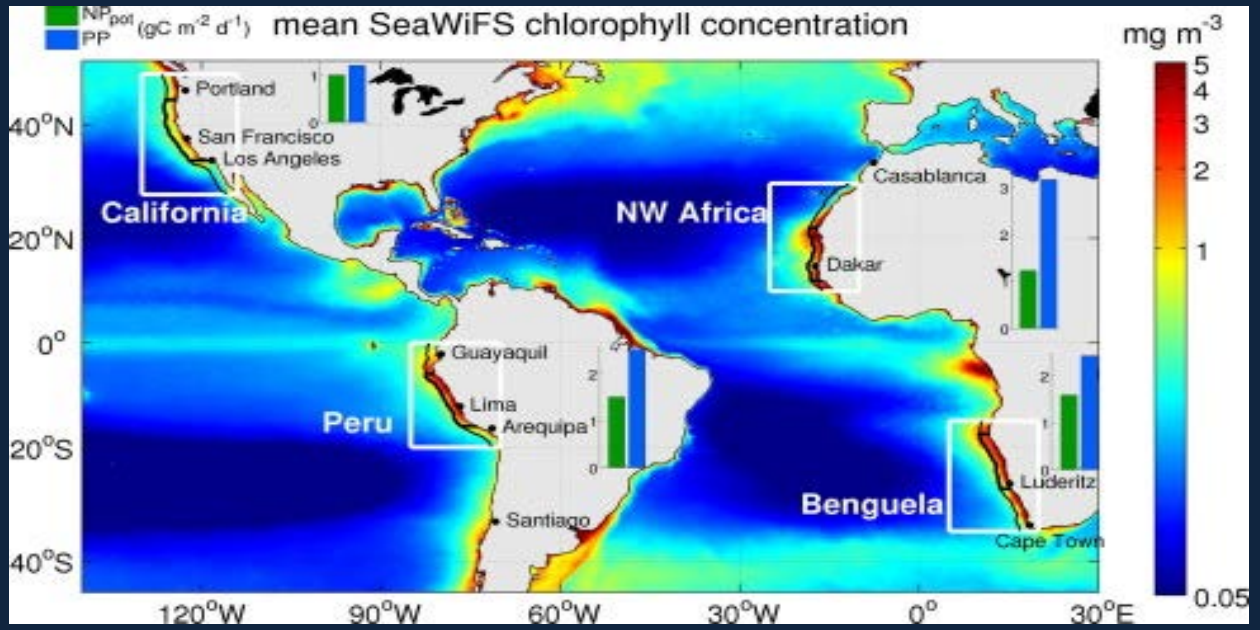
Jennings and Collingridge, PLOS One, 2015

	Biomass (10^9 t)
5th	0.34
25th	1.97
50th	4.88
75th	10.37
95th	26.12

Are there regions where fish are critical?

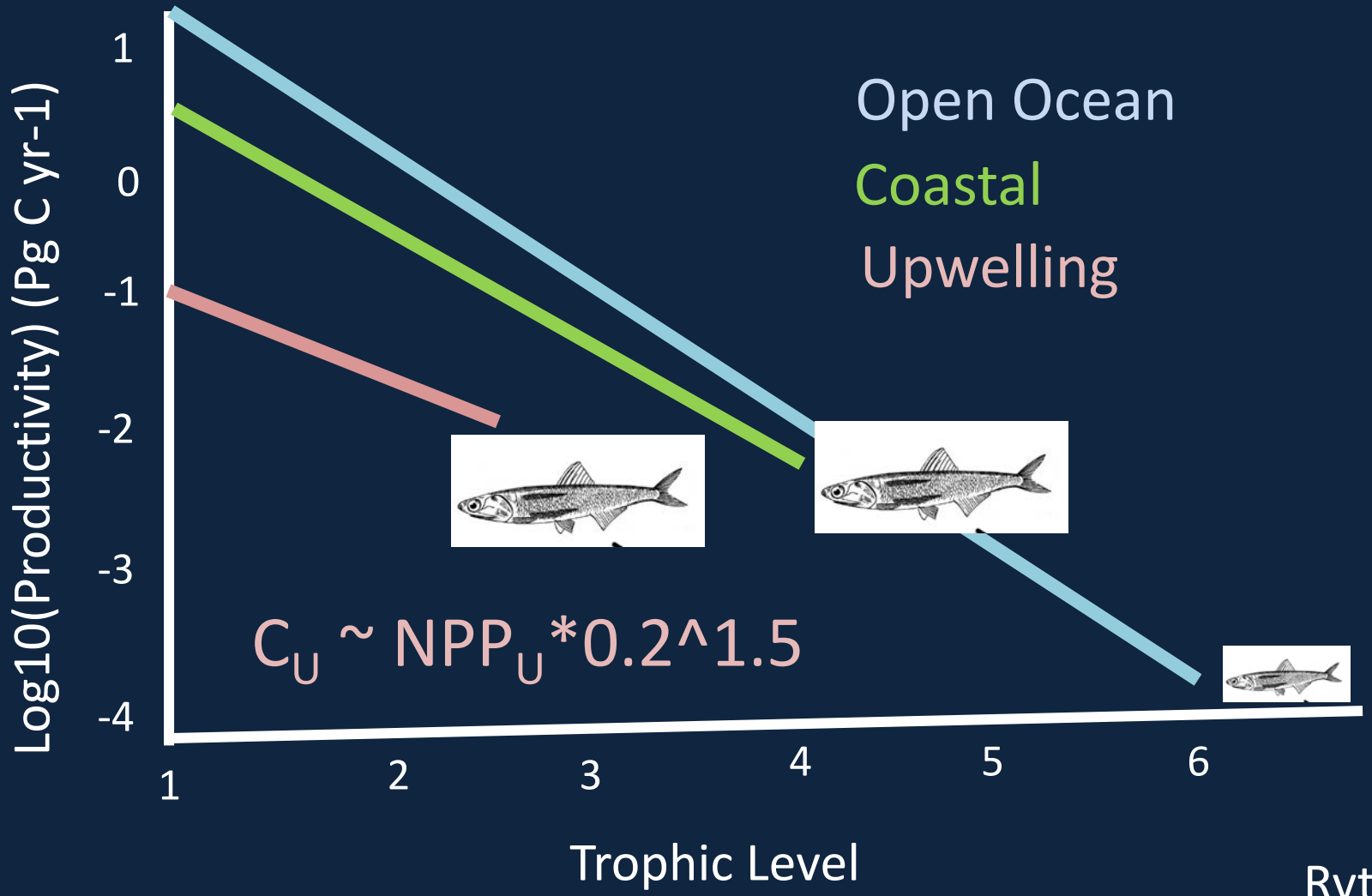
"Primary production and the associated food chain dynamics may act additively to produce differences in fish production which are far more pronounced and dramatic than the observed variability of the individual causative factors". (Ryther, 1969, Science)





Messie and Chavez PinO, 2015

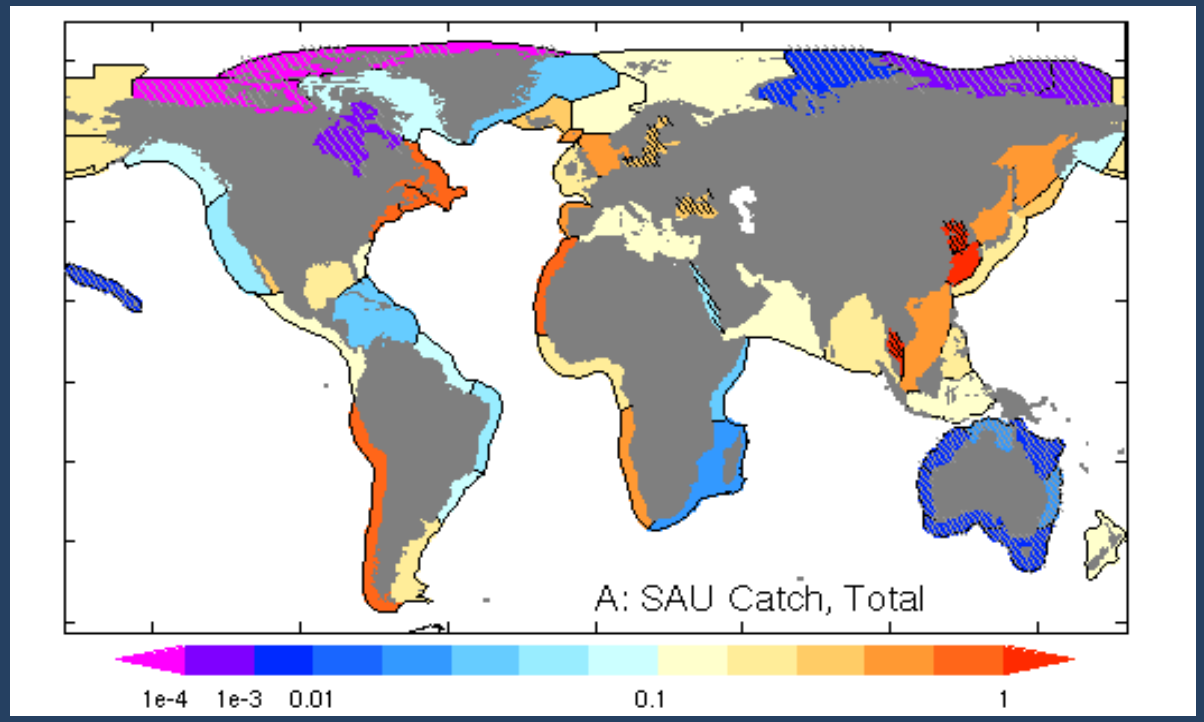
Coastal upwelling systems account 1/2 of global fish production despite covering ~0.1% of the ocean surface

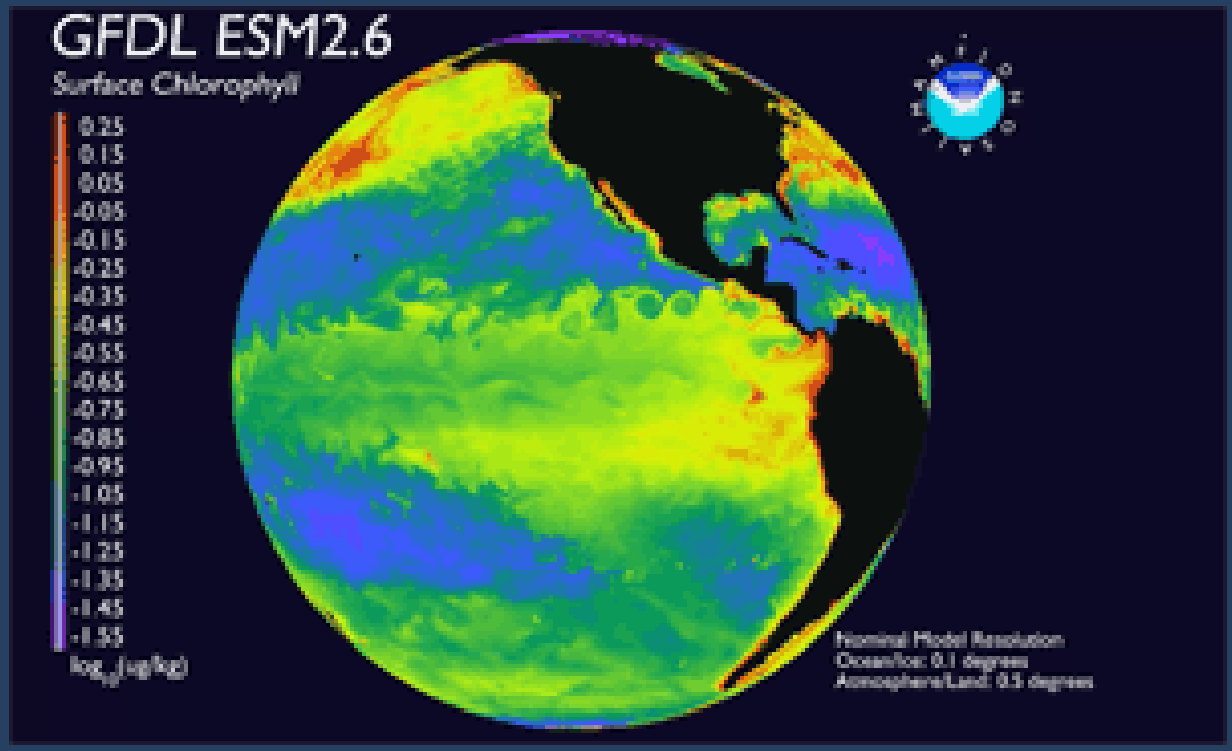


Ryther, Science, 1969

Revisiting Ryther: Do NPP and trophic dynamic factors combine to create large catch gradients?

Mean of top 10 catch years, g C m^{-2} day^{-1}

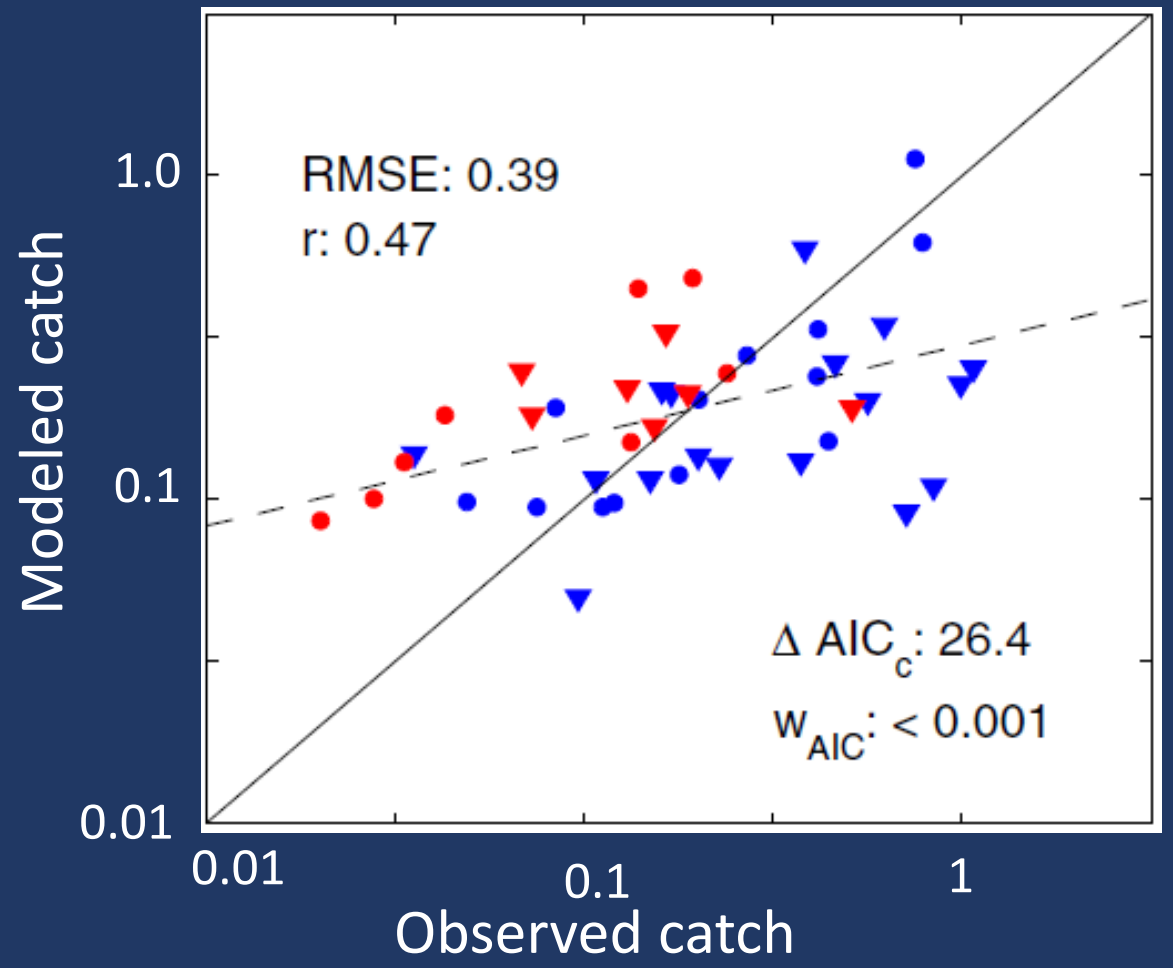




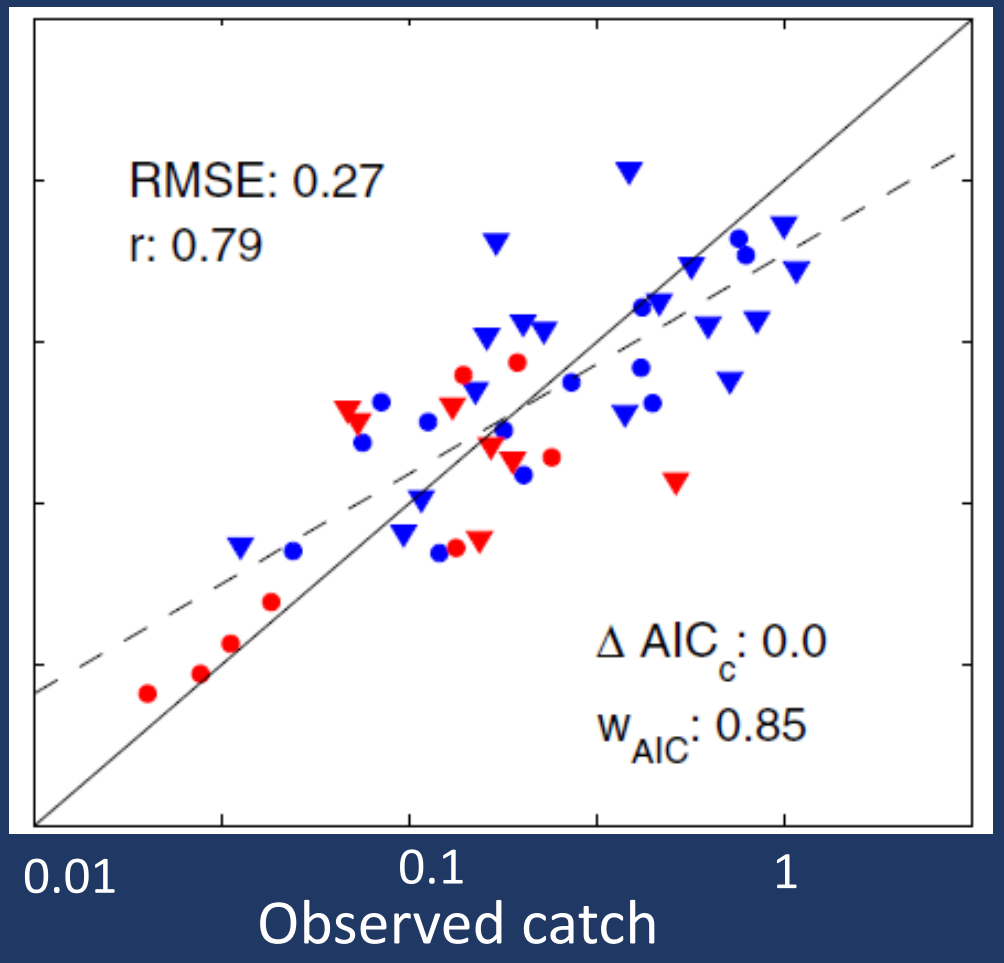
Stock et al., PNAS, 2017

Catch gradients much sharper than NPP gradients: regional differences in fish importance, CO2 implications?

NPP Only

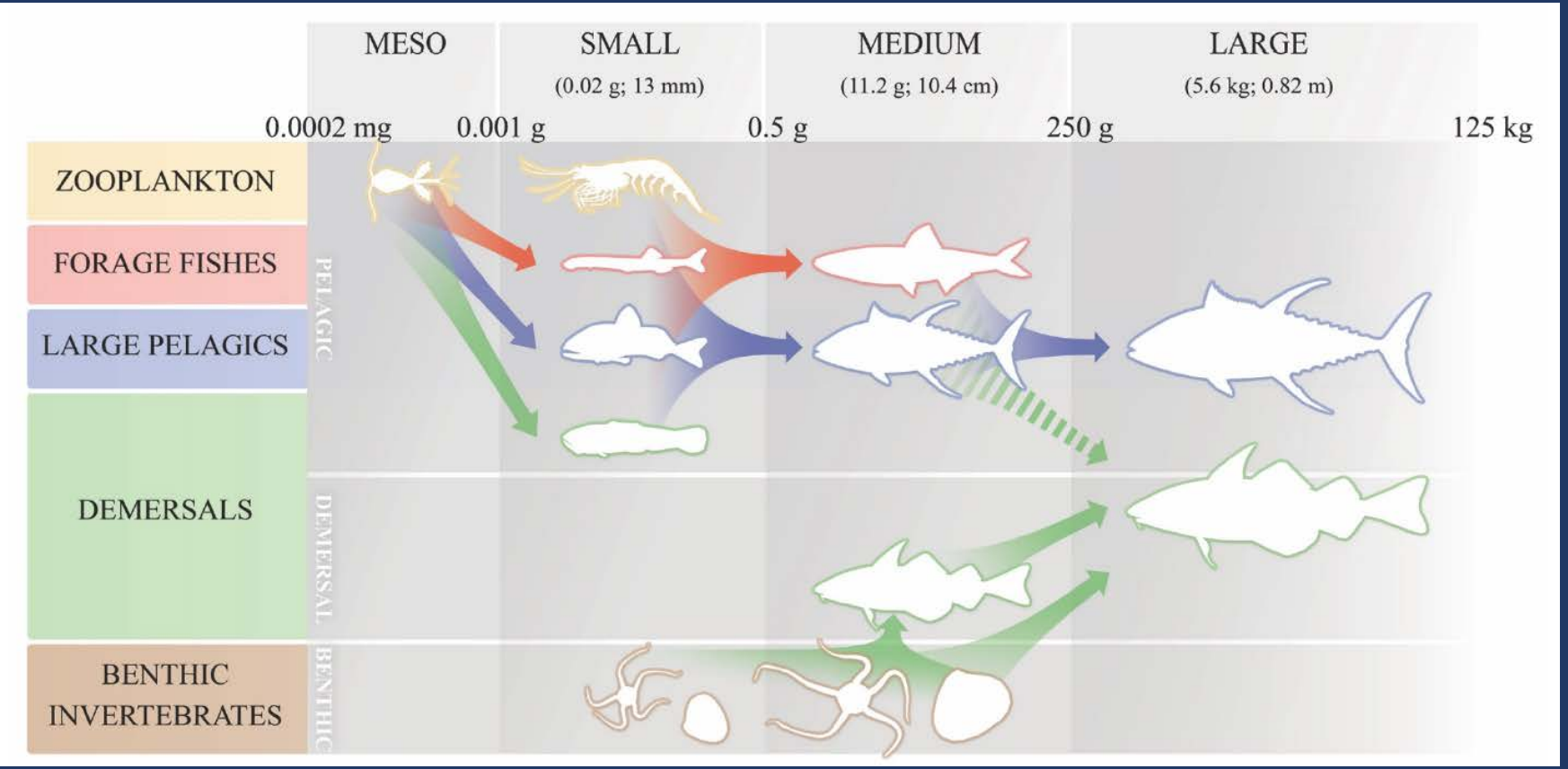


NPP + Trophodynamics



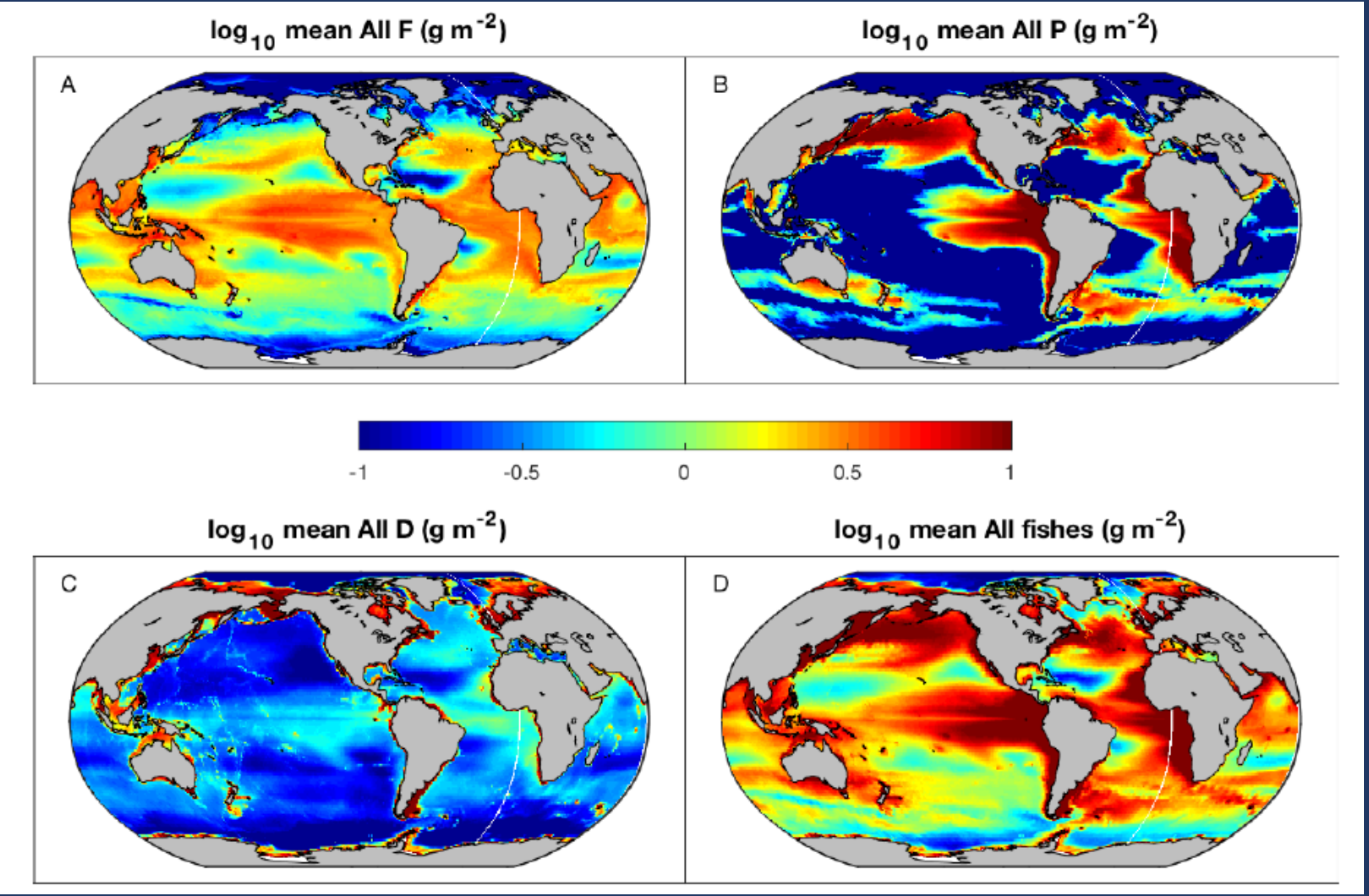
Stock et al., PNAS, 2017

FishErIes Size and functional Type (FEISTY)



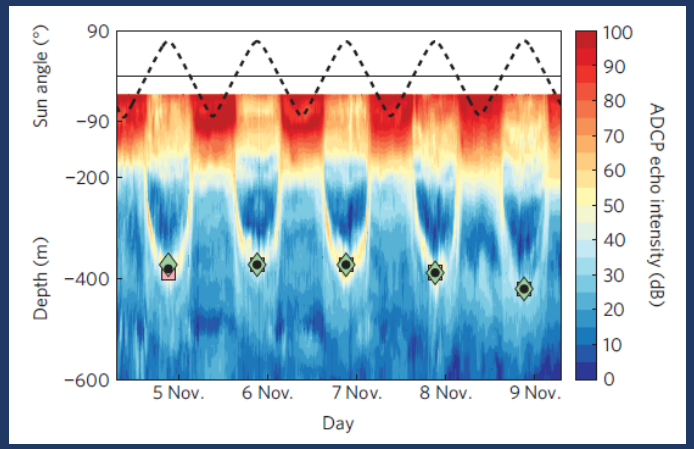
Petrik et al. (submitted)

Fish biomass by functional type

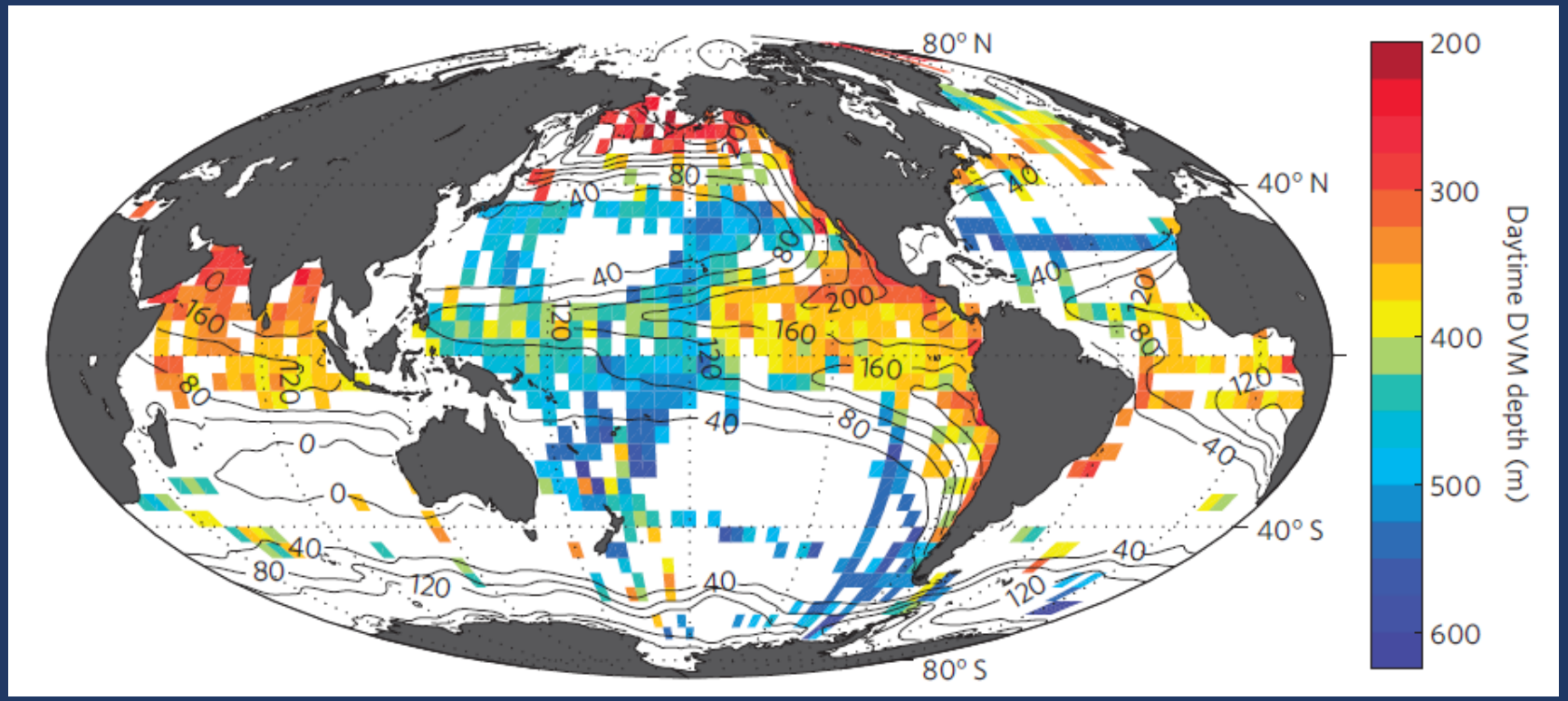


Petrik et al., PinO (submitted)

What about vertical migration?

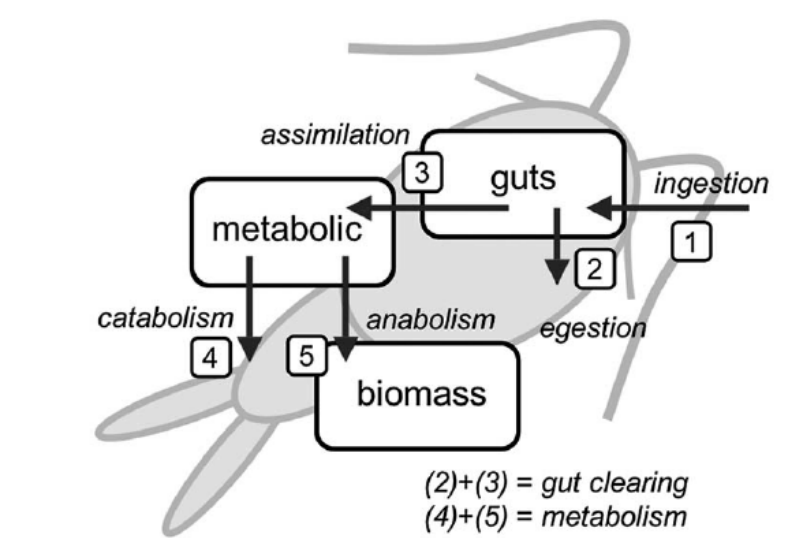


"by focusing oxygen consumption on poorly ventilated regions, DVM intensifies O2 depletion in the upper margin of OMZs"

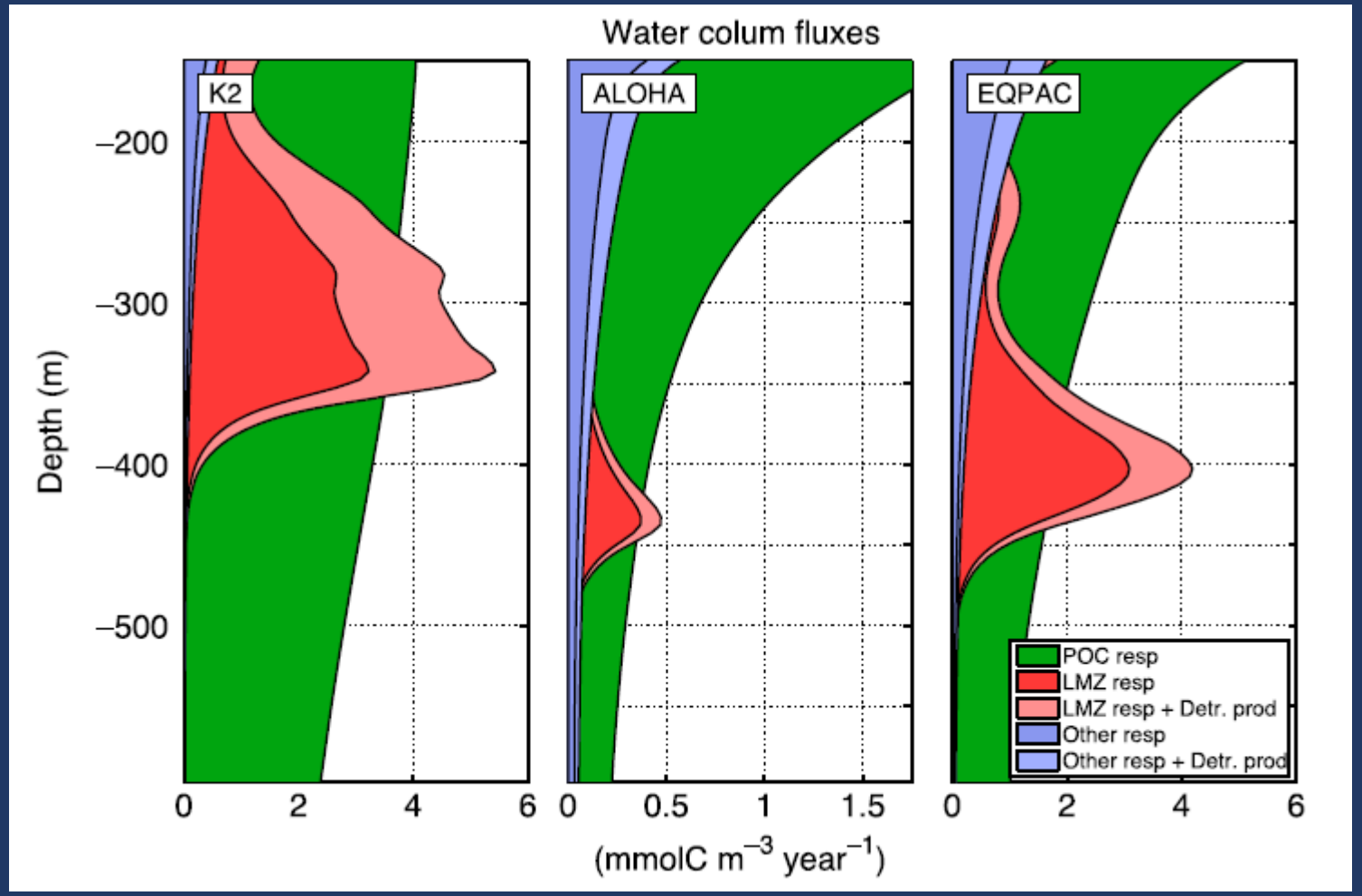


Bianchi et al., Nature Geosciences, 2013

A significant contribution to global C fluxes?



Note that this wasn't a missing flux, it was just being misattributed to other modes of export.



Bianchi et al., GBC, 2013

An even larger impact from mesopelagic fish?

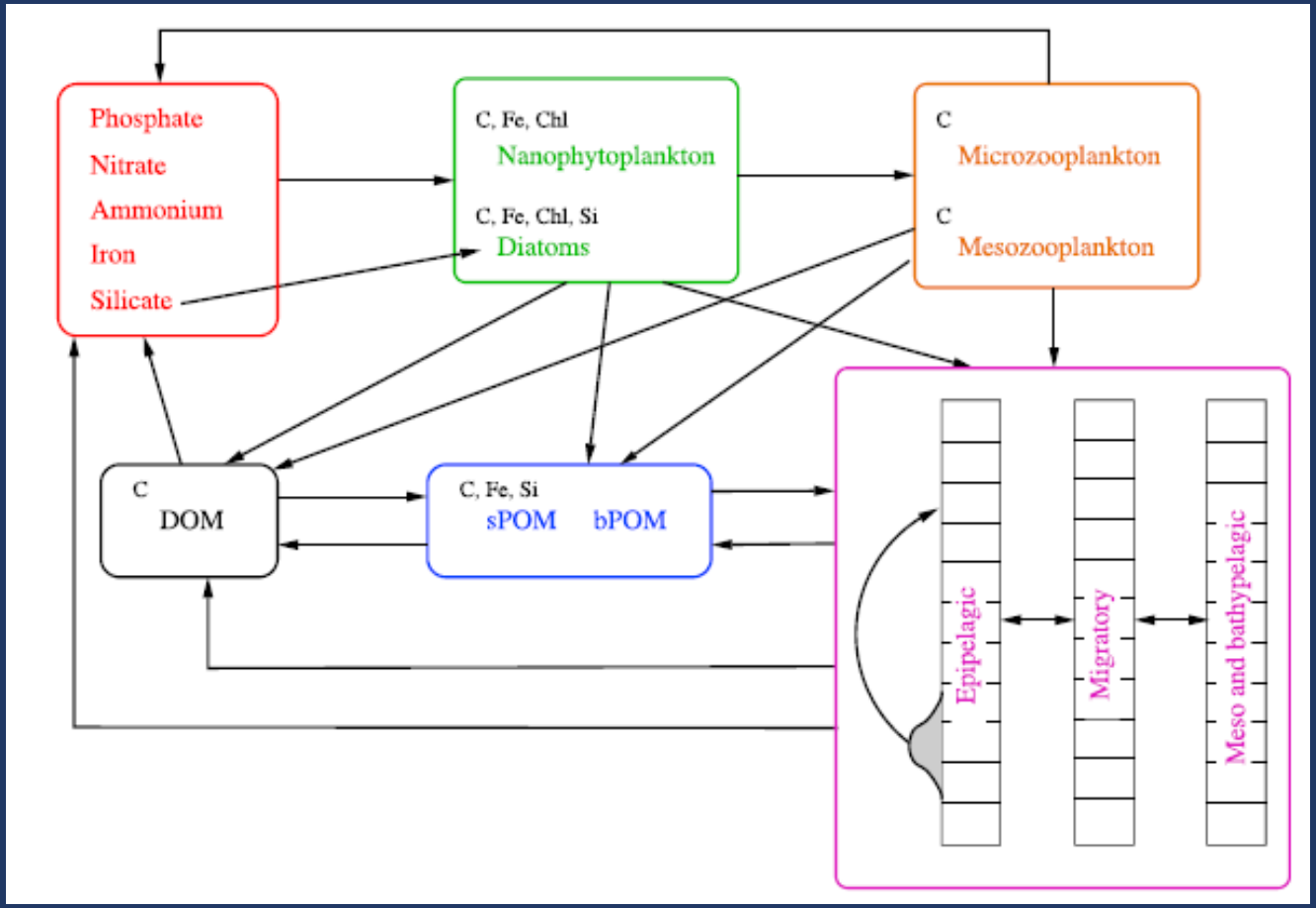
Table 1 | Acoustic fishes biomass estimates. Irigoien et al., Nature Comm., 2014

s_A estimate	Acoustic fishes biomass estimates						
	Total s_A	Average	Median	75%	25%	Max	Min
		– 34.6 db kg^{-1}	– 30.8 db kg^{-1}	– 28.4 db kg^{-1}	– 42.2 db kg^{-1}	– 26.8 db kg^{-1}	– 46.8 db kg^{-1}
OLS: s_A = 2384.4* ln(PP)—11678	4.24E + 17	28,363	11,824	6,804	163,215	4,707	470,717
OLS: ln (s_A) = 1.52* ln (PP)—1.36	4.70E + 17	31,449	13,110	7,544	180,972	5,219	521,930
GWR: ln (s_A) = 1.36* ln (PP)—0.2	5.57E + 17	37,264	15,534	8,939	214,433	6,184	618,432
GWR different equations for PP above and below 400*	4.38E + 17	29,321	12,223	7,034	168,725	4,866	486,607
Cruise average $s_A$xocean surface deeper 1,000 m	4.14E + 17	27,427	11,433	6,579	157,826	4,552	455,176

GWR, geographically weighted regression; OLS, ordinary least squares regression. Total backscatter between 40° N and 40° S estimated from PP (total s_A) and different acoustic to weight (db kg^{-1}) ratios (see Table 2).
*See Supplementary Table 1 for details on the GWR equation parameters above and below 400 mg C m^{-2} d^{-1}.

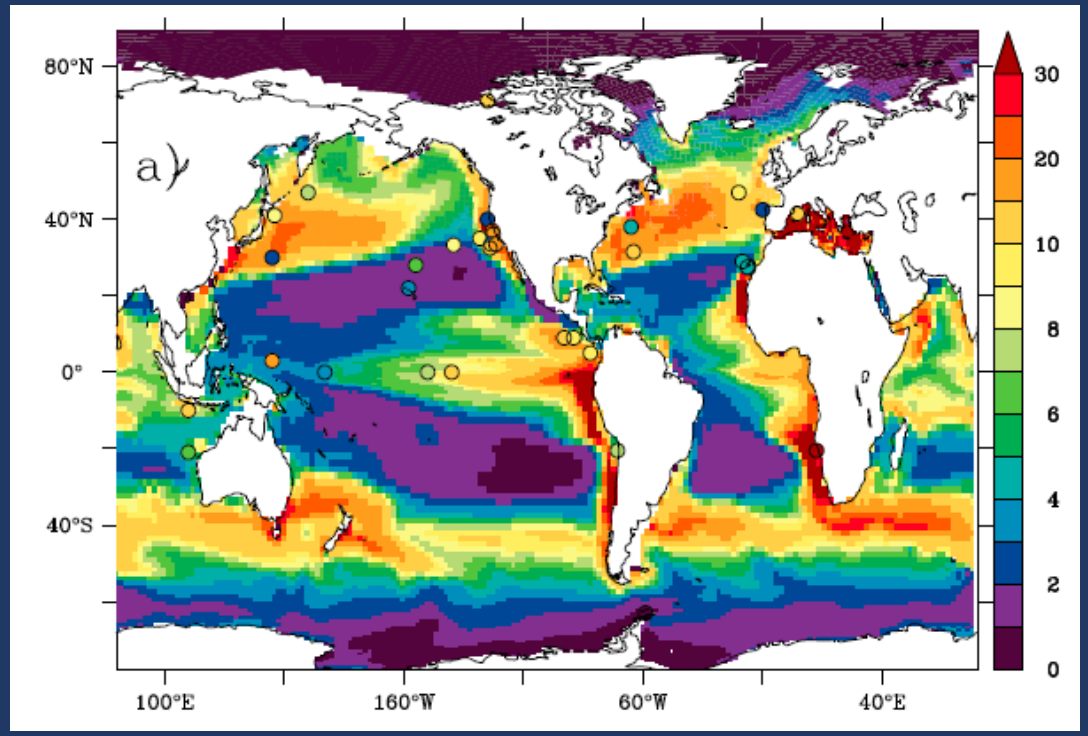
Possibly, but other energetic constraints push to lower bounds of the uncertainty range (e.g., Anderson et al., ICES JMS, 2018)

Can we fully integrate biogeochemistry to fish?

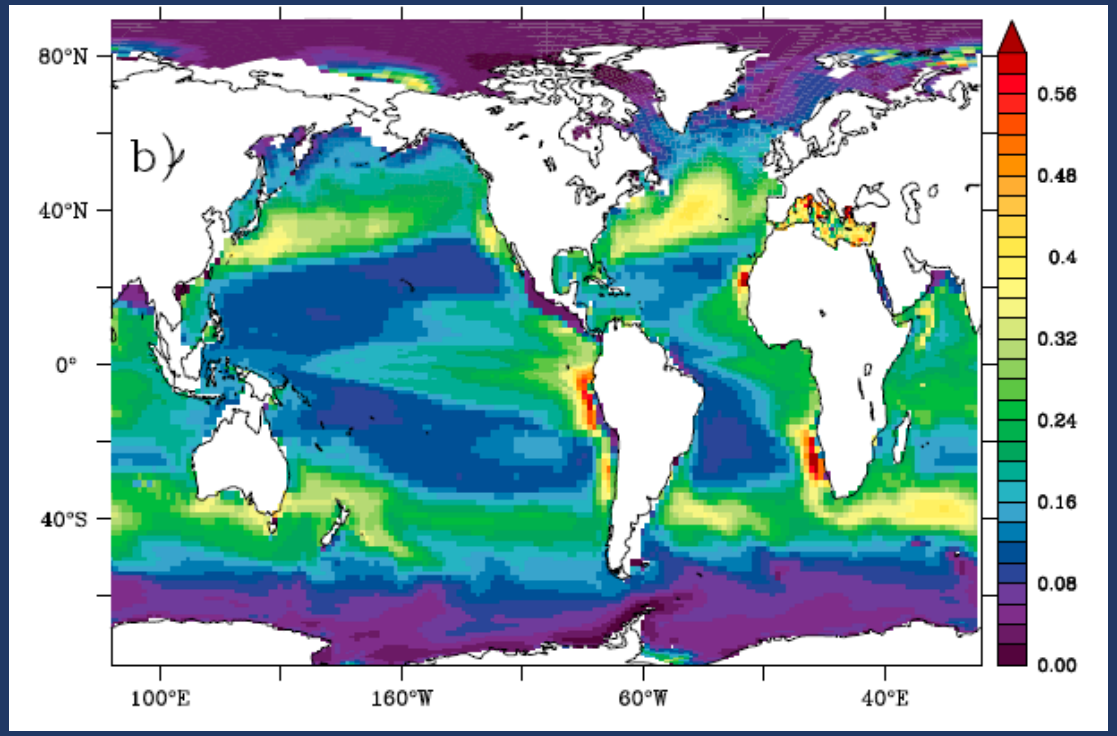


Aumont et al., GBC, 2018

What do we get when we fully integrate biogeochemistry to fish?



Contribution of DVM to sinking flux



Fraction of export at 150m due to DVM

Aumont et al., GBC, 2018

Some concluding thoughts:

- Not big energy fluxes through fish, but they are vertically active it doesn't take much to influence atmospheric CO2
- Large spatial gradients in fisheries suggest large gradients in relative importance
- Trophic transfer efficiency is a key, uncertain parameter
- Global biogeochemical models are now explicitly incorporating fish, but there are pros and cons to the "everything but the kitchen sink"