ENERGY TRANSFER EFFICIENCY FROM ZOOPLANKTON TO SMALL PELAGIC FISH OVER A EUTROPHIC TO OLIGOTROPHIC GRADIENT IN GLOBAL PELAGIC FOOD-WEBS

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Hakai
Science on the Coastal Margin

Drivers of Dynamics of Small Pelagic Fish Resources, 8 March 2017

Outline

- Overview of size based food web dynamics in pelagic ecosystems;
- Case study applying stable isotopes to measuring trophic positions of size classes in contrasting pelagic ecosystems;
- Implications for food chain length and estimates of Trophic Transfer Efficiency.

Size & Trophic position in food webs

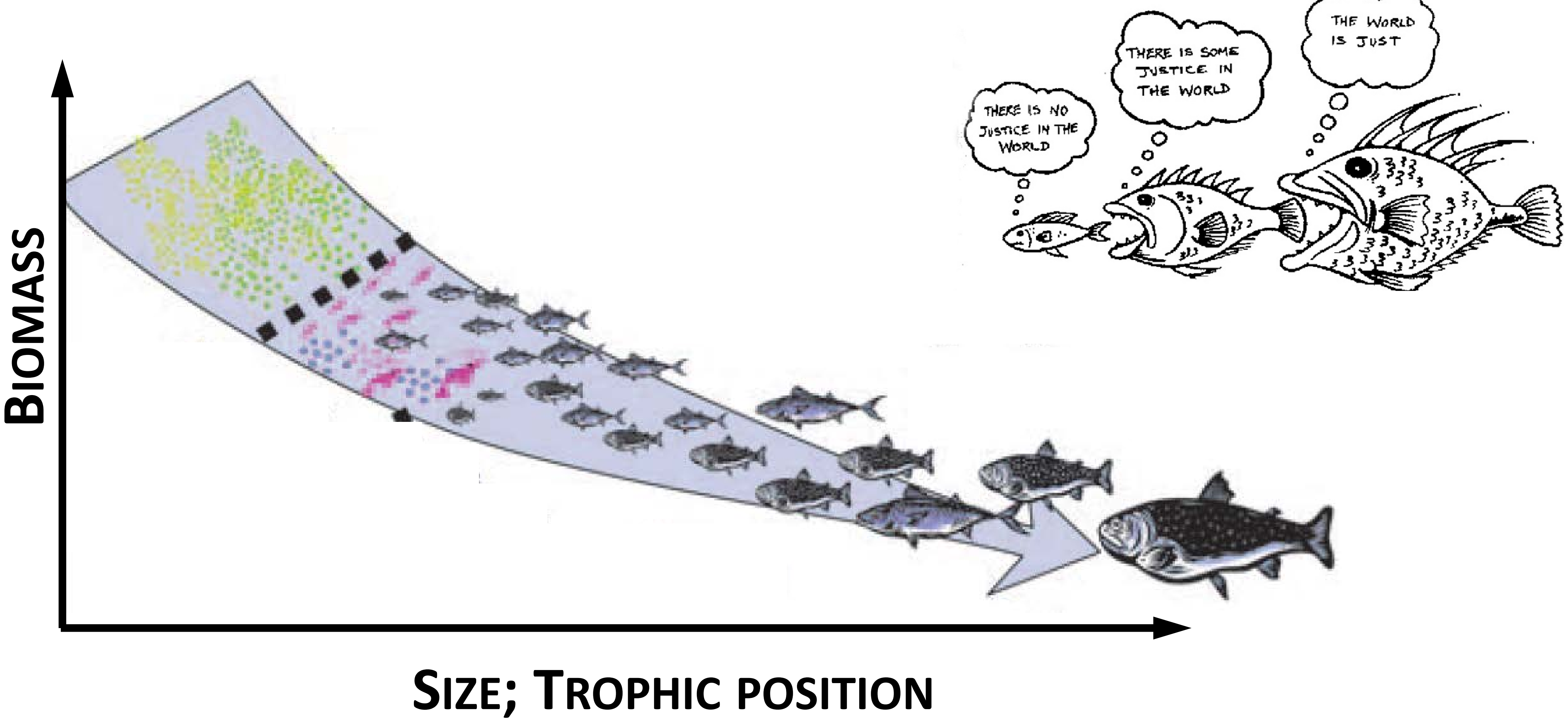
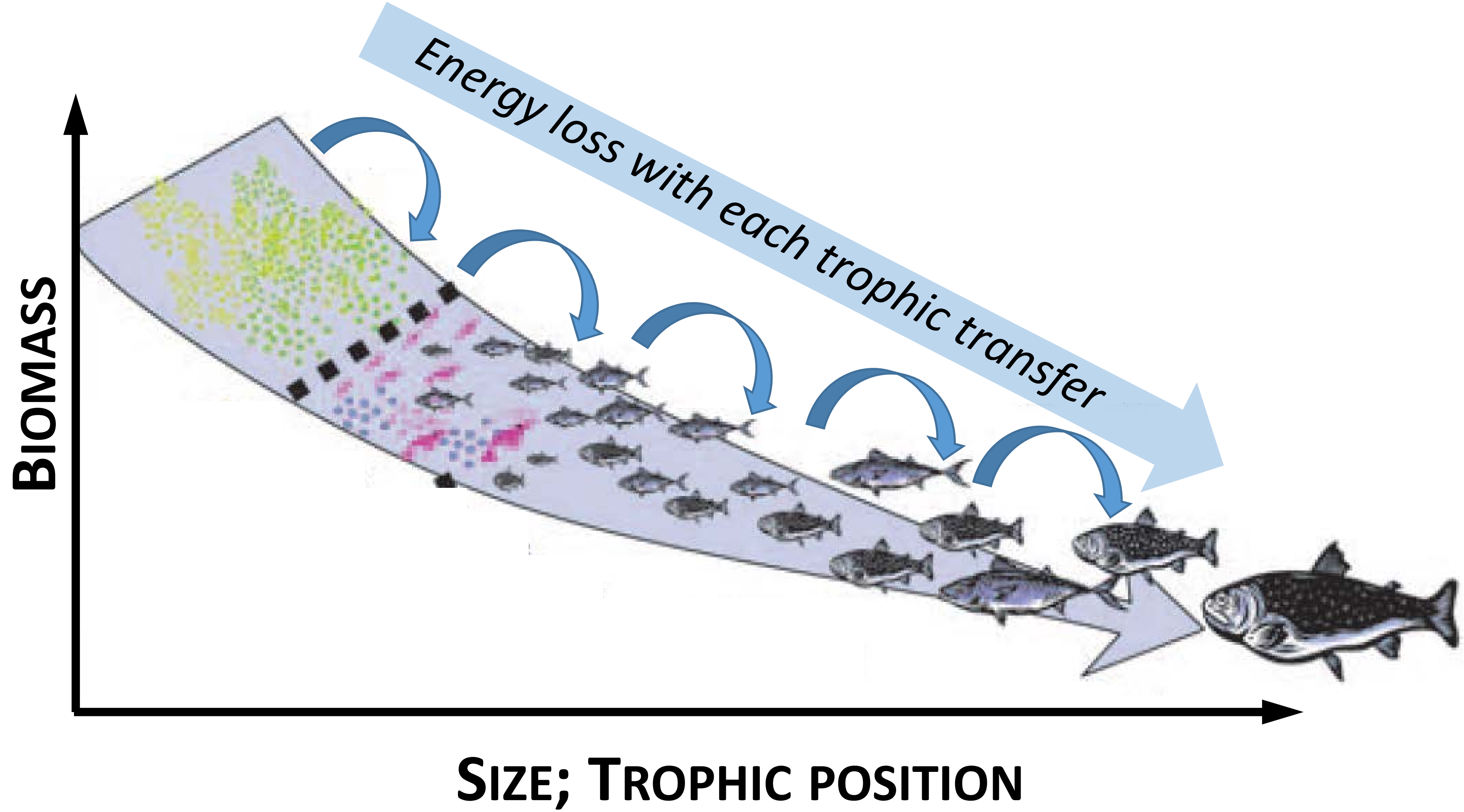


Figure adapted from Blanchard et al . 2009

Food chain length & energy transfer efficiency



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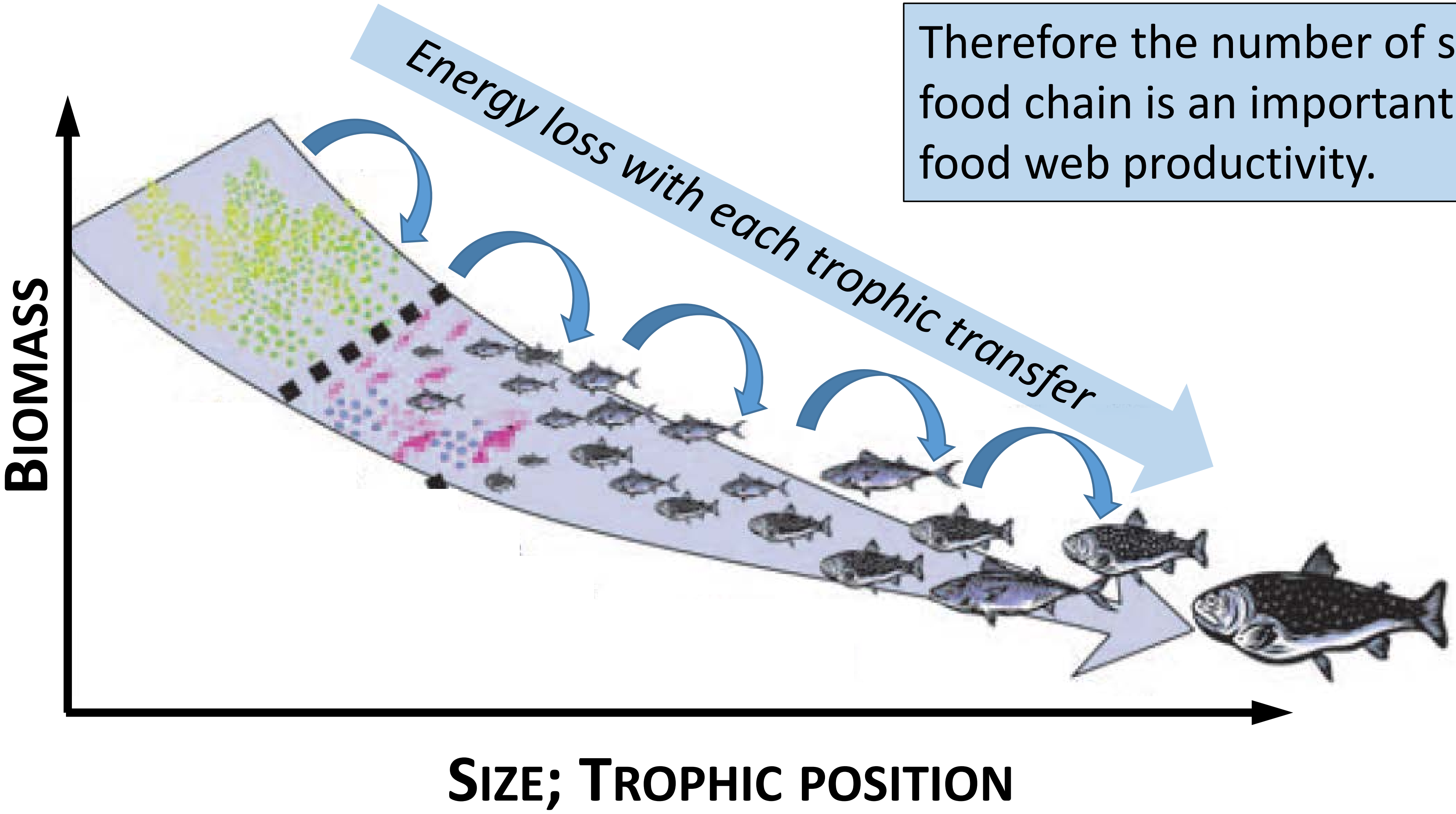
Food chain length & energy transfer efficiency

Therefore the number of steps in the food chain is an important driver of food web productivity.



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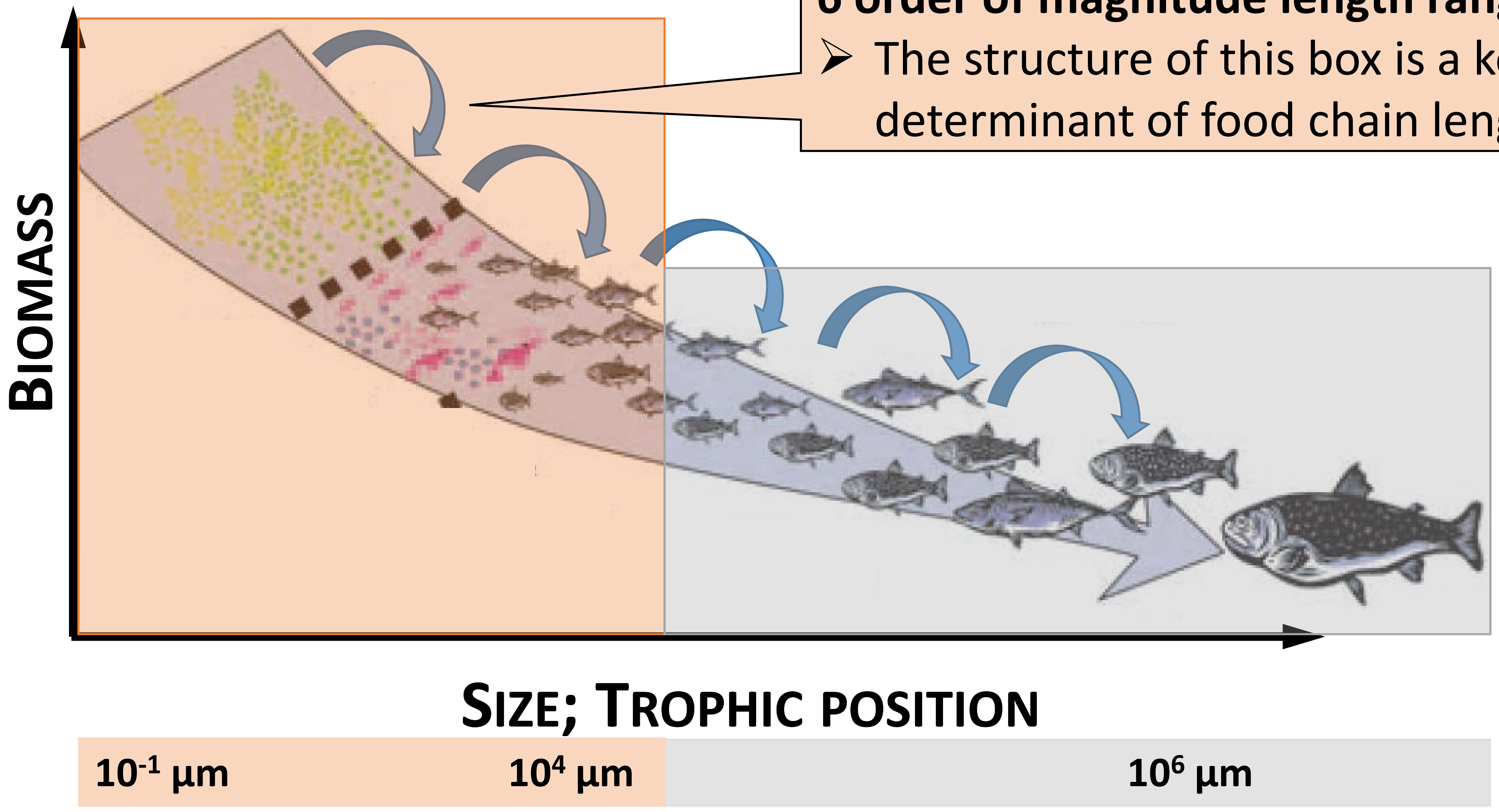
The phytoplankton-to-micronekton box

Phytoplankton ⟺ Micronekton

6 order of magnitude length range.

- ➢ The structure of this box is a key determinant of food chain length.



GLOBAL PHYTOPLANKTON SIZE STRUCTURE

MICROPHYTOPLANKTON

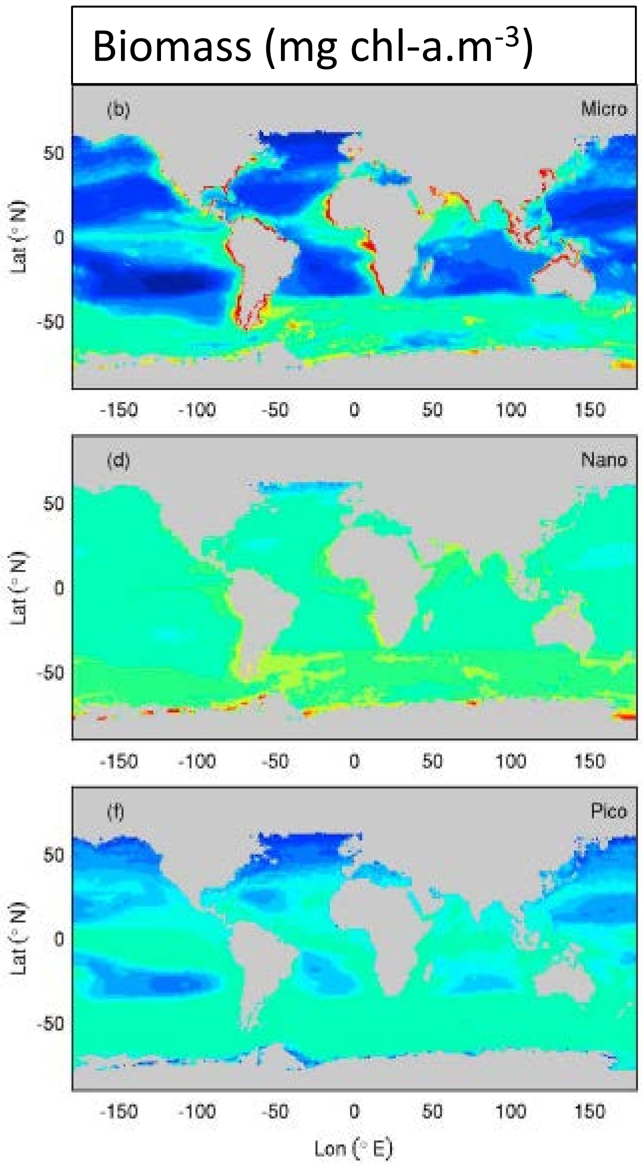
- *> 20 µm, diatoms;*
- *high nutrient regions*

NANOPHYTOPLANKTON

- *2- 20 µm;*
- *ubiquitous*

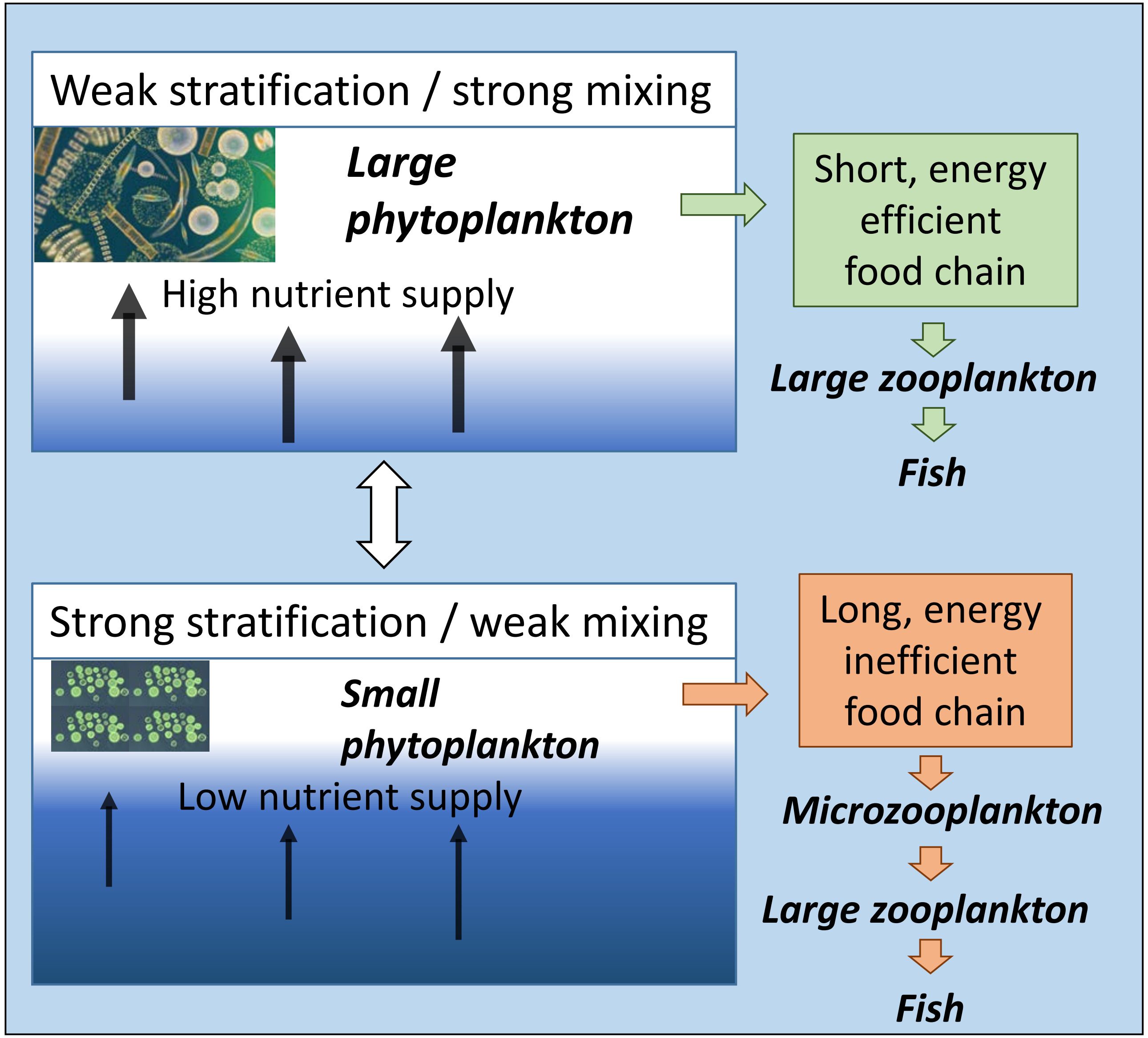
PICOPHYTOPLANKTON

- *< 2 µm;*
- *low nutrient regions*

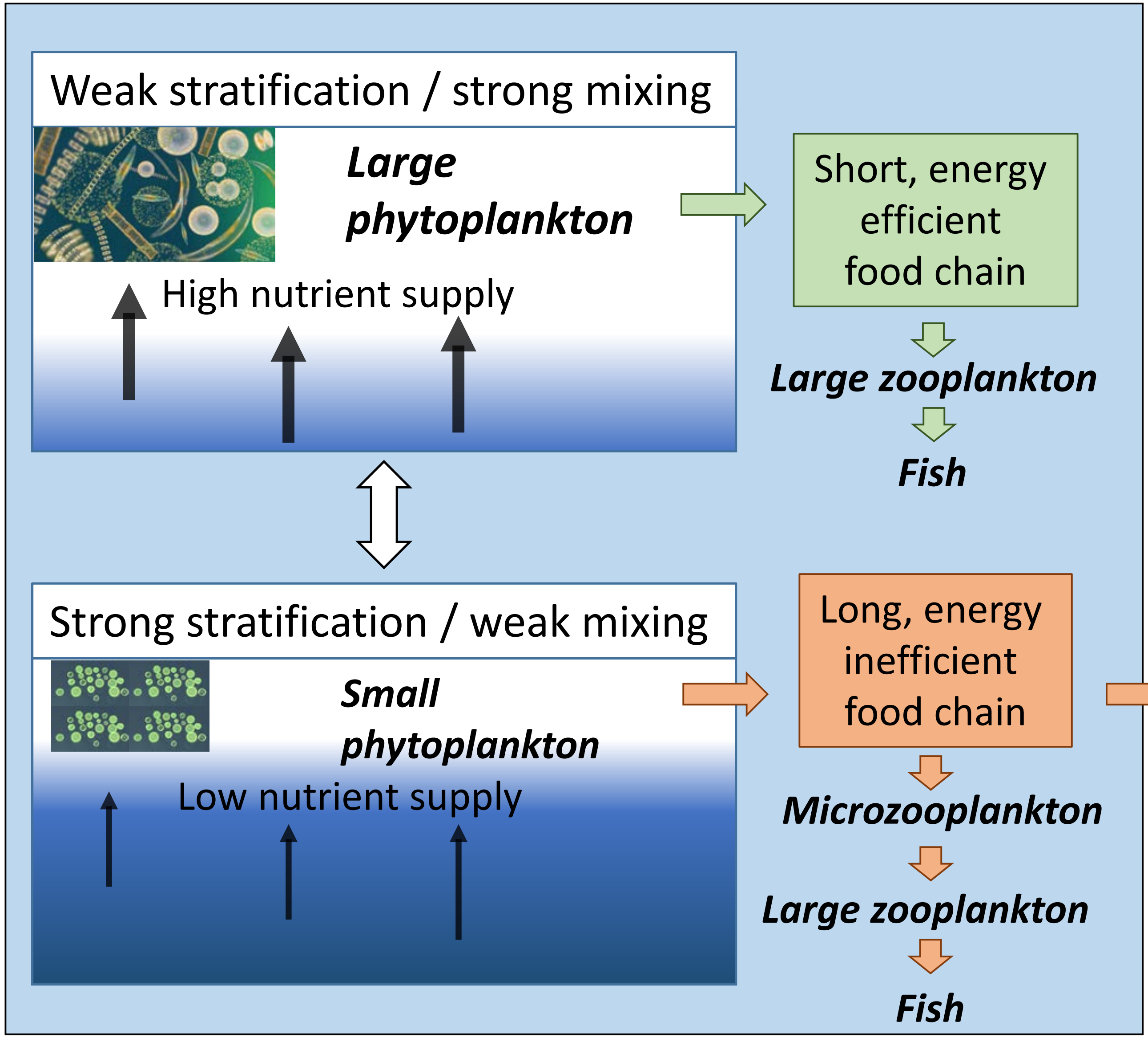


Uitz et al GCB 2010

IMPLICATIONS FOR FOOD CHAIN LENGTH



CLIMATE WARMING & FOOD WEB PRODUCTIVITY



Predicted shift to more stratified low nutrient conditions with ocean warming.

e.g., Polovina et al., IJMS, 2011

OUR STUDY AIM

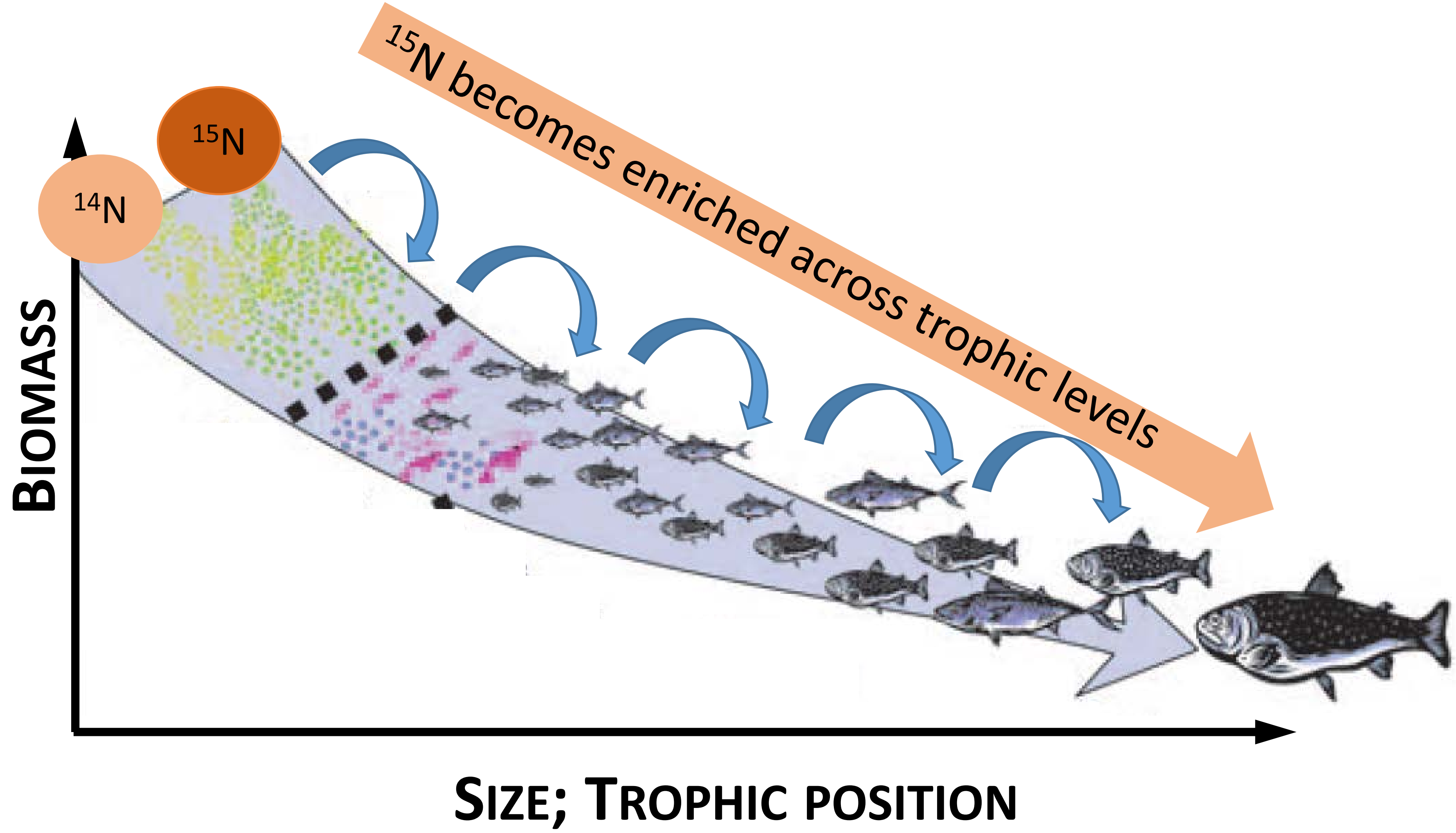
EMPIRICALLY TEST THE CONCEPT THAT THE LENGTH OF THE PLANKTON-TO-MICRONEKTON FOOD WEB IS LONG IN OLIGOTROPHIC & SHORT IN EUTROPHIC ECOSYSTEMS.

➢ Inform future food web response to warming.

APPROACH:

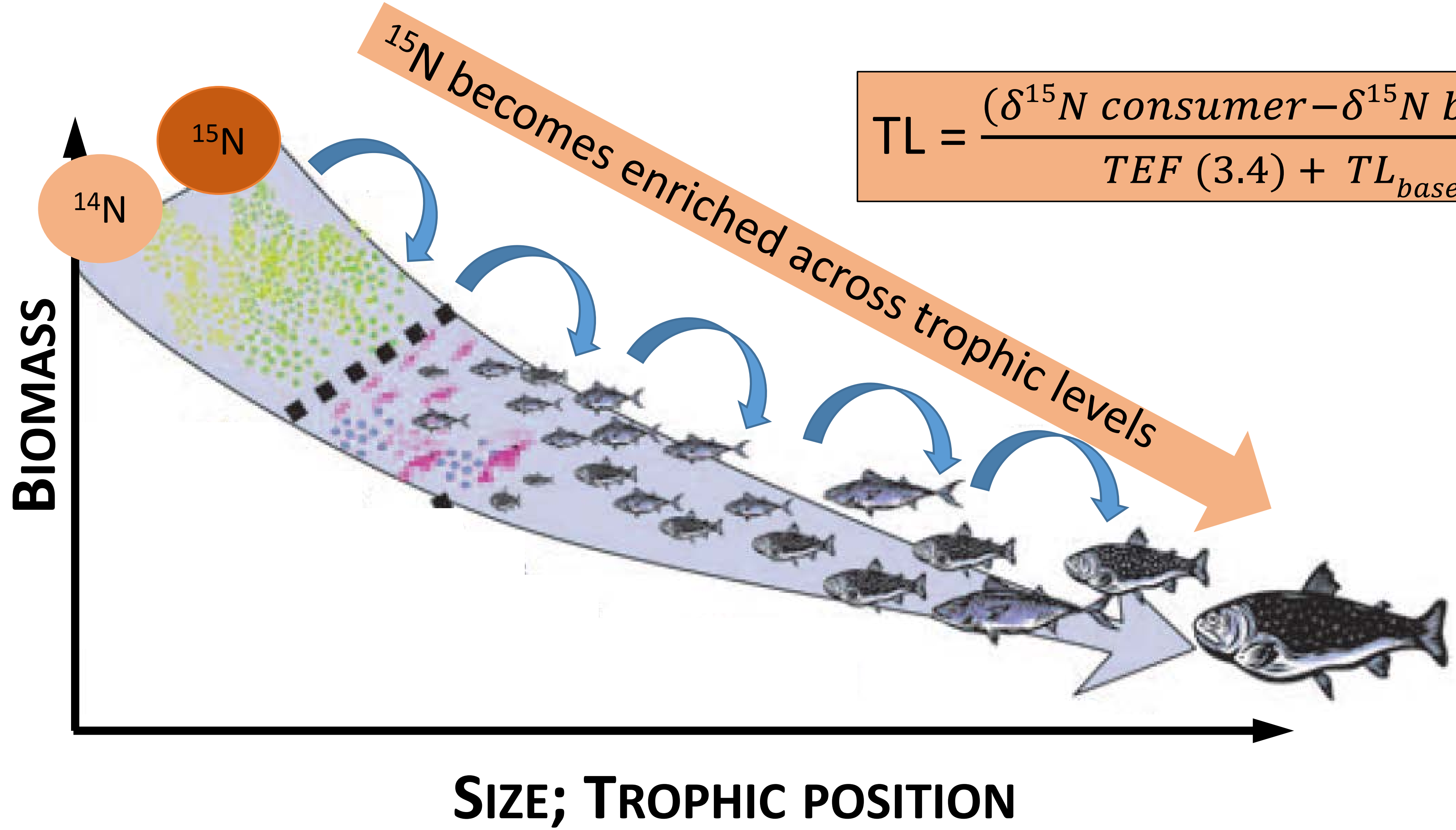
- Sampled 5 representative ecosystems;
- Derived food web dynamics from stable isotope analysis of biomass size classes.

Stable isotopes in food webs



ESTIMATING TROPHIC LEVEL

$$TL = \frac{(\delta^{15}N\ consumer - \delta^{15}N\ baseline)}{TEF\ (3.4) + TL_{baseline}}$$



SAMPLE LOCATIONS

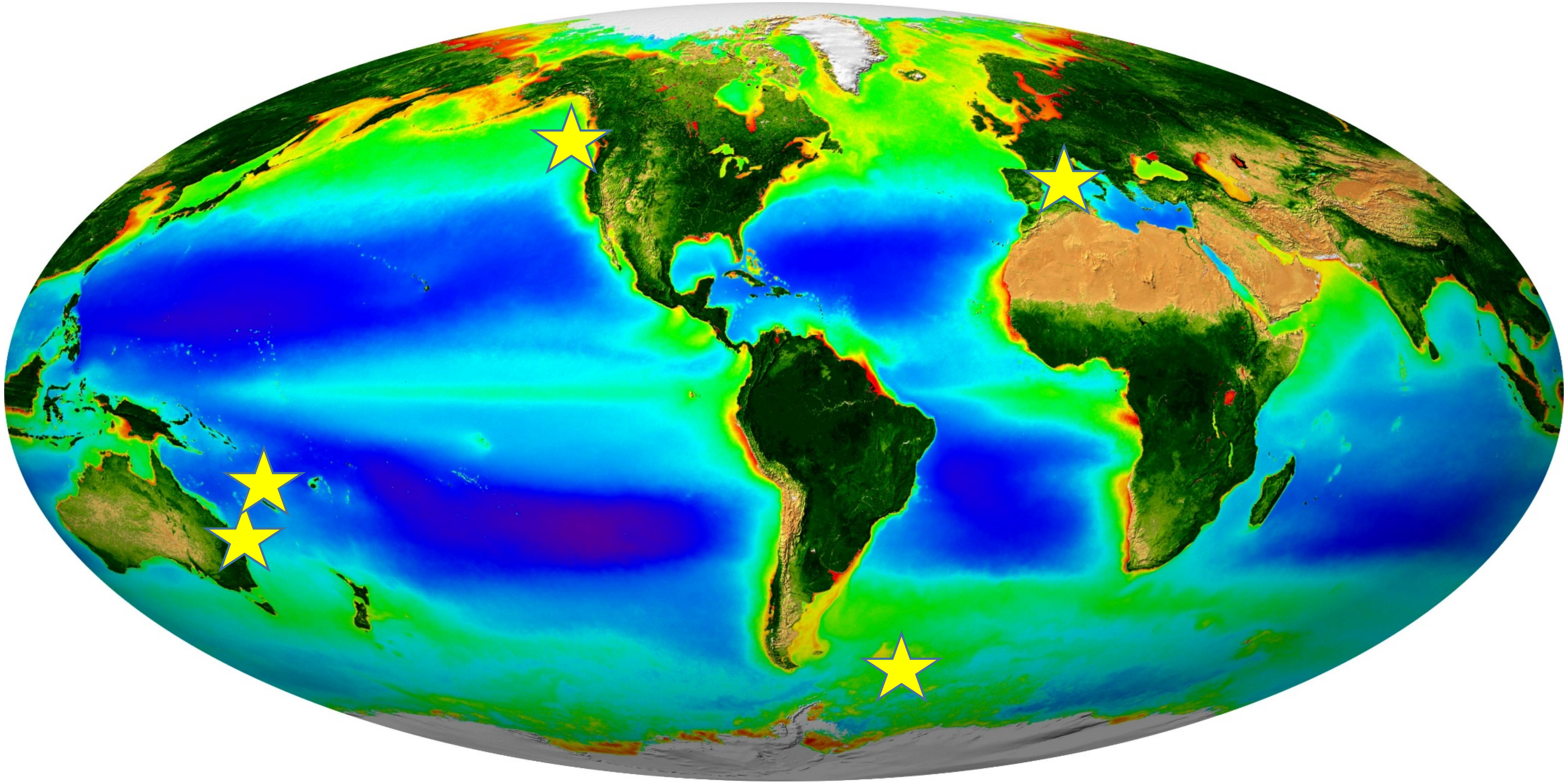


Fig. 3. Global phytoplankton biomass, average of 1997- 2010 [Chl-a concentration; mg.m^{-3}]

Low → Med → High

SAMPLE LOCATIONS

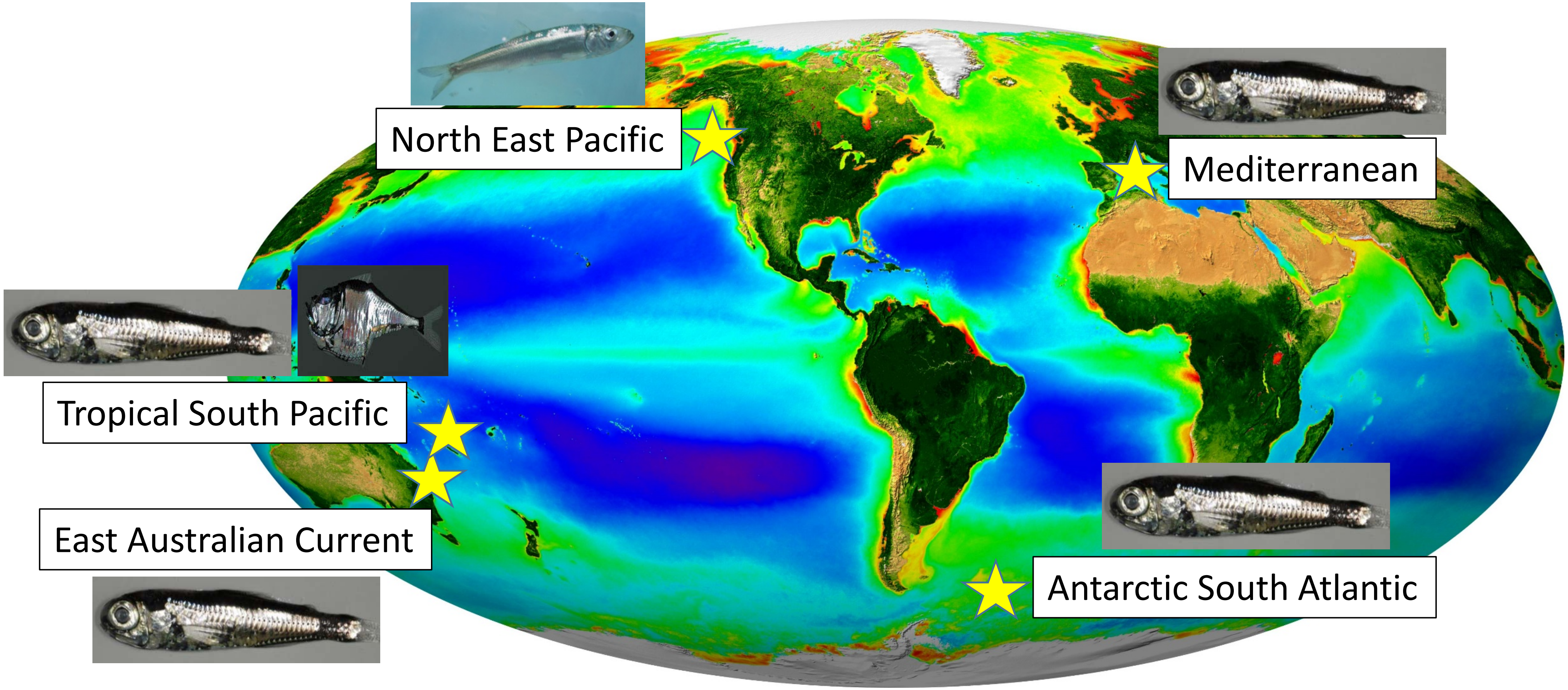
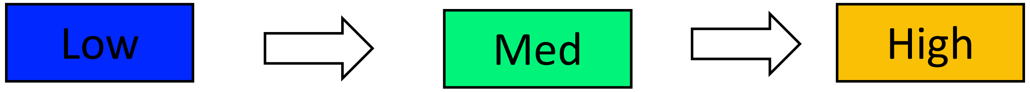
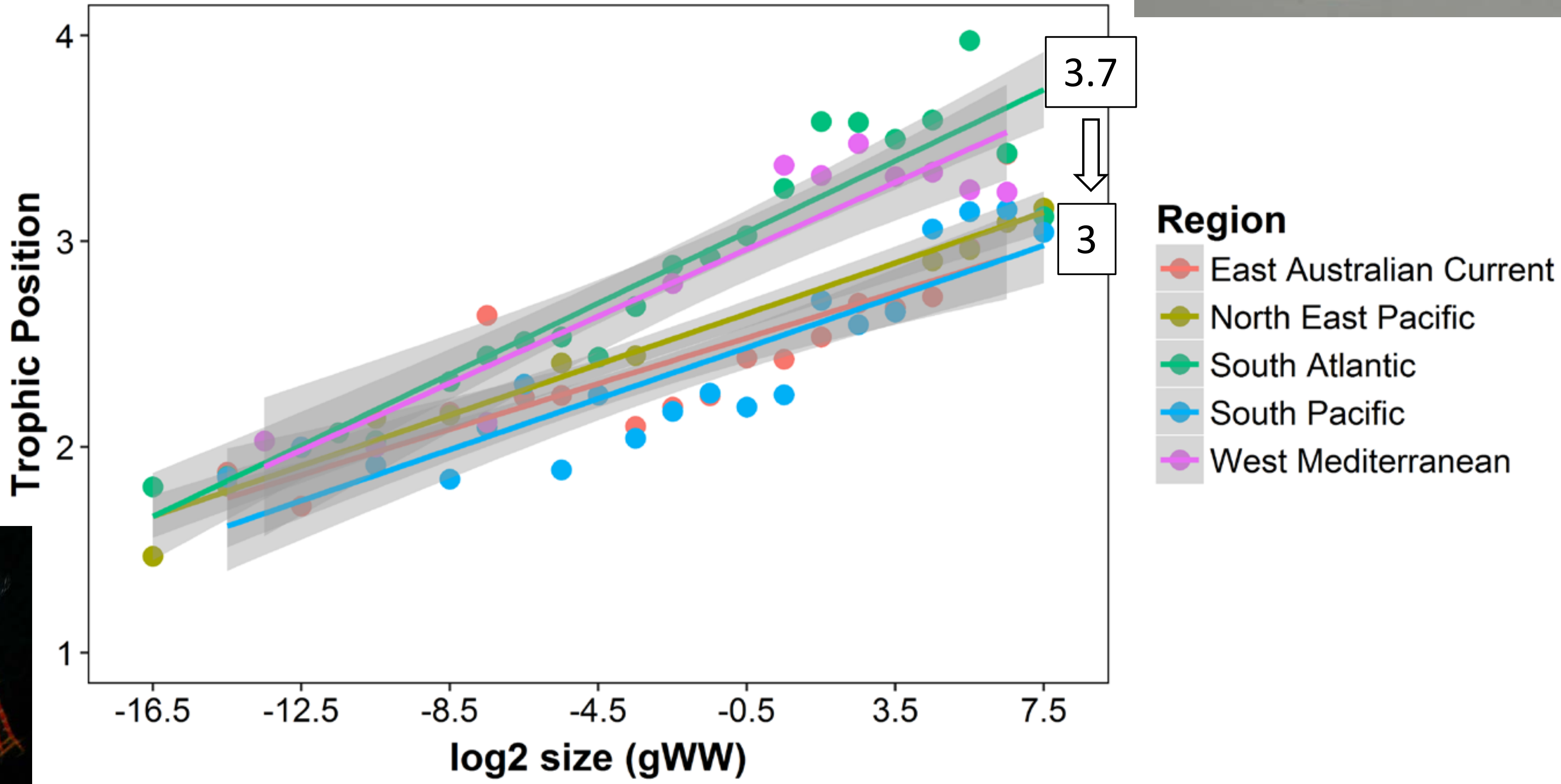


Fig. 3. Global phytoplankton biomass, average of 1997- 2010 [Chl-a concentration; mg.m^{-3}]



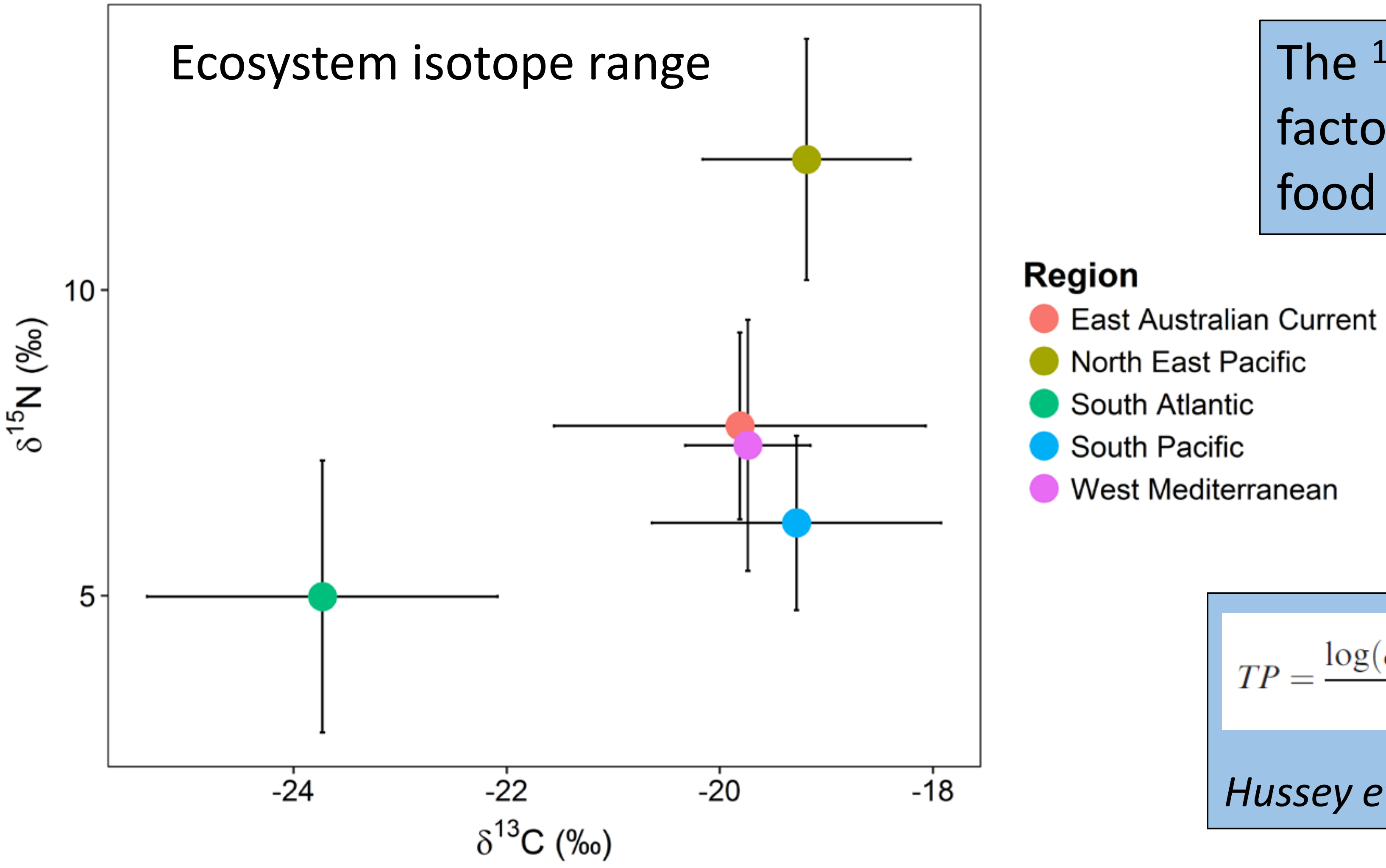
ESTIMATED TROPHIC POSITIONS

180 g WW



< 0.1mg WW

The effect of the food web $\delta^{15}N$ baseline

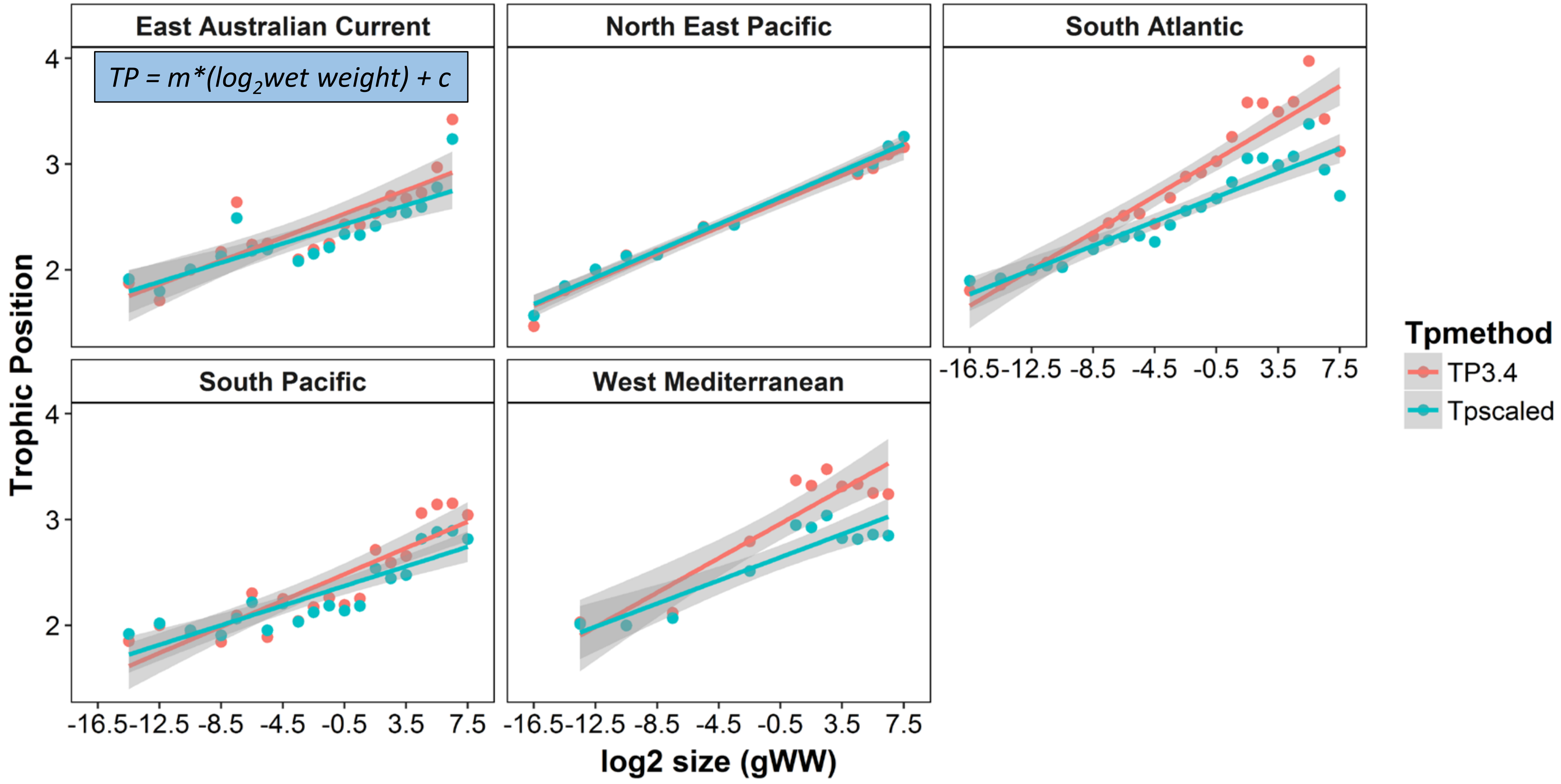


The ^{15}N trophic enrichment factor decreases as $\delta^{15}N$ of the food web baseline increases.

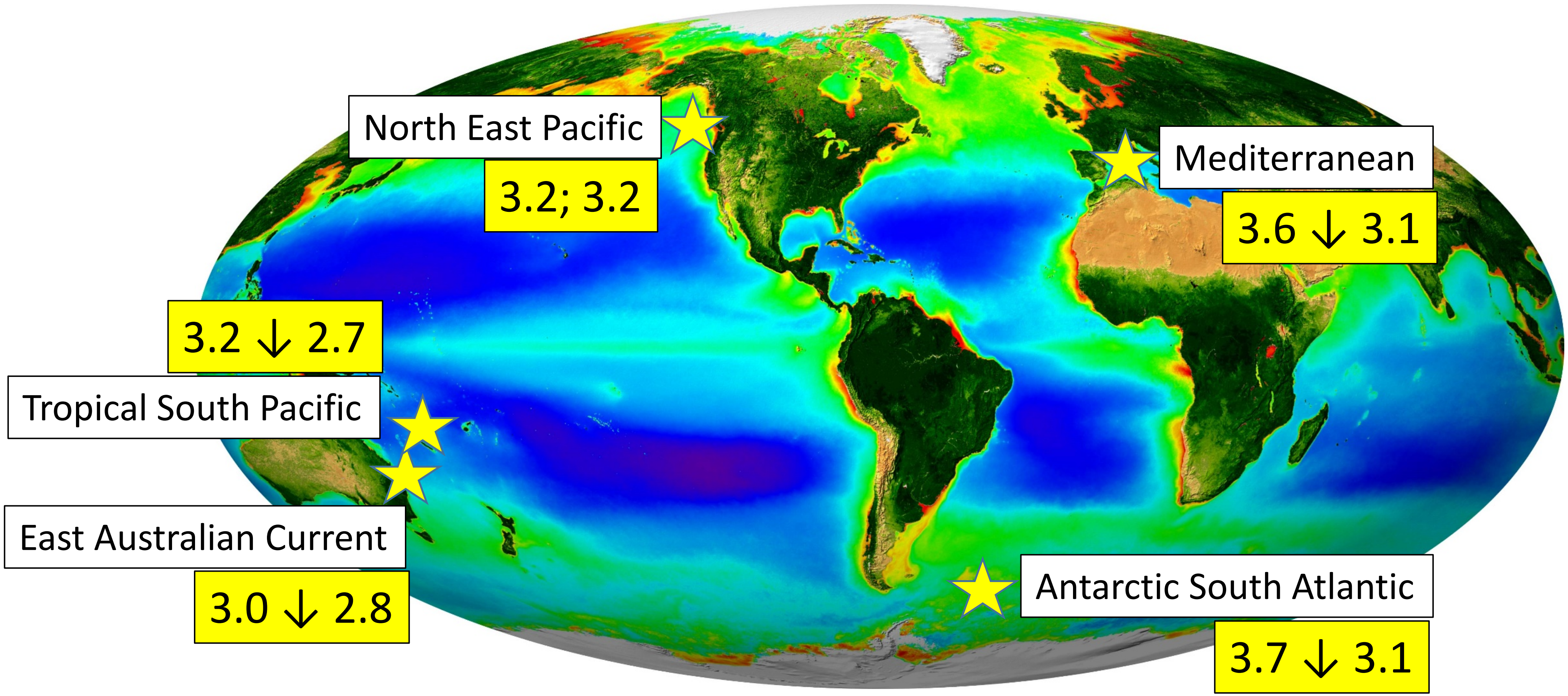
$$TP = \frac{\log(\delta^{15}N_{\lim} - \delta^{15}N_{base}) - \log(\delta^{15}N_{\lim} - \delta^{15}N_{TP})}{k}$$

Hussey et al . Ecology Letters 17, 2014

Trophic positions scaled by the $\delta^{15}N$ baseline



TROPHIC POSITIONS [USING TEF3.4:SCALED TP]



SUMMARY

- After applying scaled enrichment factors we identified a greater similarity in food chain length across ecosystems than the classical fixed TEF approach.
  - ➢ Average TL of 180g small pelagic fish = 3.

- Findings are the reverse of the predicted food-chain length dynamic
  - ➢ oligotrophic shorter than eutrophic by ~ 0.5 TL.

Is this real or a method artefact?

Summary

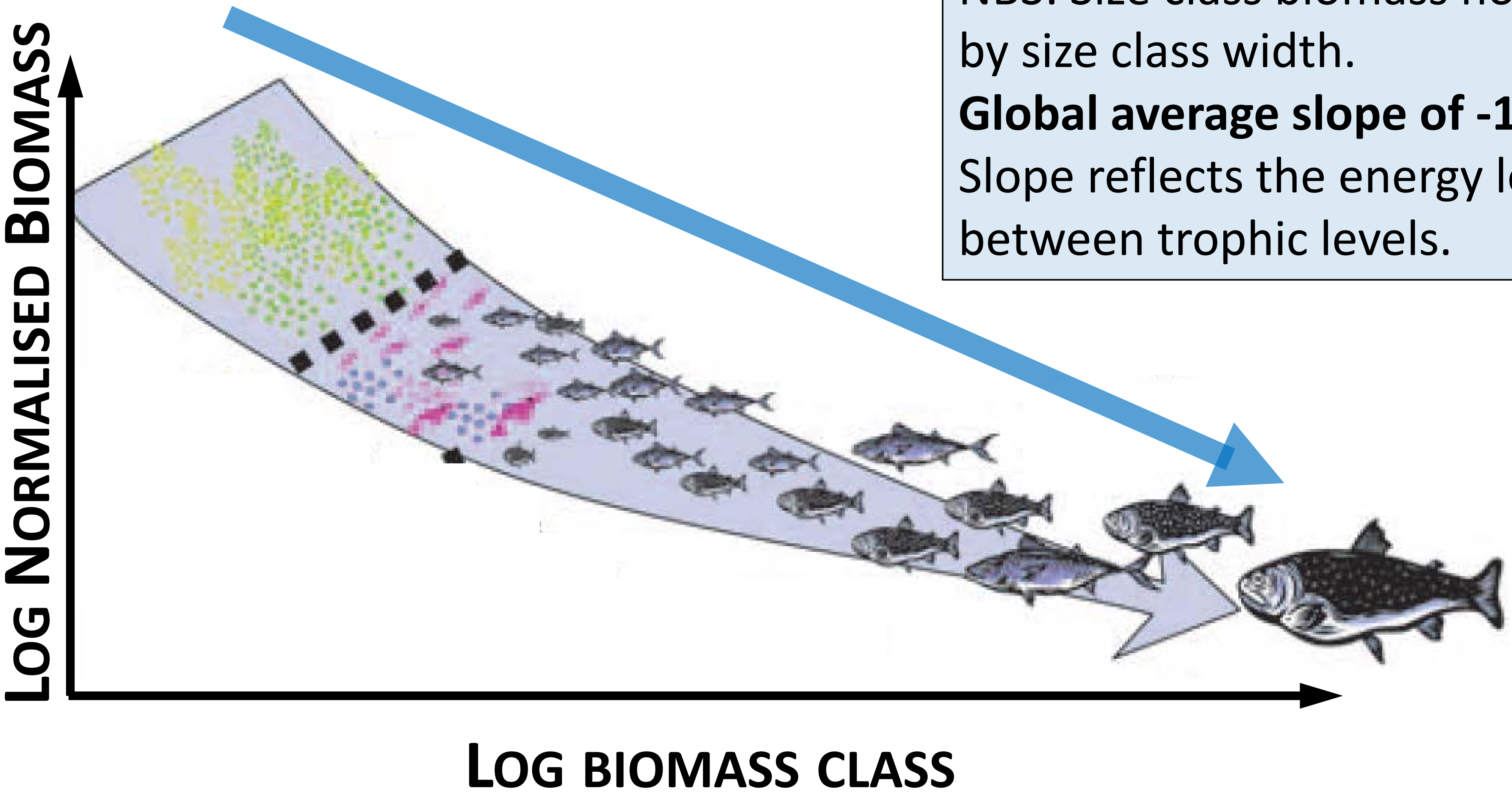
This is an artefact of the "Isotopic invisibility of protozoan trophic steps in marine food webs" *(Gutierrez-Rogriguez et al. L&O 2014)*
i.e., negligible isotopic fractionation between phytoplankton & microzooplankton.

- Isotope approach underestimates food chain length in systems where microzooplankton are an important part of trophic transfer;

- High transfer efficiency from phytoplankton to microzooplankton.

This has implications for regional transfer efficiencies through the phytoplankton-to-micronekton food web.

The normalised biomass spectrum (NBS)



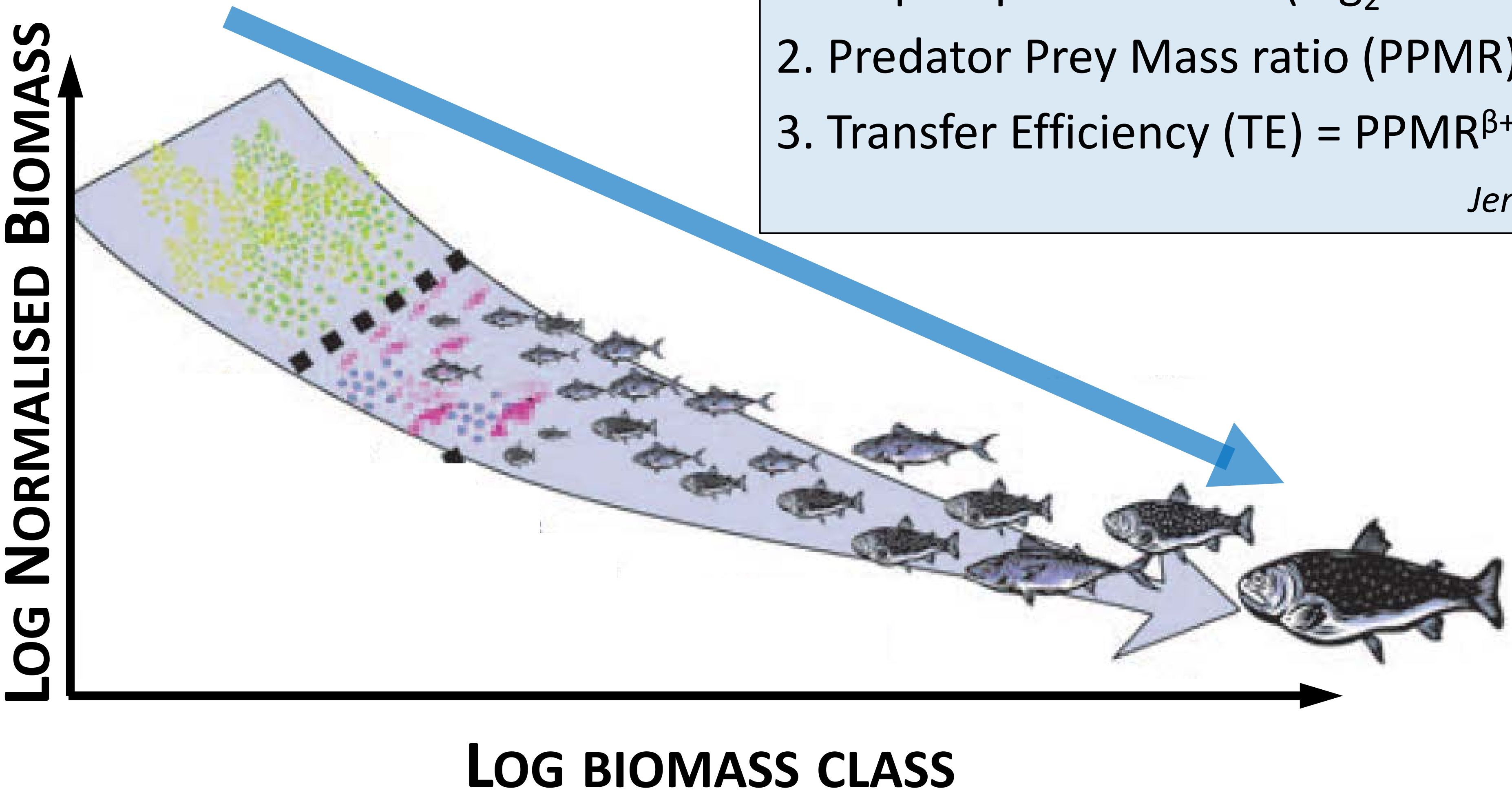
NBS: Size class biomass normalised by size class width.
Global average slope of -1.05 (β).
Slope reflects the energy loss between trophic levels.

Kerr & Dickie 2001

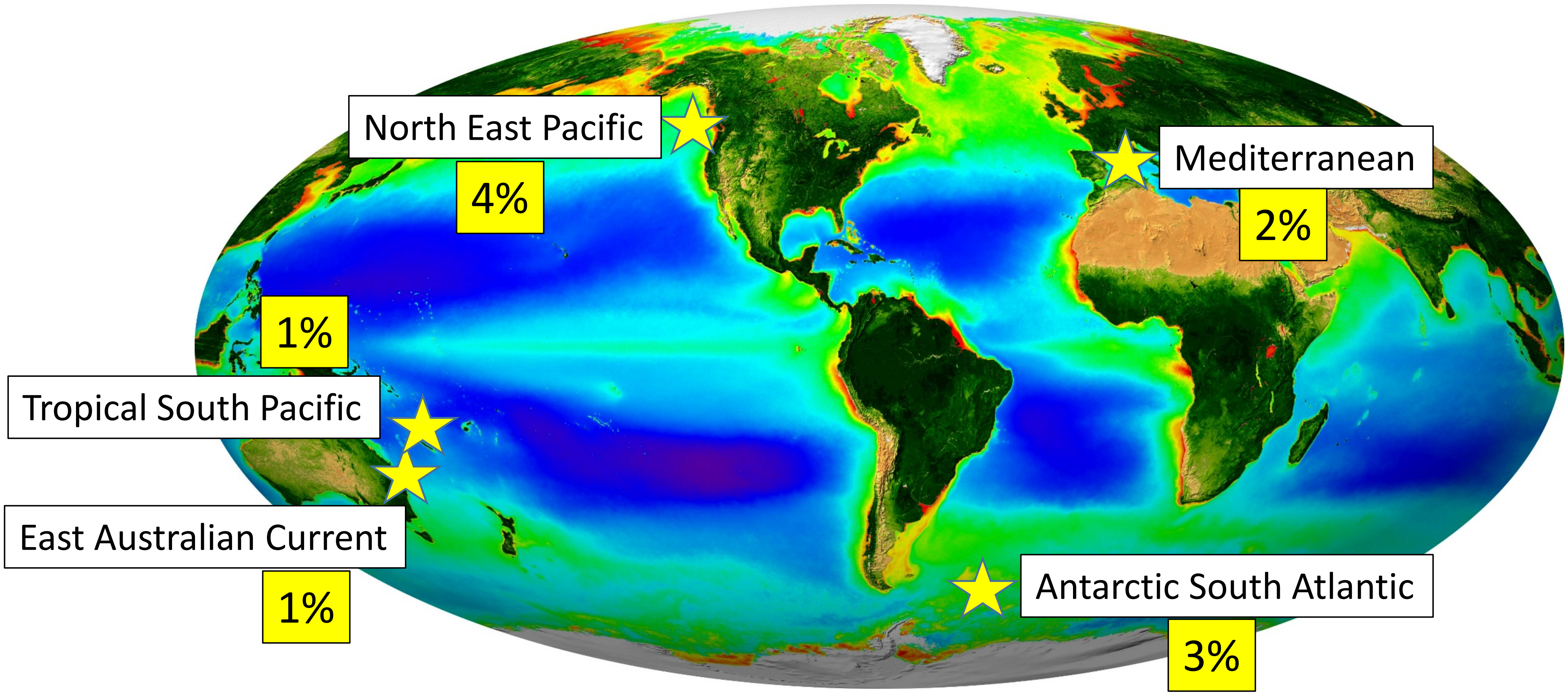
Calculating TP, PPMR & TE

1. Trophic position = m*(log_2wet weight) + c
2. Predator Prey Mass ratio (PPMR) = $2^{1/m}$
3. Transfer Efficiency (TE) = $PPMR^{\beta+0.75}$

Jennings et al 2001



Estimated transfer efficiencies



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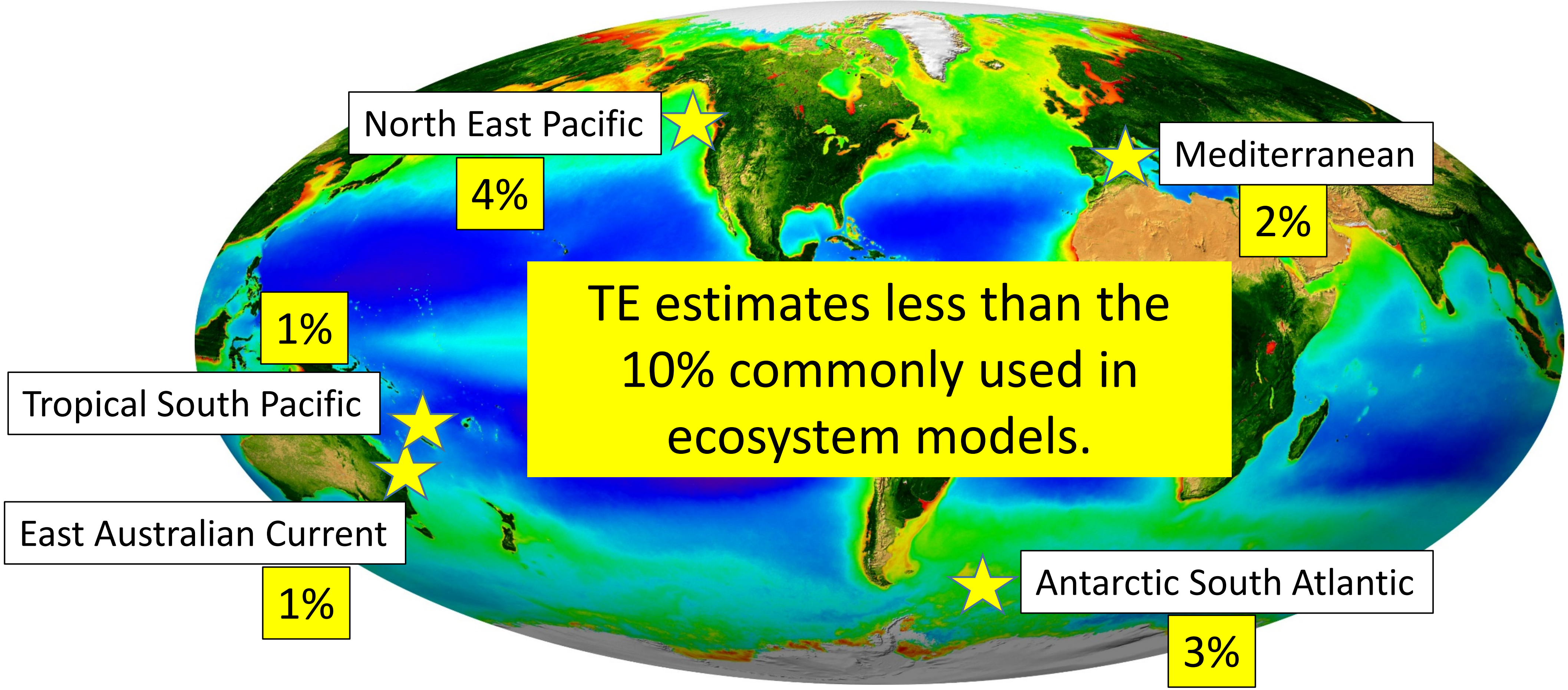
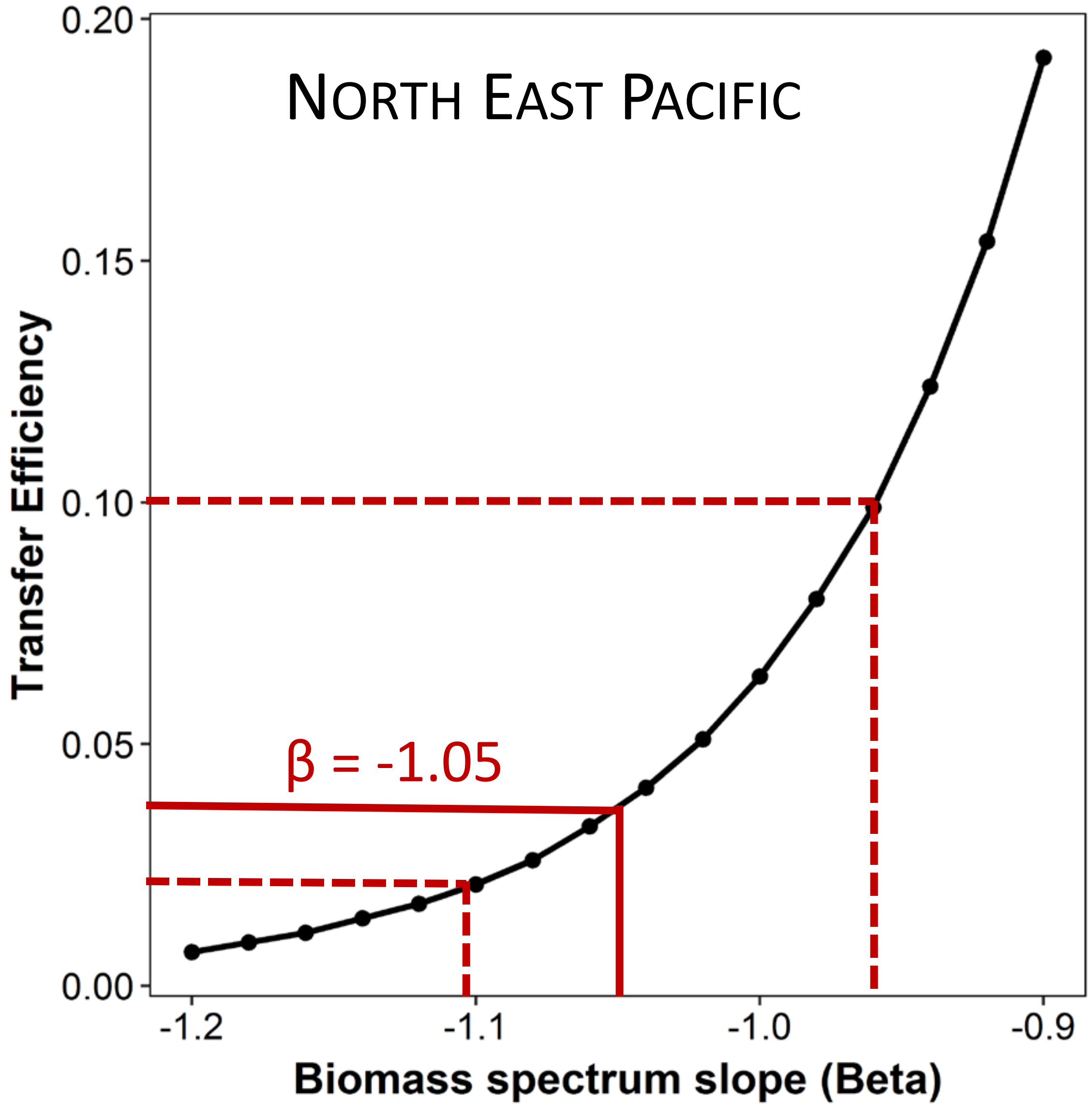


TE estimates less than the 10% commonly used in ecosystem models.

The importance of NBS slope in TE estimates



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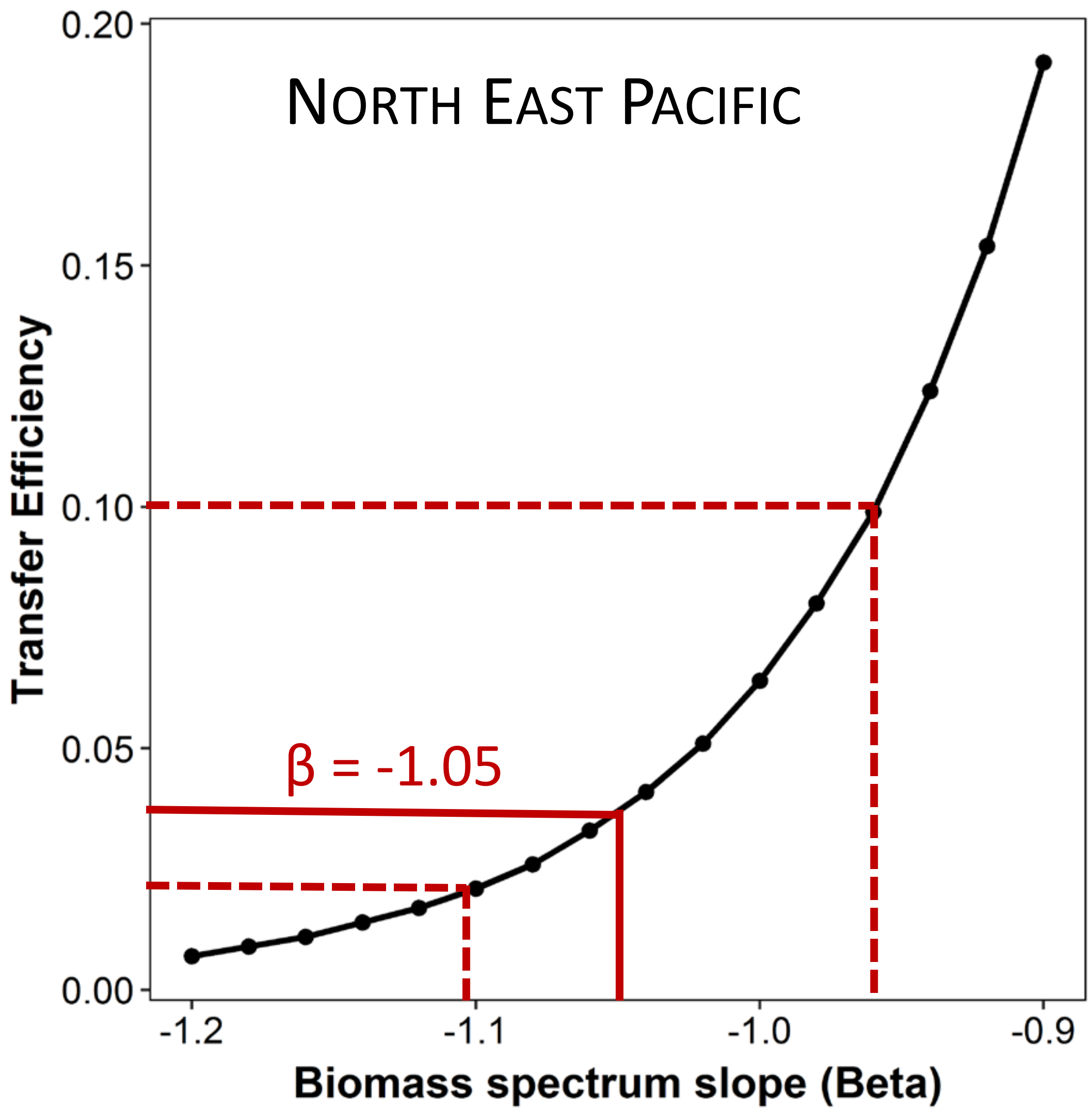
The importance of NBS slope in TE estimates



$TE = PPMR^{\beta+0.75}$

β varies over seasonal production cycles

- More –ve when 1° production dominates
- More +ve when consumption dominates

➢ Variability of β over production cycles needs to be taken into account when estimating TE.

Summary

- Notably, our estimated transfer efficiencies are less than the 10% commonly used in ecosystem models.

Our results are based on survey snapshots in time.

- ➢ Seasonal NBS time series are required to further resolve regional transfer efficiency estimates.

CONCLUSIONS

- Need to take the $\delta^{15}N$ of the food web baseline when calculating trophic positions;

- High transfer efficiencies from picophytoplankton to microzooplankton. This represents an offset to low productivity in oligotrophic ecosystems;

- Despite high TE from picophytoplankton to microzooplankton, the Isotope-NBS approach confirms higher relative transfer efficiencies in eutrophic vs oligotrophic systems.

➢ Supports reduced ecosystem productivity in warm stratified oceans.