Ecosystem Considerations: Ecological and Physical Changes in the EPO

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Scientific Advisory Committee, 4th Meeting

4a Reunión del Comité Científico Asesor

Outline

- The pelagic ocean environment is changing
  - Oxygen content
  - Primary production
  - Ocean temperatures

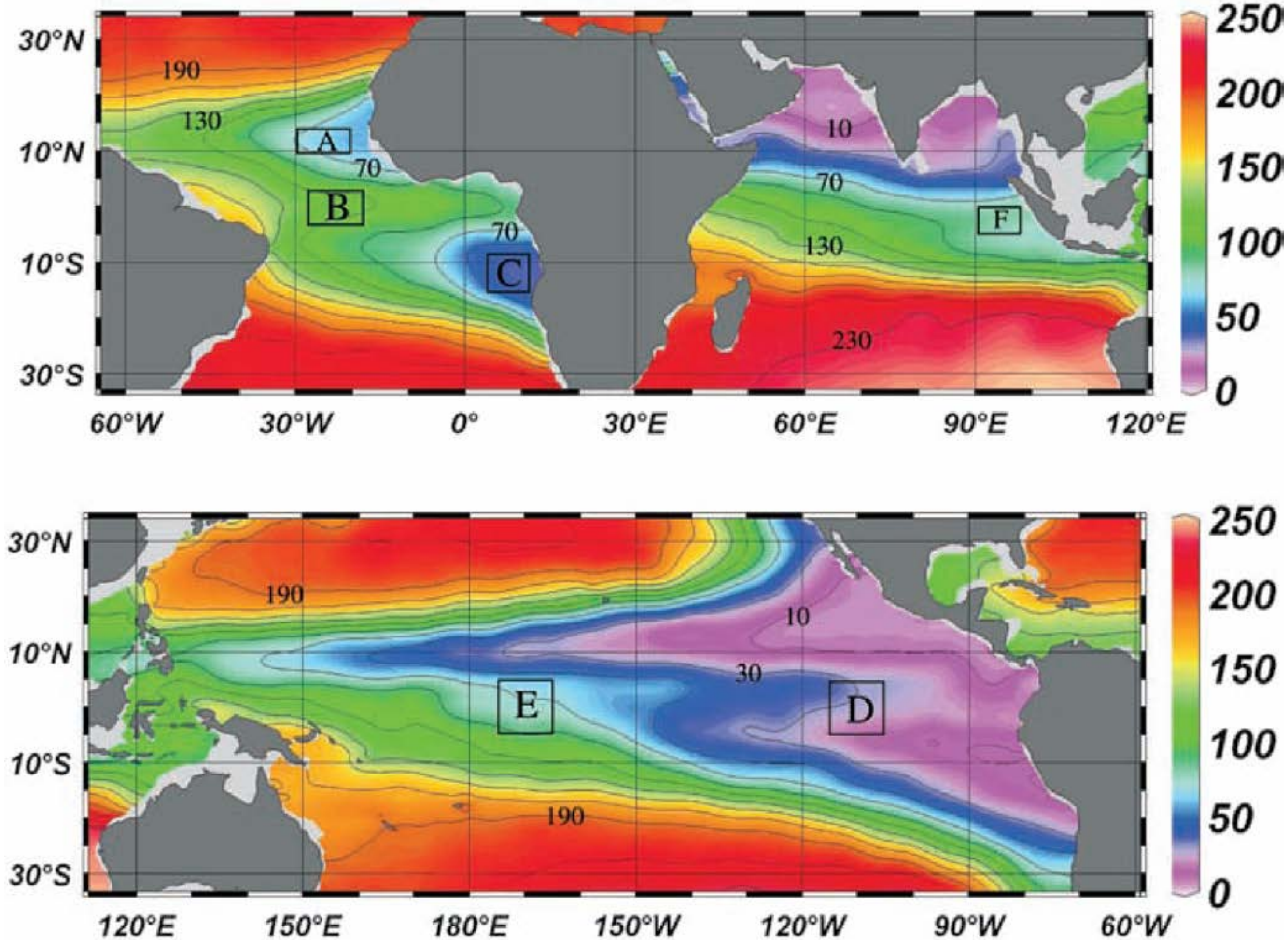
- The pelagic food web is changing
  - Size spectra, base of food web
  - Prey community

Dissolved oxygen

- Dissolved oxygen in the ocean:
  - Affects marine biogeochemical processes
  - Impacts global carbon and nitrogen cycles
  - Critical for survival of most marine animals
  - Mobile marine animals avoid hypoxic zones
  - Dependent on circulation, ventilation, air-sea exchange, production , and respiration
  - Global climate change affects dissolved O_2 concentrations

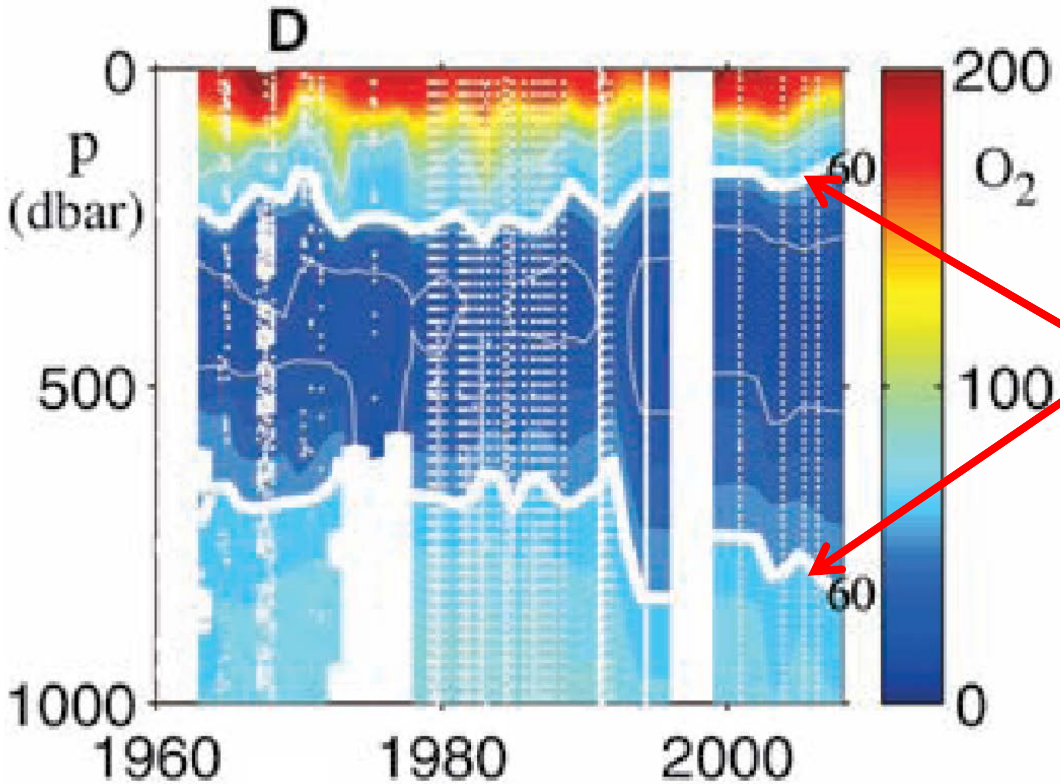
Oxygen minimum zone (OMZ)

- E side tropical oceans.
- Thick low O_2 layer, intermed depths (~200-700 m).
- OMZ suboxic in east trop Pacific & trop Indian Ocean (<~10 µmol/kg).
- OMZ hypoxic in trop Atlantic (<~60-120 µmol/kg).
- OMZ in ETP is largest in the world. Nearly anoxic in some regions.
- Stramma et al. (2008) compiled limited time series O_2 data for D in ETP.



Stramma, L., G.C. Johnson, J. Sprintall, and V. Mohrholz. 2008. Expanding oxygen-minimum zones in the tropical oceans. Science. 320 (5876): 655-658.

Dissolved O_2 concentration: time series 1960-2008



OMZ vertical expansion

Sea surface warming, enhanced near-surface stratification, decreased vertical O_2 transport

(5N-5S; 105-115 W)

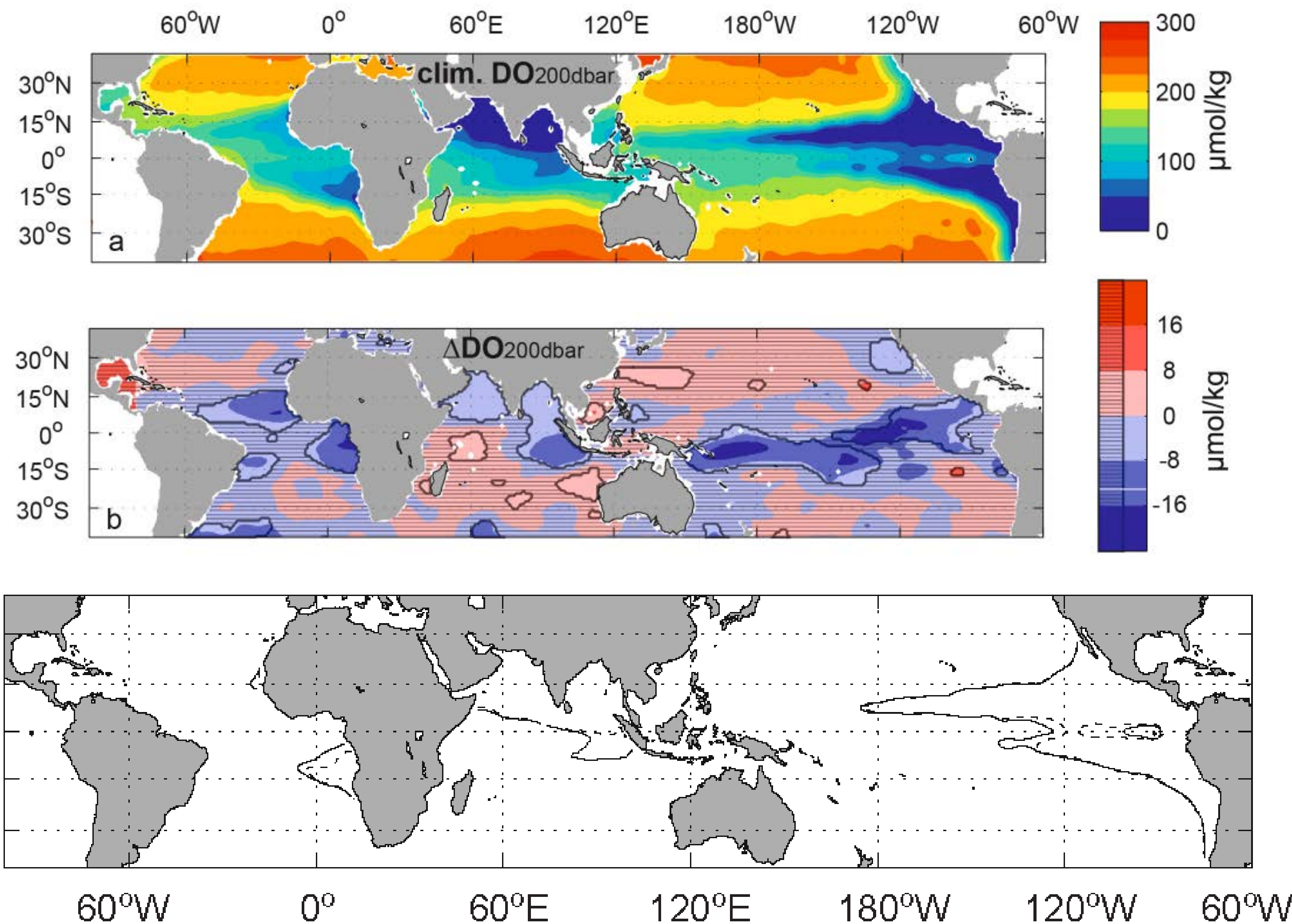
Stramma, L., G.C. Johnson, J. Sprintall, and V. Mohrholz. 2008. Expanding oxygen-minimum zones in the tropical oceans. Science. 320 (5876): 655-658.

Diss O2 changes: 1960-74 versus 1990-2008

Climatological mean dissolved O_2 at 200 m

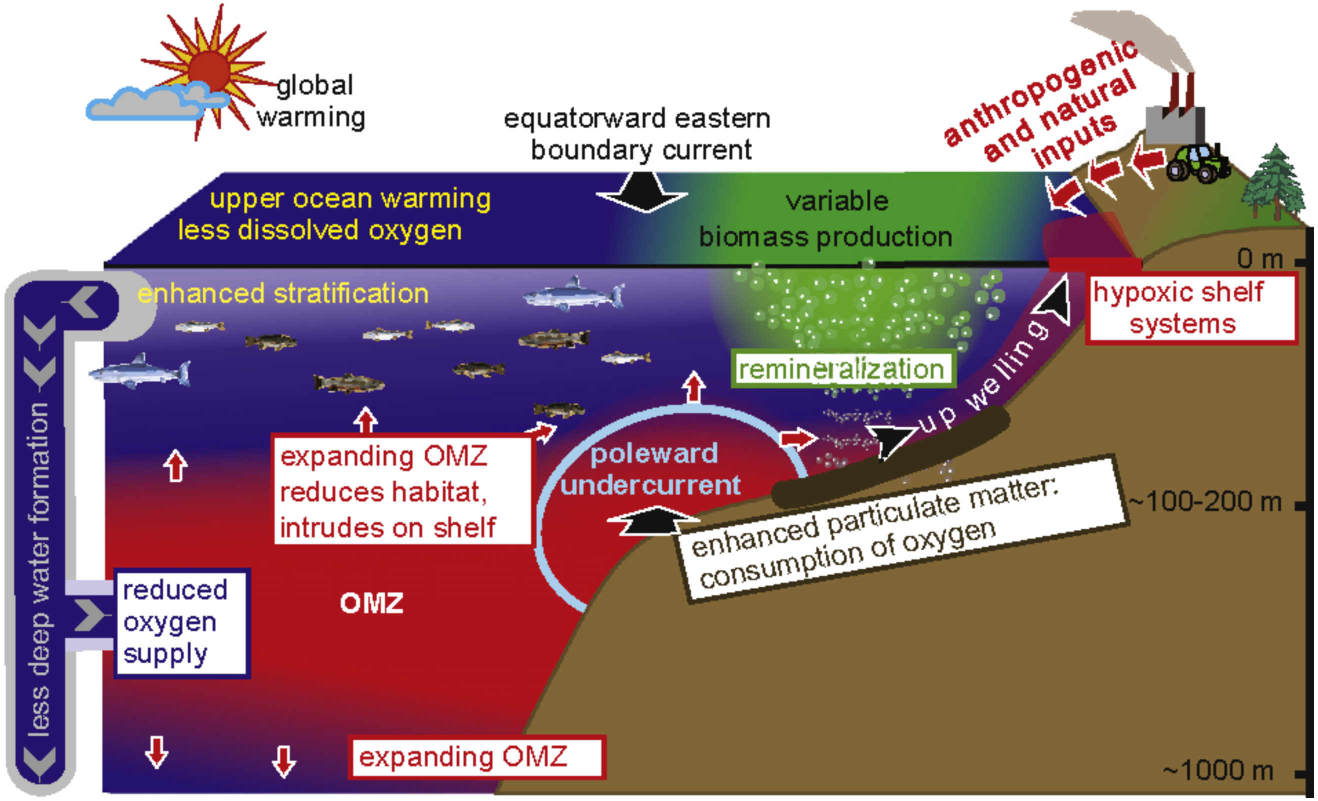
Dissolved O_2 changes at 200 m

O_2 contours 70 µmol/kg at 200 m



Stramma, L., S. Schmidtko, L.A. Levin, and G.C. Johnson. 2010. Ocean oxygen minima expansions and their biological impacts. Deep-Sea Res. I. 57 (4): 587-595.

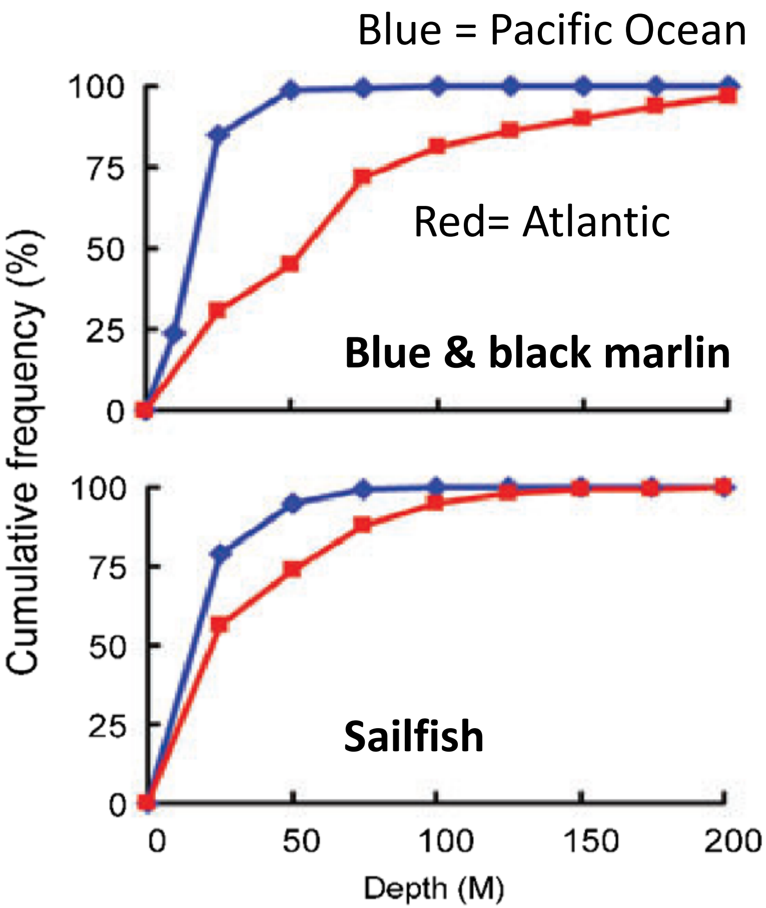
Implications of an expanding tropical OMZ

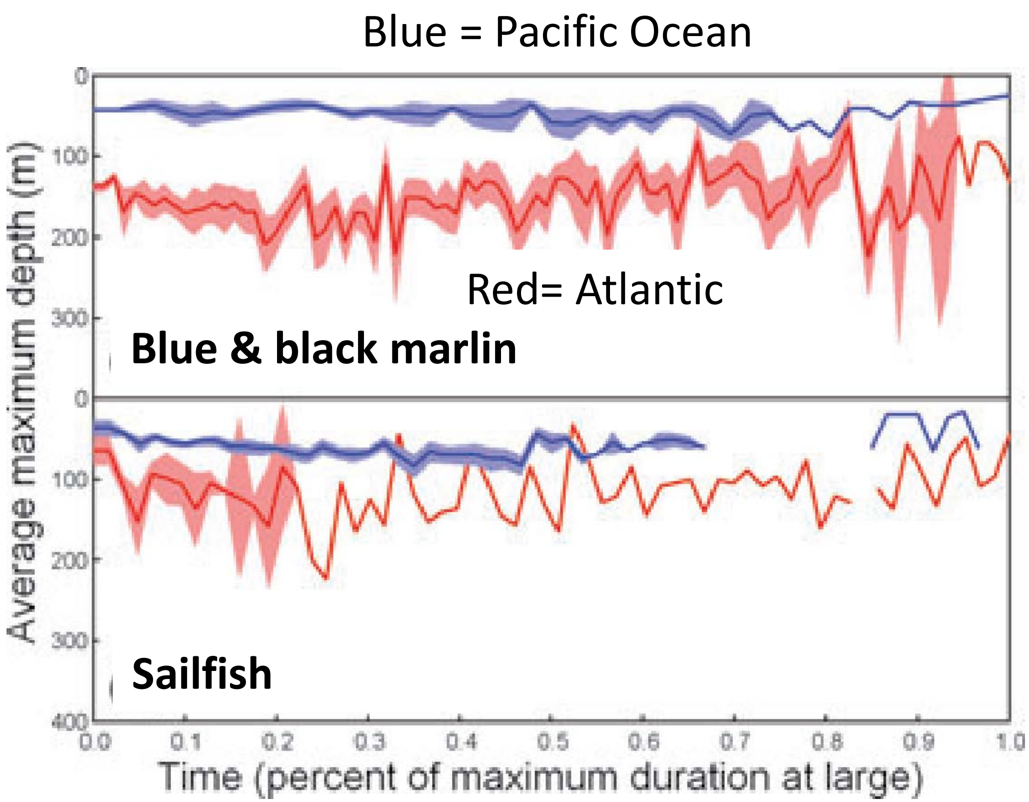


OMZ Shoaling and intensification:

- Restricts depth distribution of pelagic fishes, e.g. tunas and billfishes
  - Increased vulnerability to surface fishing gear
  - Mesopelagic prey more available
- Habitat compressed into narrow surface layer = close proximity of pred. & prey
  - Enhanced foraging opportunities; increased optimal foraging; altered trophic structure due to predation pressure on certain prey
  - Tuna early life stages more susceptible to predation, i.e. reduced recruitment

Implications of an expanding tropical OMZ: Depth distributions of pelagic fishes



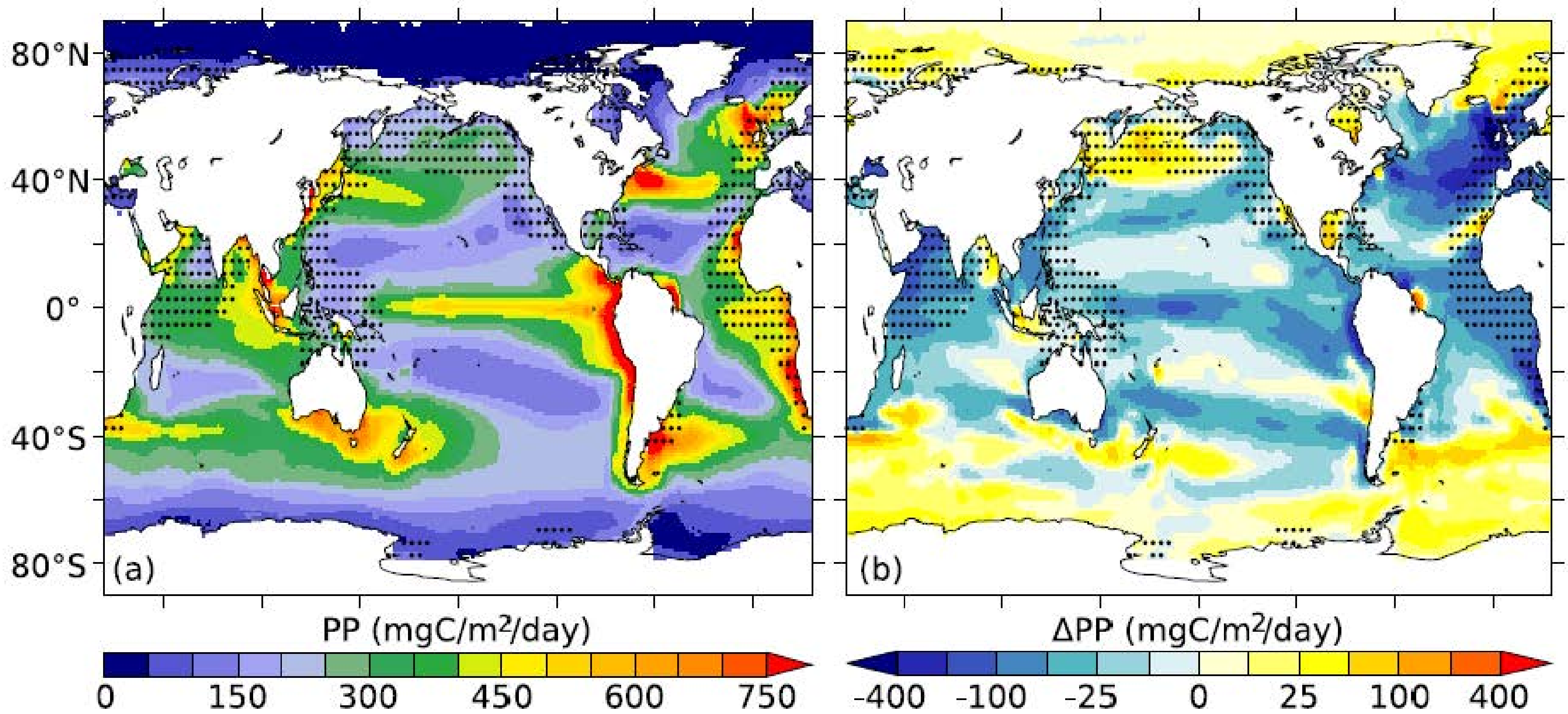


Prince, E.D., and C.P. Goodyear. 2006. Hypoxia-based habitat compression of tropical pelagic fishes. Fish. Oceanogr. 15 (6): 451-464.

Primary production

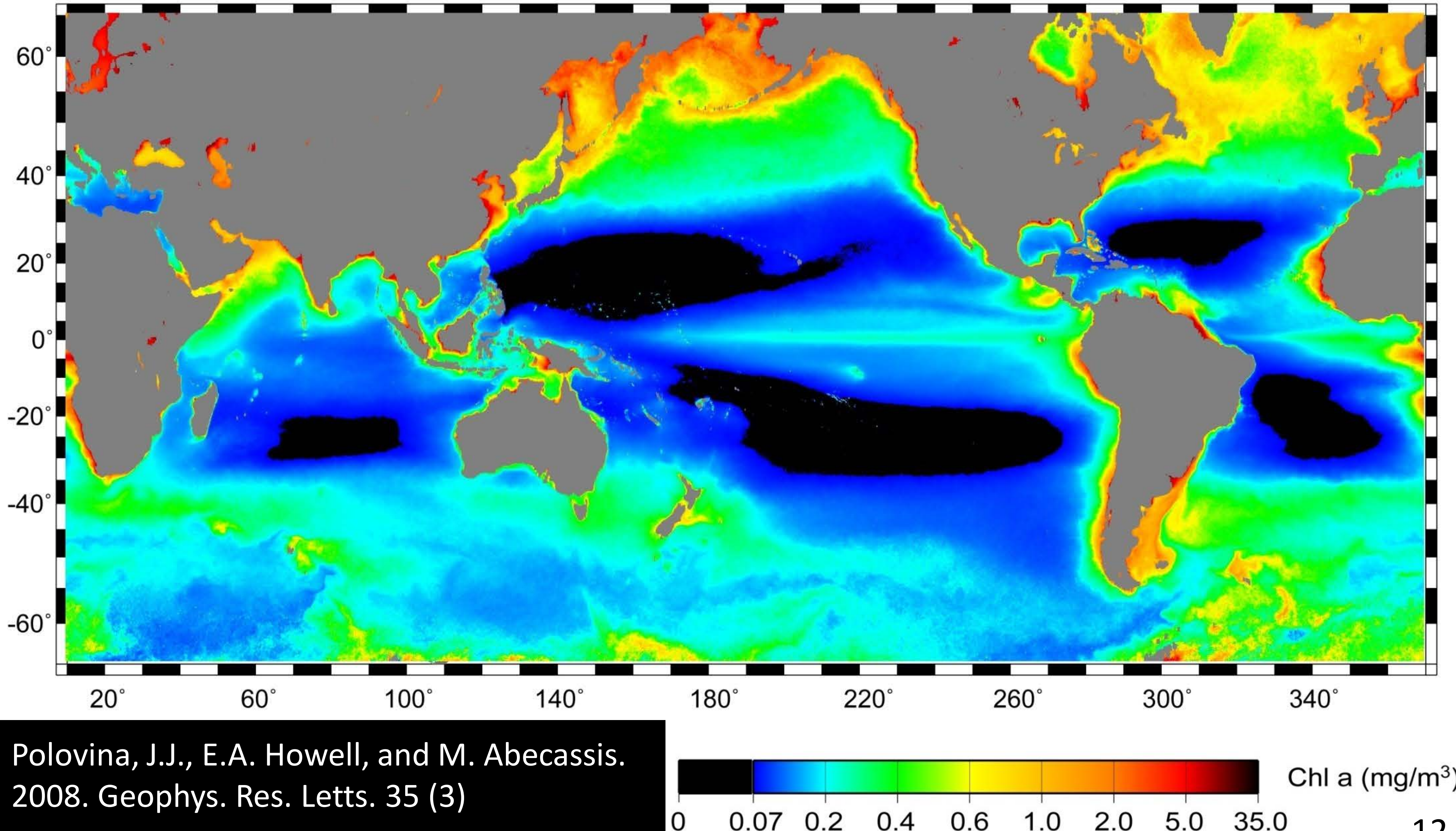
Historic
Primary
Production

Projected
Primary production
(2100)



Steinacher Biogeosciences 2010

SeawiFS surface chlorophyll climatology with oligotrophic gyres in black



Polovina, J.J., E.A. Howell, and M. Abecassis. 2008. Geophys. Res. Letts. 35 (3)

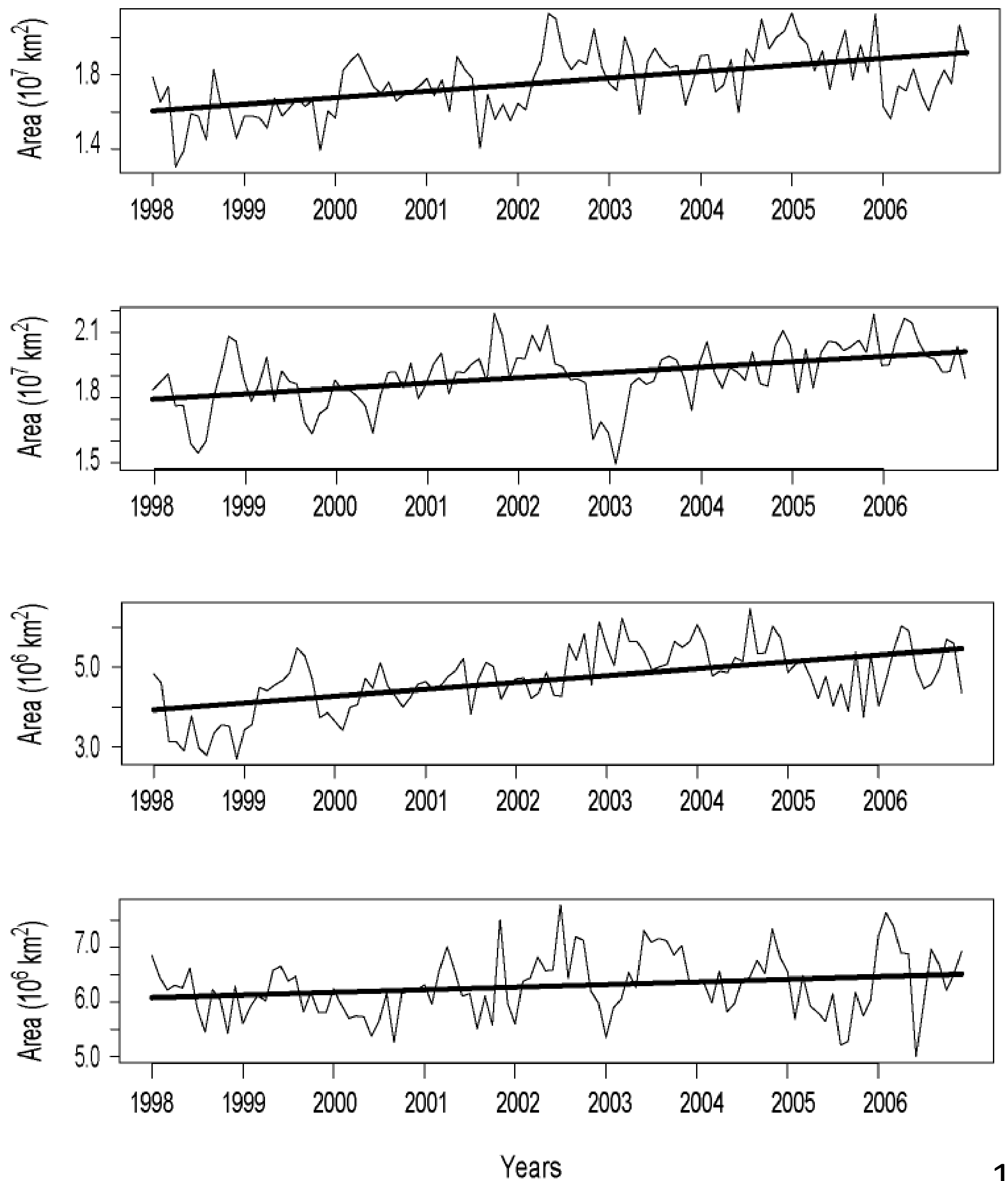
GAM Linear term

N Pacific
2.2 %/y increase

S Pacific
1.4 %/y increase

N Atlantic
4.3 %/y increase

S Atlantic
0.8 %/y increase



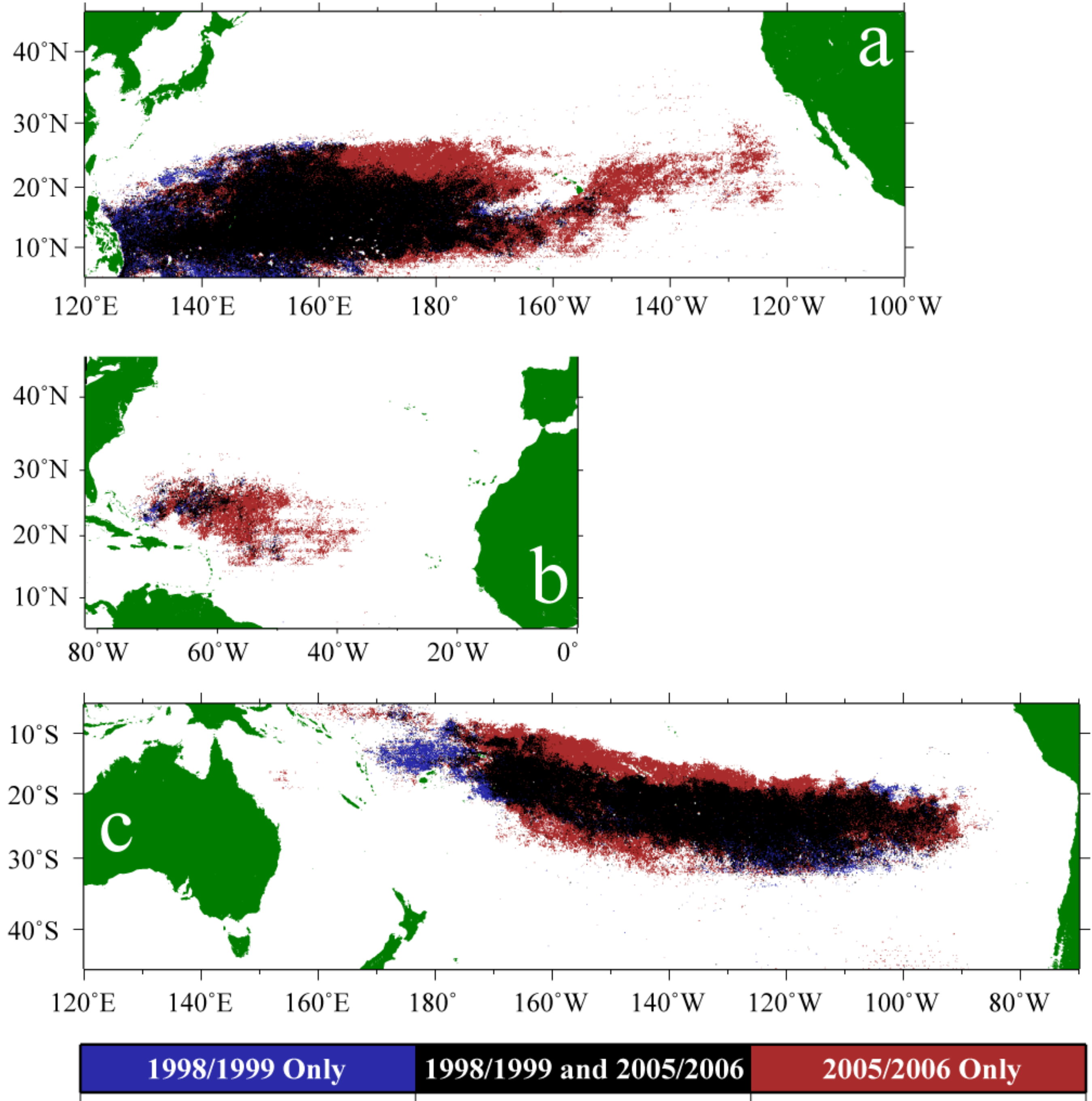
Polovina, et al. 2008

Changes in oligotrophic areas between 1998-1999 and 2005-2006 in December:

a) North Pacific,

b) North Atlantic,

c) South Pacific



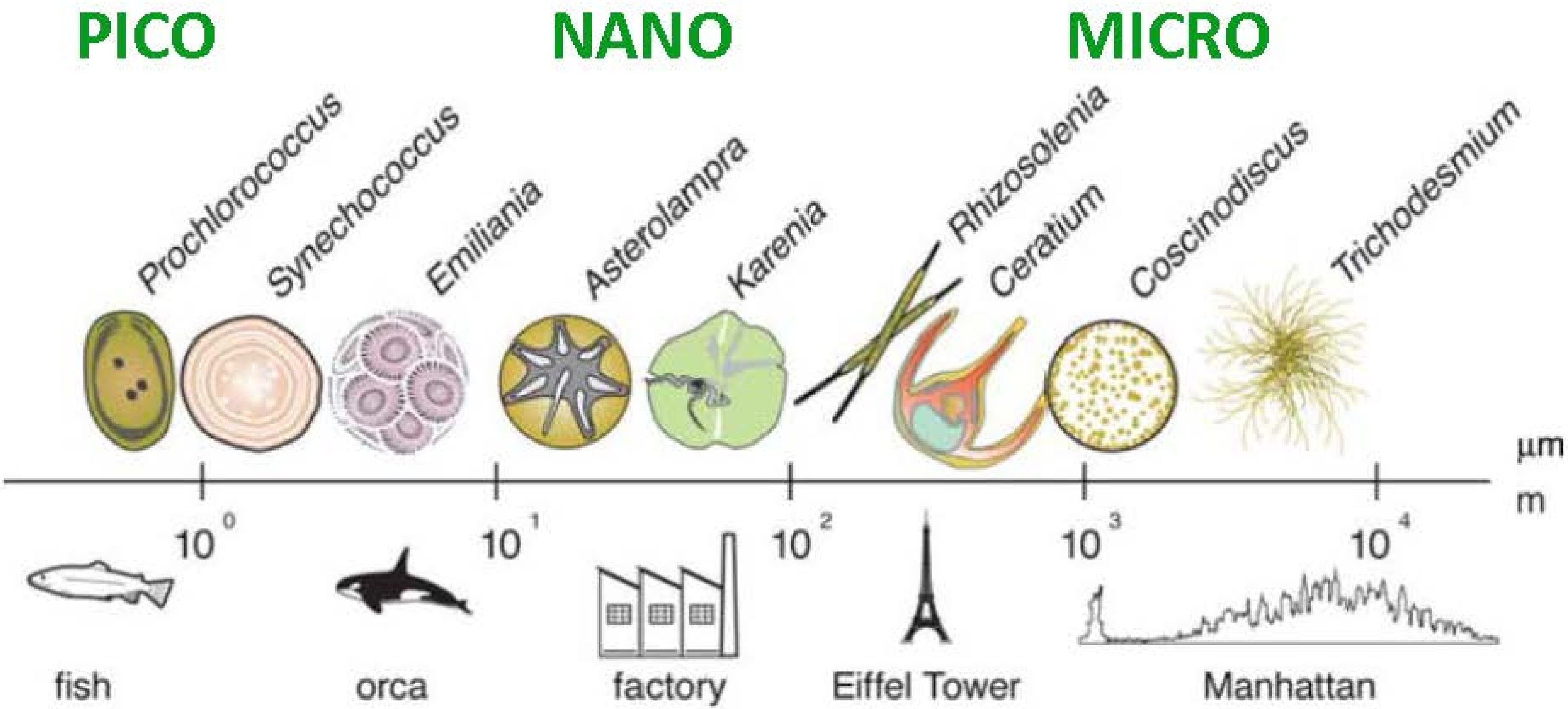
Polovina, et al. 2008

CLIOTOP WG3: Trophic pathways in the open ocean ecosystems

- Key scientific questions:
  - Is it possible to identify indicators, such as prey species or size spectra, that would highlight significant changes in trophic pathways?

PHYTOPLANKTON BASELINE AND FOOD CHAIN LENGTH

Given constant apex predator size – the size of the phytoplankton at the base of the food chain is hypothesised to be an important determinant of food chain length



Finkel et al JPR 2010

PHYTOPLANKTON BASELINE AND FOOD CHAIN LENGTH

PICO

gelatinous

microzooplankton

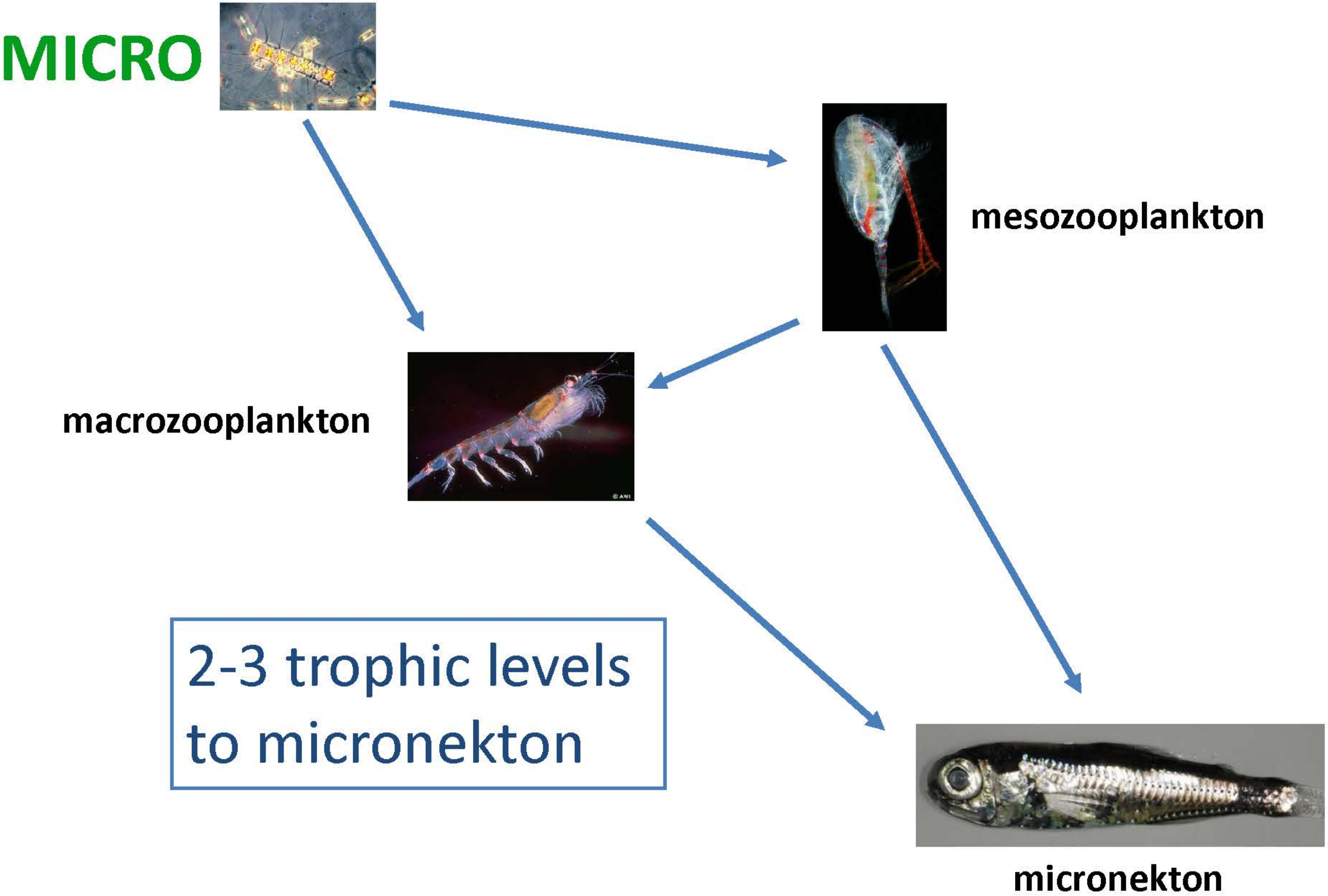
mesozooplankton

macrozooplankton

micronekton

4 or more trophic levels to micronekton

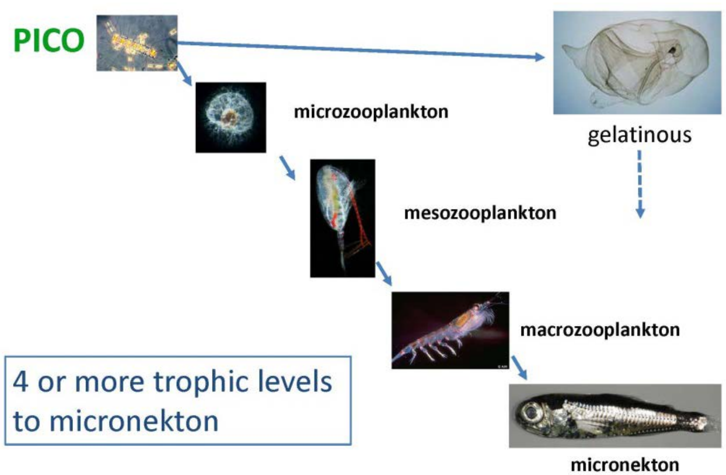
PHYTOPLANKTON BASELINE AND FOOD CHAIN LENGTH



2-3 trophic levels to micronekton

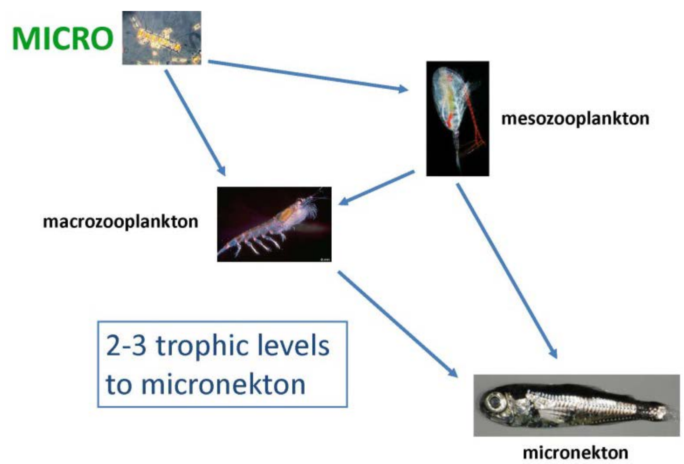
Trophic transfer efficiency

4 trophic levels phytoplankton to micronekton



1 * 10^{-4} mg C/m^2/day reaches tuna prey

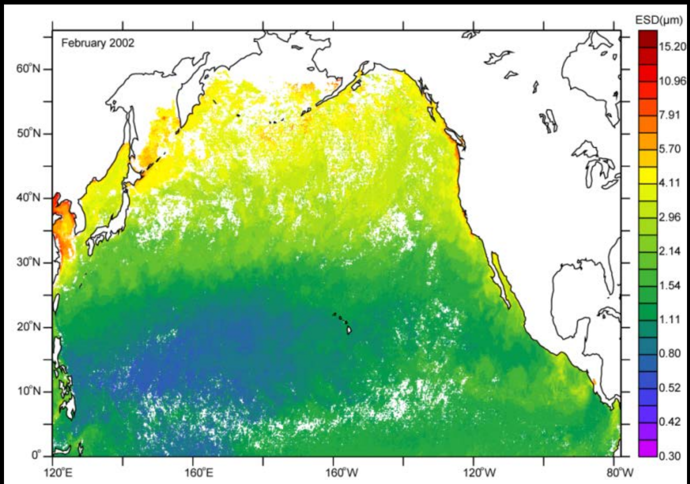
2 trophic levels phytoplankton to micronekton



1 * 10^{-2} mgC/m^2/day reaches tuna prey

Estimation of phytoplankton cell size from satellite SST and Chlorophyll

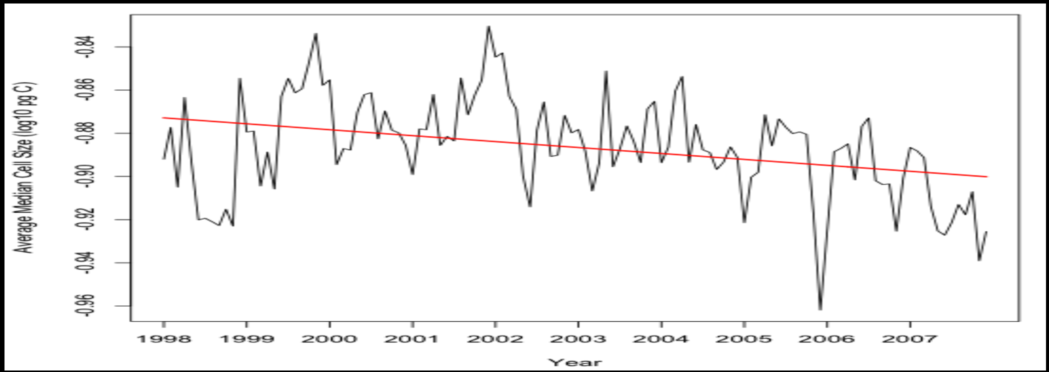
$$\log_{10}(M_{B50}) = 1.340 - 0.043(SST) + 0.929(\log_{10}(Chl)).$$



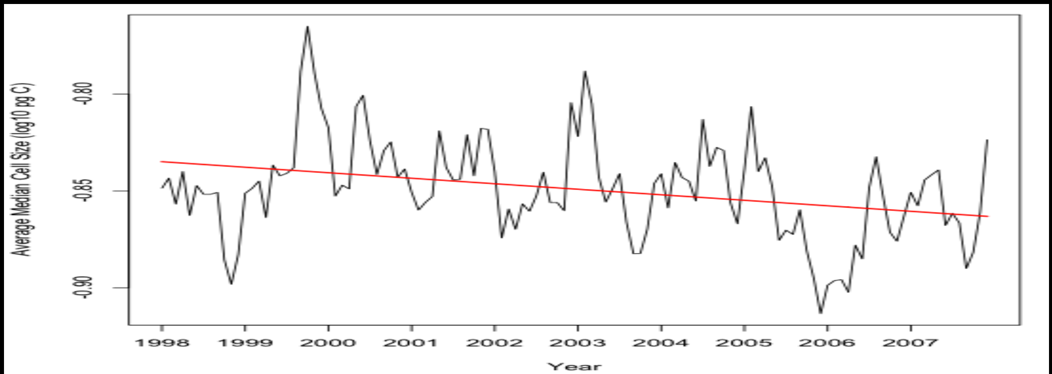
Barnes, C.,X. Irigoien, J. A. A. De Oliveira, D. Maxwell, and S. Jennings. 2010. Predicting marine phytoplankton community size structure from empirical relationships with remotely sensed variables. *J. Plankt. Res* **33(1):13-24.**

Declines in estimated median phytoplankton cell size (Log(wt)) 10º-30º N latitude

North Pacific



South Pacific



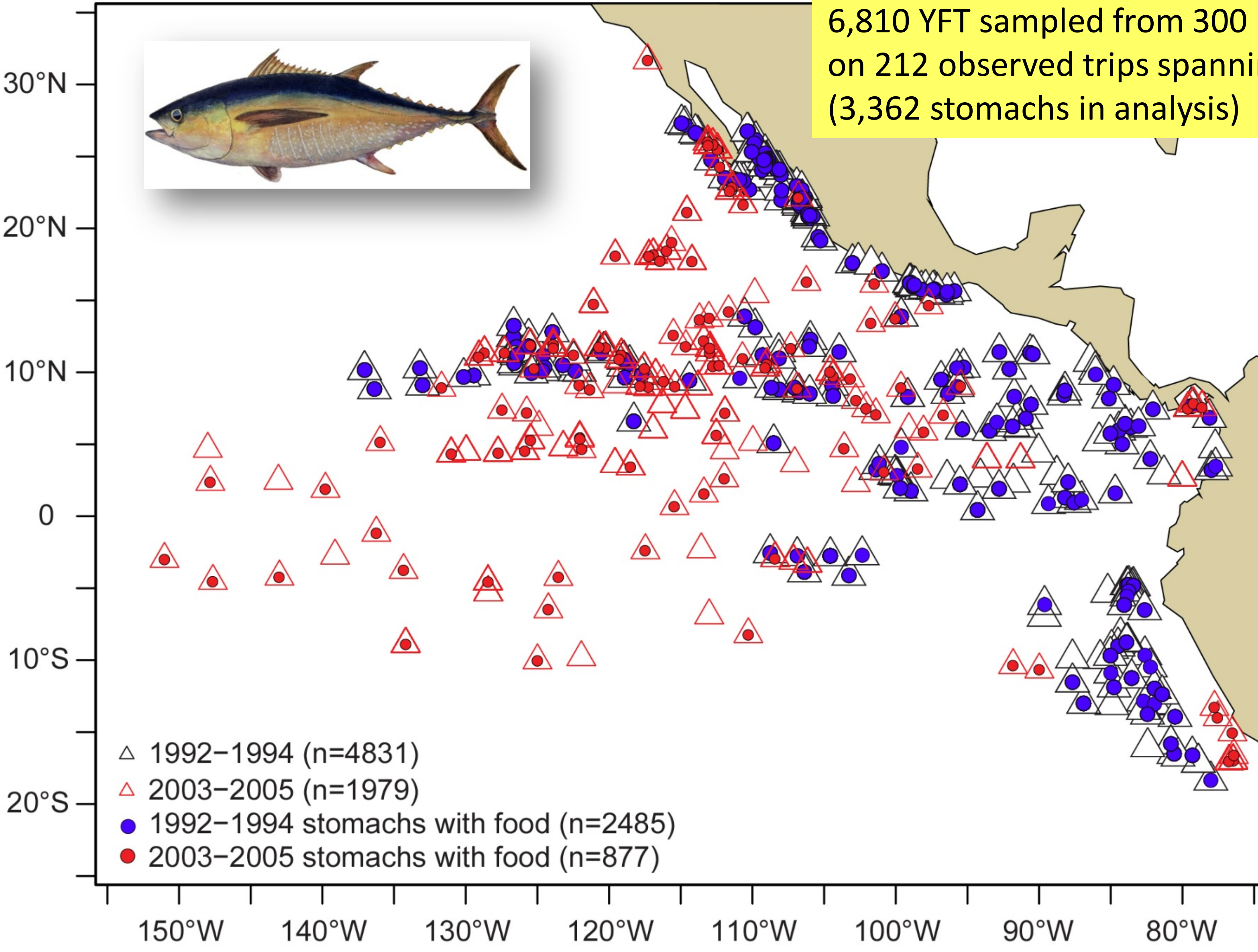
Polovina, J.J., and P.A. Woodworth. 2012. Declines in phytoplankton cell size in the subtropical oceans estimated from satellite remotely-sensed temperature and chlorophyll, 1998–2007. Deep-Sea Res Pt II. 77-80: 89-98.

Generalist predators as biological samplers

- Ubiquitous predators
- High energy requirements
- Energy limited (bioenergetics, growth)
- Low prey size selectivity (large yellowfin)
- Diversity in YFT diet in EPO mirrors broad-scale species diversity patterns described in literature.

Set locations, yellowfin tuna diet study (1990s, 2000s)

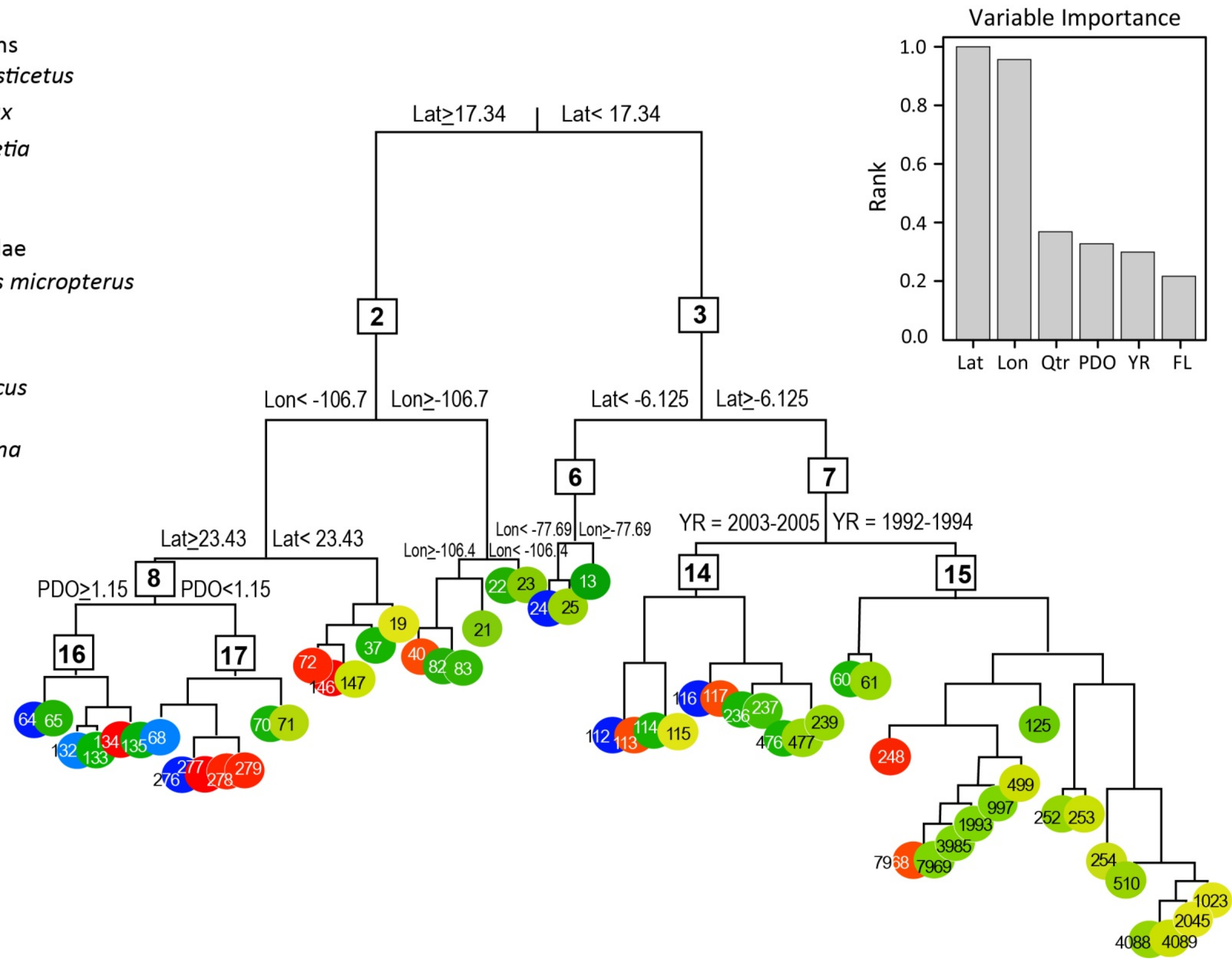
6,810 YFT sampled from 300 PS sets on 212 observed trips spanning 4 years. (3,362 stomachs in analysis)



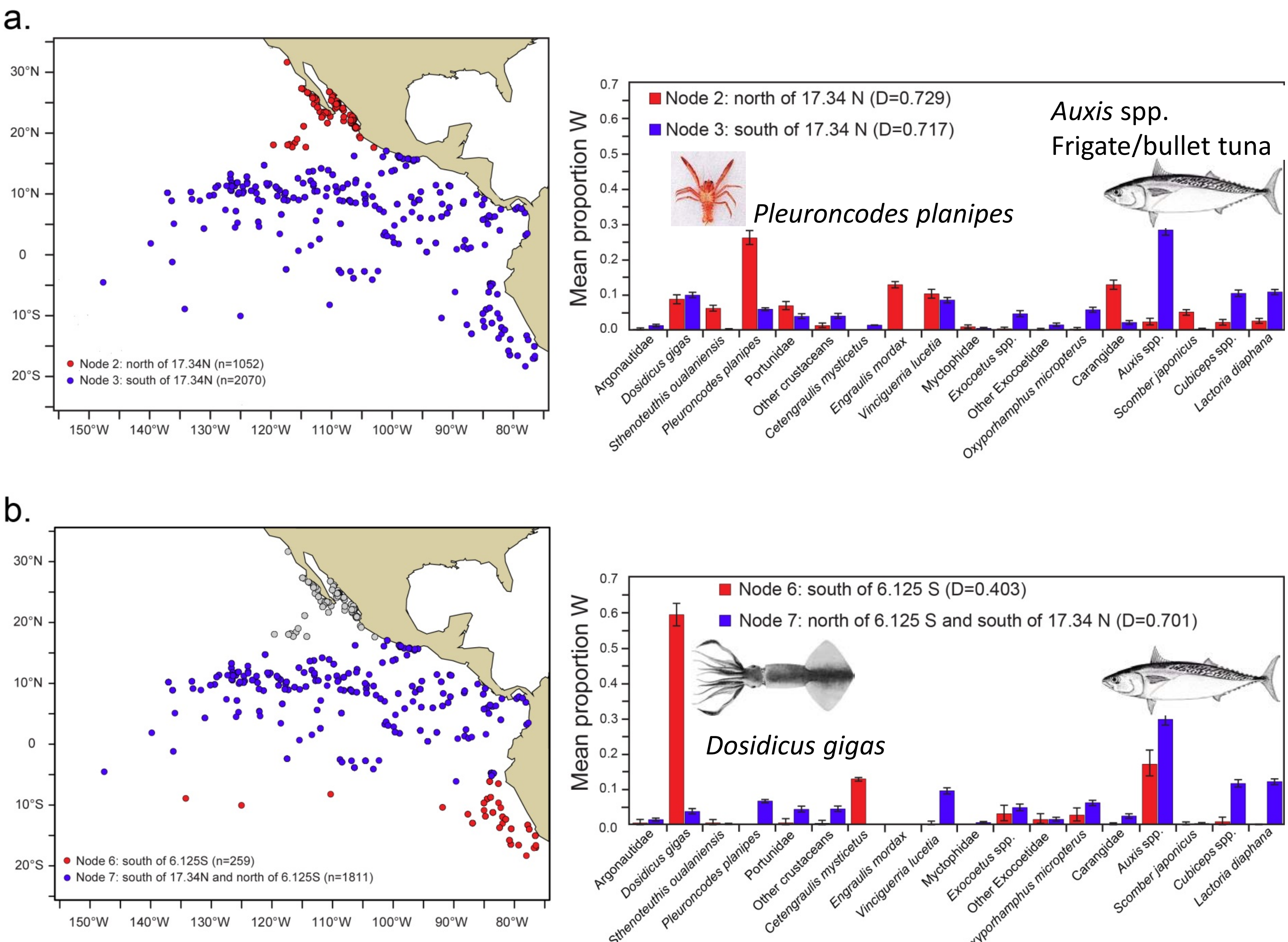
Classification Tree Analysis: 1 SE tree

- Argonautidae
- *Dosidicus gigas*
- *Sthenoteuthis oualaniensis*
- *Pleuroncodes planipes*
- Portunidae
- Other crustaceans
- *Cetengraulis mysticetus*
- *Engraulis mordax*
- *Vinciguerria lucetia*
- Myctophidae
- *Exocoetus* spp.
- Other Exocoetidae
- *Oxyporhamphus micropterus*
- Carangidae
- *Auxis* spp.
- *Scomber japonicus*
- *Cubiceps* spp.
- *Lactoria diaphana*

1 SE tree.
Cross-validated error rate low: 0.376,
R^2 = 62%



Classification tree analysis: first 2 splits



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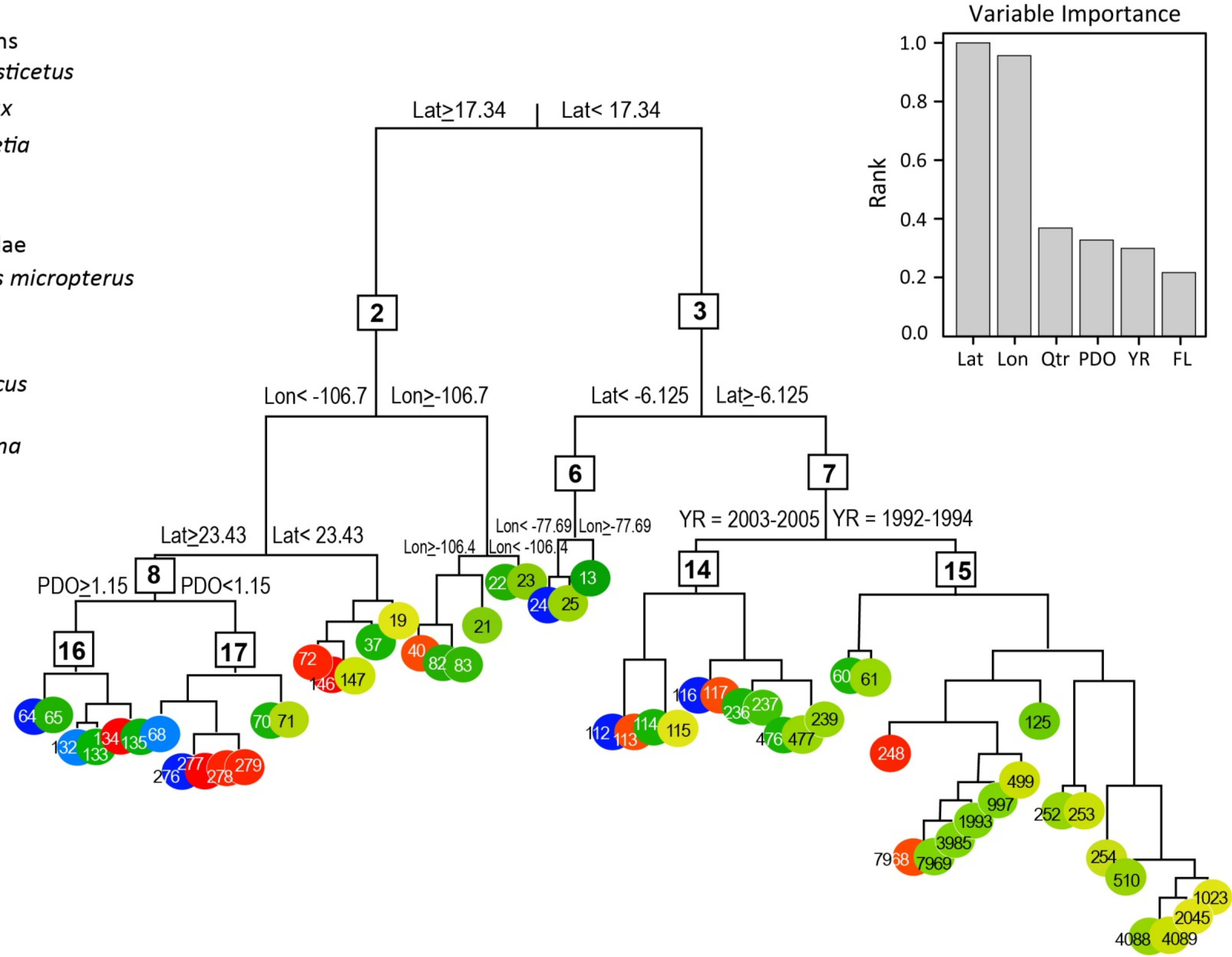
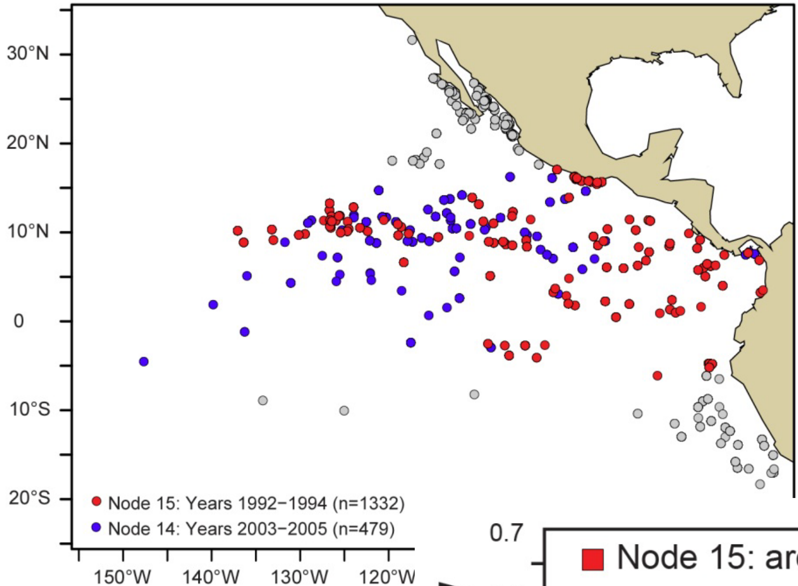
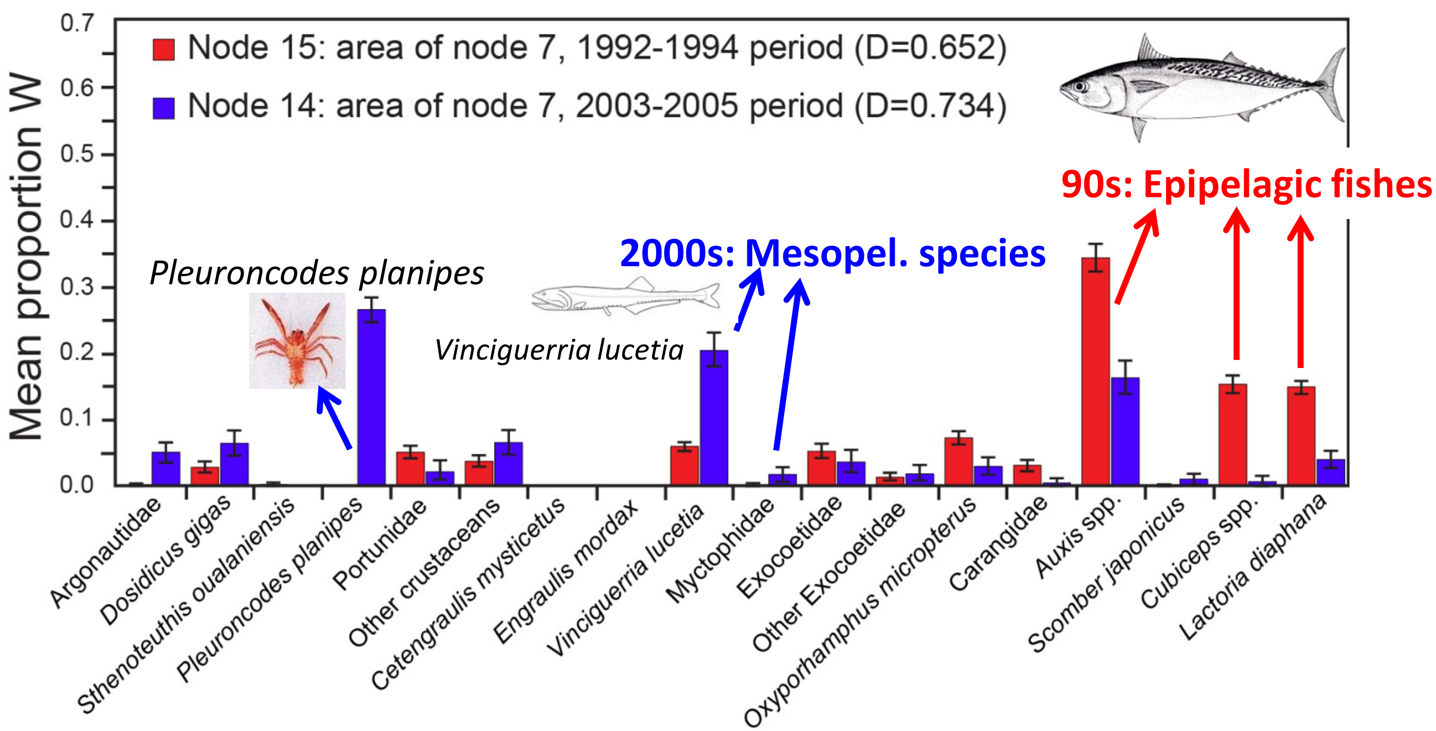
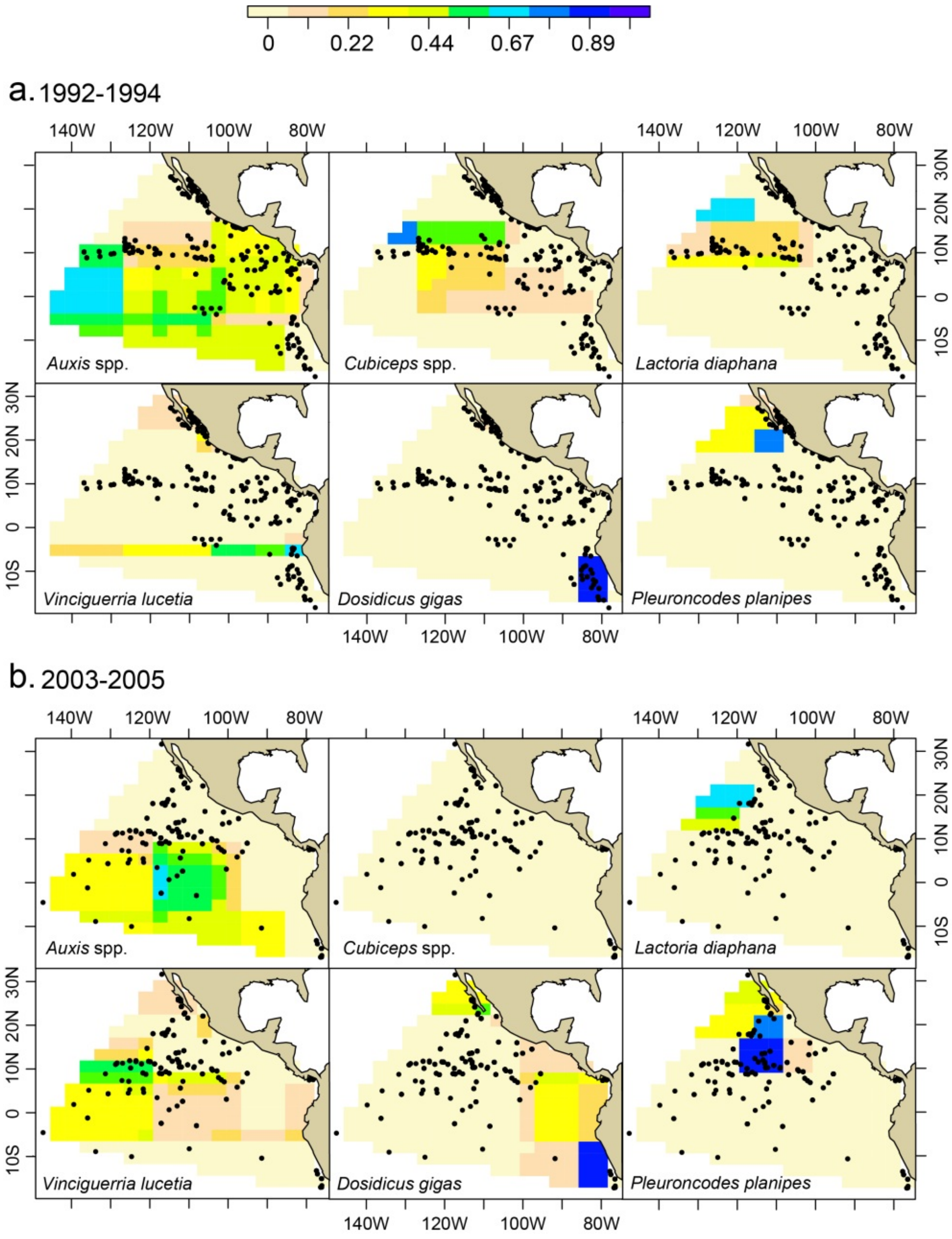


Classification tree analysis: split on node 7

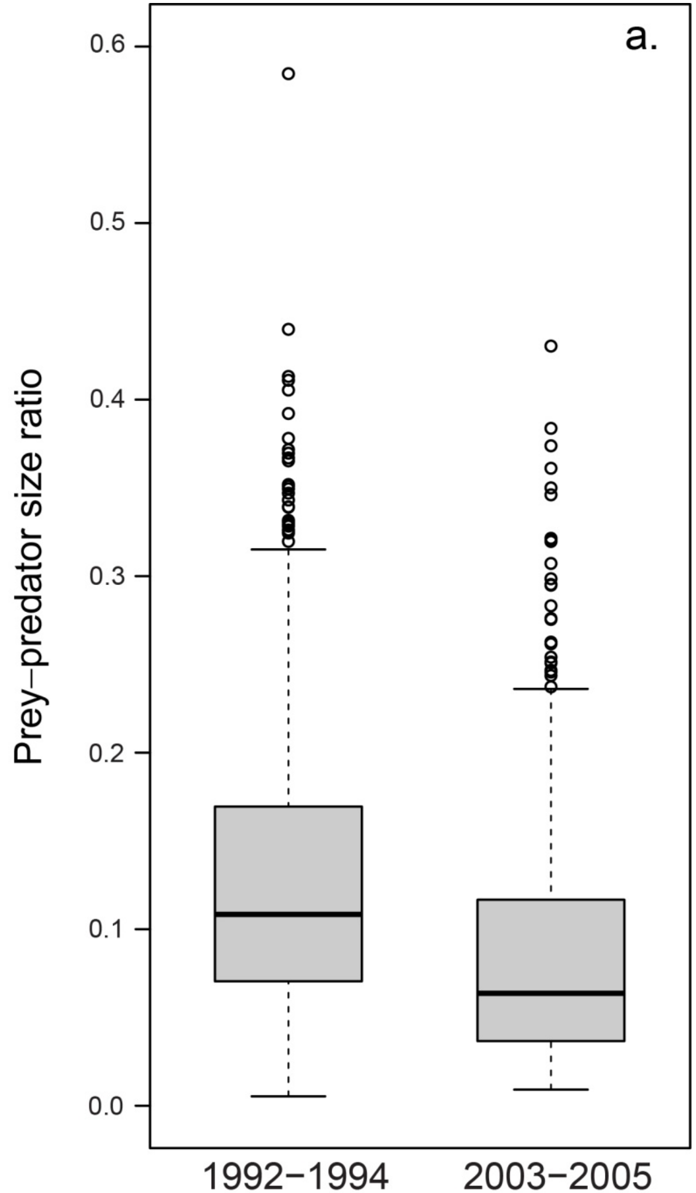




Spatial partial dependence plots

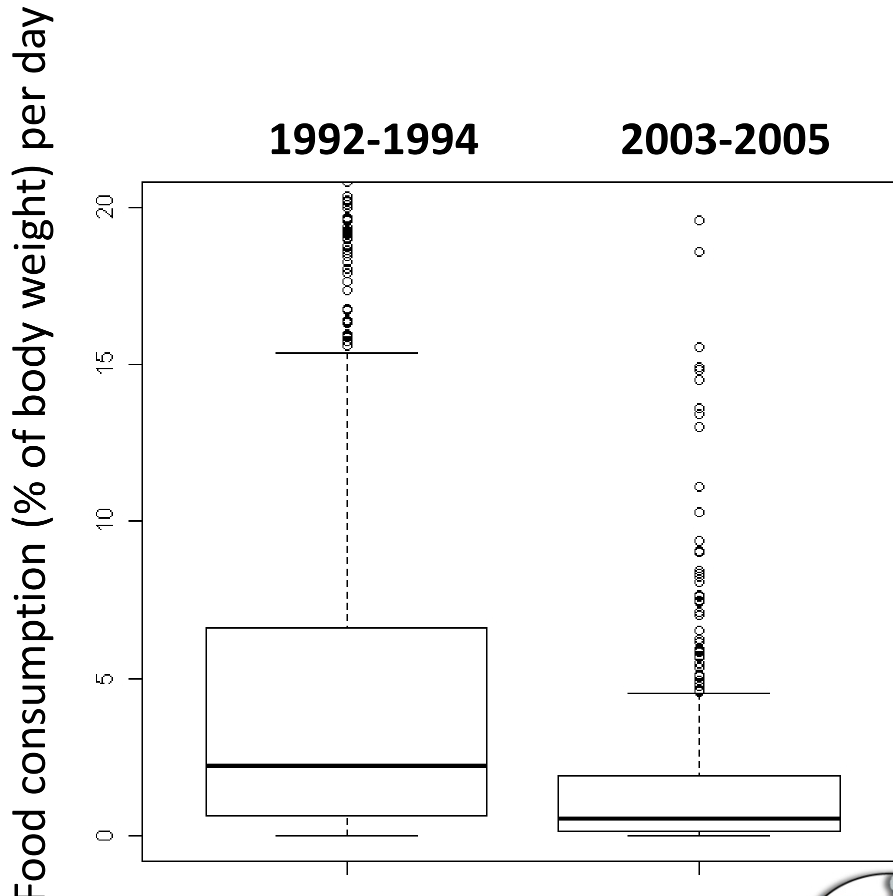


Prey size distributions



Daily rations

1992-1994 2003-2005



Conclusions

- Physical changes in the pelagic EPO
  - Oxygen Minimum Zone expansion & shoaling
  - Primary production decreasing
  - Ocean temperatures rising
- The pelagic food web is changing
  - Phytoplankton communities are changing, smaller cell sizes
  - Prey community has changed/is changing.