Ecosystem Considerations in the eastern Pacific Ocean

Robert Olson

Scientific Advisory Committee, 2nd Meeting

2ª Reunión del Comité Científico Asesor

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Document SAC-02-12, IATTC Fishery Status Report

INTER-AMERICAN TROPICAL TUNA COMMISSION

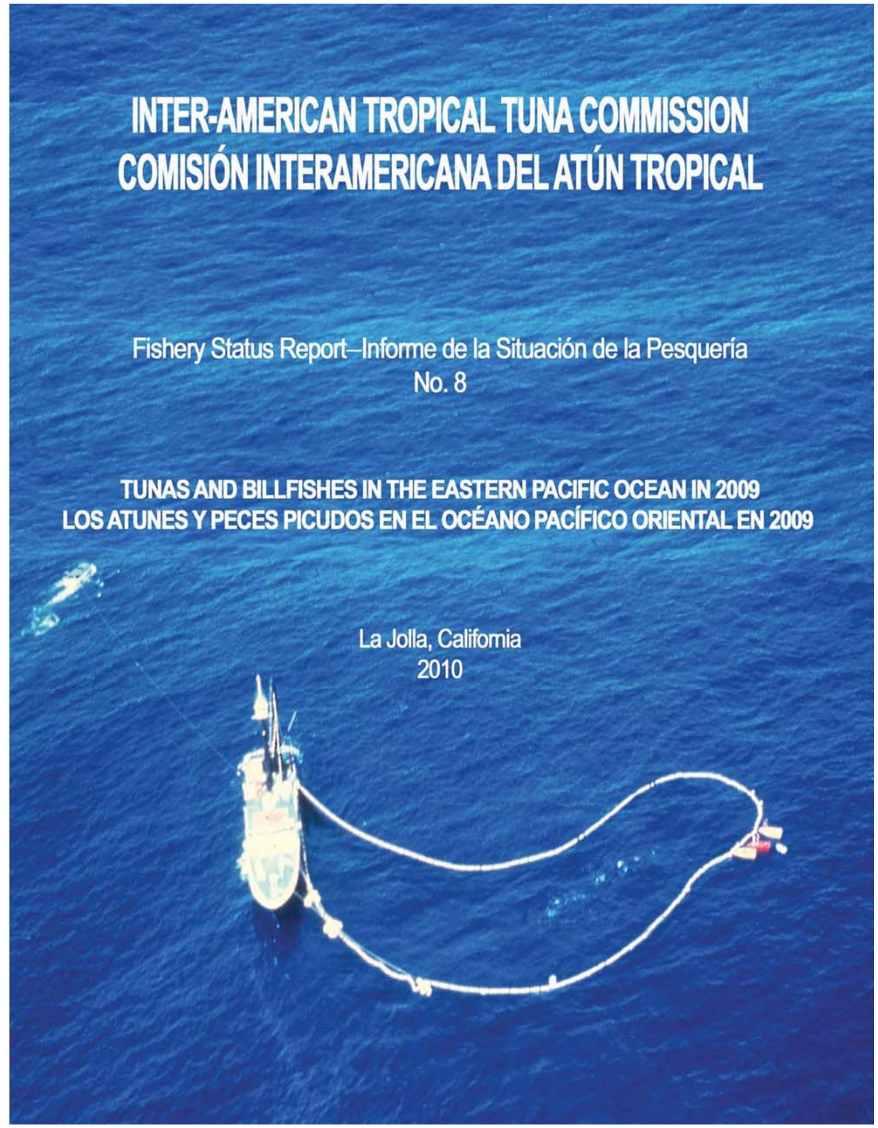
SCIENTIFIC ADVISORY COMMITTEE

2ND MEETING

La Jolla, California (USA)
9-12 May 2011

DOCUMENT SAC-02-12

ECOSYSTEM CONSIDERATIONS



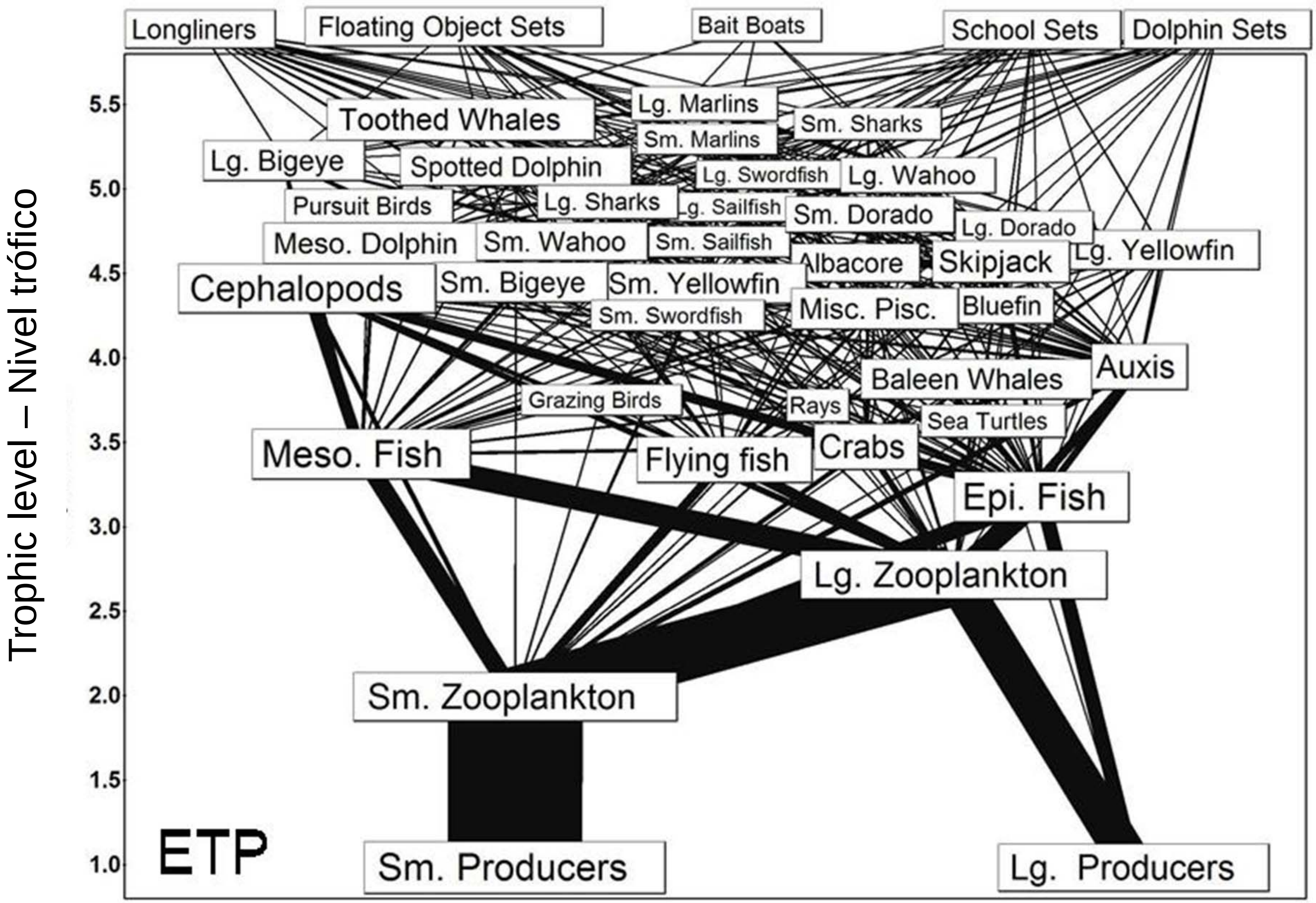
Talk outline – Ecosystem change

- Studies of ecosystem structure and function are important.
- Ecosystem change over time. Three scales: 1. stock assessments, 2. large scale biological oceanography, 3. diet shift in yellowfin tuna.
- YFT diet data show important changes over decadal scale. Justify YFT as effective biological samples of mid-trophic taxa.
- Daily rations (consumption rates) of YFT decreased over decade.
- Prey size of YFT decreased over decade.
- Trophic pathways in the EPO.
- Discuss possible mechanisms of change.
- Recommended research needs.

Food-web structure and function

- IATTC research largely focused on the structure and function of pelagic food web in the EPO.
  - Trophic structure represented in food webs is thought to be the central organizing concept in ecology (Martinez 1995).
  - Fishing has direct and indirect effects on ecosystems
    - Direct effects: e.g. bycatches of non-target species (some sensitive)
    - Indirect effects: predator-prey connections and competition via the food web
  - Anticipating changes induced by fishing requires understanding of food web structure and function.
  - Knowledge of <u>pelagic</u> food webs is still rudimentary, in many aspects

Food web of pelagic EPO (a hypothesis)



Olson, R.J., and G.M. Watters. 2003. A model of the pelagic ecosystem in the eastern tropical Pacific Ocean. Inter-American Tropical Tuna Commission, Bulletin 22 (3): 133-218.

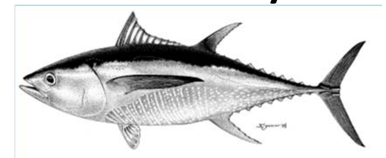
Eight ecosystem characteristics

US NMFS Ecosystem Principles Advisory Panel:

1. The ability to predict ecosystem behavior is limited
2. Ecosystems have thresholds and limits which, when exceeded, can effect major ecosystem restructuring
3. Once thresholds and limits have been exceeded, changes can be irreversible
4. Diversity is important to ecosystem functioning
5. Multiple scales interact within and among ecosystems
6. Components of ecosystems are linked
7. Ecosystem boundaries are open
8. Ecosystems change over time

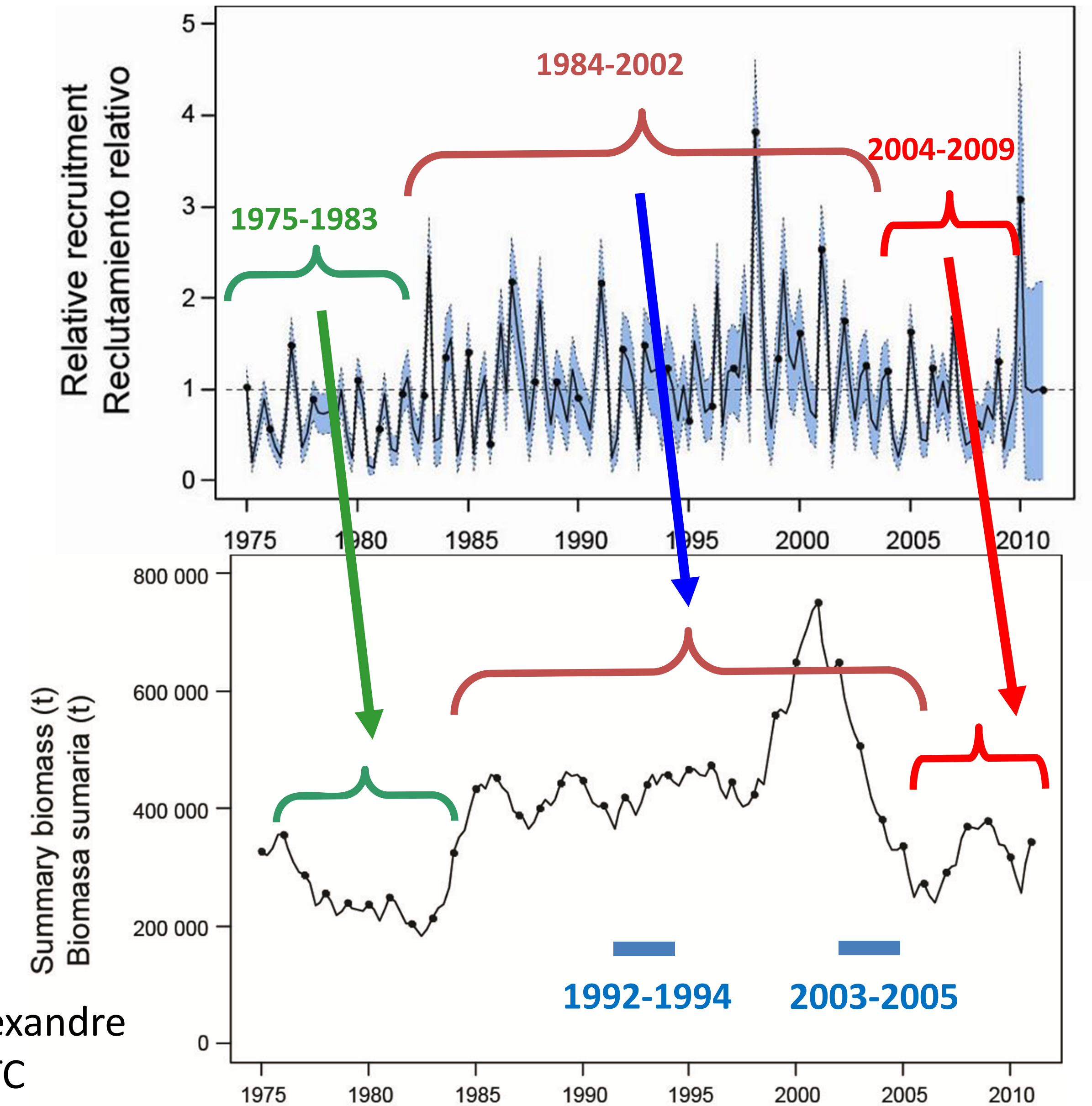
Scales of change

- Yellowfin stock assessments suggests changes in productivity regimes in the EPO
- Satellite oceanography shows large-scale ecosystem changes in productivity over time in Pacific Ocean
- Stomach-contents analysis shows decadal changes in yellowfin tuna diet in EPO. Does diet reflect changes in prey availability?



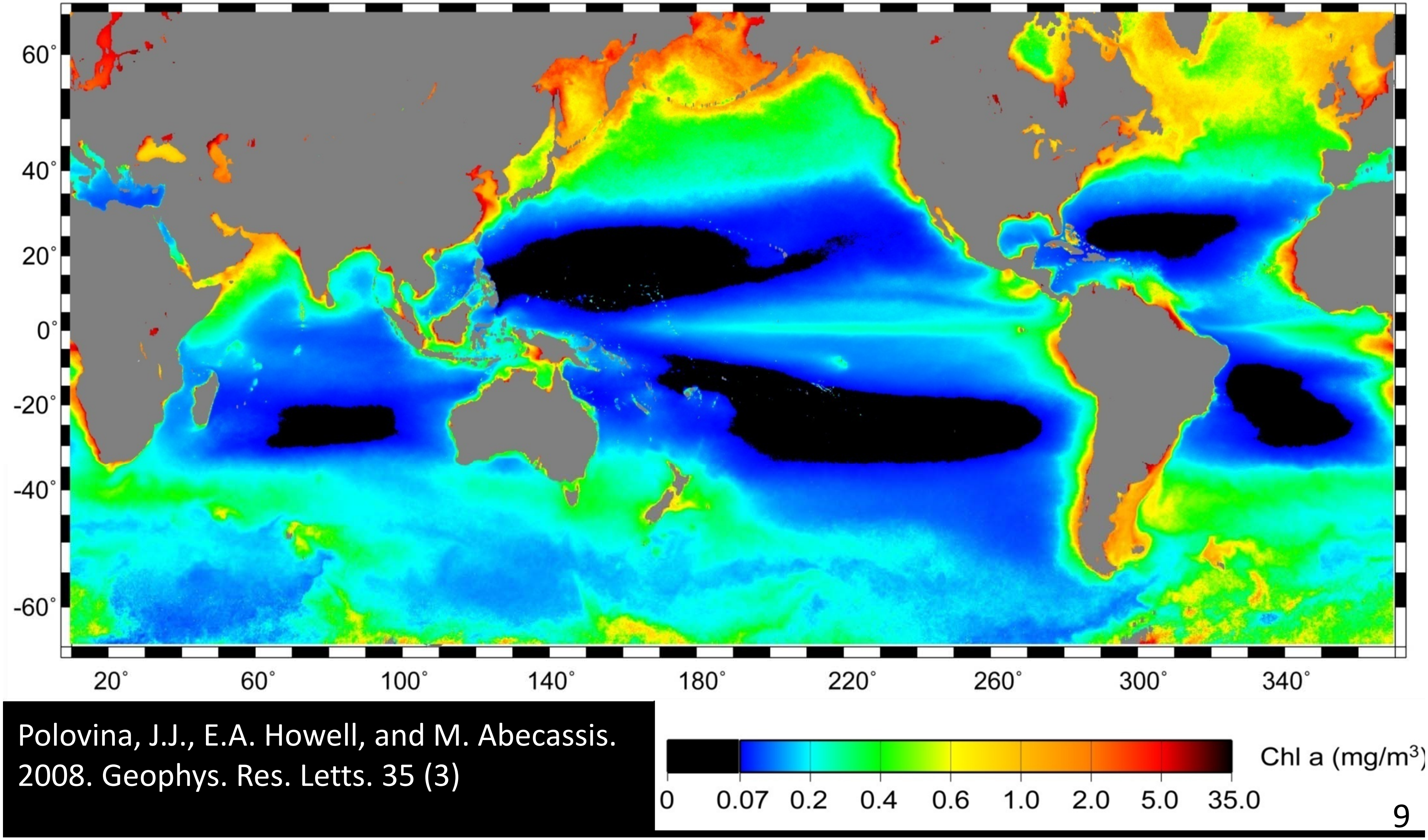
Summary: key results (cont.)

- The population may have recently switched from a high to a lower productivity regime



Compliments of Alexandre Aires-da-Silva , IATTC

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

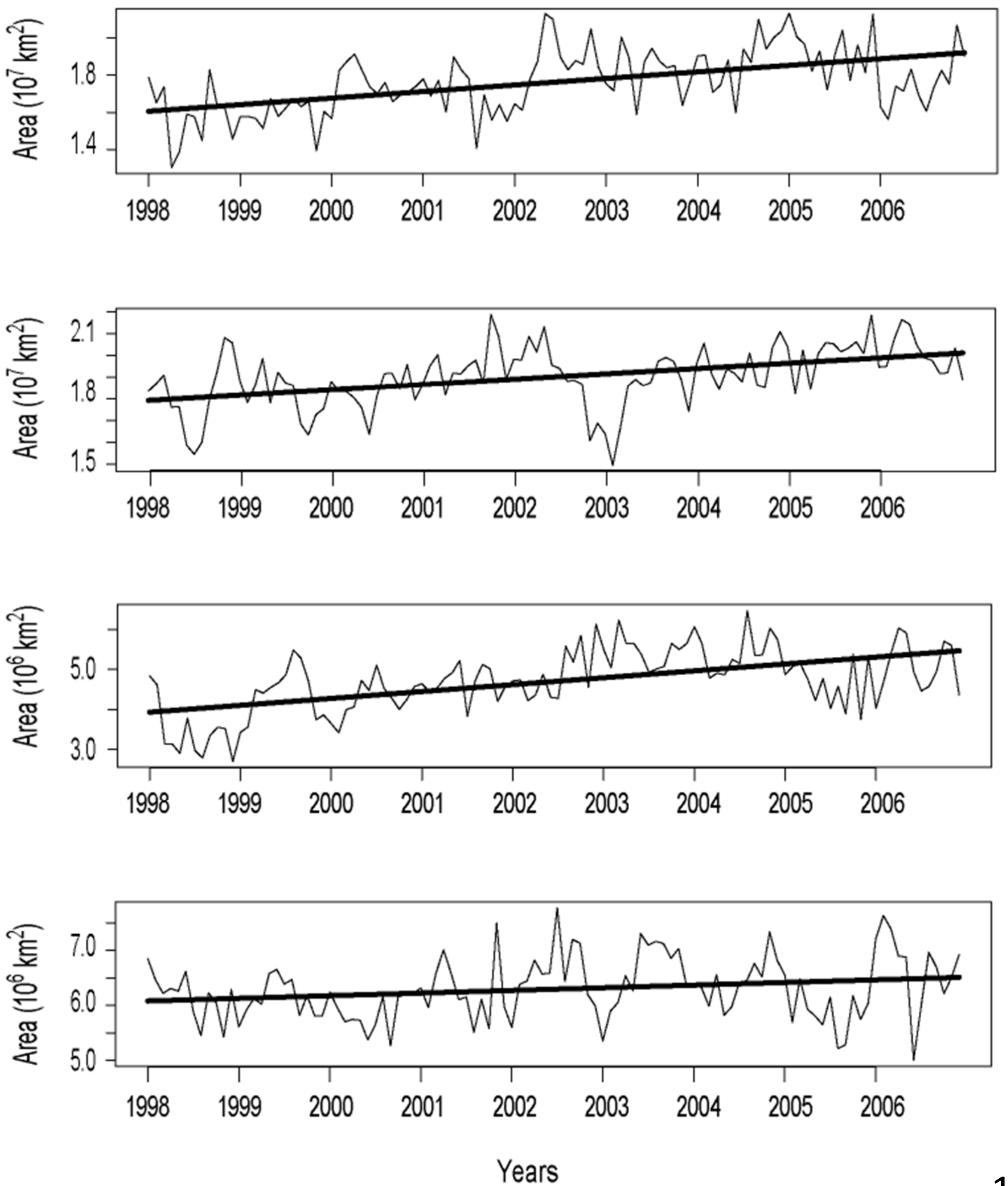
N Atlantic

4.3 %/y increase

S Atlantic

0.8 %/y increase

Polovina, et al. 2008

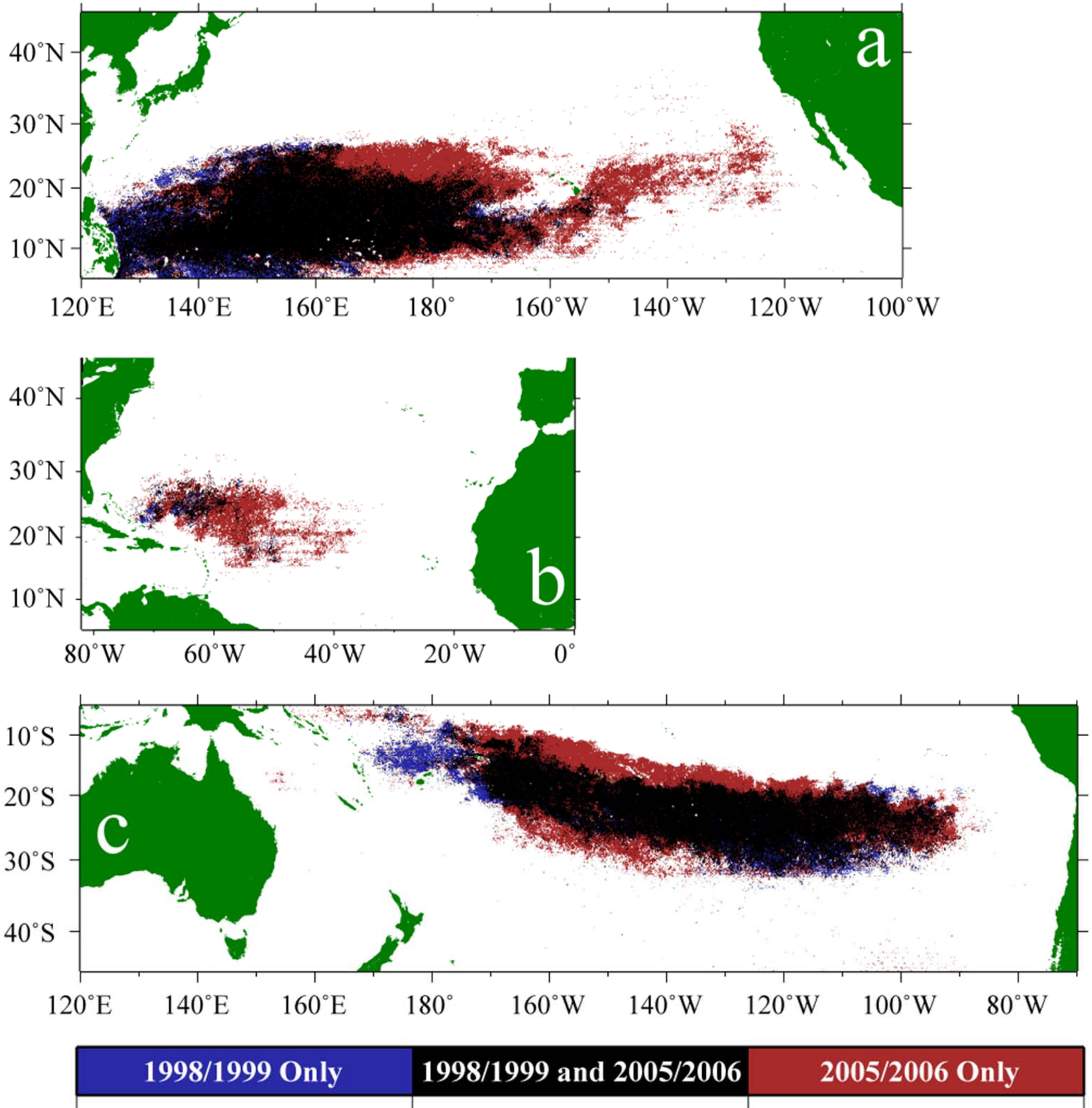


Changes in oligotrophic areas between 1998-1999 and 2005-2006 in December:

a) North Pacific,

b) North Atlantic, and August:

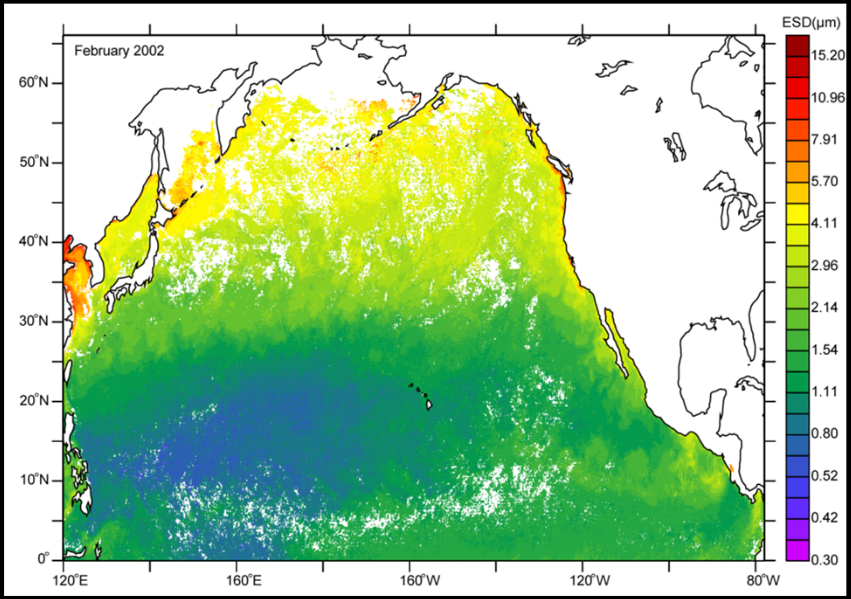
c) South Pacific



Polovina, et al. 2008

Estimation of phytoplankton cell size from satellite SST and Chlorophyll

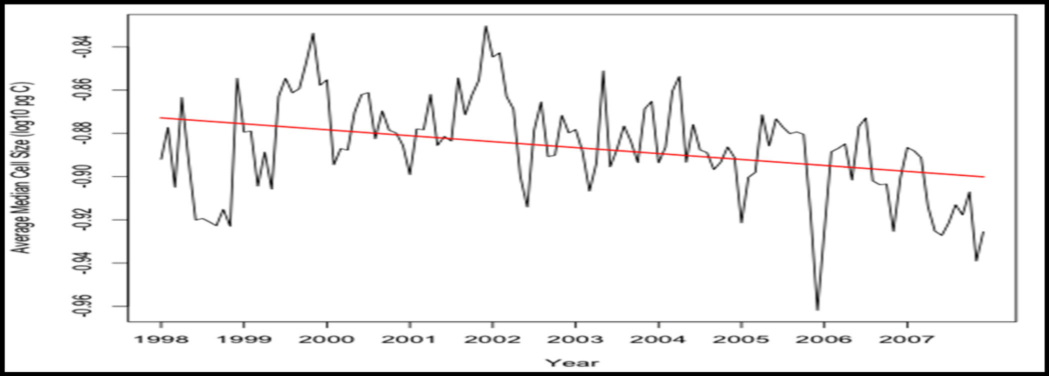
$$\log_{10}(M_{B50}) = 1.340 \ -0.043(SST) + 0.929(\log_{10}(Chl)).$$



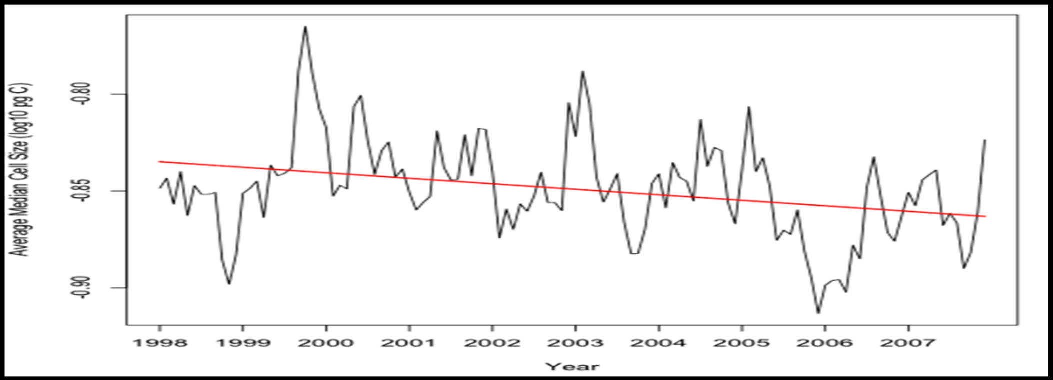
Barnes, C.,X. Irigoien, J. A. A. De Oliveira, D. Maxwell, and S. Jennings. 2010. Predicting marine phytoplankton community size structure from empirical relationships with remotely sensed variables. *J. Plankt. Res* **33(1):13-24.**

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

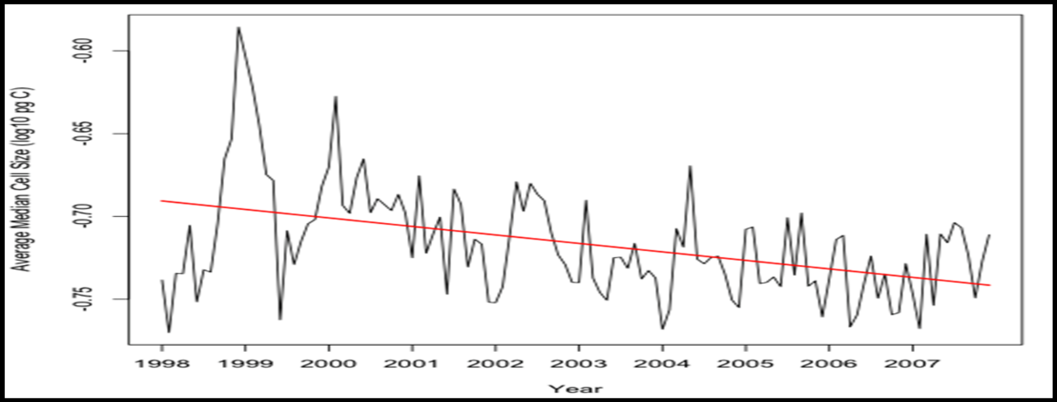
N Pacific



S Pacific

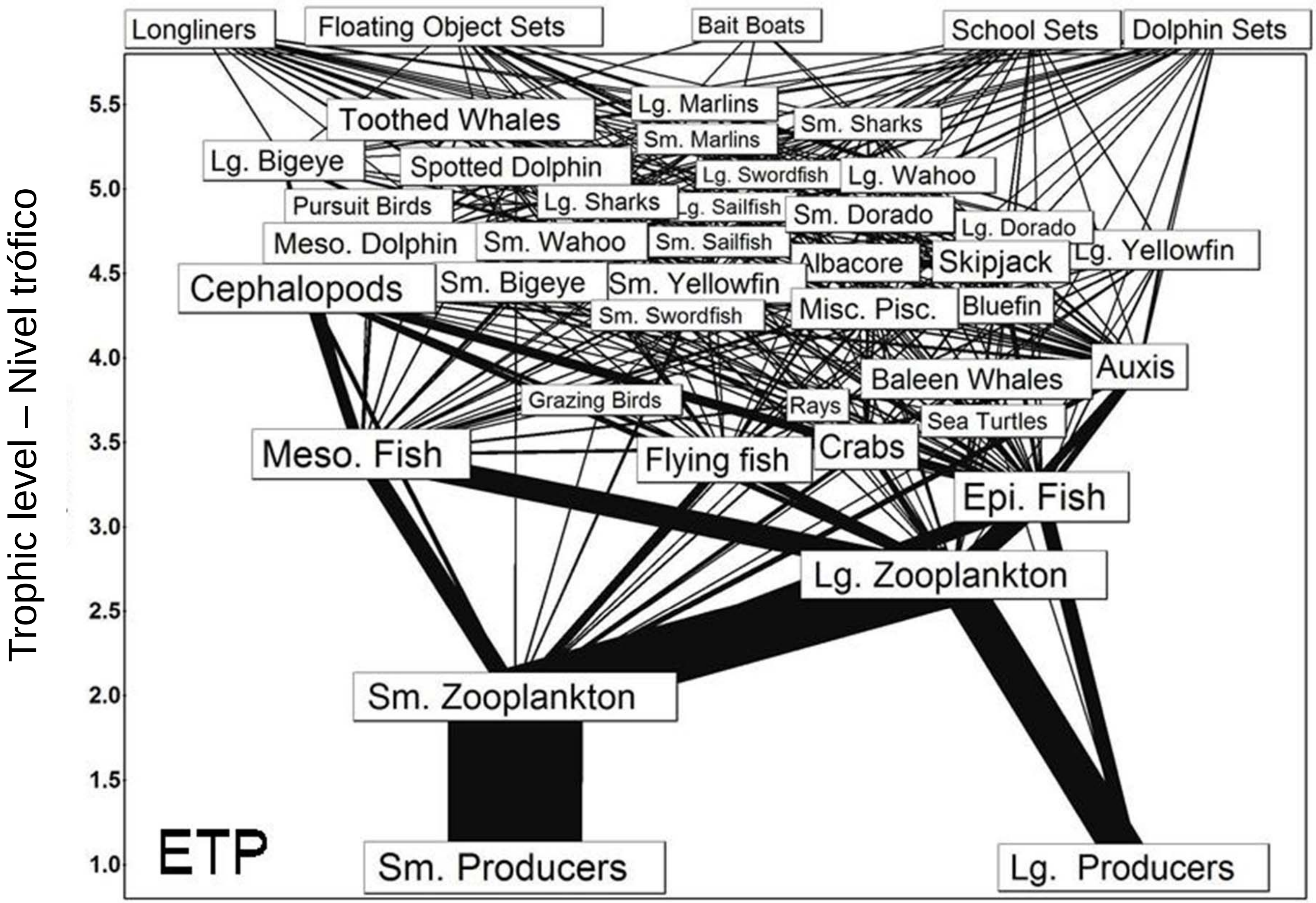


N Atlantic

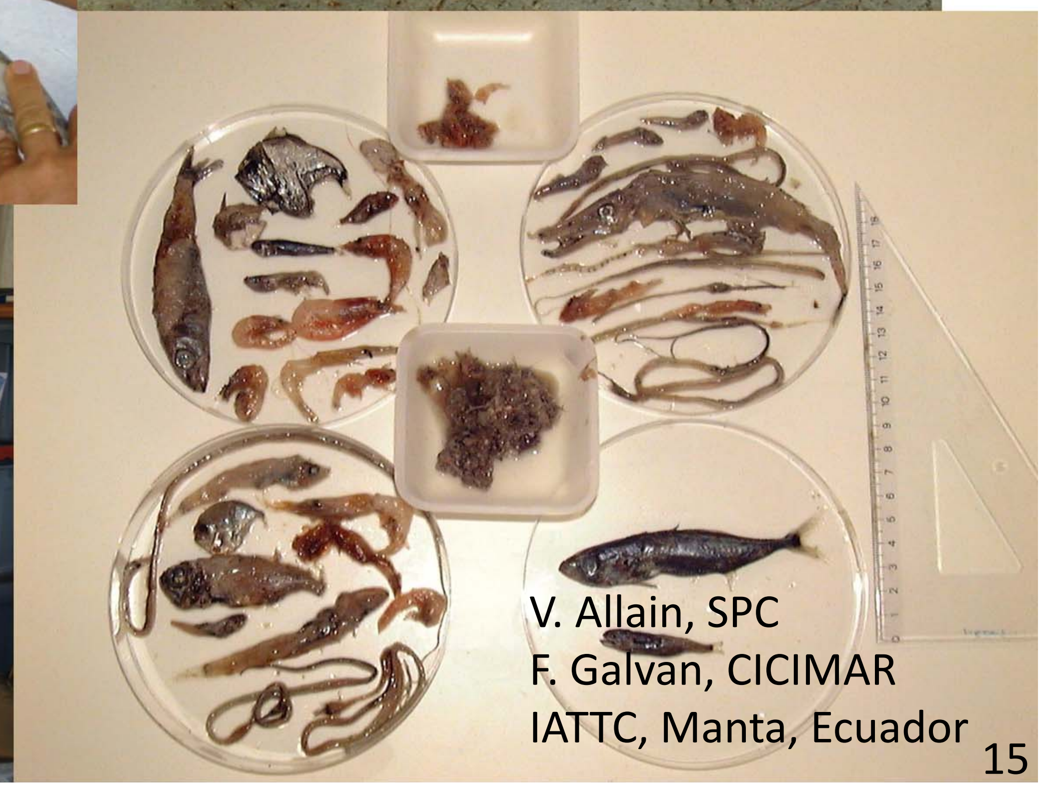


Polovina and Woodworth, In prep.

Why is phytoplankton cell size important?



Stomach-contents analysis (species identification) (and monitoring)



V. Allain, SPC
F. Galvan, CICIMAR
IATTC, Manta, Ecuador

Yellowfin tuna diet studies

Two study periods: 1992-1994, 2003-2005.

Samples: Purse seine, observers at sea, frozen at sea.

Sample analysis: Laboratory based: IATTC La Jolla, CICIMAR La Paz México, IATTC Cumaná Venezuela, IATTC Manta Ecuador.

Data analysis:

- Historically, lack of robust statistical methods.
- New classification tree methodology extended to fish diet data by Petra Kuhnert, CSIRO Australia and Leanne Duffy, IATTC.
  - Non-parametric
  - Explanatory covariates explain variation of a response variable (prey groups % weight), by repeatedly partitioning the data into groups that are as homogenous as possible (minimize Gini index)
  - Trees pruned using 10-fold cross-validation (1-SE Rule)

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Classification tree analysis

Response variable

% W (18 dominant prey groups)

Cephalopods

- *Argonauta* spp.
- *Dosidicus gigas*
- *Sthenoteuthis oualaniensis*

Crustaceans

- *Pleuroncodes planipes*
- Portunidae family
- Other Crustaceans

Fishes

- *Cetengraulis mysticetus*
- *Engraulis mordax*
- Phosichthyidae family
- Myctophidae family
- *Exocoetus* spp.
- Other Exocoetids
- *Oxyporhamphus micropterus*
- Carangidae family
- *Auxis* spp.
- *Scomber japonicus*
- *Cubiceps* spp.
- *Lactoria diaphana*

Explanatory variables

- Year
- Quarter of year
- Latitude
- Longitude
- Yellowfin size
- Pacific Decadal Oscillation Index (PDO)

Other variables

- Set type
- Set time of day
- Yellowfin sex
- Stomach fullness
- Moon phase

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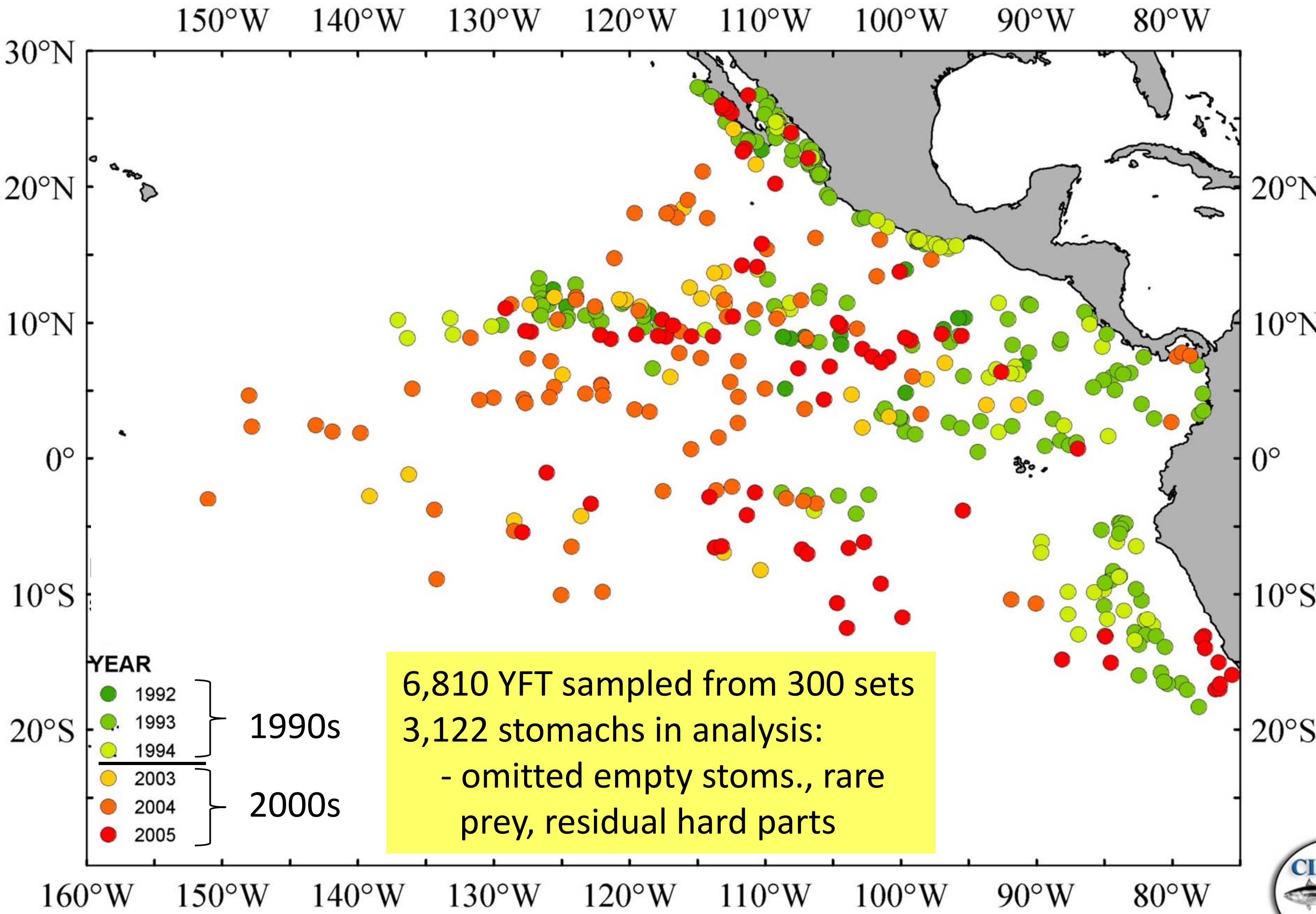
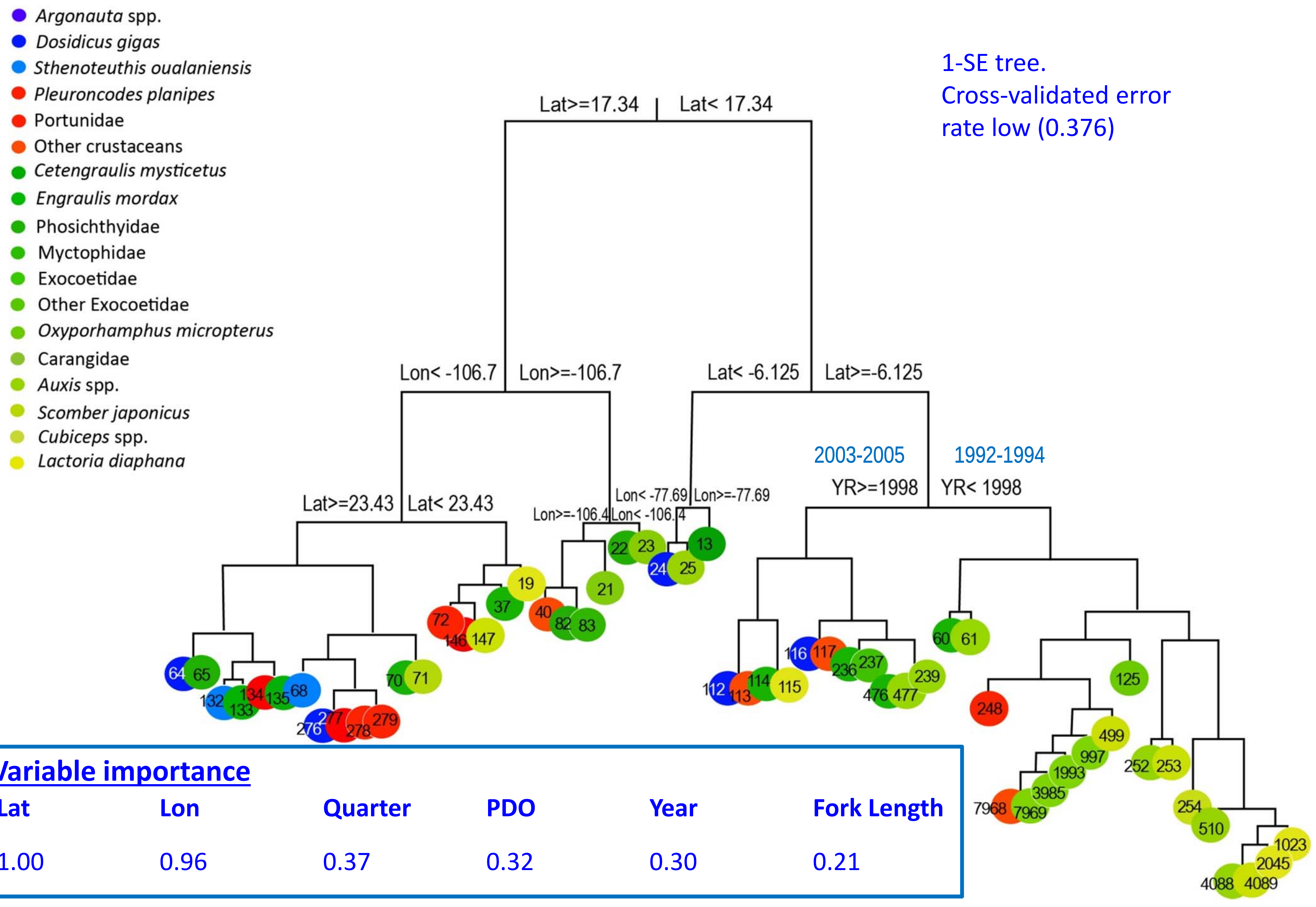
Set locations, yellowfin tuna diet study (1990s, 2000s)



6,810 YFT sampled from 300 sets
3,122 stomachs in analysis:
- omitted empty stoms., rare prey, residual hard parts

Classification Tree Analysis: 1-SE tree

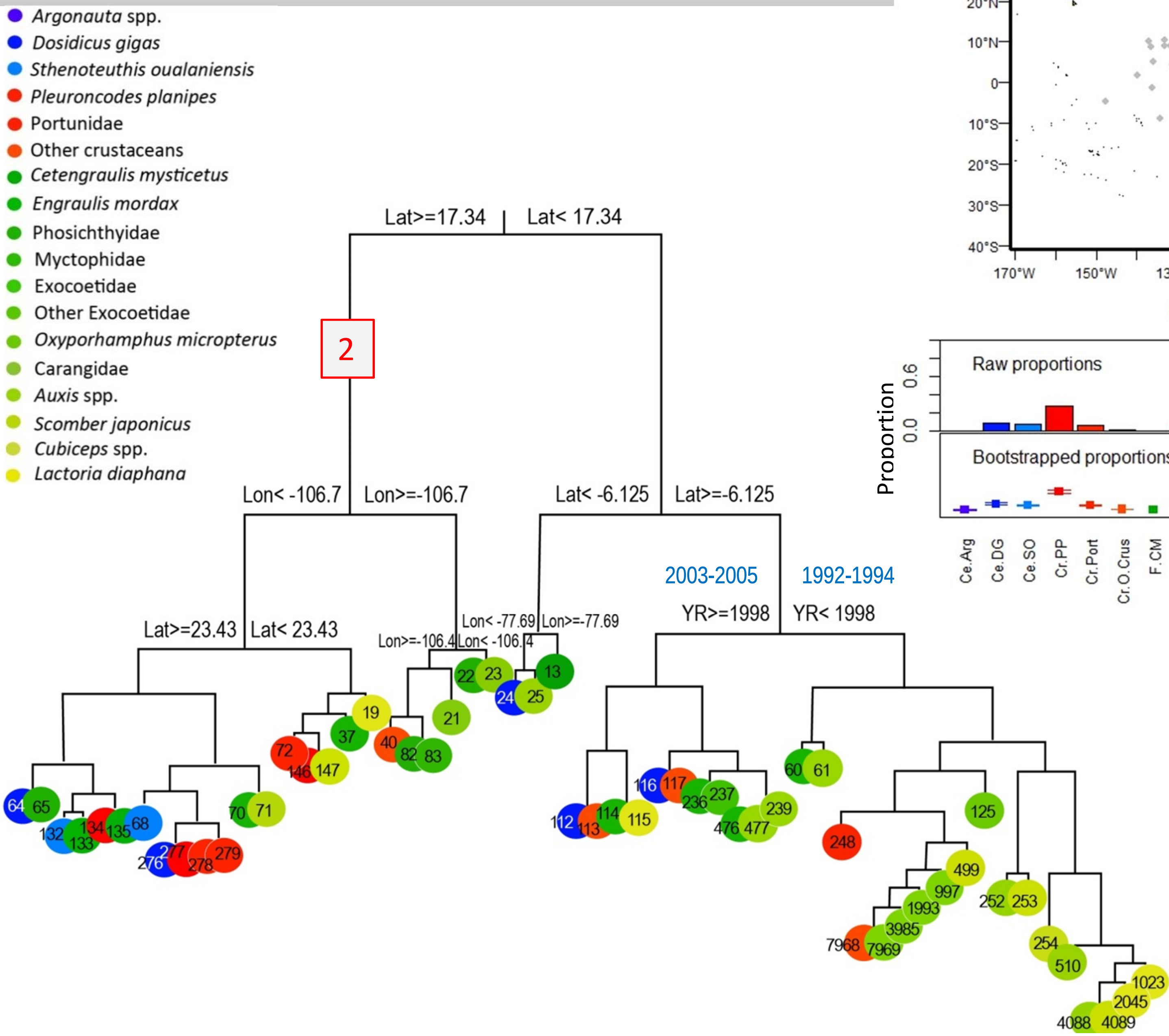


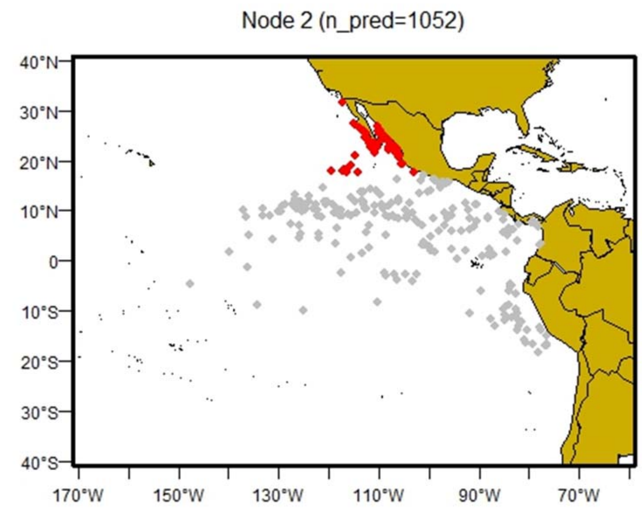
1-SE tree.
Cross-validated error rate low (0.376)

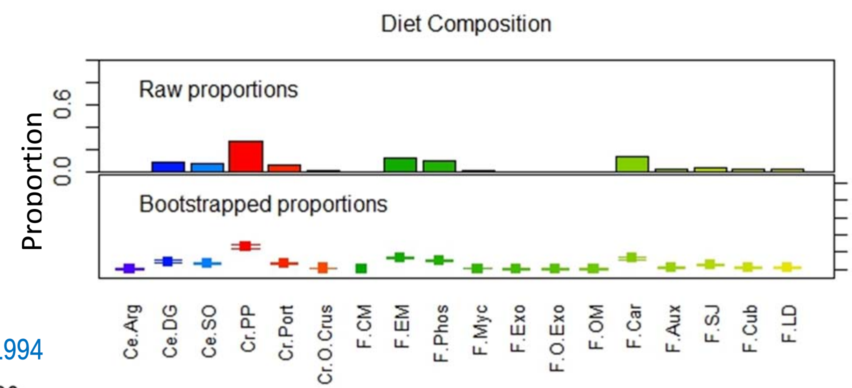
Variable importance

Lat	Lon	Quarter	PDO	Year	Fork Length
1.00	0.96	0.37	0.32	0.30	0.21

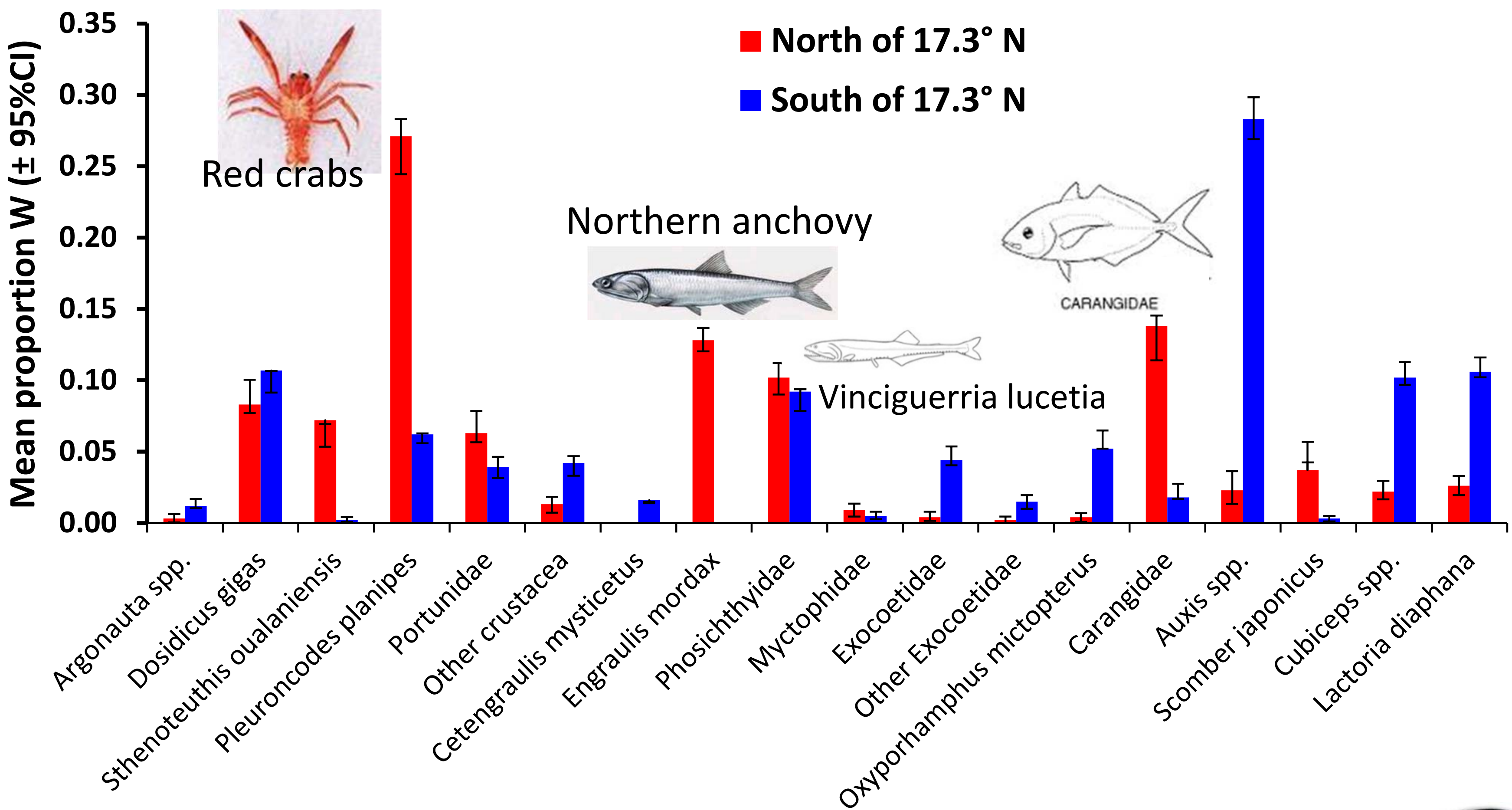
Classification Tree Analysis



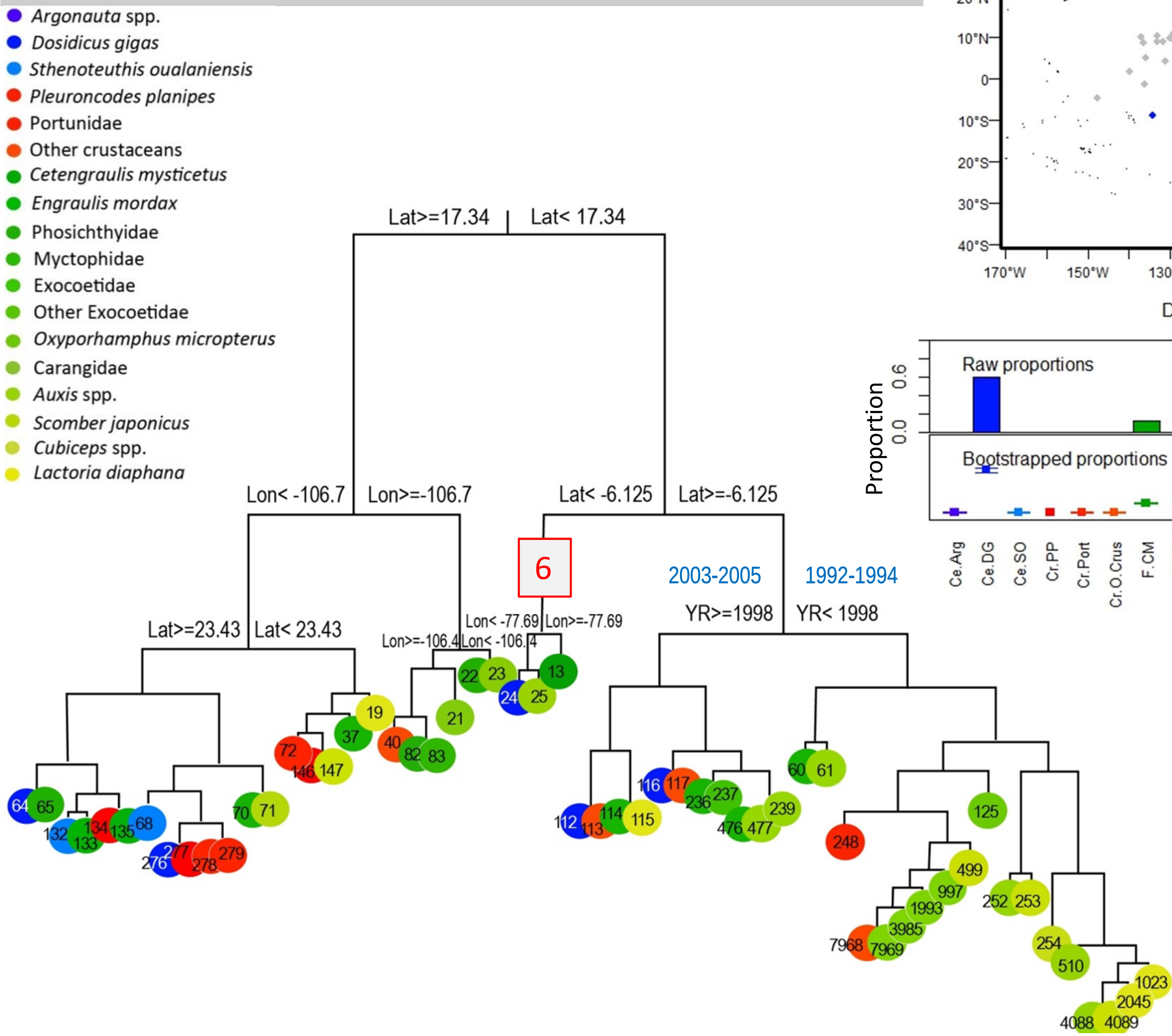


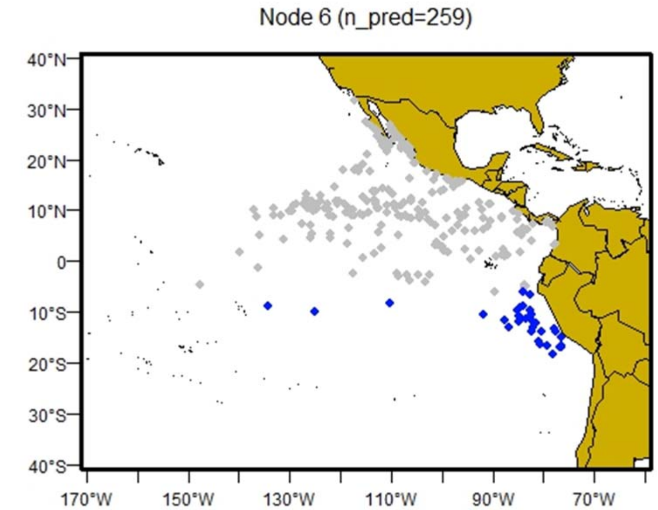


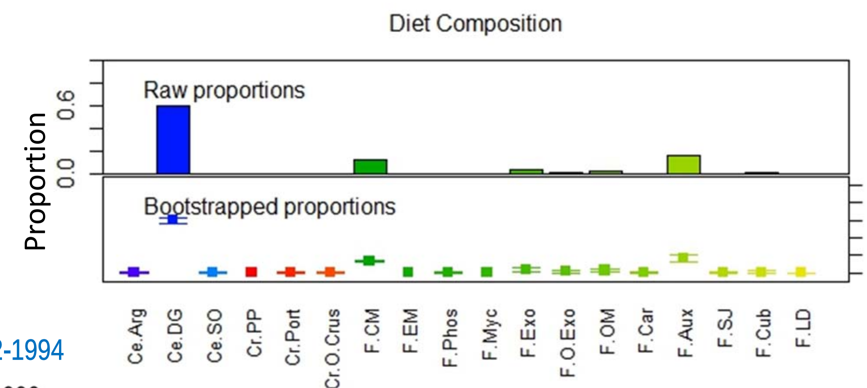
Yellowfin tuna diet composition at first split



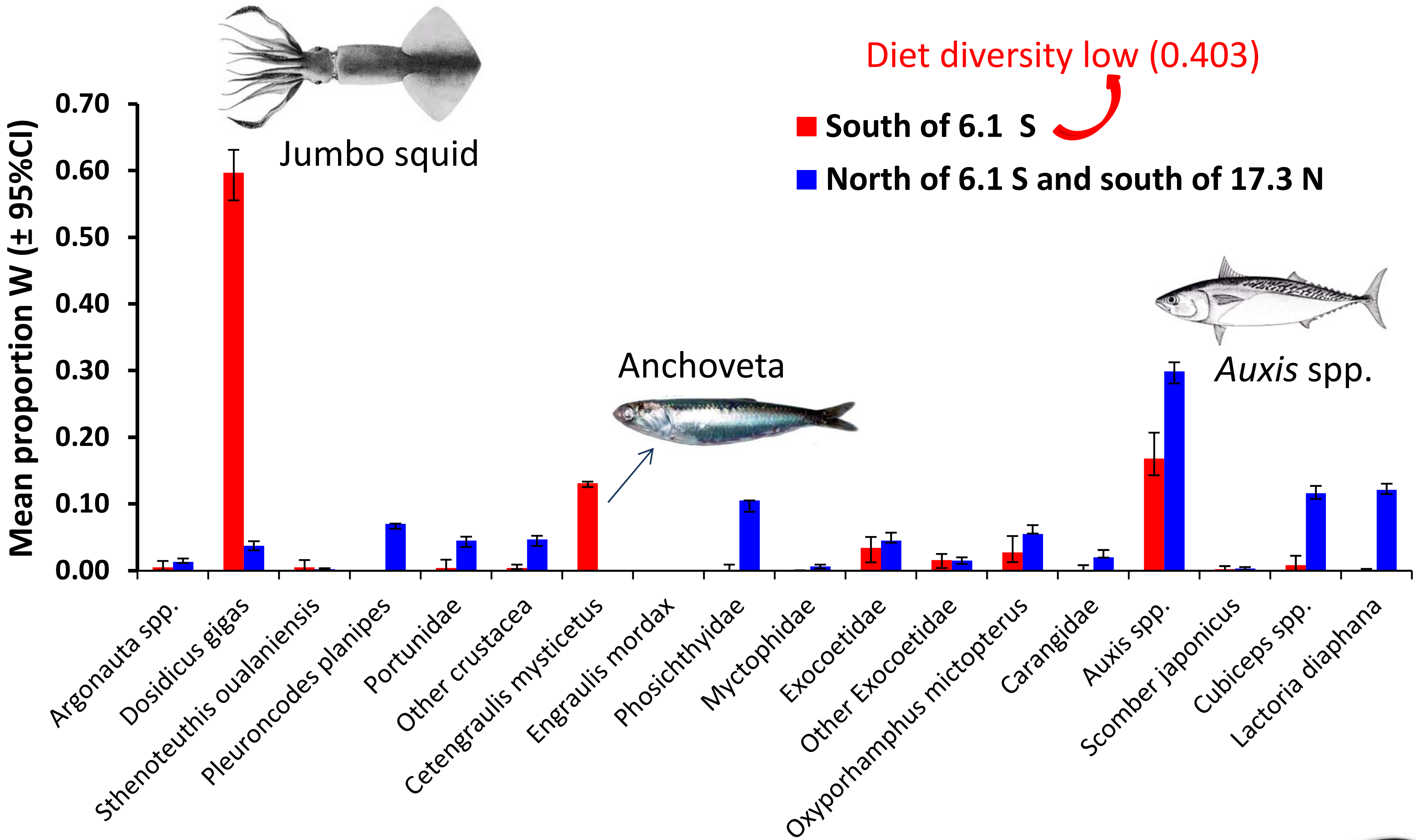
Node 6: south of 6.1° S



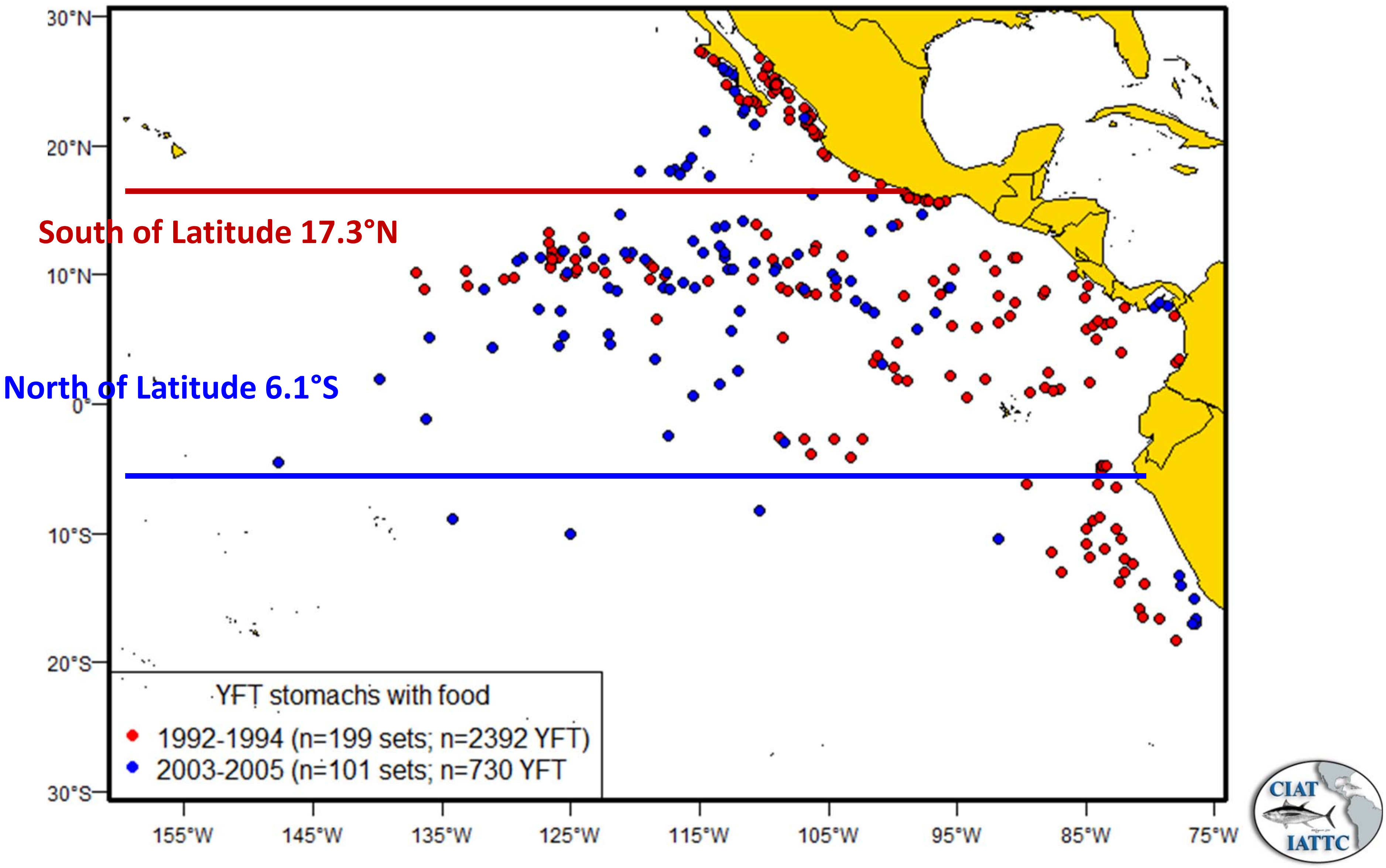




Yellowfin tuna diet composition at Nodes 6 & 7

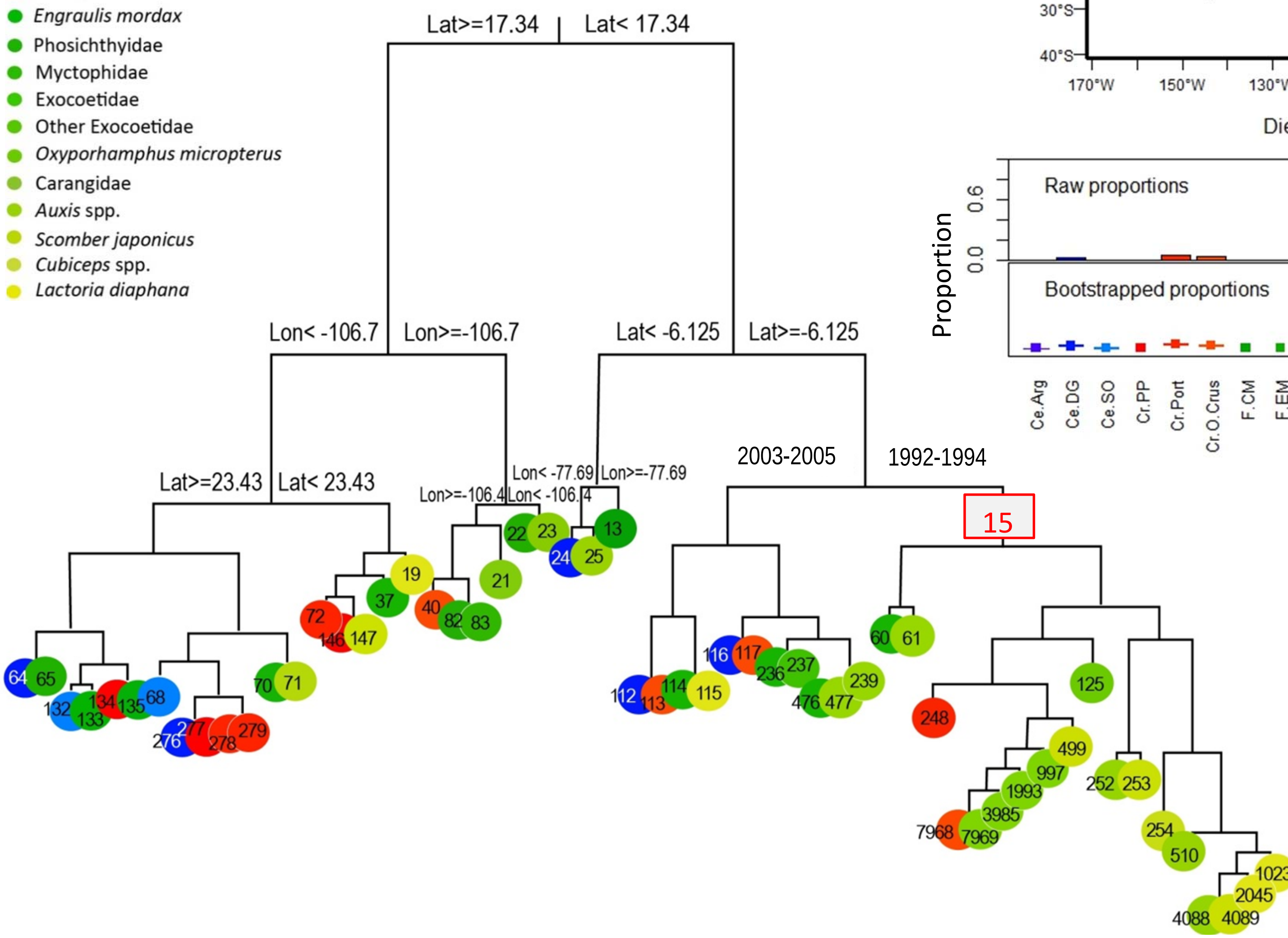


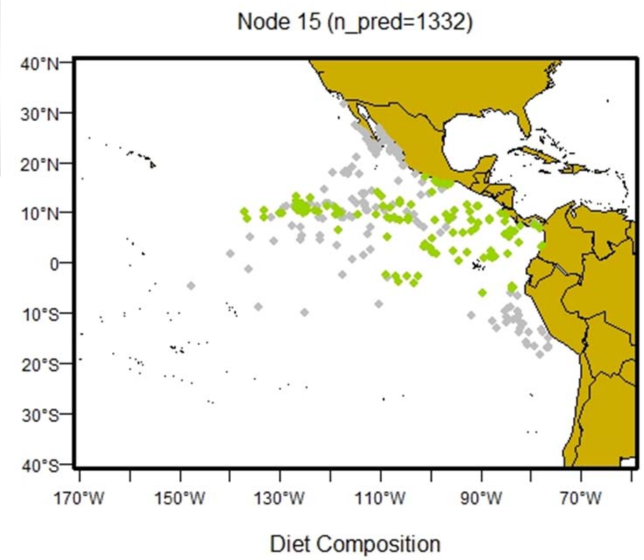
Yellowfin tuna stomach sample locations

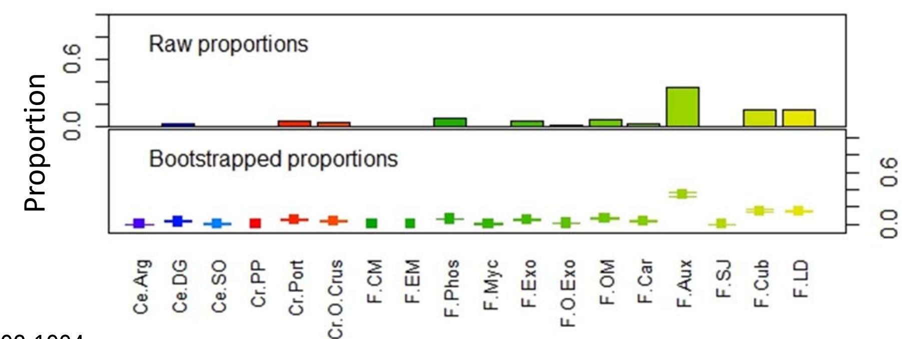


Node 15: bet 17.3 N & 6.1 S 1992-1994

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







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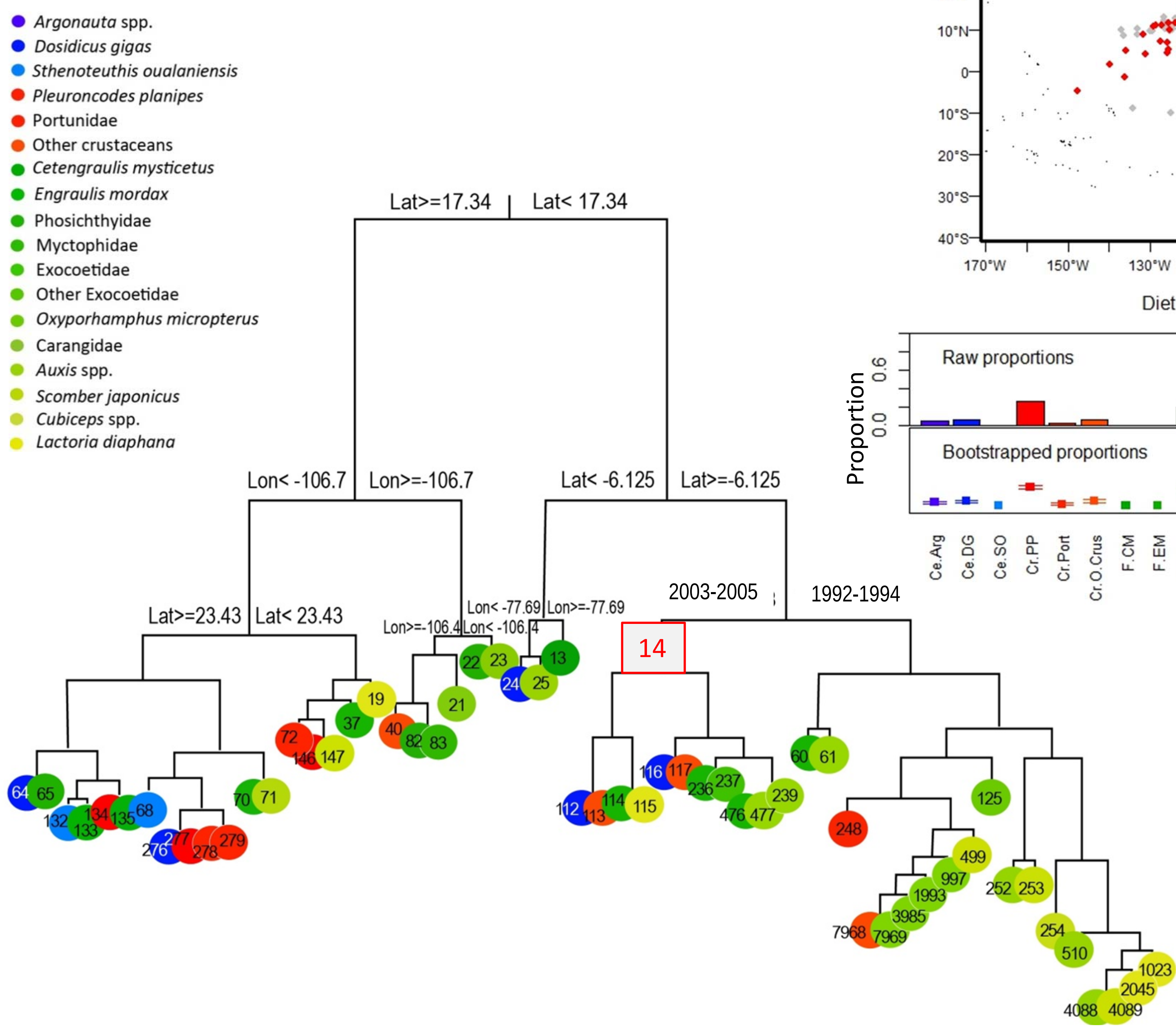
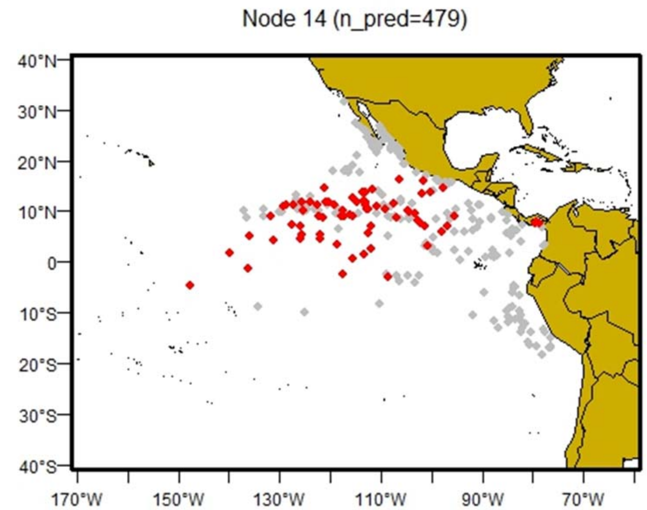
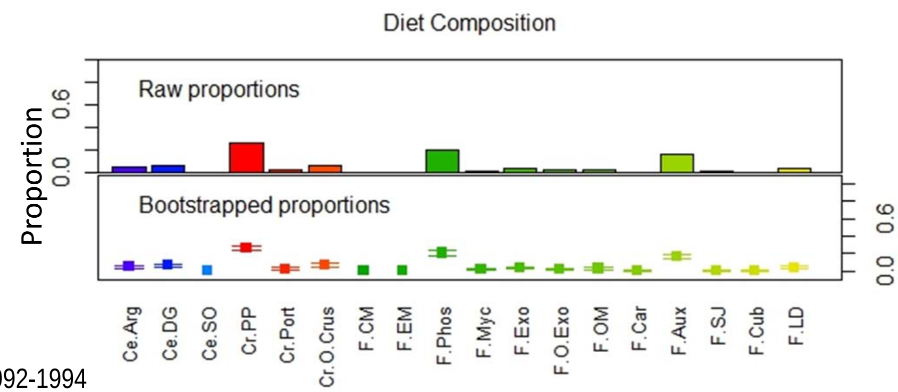
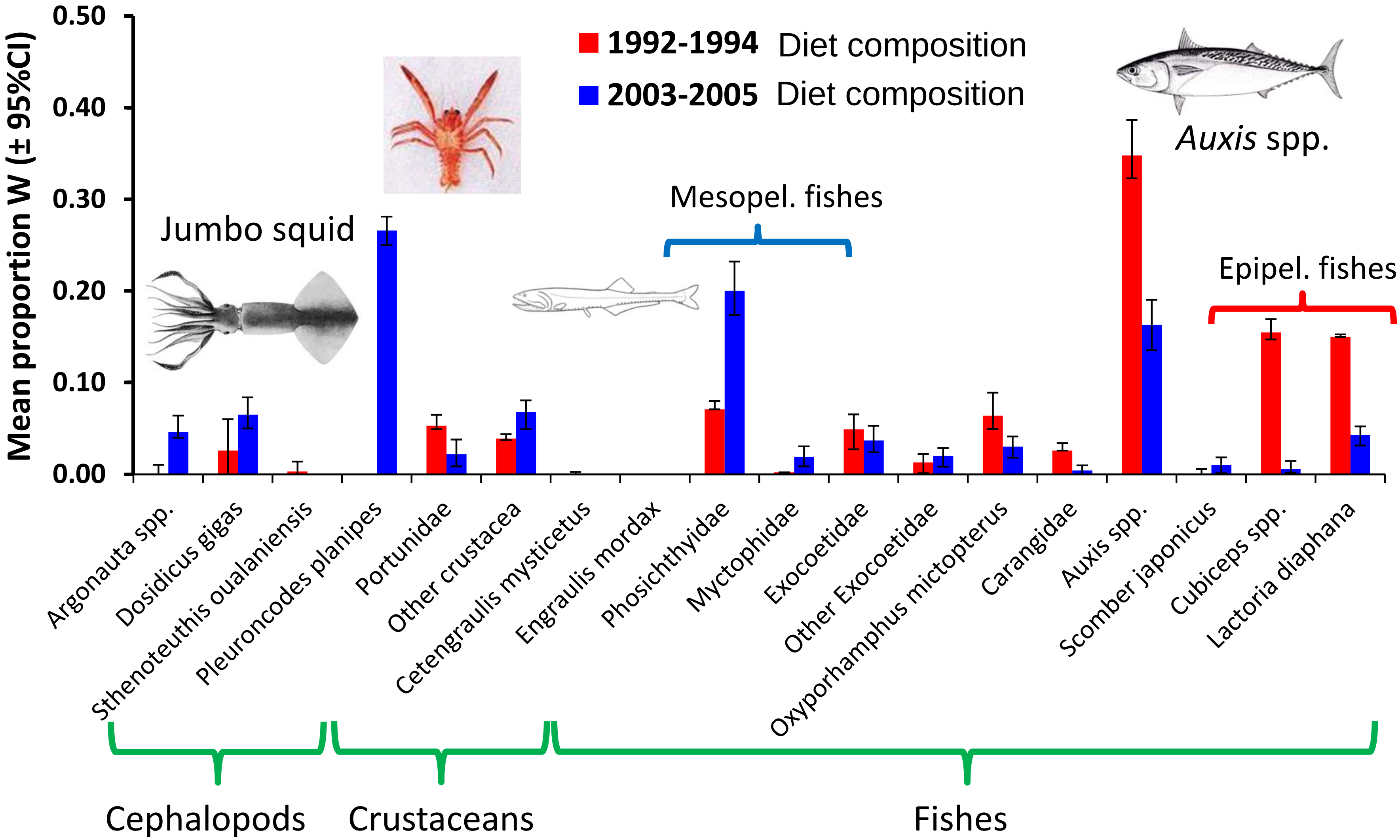
Node 14: bet 17.3 N & 6.1 S 2003-2005



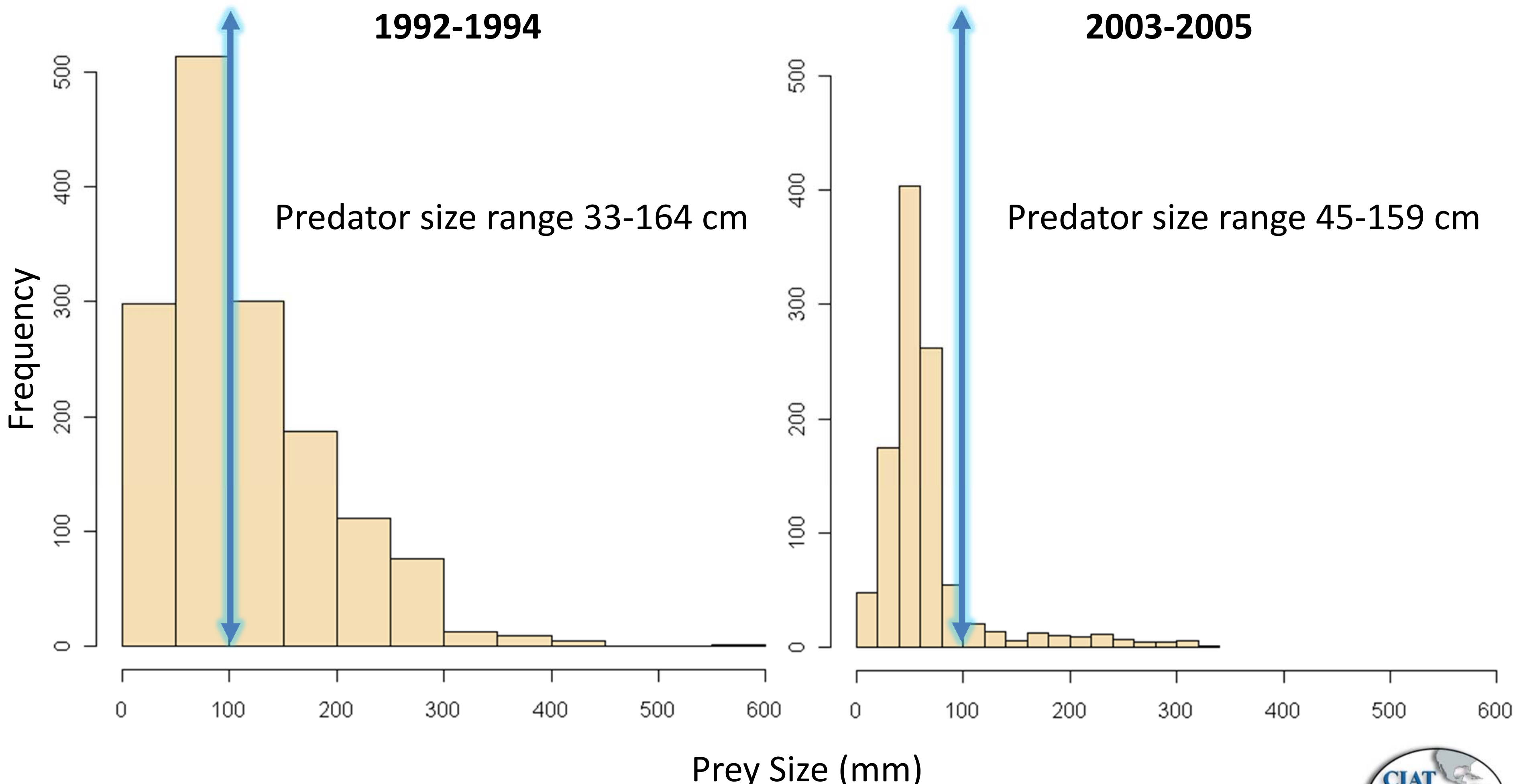




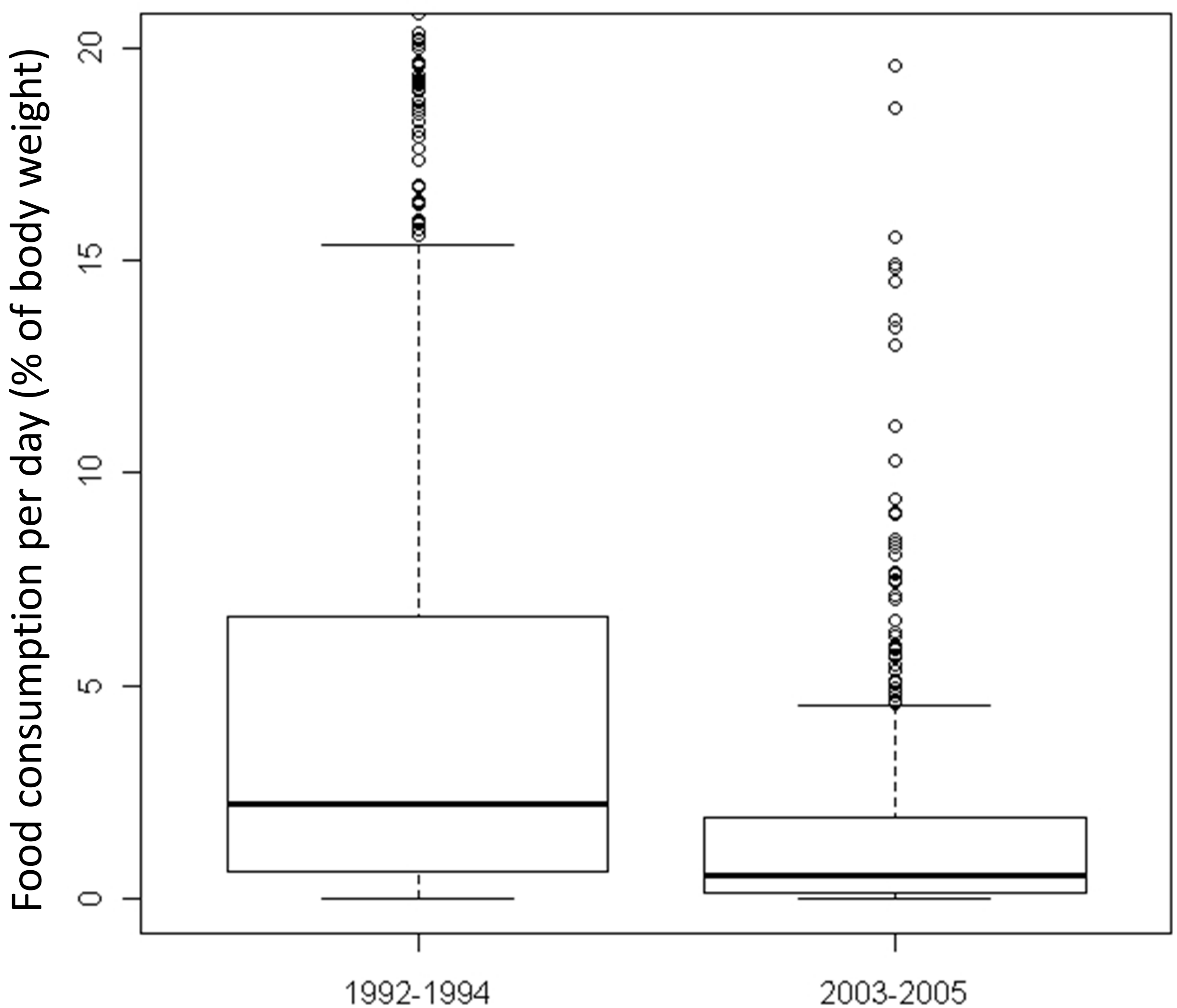
Yellowfin tuna diet composition at year split



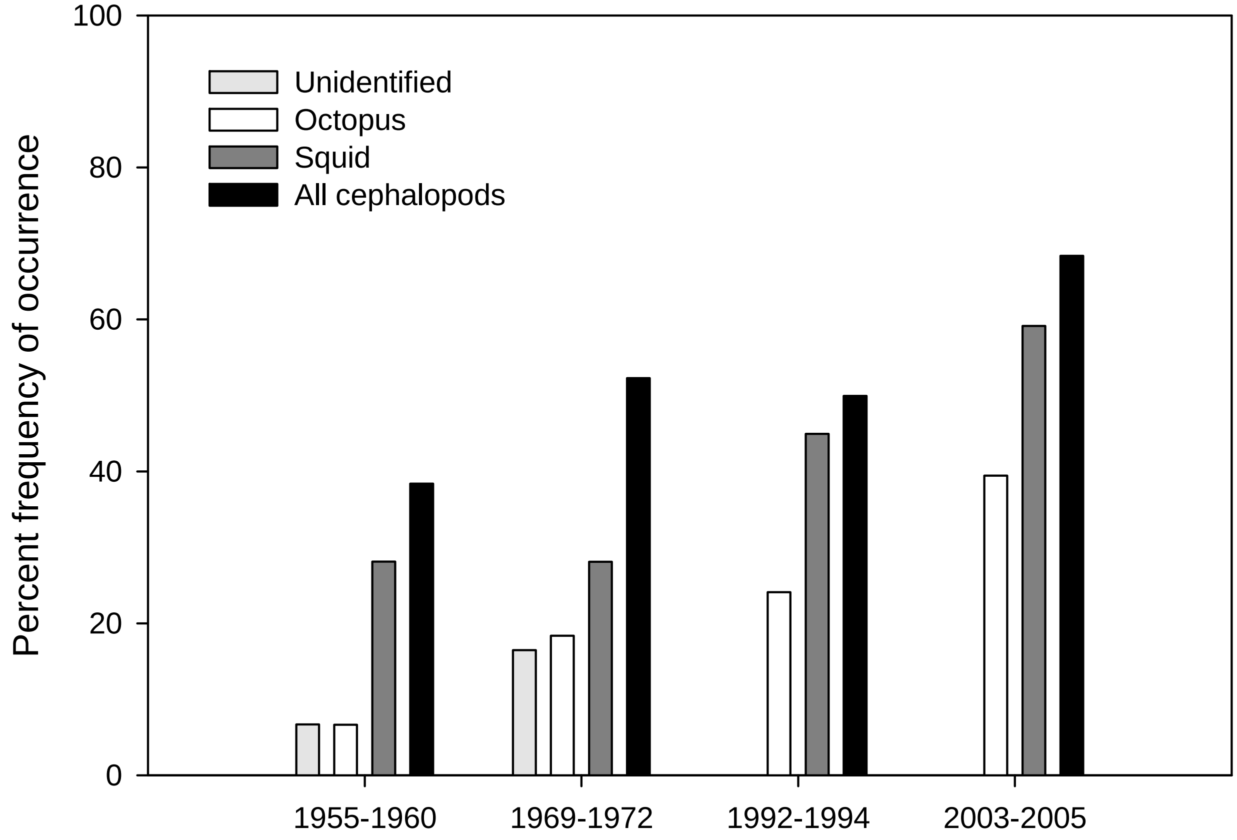
Prey size distributions



Daily rations



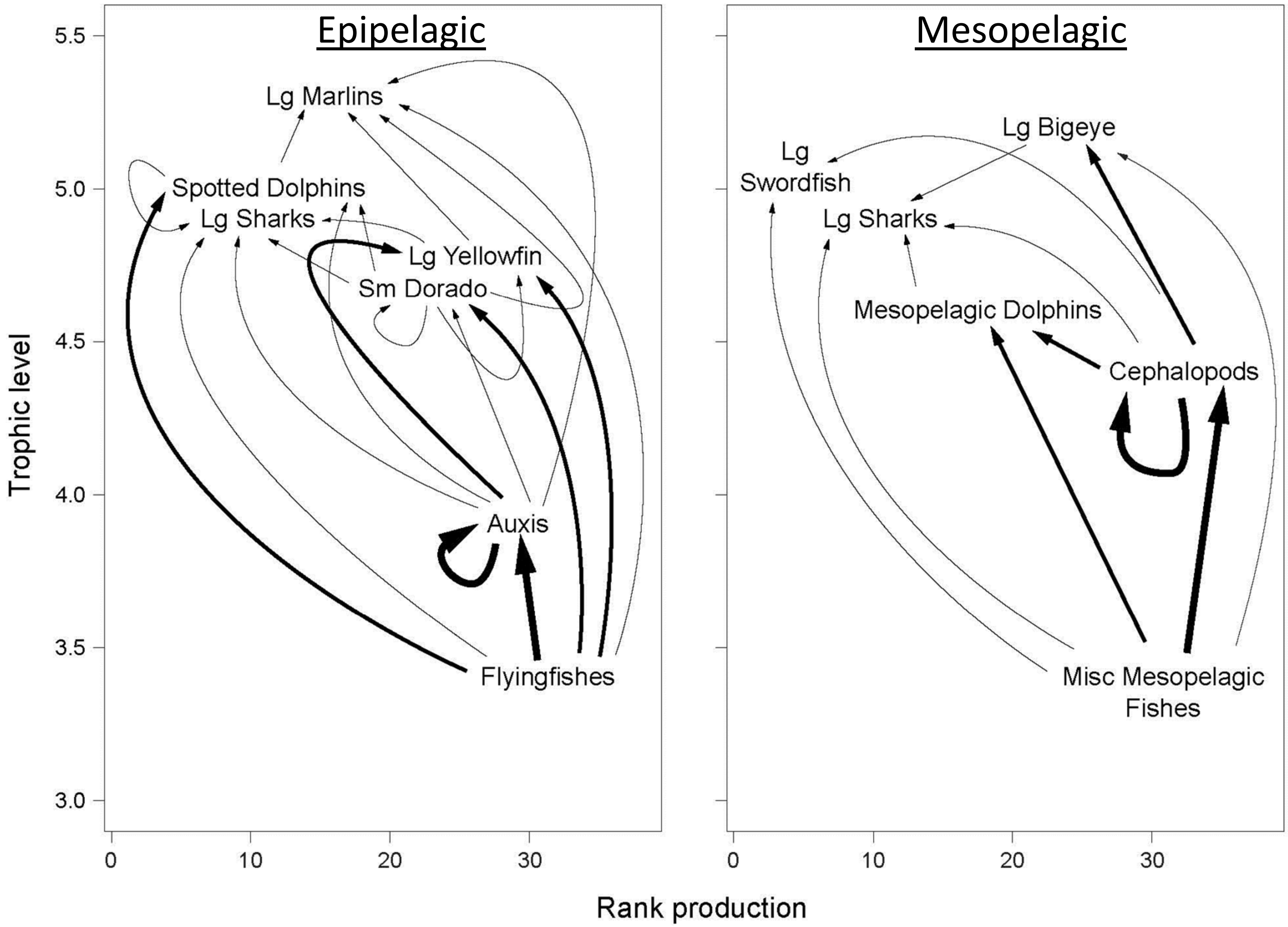
Percent frequency of cephalopods in the stomach contents of yellowfin tuna in the eastern Pacific Ocean



PFRP, F. Galvan, N. Bocanegra, V. Alatorre, J. Martinez, F. Alverson

Hunsicker, Essington, Olson, Duffy. Manuscript in prep. “Evidence of increased cephalopod production in a large marine ecosystem.”

Two trophic pathways – *Auxis*, cephalopods



Watters, G.M., R.J. Olson, R.C. Francis, P.C. Fiedler, J.J. Polovina, S.B. Reilly, K.Y. Aydin, C.H. Boggs, T.E. Essington, C.J. Walters, and J.F. Kitchell. 2003. Physical forcing and the dynamics of the pelagic ecosystem in the eastern tropical Pacific: simulations with ENSO-scale and global-warming climate drivers. Can. J. Fish. Aquat. Sci. 60 (9): 1161-1175.

Diet shift: possible mechanisms

Bottom-up

- Ocean conditions (e.g. expanding oligotrophic regions (Polovina et al.))
- PDO, ENSO shifts

Forage communities

- Community changes (e.g. ocean warming)

Top-down

- Trophic structure changes due to changes in predation pressure (species composition)

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Examine hypotheses

Model analyses

- Current 1990s model: run forward with historical changes in fishing and compare end diet predicted for 2003-5005.
- 1990s model: force with observed 2000s diet data and predict resultant changes in predator biomass
- Build new model for 2003-2005. Can 90s model transition into 2000s ecosystem state? Under what conditions?

Data analyses

- Analyze existing diet data for other ETP top predators over same decade. Did diets change, if so is diet shift consistent with two trophic pathways?

Understanding changes in pelagic ecosystems: 1. Monitoring

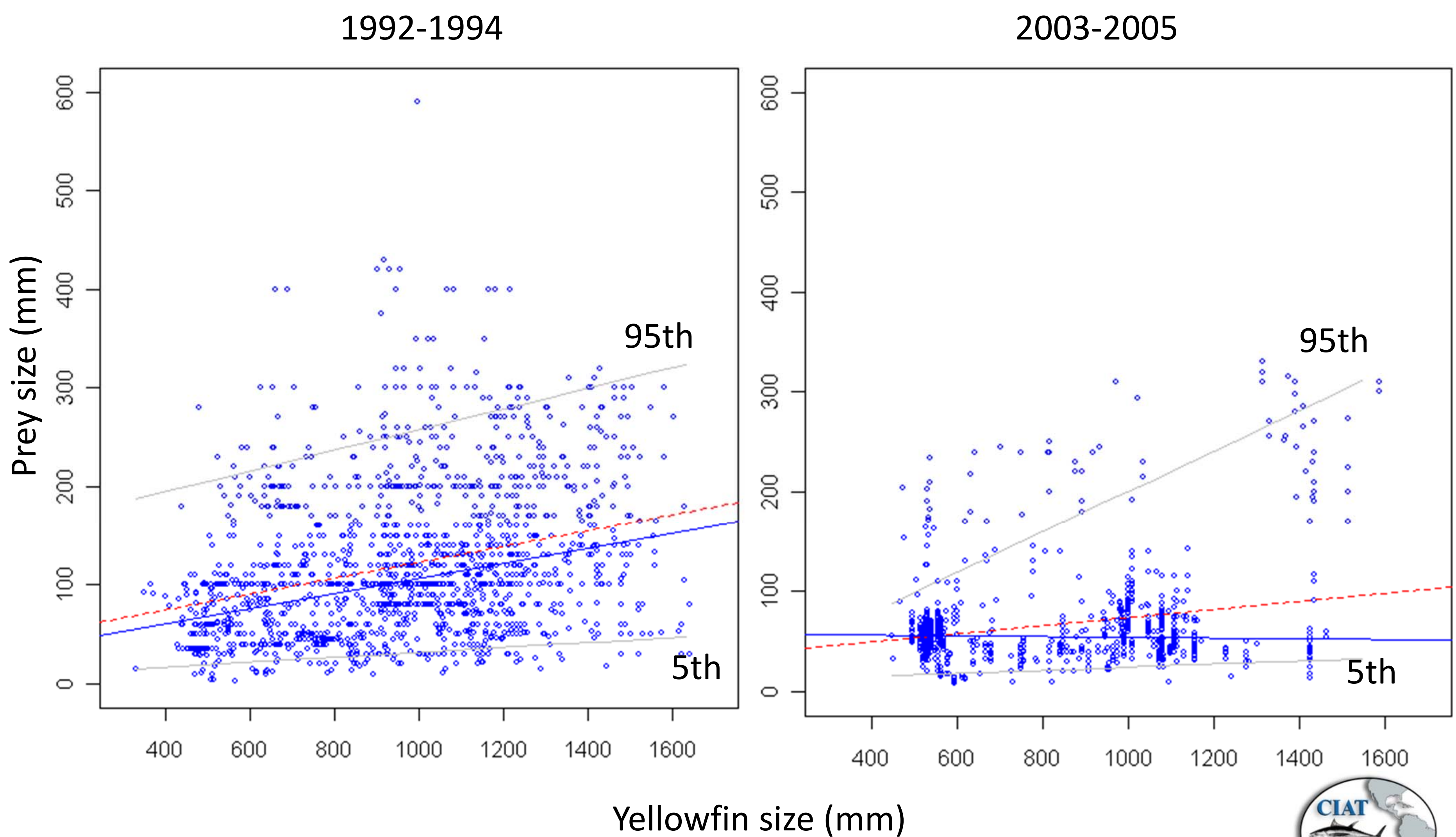
Issue: Fisheries-independent surveys of micronekton forage communities using nets or acoustics expensive and difficult.

Recommendation: Establish low-level, carefully-designed, continuous stomach sampling program of tunas to monitor changes in mid-trophic levels.

Generalist predators as biological samplers:

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

Prey-predator size relationships



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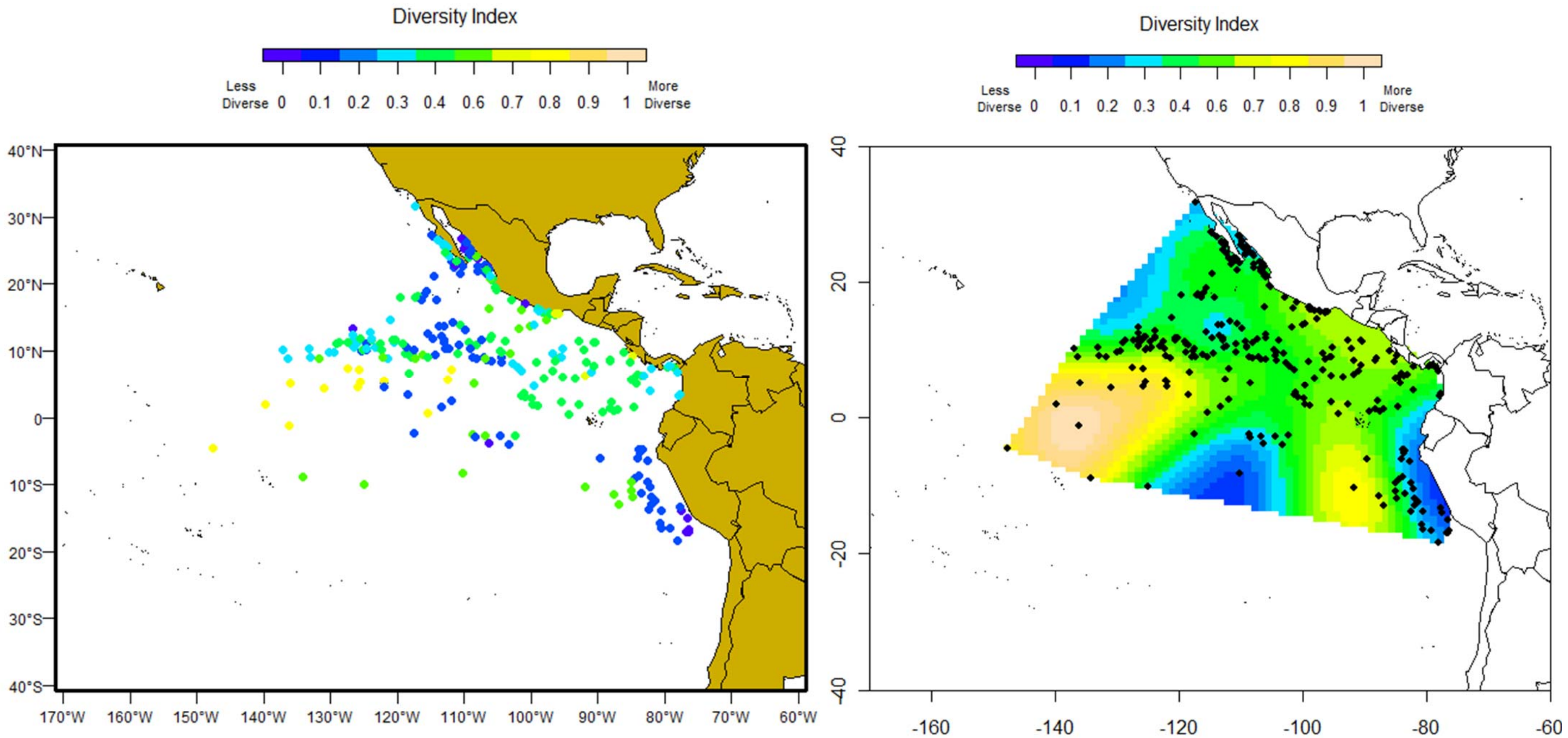
Classification tree analysis: eastern Pacific YFT

Diet diversity at terminal nodes



Understanding changes in pelagic ecosystems: 2. Modeling

Issues:

- Ability to interpret observations is limited (e.g. jumbo squid range expansion, YFT diet shift, productivity regimes suggested by stock assessments).

Recommendations:

- Increase ecosystem (food web) modeling efforts. Spatially-explicit models are needed.
  - Identify testable hypotheses.
  - Identify indicator species.
  - Identify critical food-web connections.

Summary: Ecosystem change (without caveats)

1990s	2000s
High YFT recruitment (1984-2002)	Intermediate YFT recruitment (2004-2010)
Higher productivity regime	Lower productivity regime
Less jumbo squid, smaller range	More jumbo squid, range expansion
Abundance of highly productive epipelagic prey (*i.e. Auxis* spp.)	Increase in highly productive mesopelagic prey (*e.g.* mesopel. fishes, cephalopods)
Higher daily rations	Lower daily rations
Larger prey sizes	Smaller prey sizes
Shorter food webs (greater transfer efficiency)	Longer food webs (lower transfer efficiency)