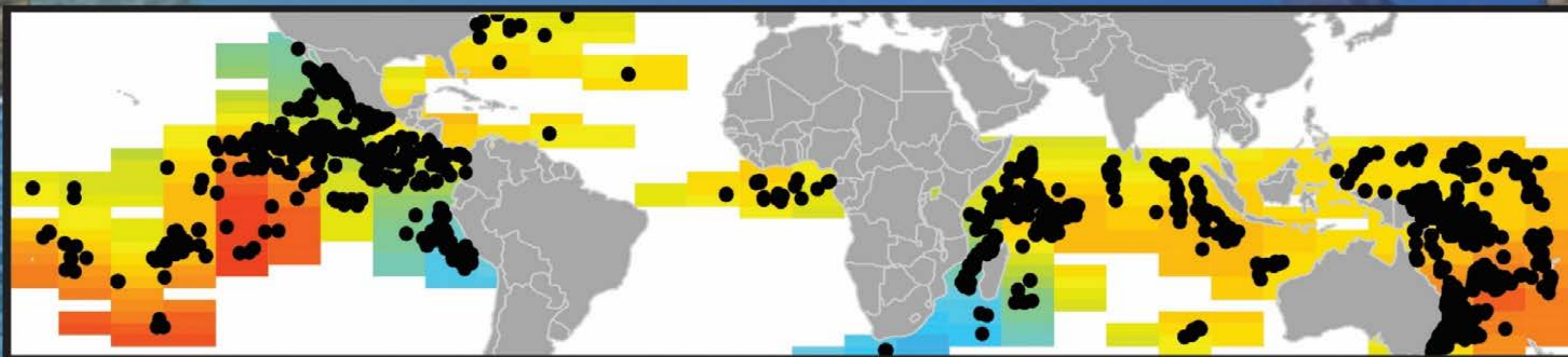
From regional to global-scale understanding of tuna food webs

Jock Young and CLIOTOP working group 3



(Image:
L. Duffy, IATTC)

CLIOTOP WG3: J. Young (CSIRO, Australia), R. Olson (IATTC, USA), F. Menard (IRD, France), H. Pethybridge (CSIRO), V. Allain (SPC, New Caledonia), N. Bodin (IRD, Seychelles), A. Choy (MBARI, USA), N. Goni (AZTI, Spain); L. Duffy (IATTC, USA) B. Graham (NIWA, New Zealand), A. Hobday (CSIRO), B. Hunt (UBC, Canada), P. Kuhnert (CSIRO), C. Langlais (CSIRO), J. Logan (MA DMF, USA), A. Lorrain (IRD, New Caledonia), F. Menard (IRD, France), C. Somes (GEOMAR, Germany).

Introduction

- Most marine food web studies are by necessity regional in nature. They are limited in time and space. Thus, predicting the impacts of major global changes such as ocean warming on marine food webs, particularly of top predators is limited. This is particularly true for the tunas that travel vast differences and through multiple country jurisdictions. It also means that predictive models for one region may not be applicable to another.

- I present here the development and application of a global data base that aimed to bring data from different methodologies to examine the impact of ocean warming on, in this case three tuna species, yellowfin (Thunnus albacares), bigeye (T. obesus) and albacore (T. alalunga) tuna.

Seeking “trophic clarity”

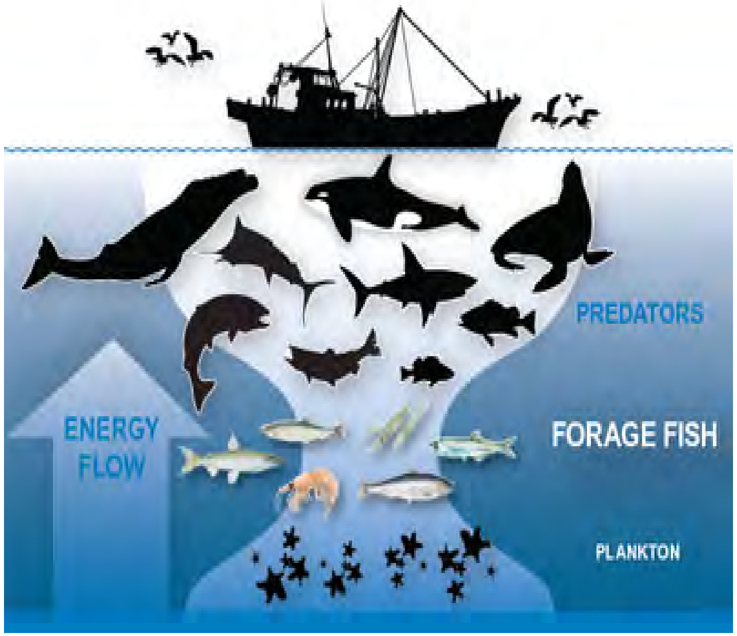
Widespread concern that fisheries and climate are altering the structure and function of marine ecosystems, e.g. through trophic cascades.

Ecosystem-based management: recognizes the full array of interactions within an ecosystem, including humans.

Community and ecosystem models are key tools that depend on accurate depictions of prey-predator interactions.

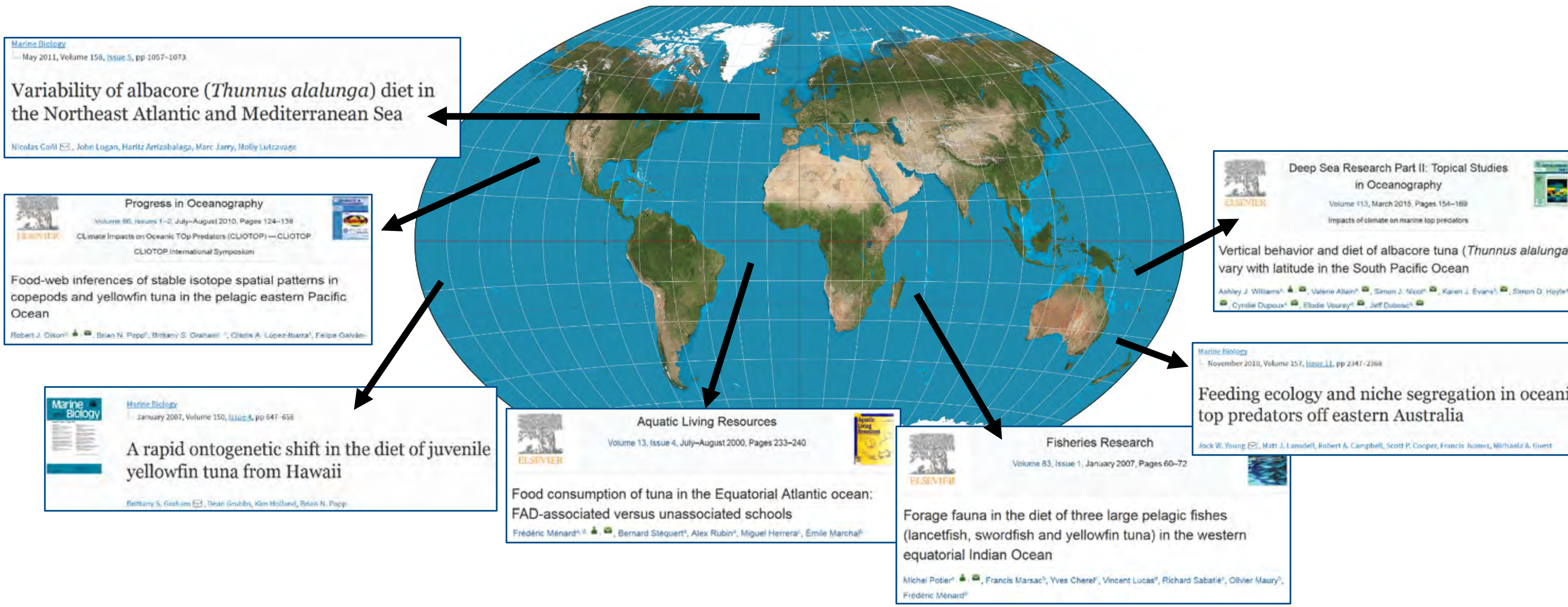
Knowledge of oceanic food webs still rudimentary, in many aspects (micronekton).

Often based on generic trophic data.



Top predators as biological samplers

Tuna diet provides insight on predator-prey interactions; distribution of micronekton and energy/nutrient flows.



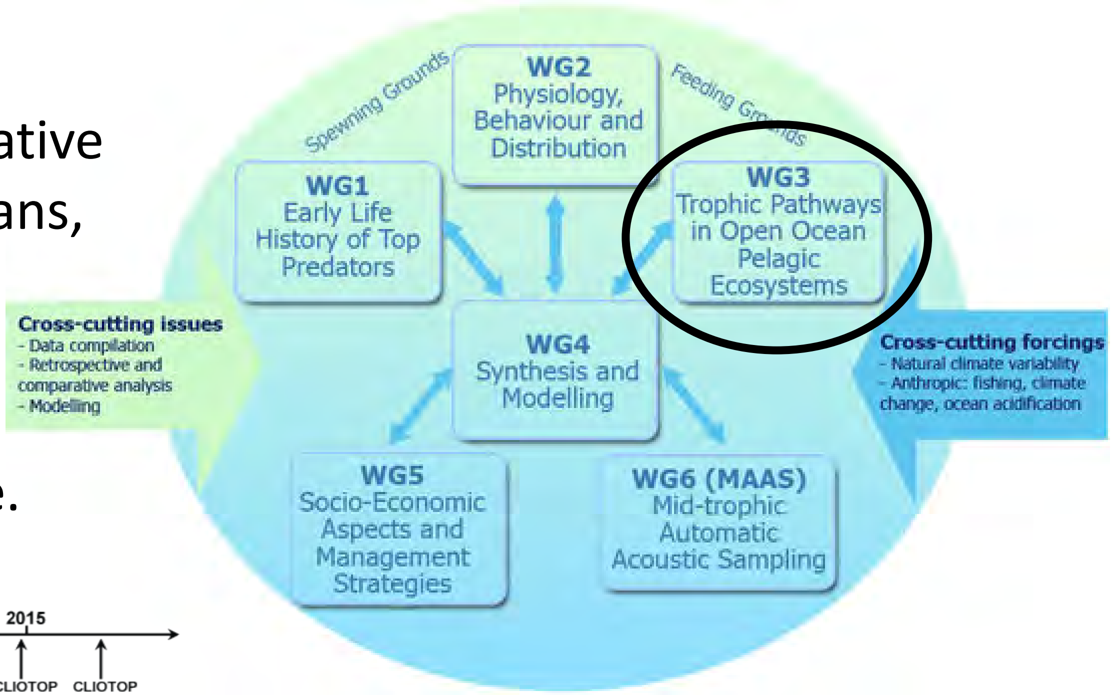
Provide limited information on macro-scale patterns & processes...

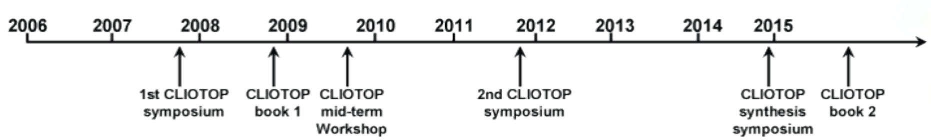
GLOBEC-CLIOTOP: CLimate Impacts on Oceanic TOP predators

Aim: to elucidate key patterns and processes involved in the impact of climate variability and fishing on the open ocean ecosystems and their top predators.

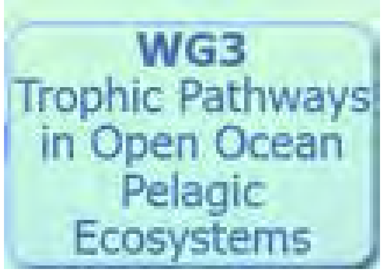
Based on a worldwide comparative approach: among regions, oceans, and species.

In support of international oceanic ecosystem governance.





GLOBEC-CLIOTOP: Climate Impacts on Oceanic Top Predators



Aims of WG3, now task-team 2016-01:

1. What are the main trophic pathways and how do they differ among oceans?
2. What is the importance of spatial, biological and environmental variables on trophic parameters and global patterns?
3. Can any variable(s) be used as a proxy to reliably predict the effects of ocean climate variability on oceanic food webs?

1st inter-oceanic comparison of top predator diets and isotopes ever conducted at a global scale.

A multi-disciplinary international effort

WG3: Trophodynamics
2009-2015
Data compilation, diet work.
Co-leaders: R. Olson, J. Young, F. Menard

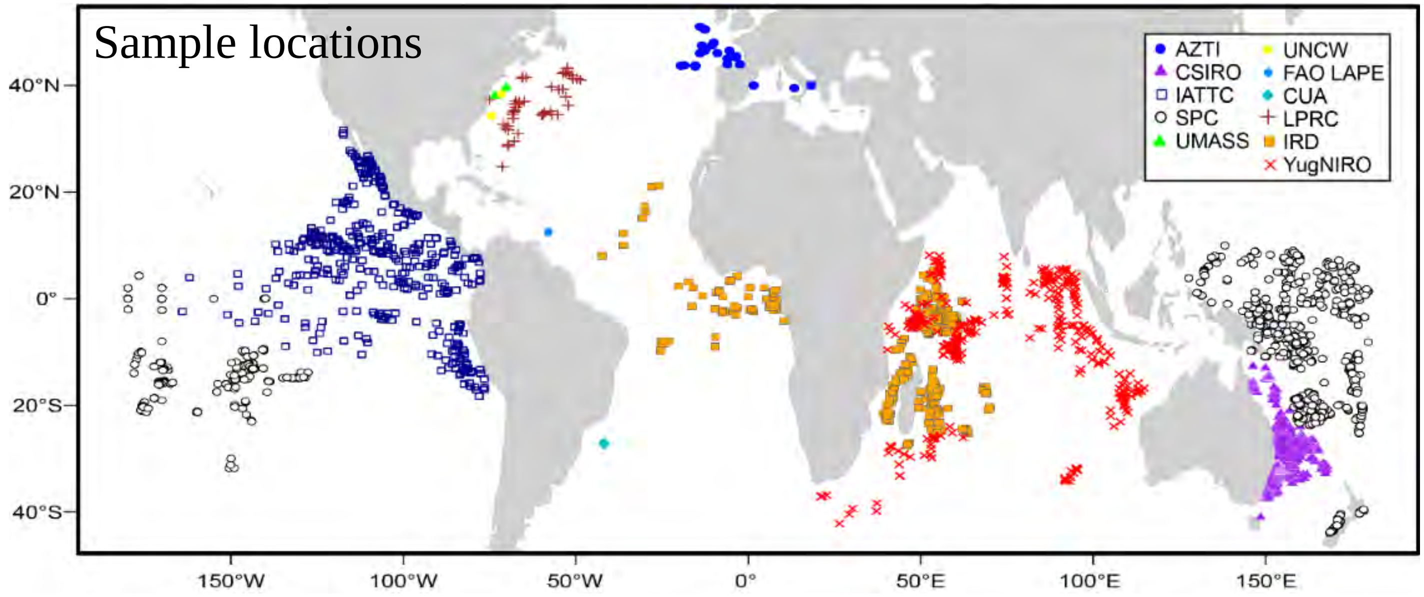
Current task-team: isotopes
2016-2017
Isotope work
Co-leaders: me, A. Choy, L. Duffy

>18 members; 8 Countries;
16 Research institutions.
Statisticians, ecologist, biochemists, physical and biological oceanographers, fisheries scientist.

Two global databases compiled

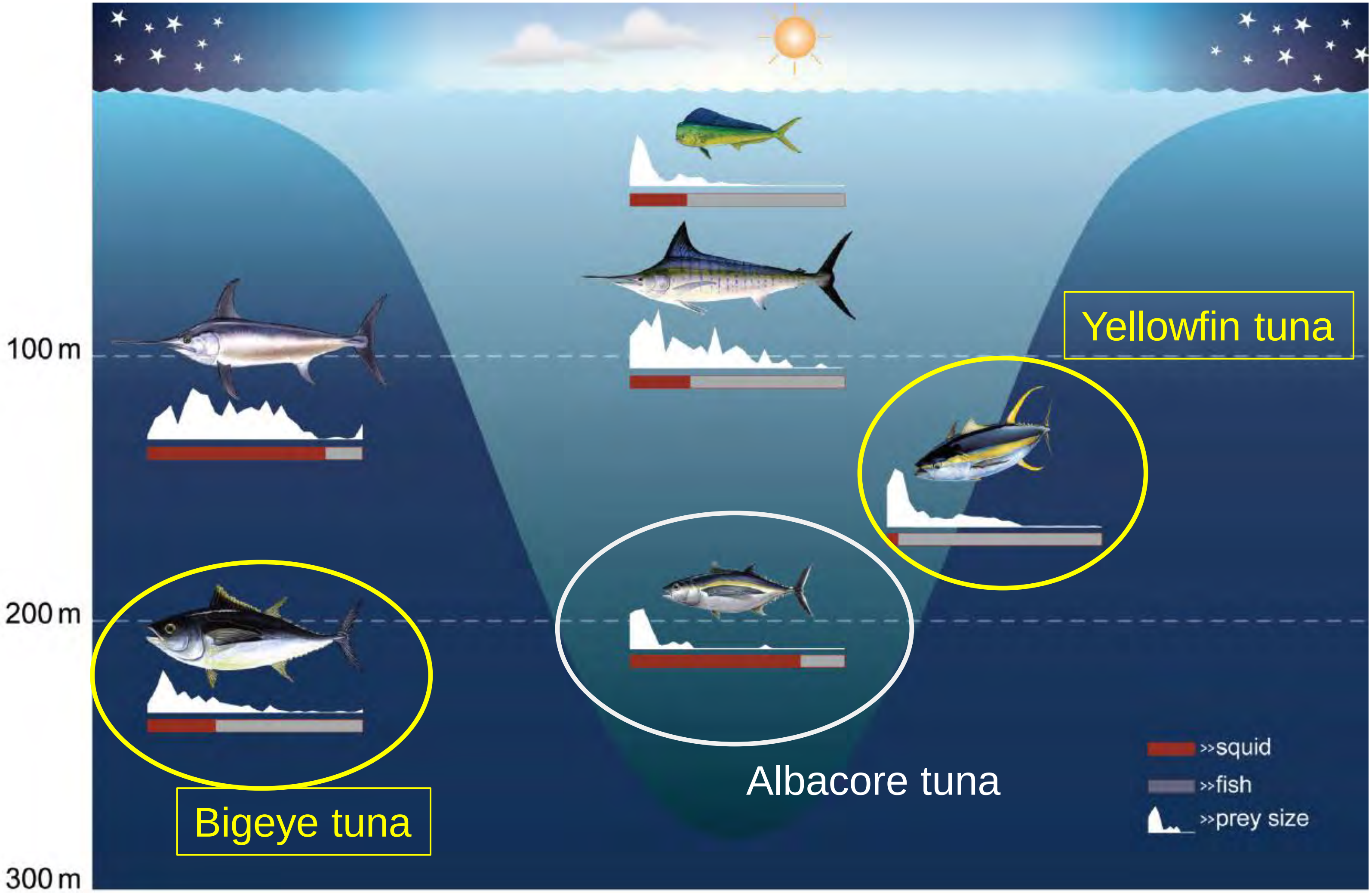
1. **>25,000 stomach samples**
   > 330 prey taxa from tunas collected 1969-2014.

2. **>6,000 stable isotope records**
   $\delta^{15}N$ and $\delta^{13}C$ values, tuna sampled 2000-2015.



7 Top-predators: Bigeye tuna (BET), Albacore tuna (ALB), Yellowfin tuna (YFT), Lancet Fish (ALX), Dolphinfish (DOL), Skipjack tuna (SKJ), Swordfish (SWO)

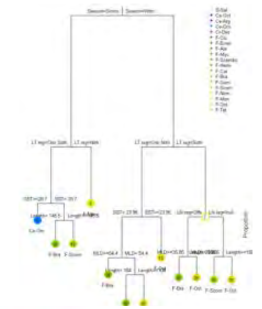
Focus here on three tuna species

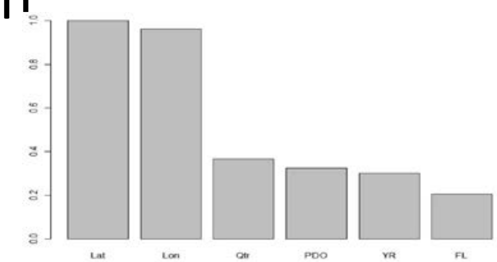


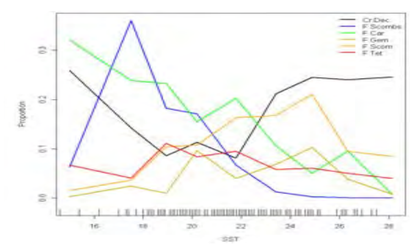
Young et al. 2010 *Marine Biology 157*

Classification tree methodology

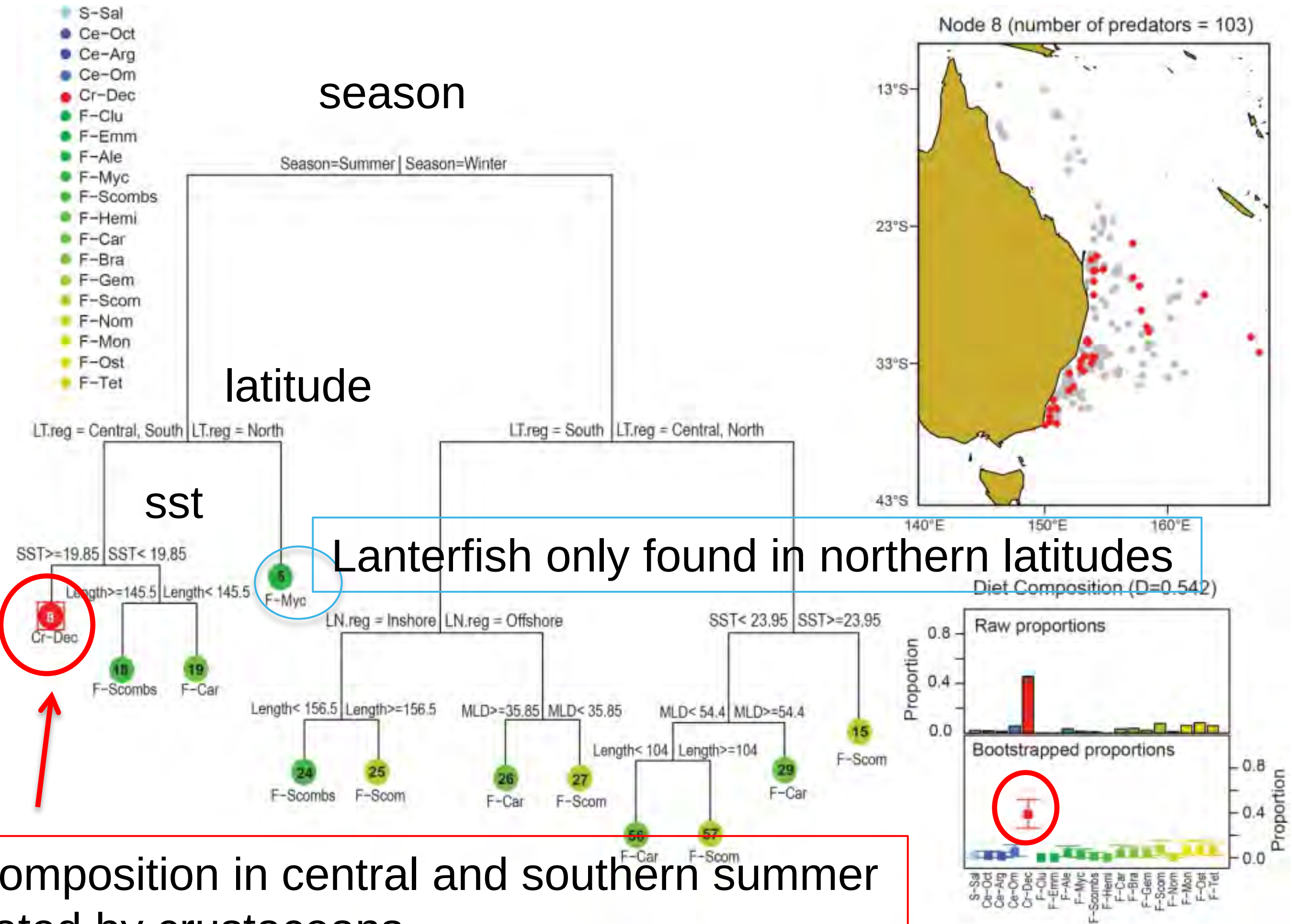
- P. Kuhnert’s methodology for diet composition extends classification tree method : <u>Exploratory and predictive</u>.
- <u>Spatial bootstrap approach</u> provides standard errors around predicted prey composition.
- Variable importance measures indicate which <u>explanatory variables</u> most important in partitioning.
- <u>Partial dependence plots</u> for examining relationships between explanatory variables and the response in the model.





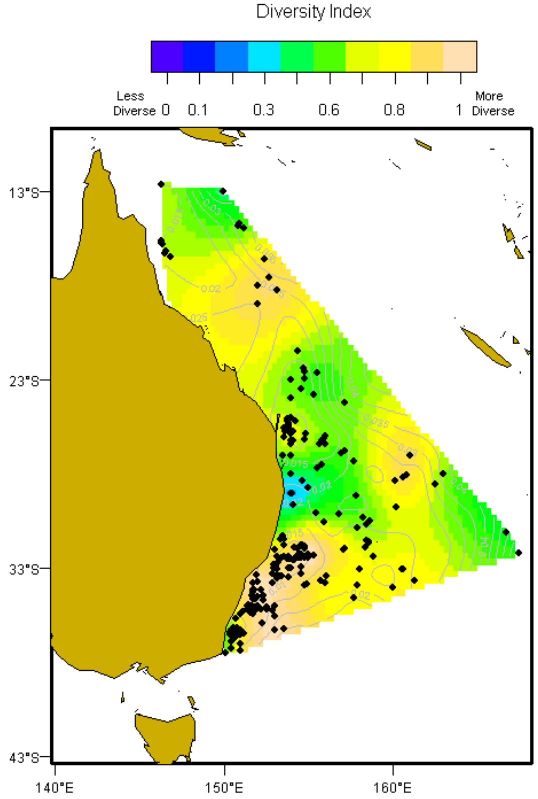


Regional analysis (SW Pacific, Kuhnert et al 2012)



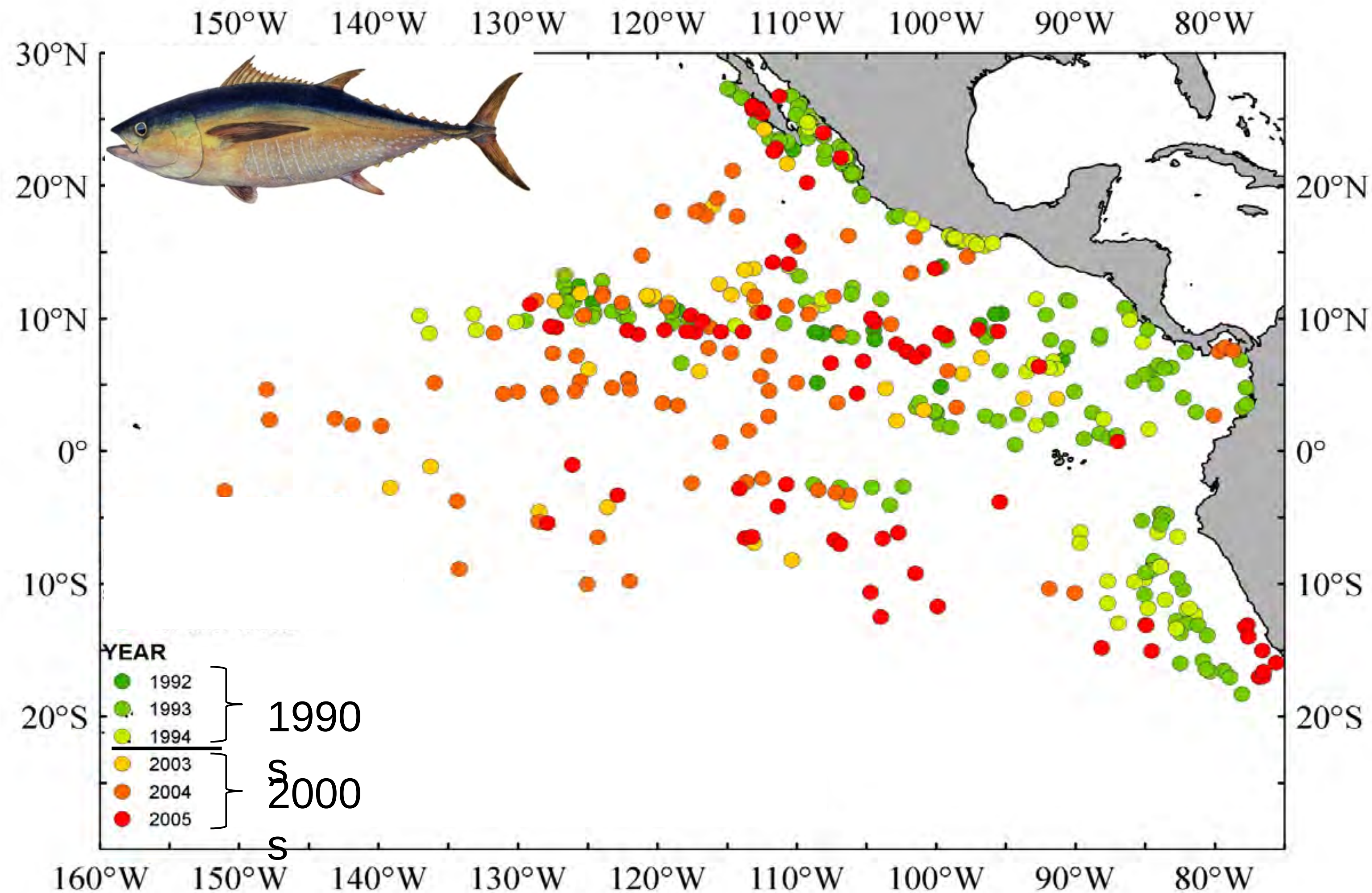
Prey composition in central and southern summer dominated by crustaceans

Diversity contouring of yellowfin tuna prey off eastern Australia



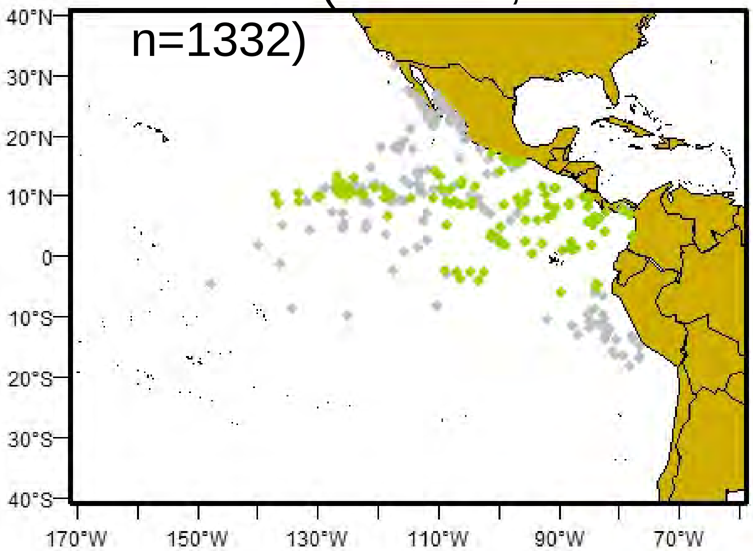
Map of diversity values ranging between 0 and 1 showing the diversity of the distribution of prey predicted for each yellowfin tuna.

Eastern Pacific (1990s, 2000s)
(Olson et al in 2014)

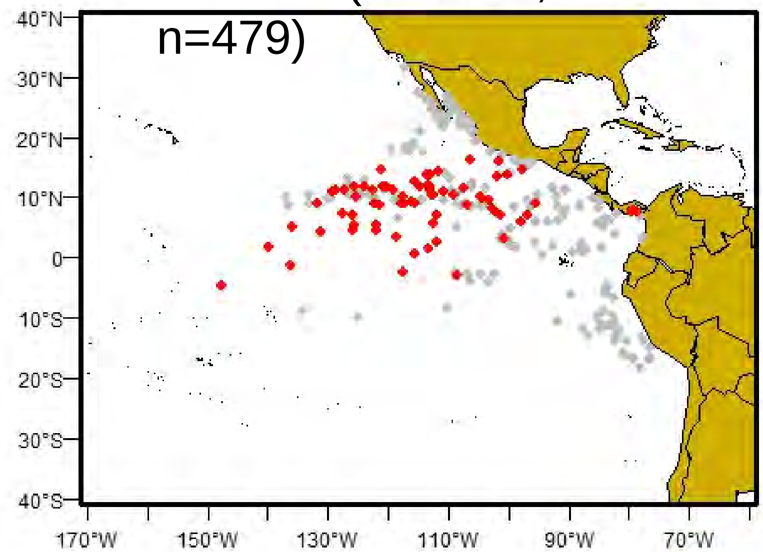


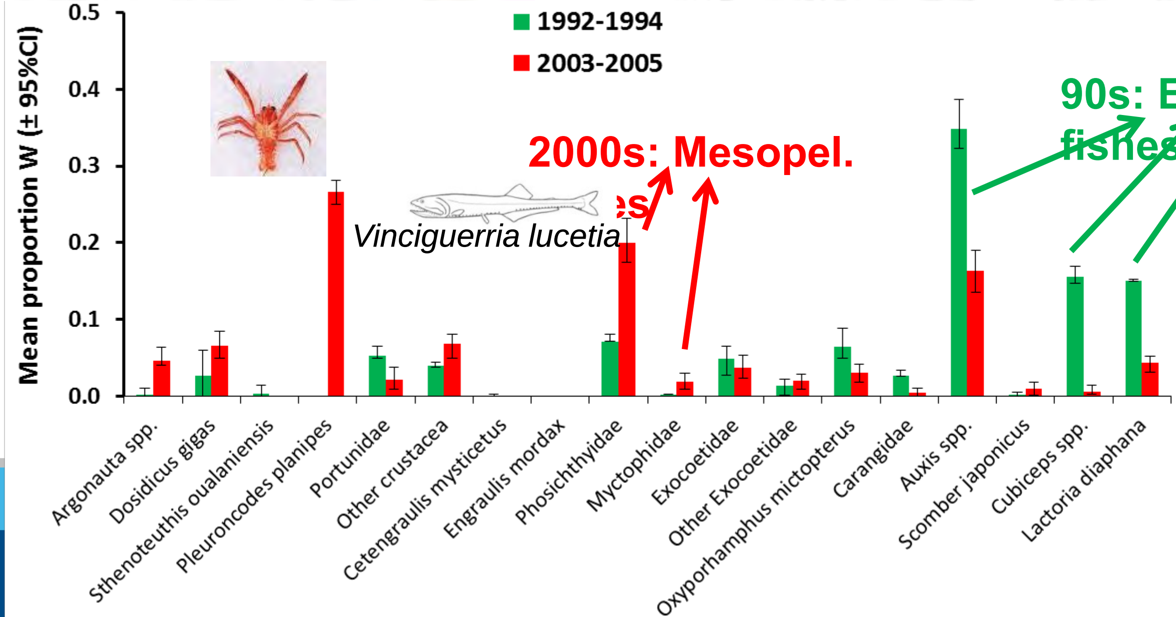
Diet contrast: 1990s versus 2000s (Olsen et al)

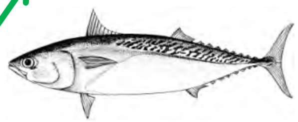
1992-94 (node 15, n=1332)



2003-05 (node 14, n=479)

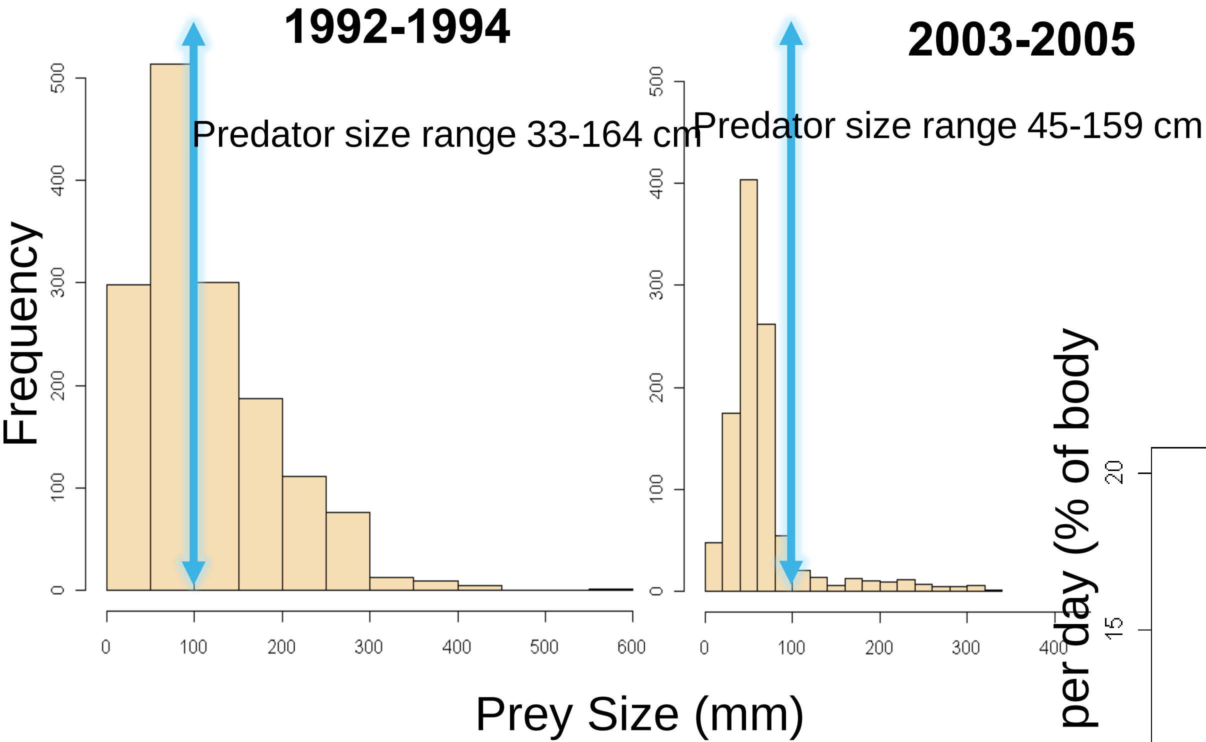




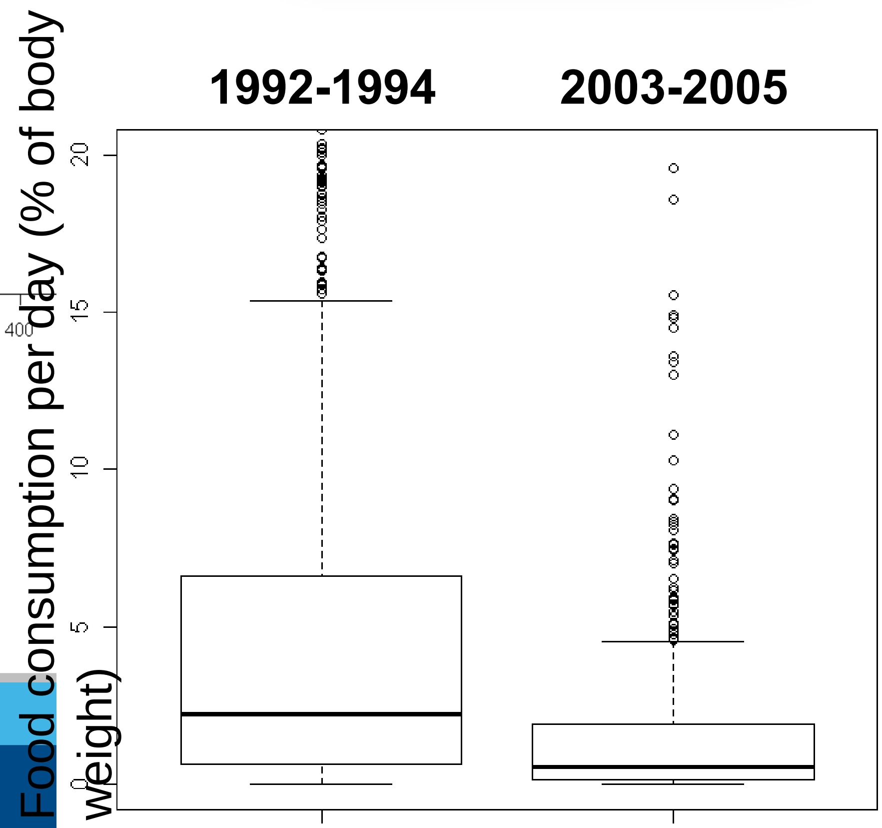


Auxis spp. Frigate/bullet tuna

Prey size distributions



Daily rations



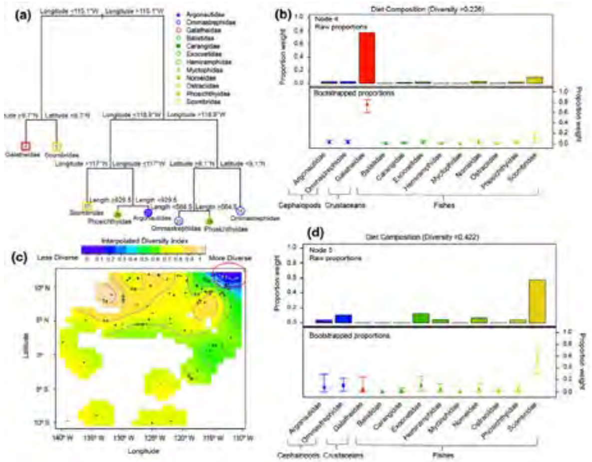
Global analysis of tuna diet (Duffy et al 2017)

Bagged classification tree and ‘diet’ R package for analysing complex diet data:

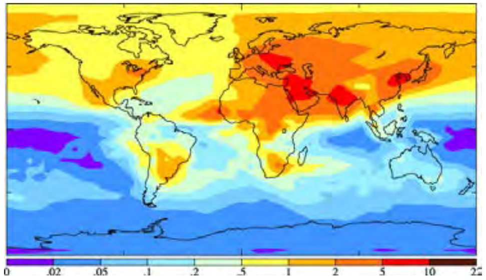
Data:

Stomach contents: prey proportions by weight, grouped to the family level.

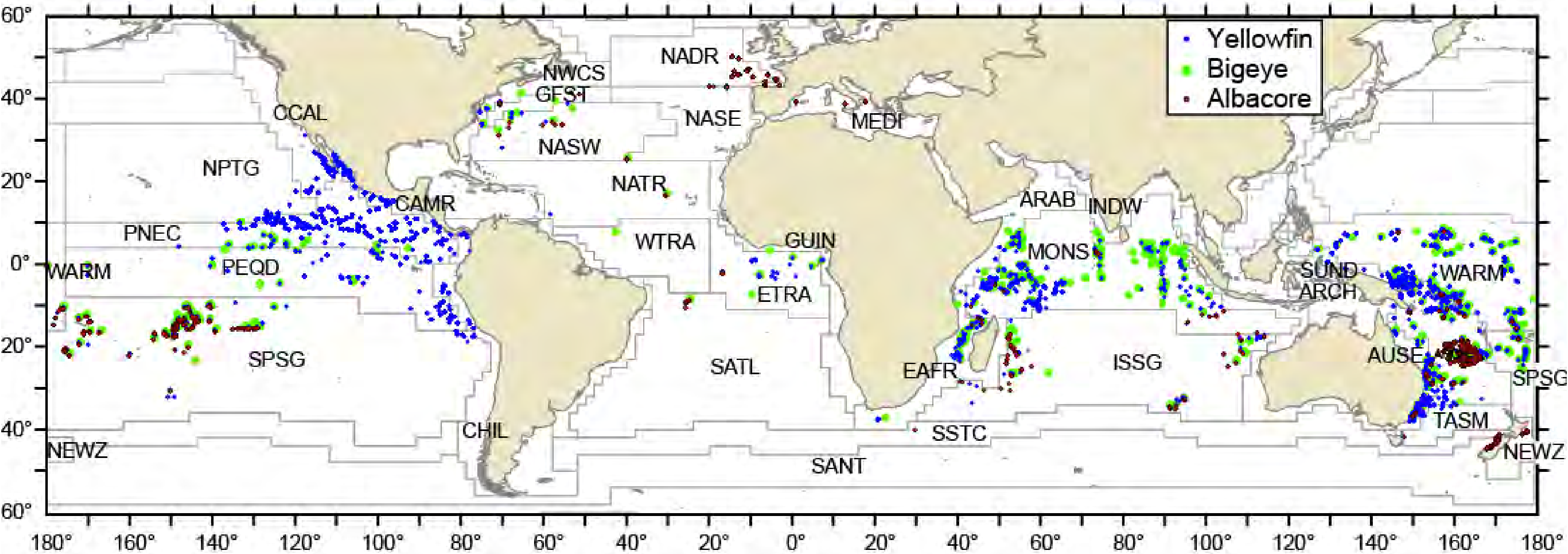
Environmental data: Climatologies of SST.



(Young et al 2015)



Sample locations of diet data used to examine broad-scale diet patterns



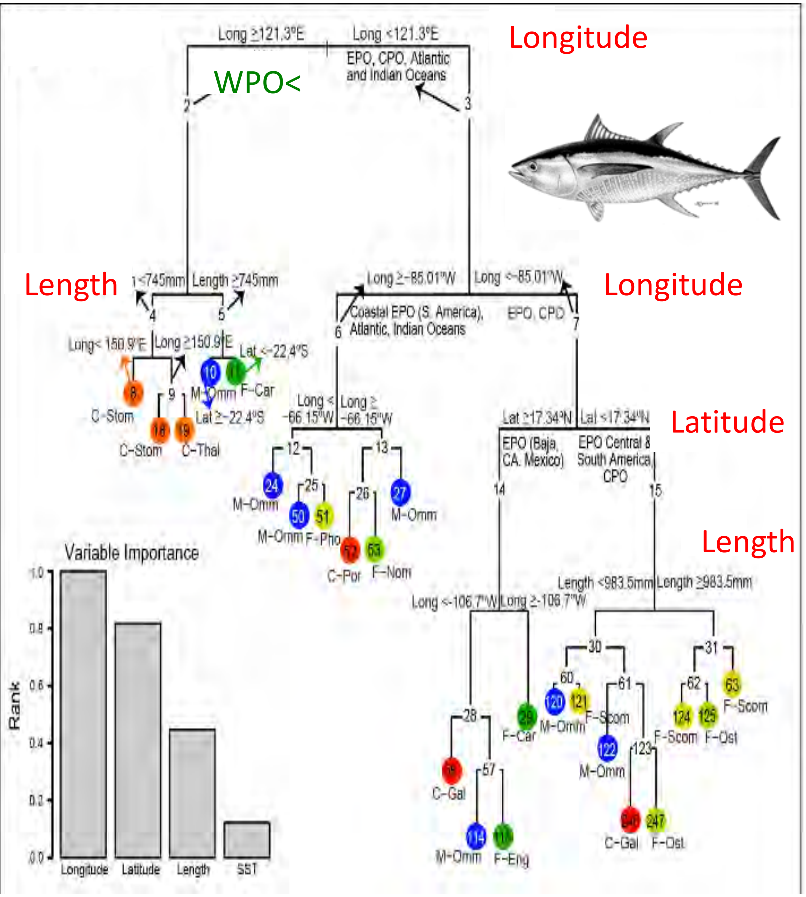
Data spanning 40 years (1969-2013) was compiled for 14,185 yellowfin, bigeye and albacore tunas by scientists from research organizations around the world

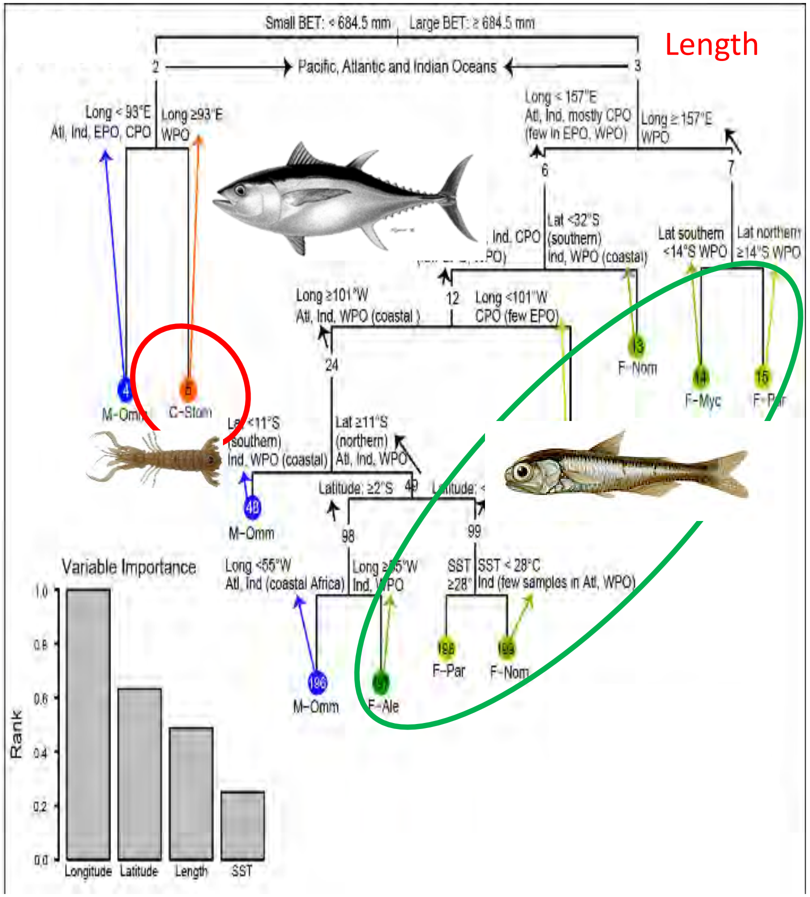
Objectives using YFT, BET and ALB tunas as biological samplers:

- Elucidate predator-prey relationships globally and by ocean basin
- Identify spatial and biological patterns in diet composition and diversity
- Investigate potential influence of oceanographic features on foraging behavior of tunas on a subset of data from 2003-2011

Global patterns in diet composition

(Duffy et al 2017)





Salps

- S–Salpidae

Squid

- M–Ommastrephidae

Crustaceans

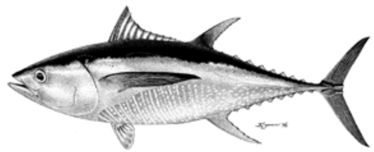
- C–Euphausiacea
- C–Galatheidae
- C–Portunidae
- C–Stomatopoda
- C–Thalassocarididae

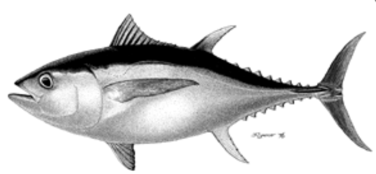
Fish

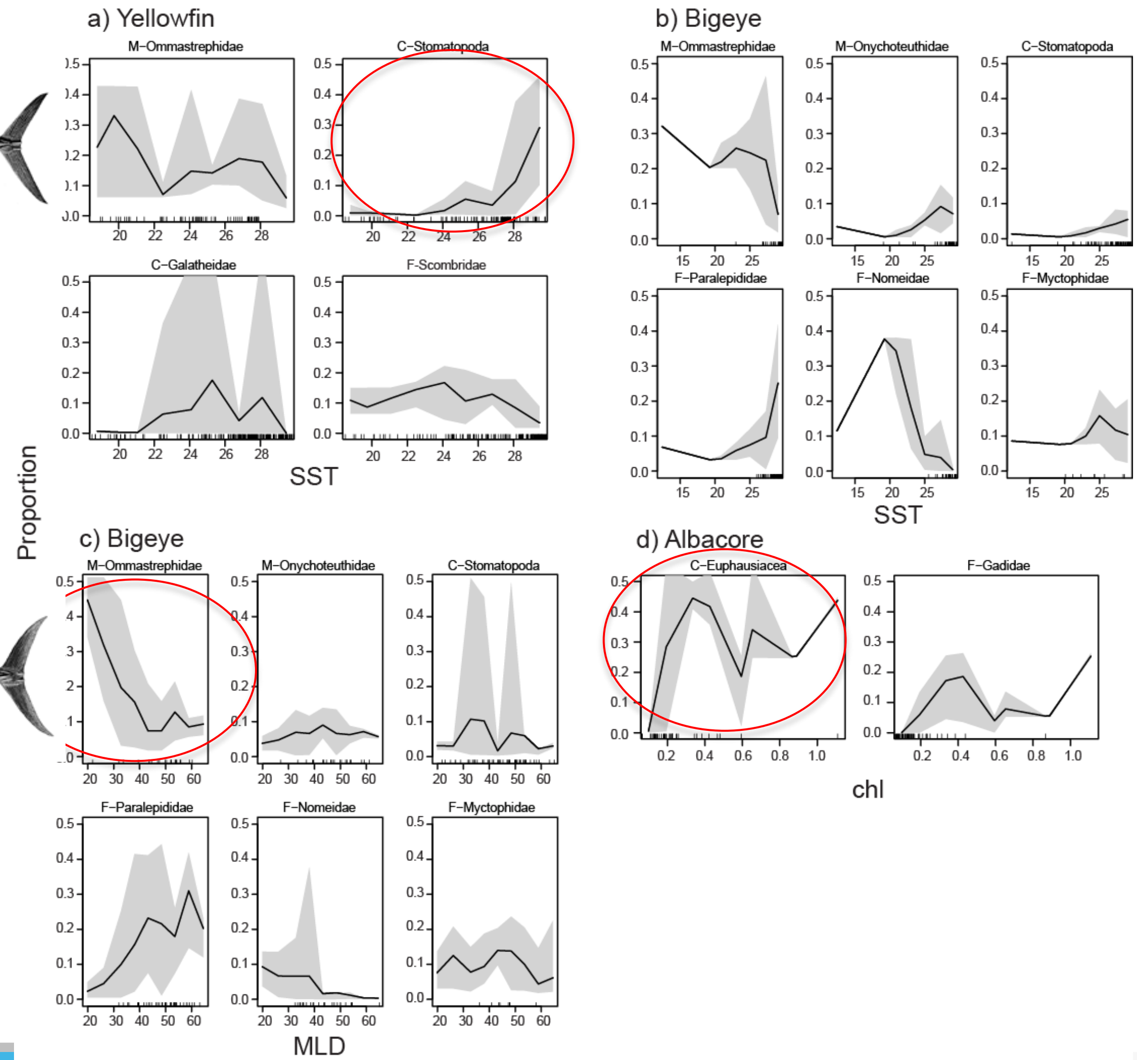
- F–Alepisauridae
- F–Carangidae
- F–Engraulidae
- F–Gadidae
- F–Myctophidae
- F–Nomeidae
- F–Ostraciidae
- F–Paralepididae
- F–Phosichthyidae
- F–Scomberesocidae
- F–Scombridae

Main drivers of diet: (1) spatial variables, (2) size, and (3) SST.

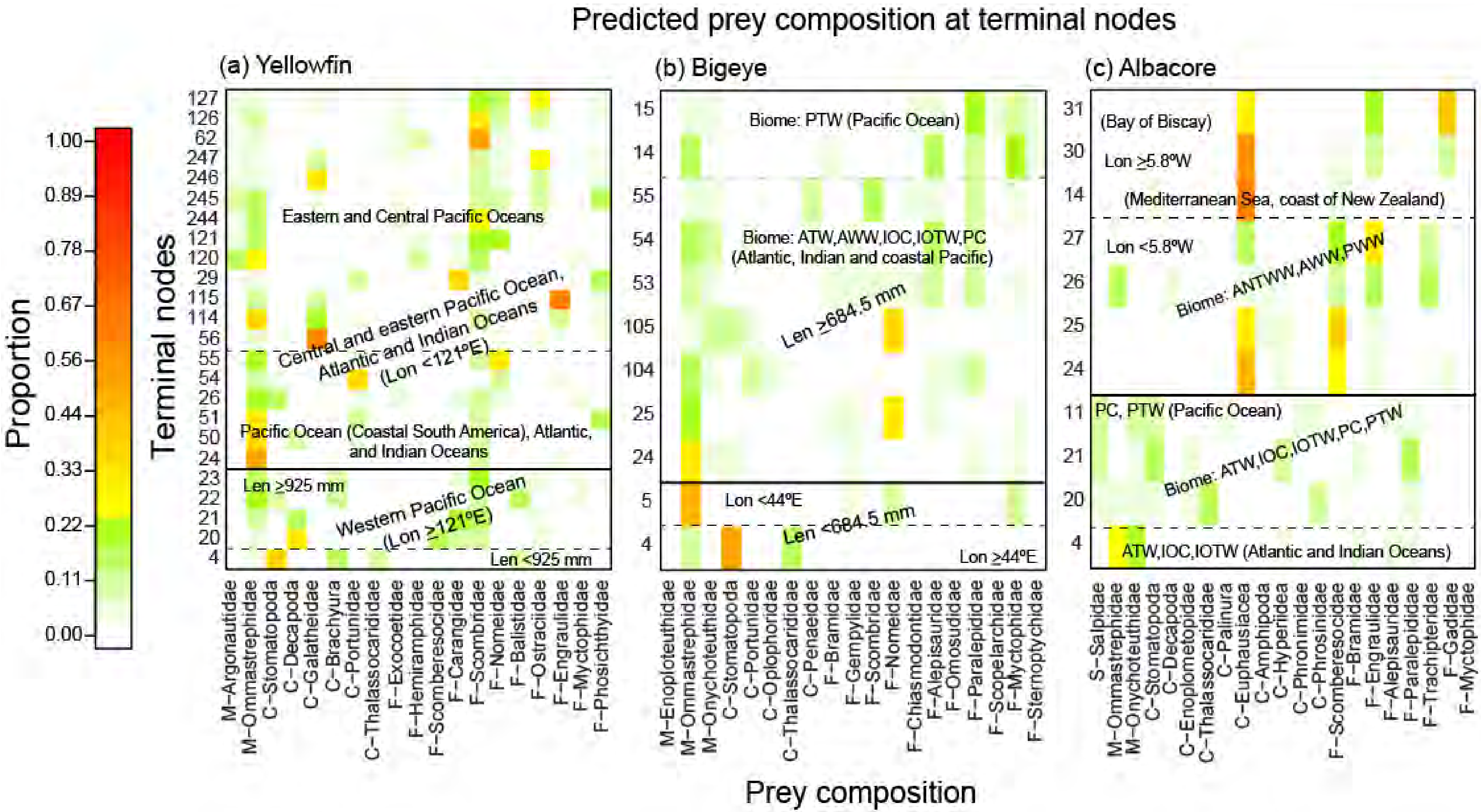
Partial dependence plots for the tunas against particular environmental variables (from Duffy et al 2017)

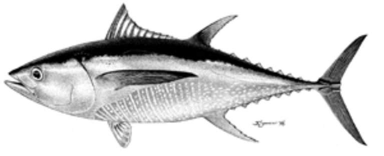


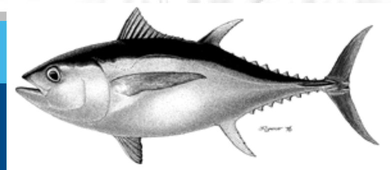




Heat maps of prey proportions (from Duffy et al 2017)

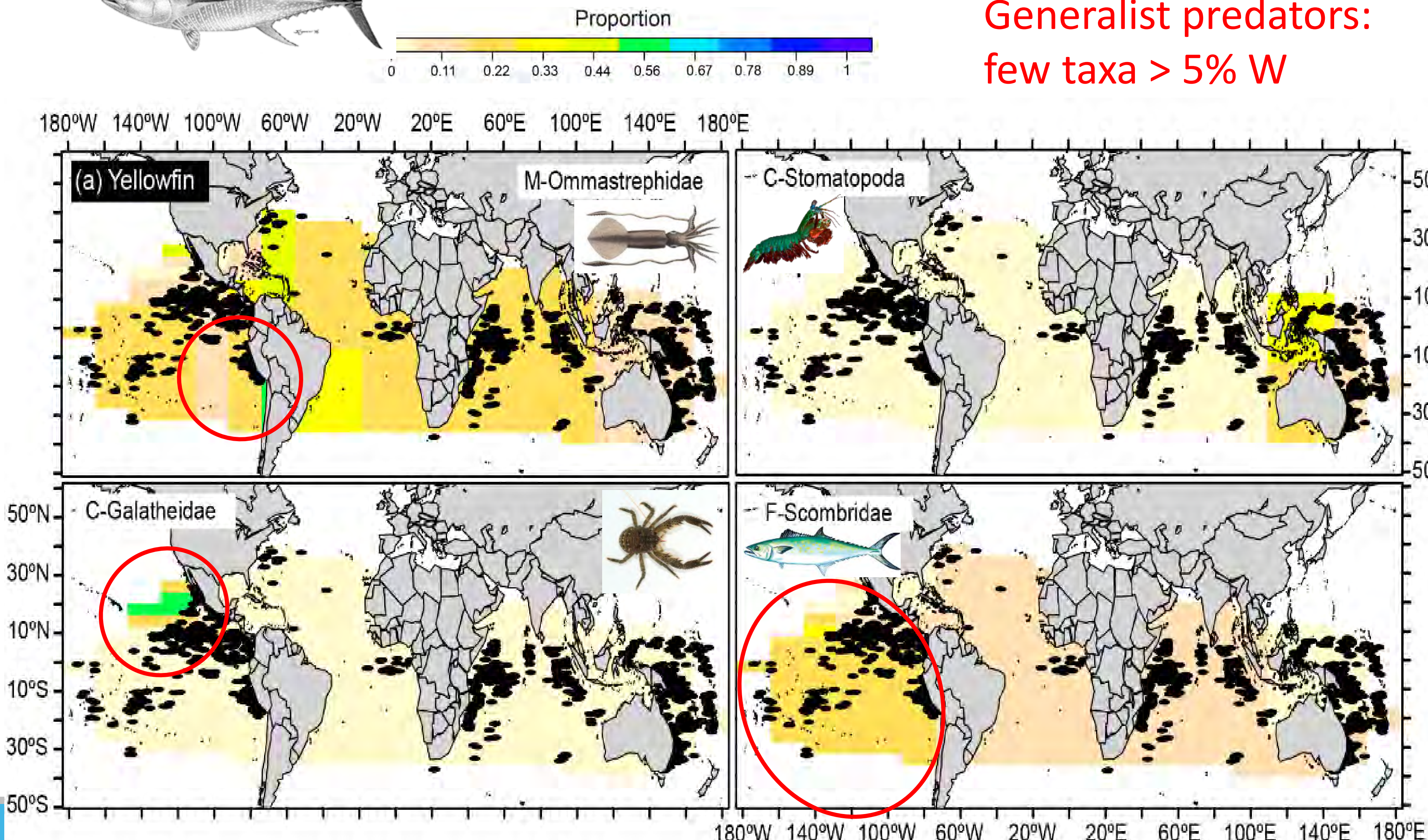






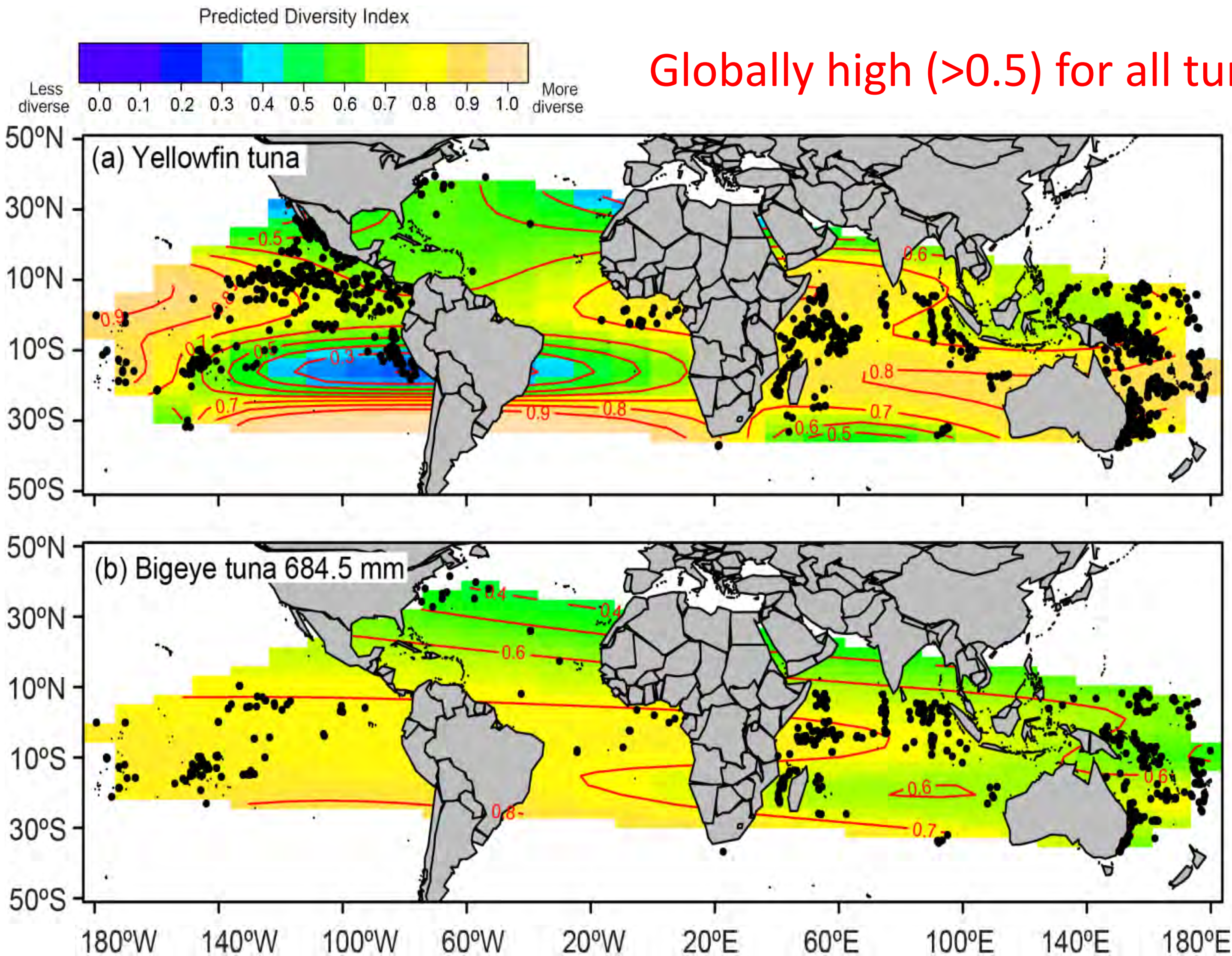
Global patterns in tuna prey (micronekton)

Generalist predators:
few taxa > 5% W



Global patterns in diet (prey) diversity

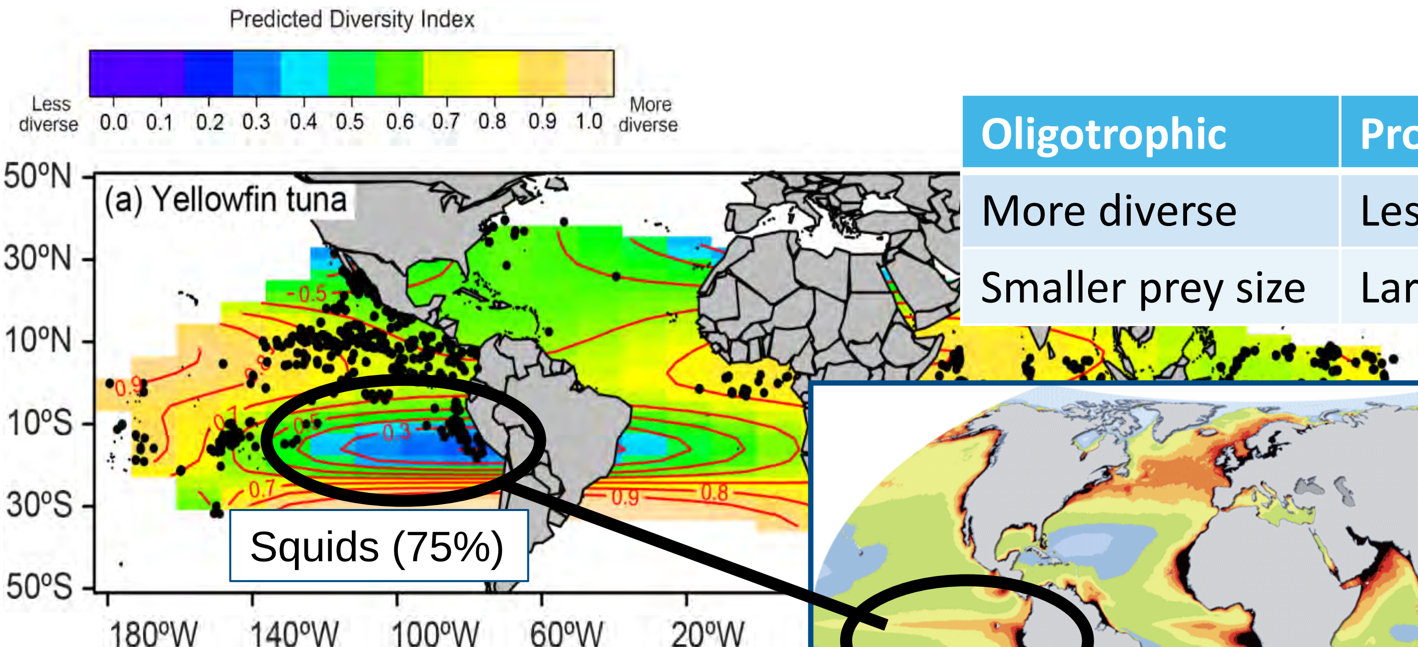
Globally high (>0.5) for all tunas



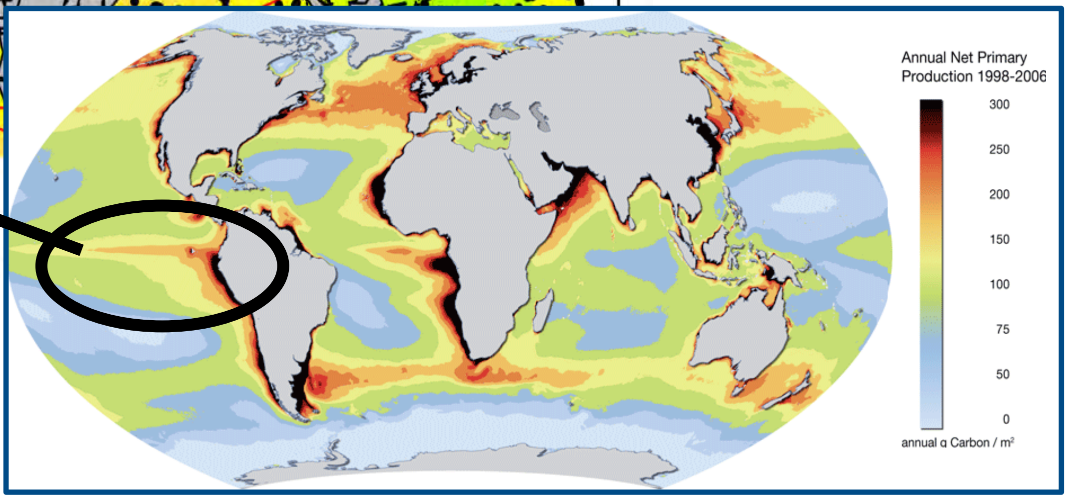
Inter-specific differences in spatial patterns reflect vertical foraging habitat.

No spatial gradients or clear spatial patterns in the diversity of micronekton consumed.

Diet diversity and regional productivity



Oligotrophic	Productive
More diverse	Less diverse
Smaller prey size	Larger prey size



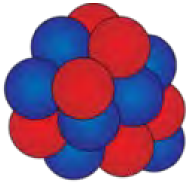
Consistent with broad-scale diversity patterns in the literature: inverse relationship between primary productivity and species richness.

The addition of biochemistry

Stomach content data

New information	Potential biases
- Taxonomic descriptions of global tuna diet - Information about prey availability (distributions and abundances) - Diet (prey) diversity	- Snap-shot in time (last meal) - Small temporal scale - Depends on taxonomic resolution and expertise - (See review Young et al 2015)

New tools can help give greater trophic insight at broader scales….

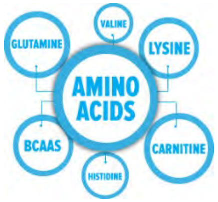


Isotopes

fatty acids

DNA

trace metals



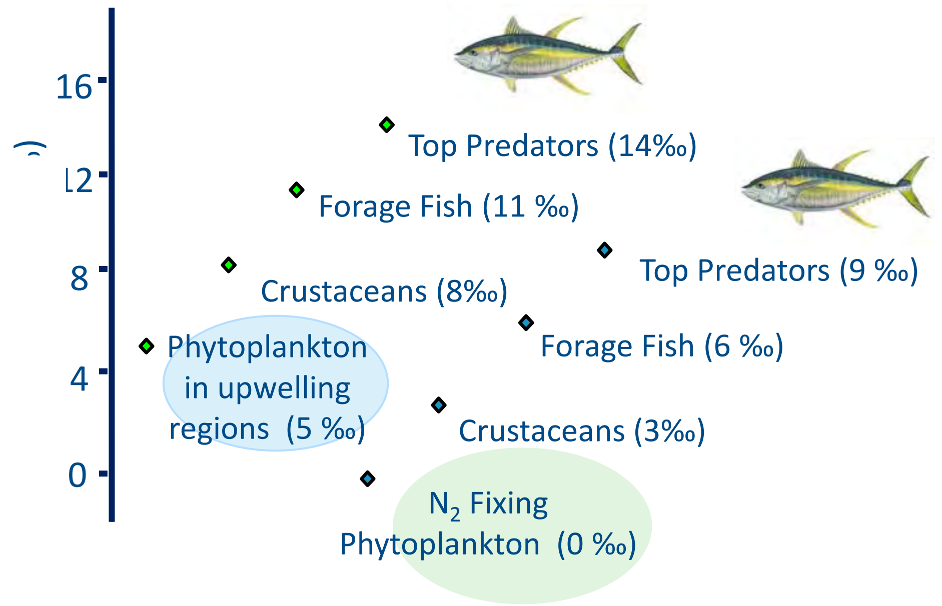
CSIA

Stable isotopes ($\delta^{15}N$ and $\delta^{13}C$)

Time- and space-integrated “signatures” of all assimilated prey components.

$\delta^{15}N$‰ estimates trophic level and trophic efficiency.

Variations in $\delta^{15}N$‰ reflect nitrogen sources (pool size) and processes of primary producers.



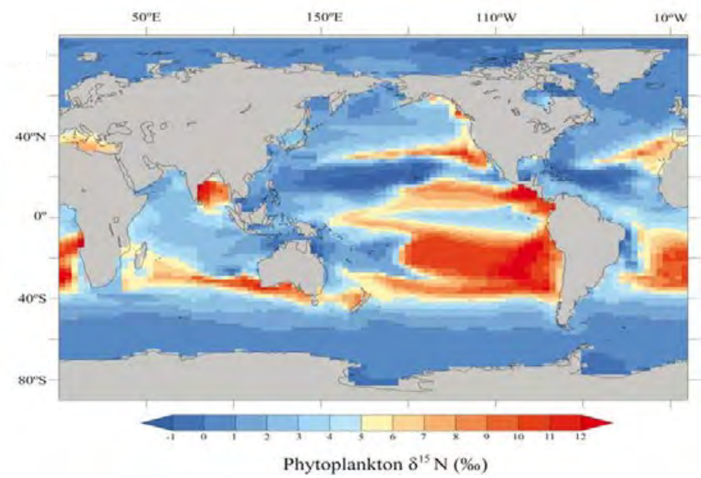
Global analysis of δ^{15}N (trophic level)

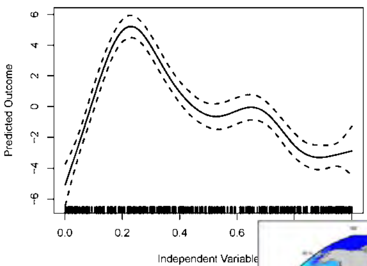
Method:

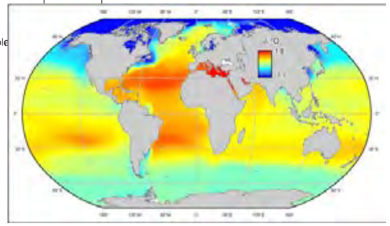
Corrected for δ^{15}N baseline effects using a global model (Sommes et al. 2010).

Generalized Additive Mixed Models:
Predictive variable: δ^{15}N corrected values (TL)
Explanatory variables:
Spatial: (latitude, longitude)
Biological: (fork length)
Environmental: (SST), (NPP), (MLD);
Quarterly climatologies; with time-lags.

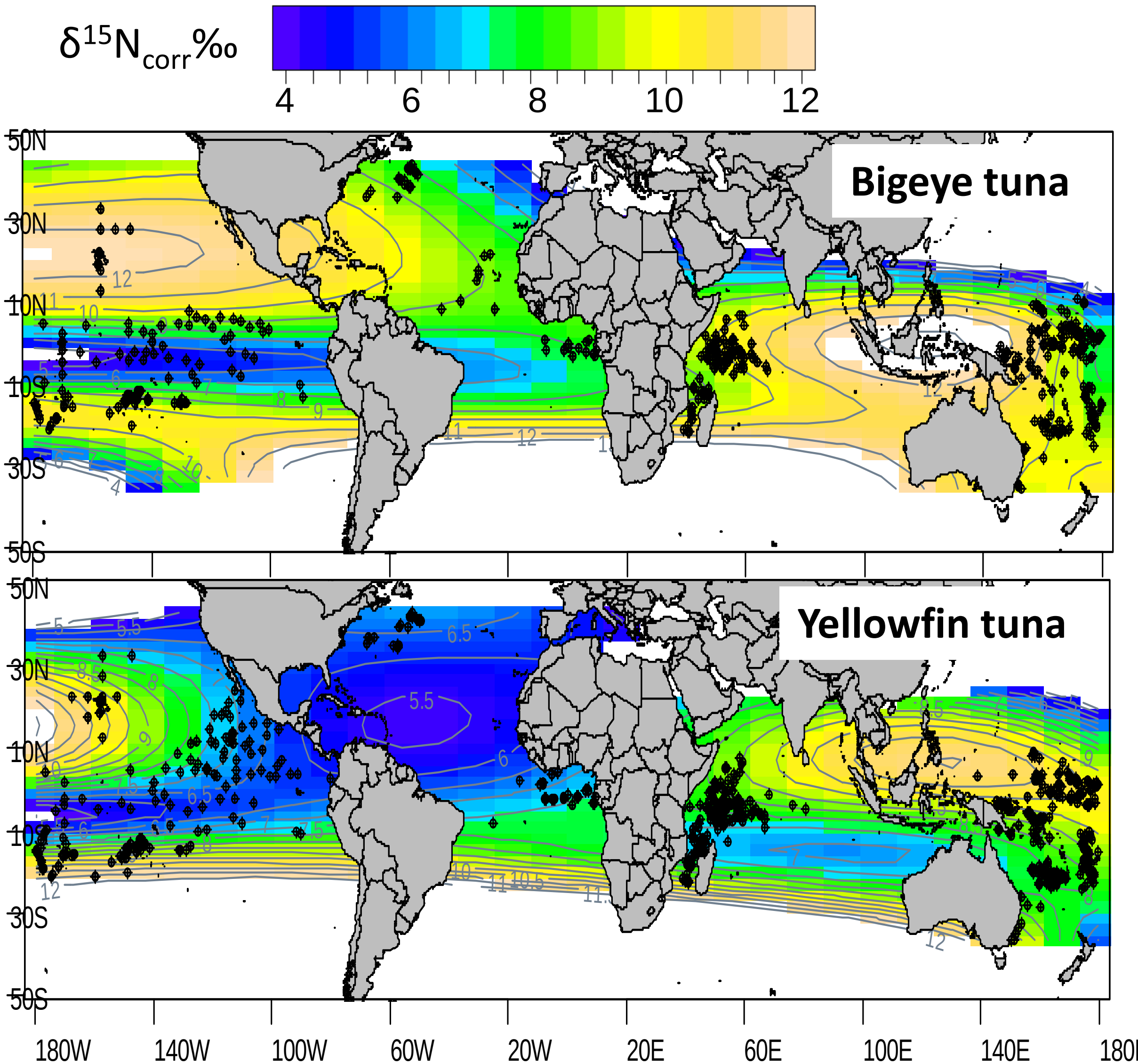
Interpolated results relayed on contour maps (isoscapes: spatially explicit predictions).







Global patterns in $\delta^{15}N$ (Pethybridge et al in review)



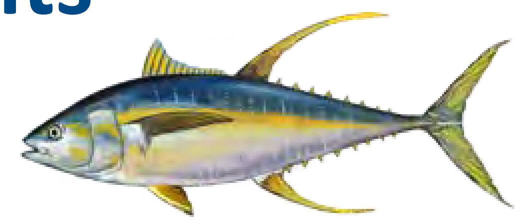
Spatial patterns differ between species in some regions (IO, WPO), but are typically:

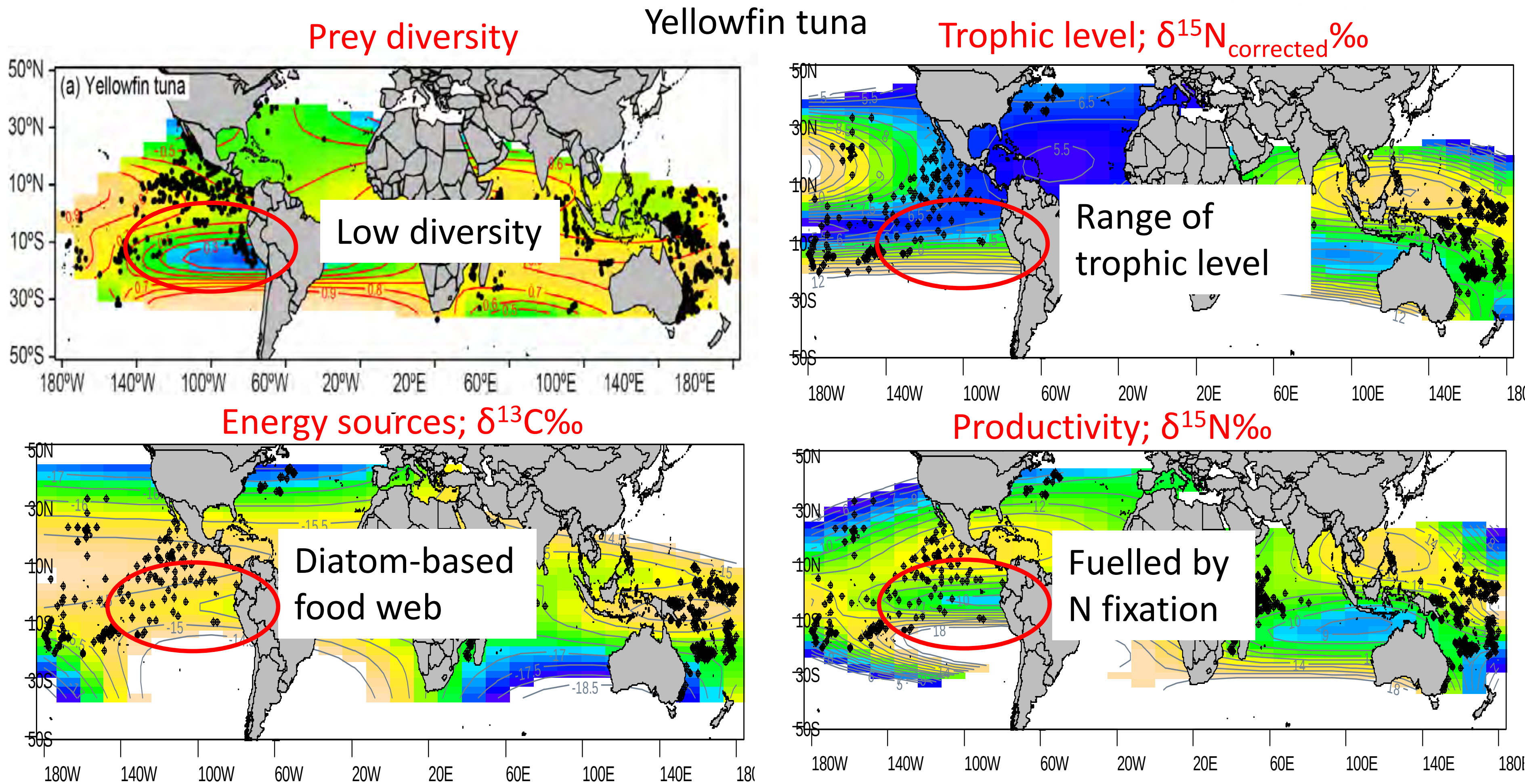
High: SW & N Pacific

Low: Atlantic

Comparing diet and isotope results

To obtain a complete global picture of food webs





Summary

- Widespread concern marine food webs are being altered. Greater understanding of predator-prey interactions needed.
- CLIOTOP WG3 undertook the 1st inter-oceanic comparison of top predator diets and isotopes ever conducted at a global scale.
- Our approach provides a novel global picture of spatial patterns of tuna diet, prey diversity, micronekton distribution, and trophic level.
- Spatial variables are good predictors of tuna trophodynamics.
- Results can assist ecosystem models (EBM) by providing macro-scale understanding of oceanic food webs

Ongoing work

Writing up:
- Isotope companion papers: Global Ecol Biogeogr.

More detailed regional work:

WCPO: A. Lorrain, IRD Noumea.

IO: PhD, Z. Duhmeea, Uni of Mauritius.

More global analyses (L. Couturier, IRD Postdoc):

(i) Isotopes of swordfish, skipjack tuna, whale shark.
(ii) Fatty acid biomarkers of albacore tuna.
(iii) Mercury isotopes in various tunas.

If you have diet data; get in contact with us!!