TUNA DIET IN THE EQUATORIAL PACIFIC OCEAN EAST TO WEST

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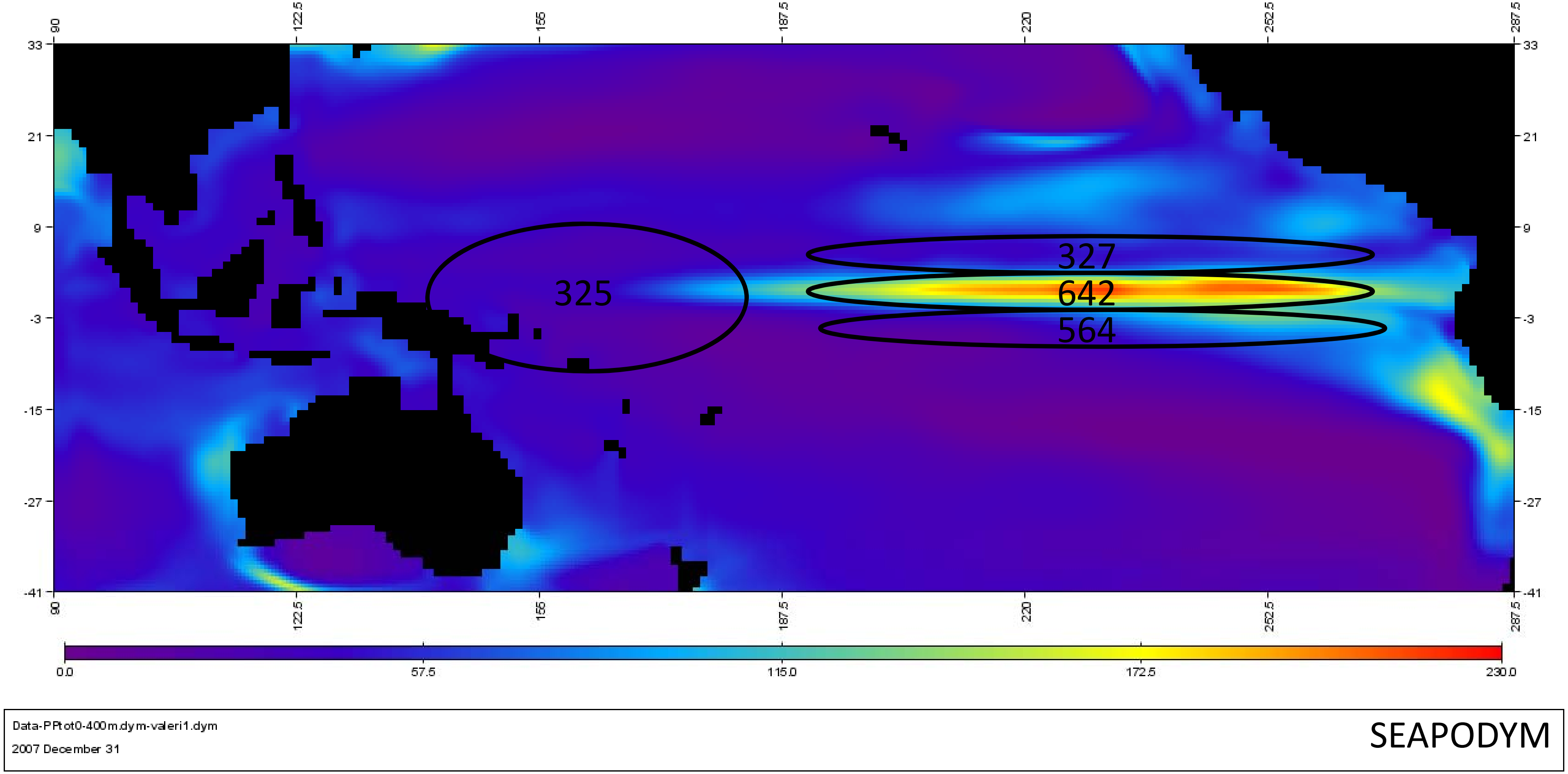
TROPHIC STRUCTURE AND TUNA MOVEMENT IN THE EQUATORIAL PACIFIC PELAGIC ECOSYSTEM

PFRP funded project #659559

CHARACTERISTICS OF THE AREA

Average Primary production from the surface to 100m 2001-2004



Primary production integrated from 0 to 100m depth in $mgC.m^{-2}.d^{-1}$ (Pennington et al. 2006)

The project developed from the hypothesis that tuna productivity in the western and central Pacific Ocean was tied to upwelling along the equator in the central and eastern Pacific (Lehodey 2001) resolving then the apparent discrepancy between primary production (high in Eastern-low in western) and tuna productivity (in 2007, 2.8 million tons, 16% in eastern-84% in western- Williams & Terawasi 2007)

OBJECTIVES

1- to define the trophic structure of the pelagic ecosystems

2- to establish an isotope-derived (upwelling-related) biogeography, and

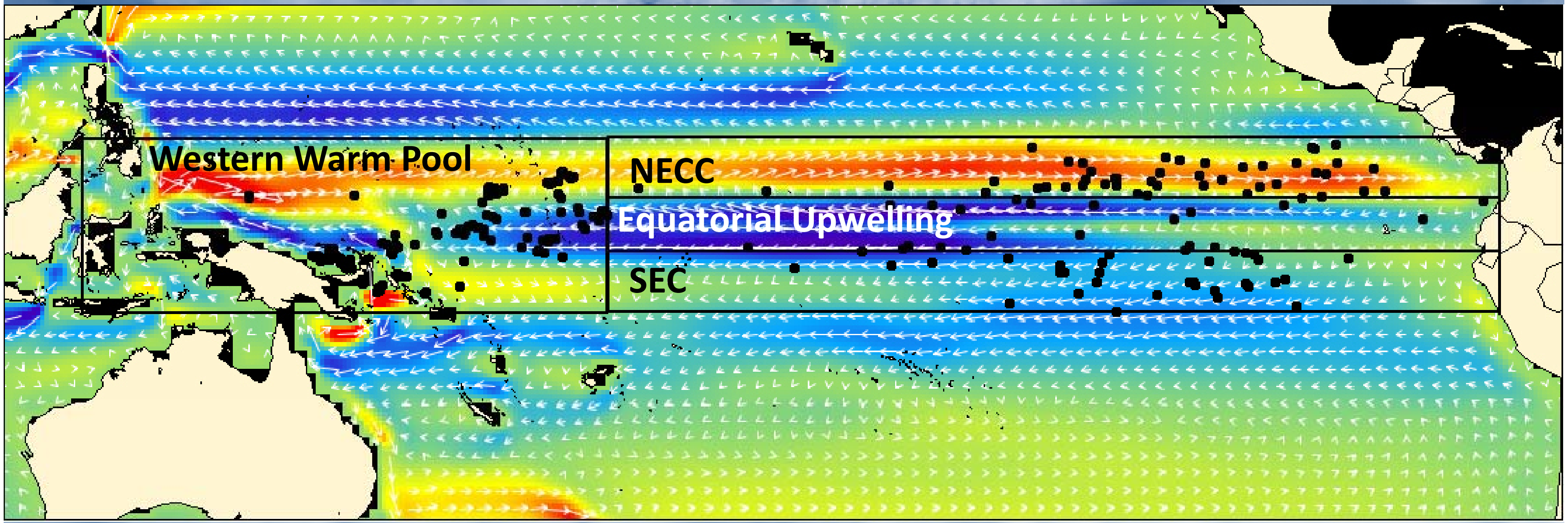
3- to characterize large-scale tuna movements related to upwelling along the equator.

METHODS

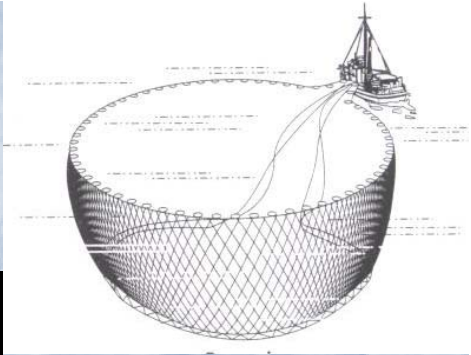
-diet analysis

-food-web modeling

BIOGEOGRAPHIC REGIONS



Sampling technique:
fish were collected by observers onboard purse-seiners fishing free schools and FAD schools



Number of samples collected

		WTP	SEC	EqUp	NECC
FAD	YELLOWFIN	242	375	216	518
	BIGEYE	122	436	239	359
	SKIPJACK	223	425	262	575
	RAINBOW RUNNER	148	134	68	372
Free	YELLOWFIN	17			56
	SKIPJACK	205		15	18
	Total	957	1370	800	1898

Average length (cm) of fish collected

		WTP	SEC	EqUp	NECC
FAD	YELLOWFIN	56	48	49	49
	BIGEYE	56	53	53	52
	SKIPJACK	47	46	48	47
	RAINBOW RUNNER	58	53	58	55
Free	YELLOWFIN	87			73
	SKIPJACK	57		75	55

similar average length in all areas

Percentages of empty stomachs

		WTP	SEC	EqUp	NECC
FAD	YELLOWFIN	85%	83%	83%	82%
	BIGEYE	90%	81%	90%	90%
	SKIPJACK	98%	95%	97%	95%
	RAINBOW RUNNER	47%	63%	69%	59%
Free	YELLOWFIN	12%			13%
	SKIPJACK	60%		100%	17%

values are similar in all areas

Fullness (%) of non-empty stomachs: weight of stomach content/weight of predator

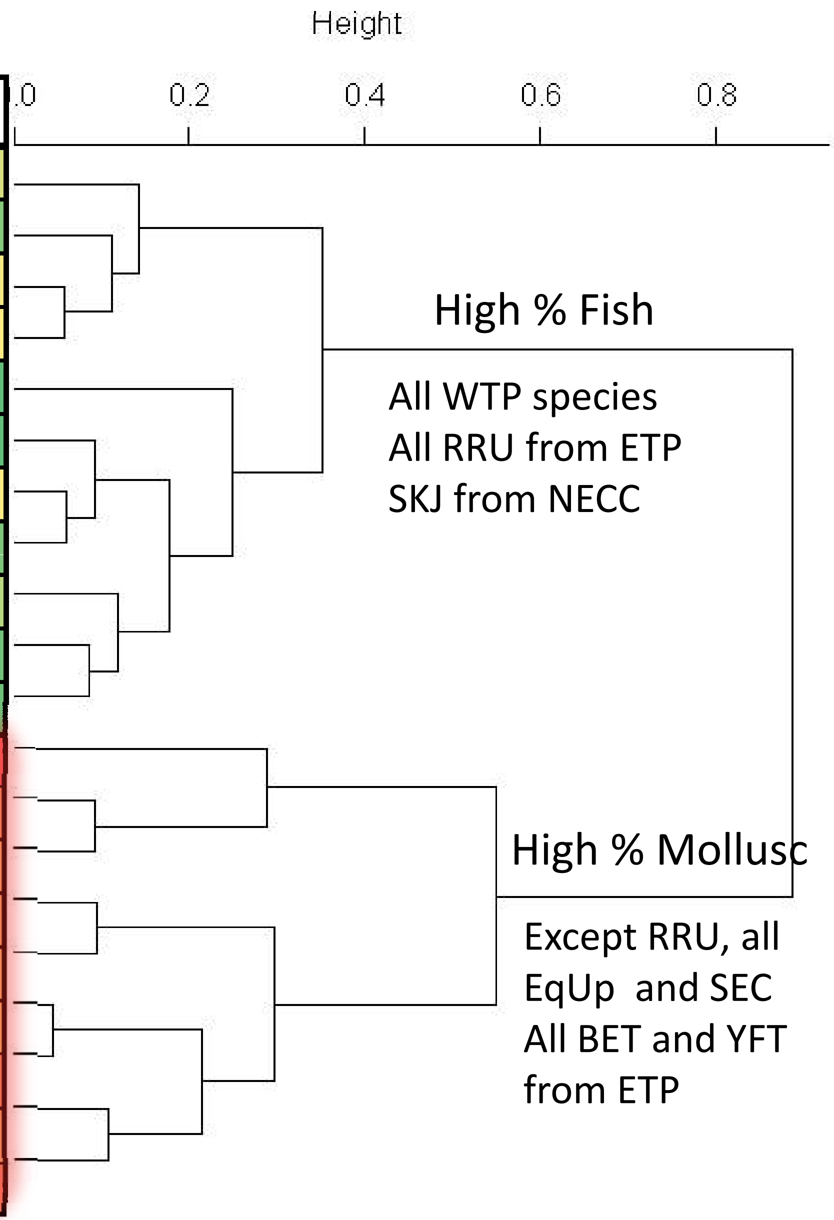
		WTP	SEC	EqUp	NECC
FAD	YELLOWFIN	0.591%	0.105%	0.175%	0.342%
	BIGEYE	0.303%	0.076%	0.052%	0.079%
	SKIPJACK	0.433%	0.105%	0.167%	0.159%
	RAINBOW RUNNER	1.132%	0.526%	0.508%	0.682%
Free	YELLOWFIN	0.553%			0.613%
	SKIPJACK	1.028%			0.415%

WTP values are 2 to 4 times higher than in ETP on average

Prey categories: mean proportion by weight (Chipps & Garvey 2007)

Cluster analysis:
Variables = %Crustaceans, %Fish, %Molluscs
Distance= Bray Curtis
Linkage=Complete

			%Crust	%Fish	%Moll
FAD	NECC	SKJ	10.3	50.0	15.5
FAD	EqUp	RRU	9.5	85.7	4.8
FAD	NECC	RRU	12.9	61.9	19.5
FAD	WTP	BET	6.3	64.1	21.3
FAD	WTP	SKJ	0.0	60.0	0.0
Free	NECC	SKJ	7.2	92.8	0.0
FAD	SEC	RRU	21.3	58.3	20.4
Free	WTP	SKJ	0.0	86.3	3.6
Free	WTP	YFT	10.0	78.4	11.6
FAD	WTP	RRU	6.7	73.7	2.0
FAD	WTP	YFT	20.3	75.3	1.7
FAD	NECC	BET	0.0	11.1	88.9
FAD	EqUp	BET	0	44.3	55.7
FAD	EqUp	YFT	0	59.9	40.1
Free	NECC	YFT	22.1	34.6	43.2
FAD	EqUp	SKJ	0	64.3	35.7
FAD	SEC	SKJ	25.0	41.1	33.9
FAD	SEC	YFT	8.5	31.3	59.9
FAD	NECC	YFT	10.8	42.8	46.4
FAD	SEC	BET	2.4	28.4	69.2



Prey items: mean proportion by weight (Chipps & Garvey 2007)

CRUSTACEANS	BET				RRU				SKJ						YFT					
	N Float	Eq Float	S Float	W Float	N Float	Eq Float	S Float	W Float	N Float	N Free	Eq Float	S Float	W Float	W Free	N Float	N Free	Eq Float	S Float	W Float	W Free
Amphipoda															2.08					0.19
Brachyura					1.31										0.26					
Callinectes sp.																2.26				
Caprellidae															1.04					
Caridea								0.97												
Portunidae																0.47				
Penaeidae	0.01				0.65	6.67									1.04	0.01		1.68		
Decapoda			0.89				0.01											1.62		
Enoplometopus sp.				2.83																
Hyperiidea								0.67						0.33						
Isopoda							1.05							0.17				1.52		
Lepas sp.								0.12												
Megalopa stage								0.13												
Ostracoda					1.03				3.45			20.00						1.26		
Phronima sp.														0.17						1.33
Shrimp								2.26											17.59	
Squilloidea																			1.35	
Stomatopoda				2.83				1.32											1.35	1.50
Streetsia sp.								0.48												
Thalassocaris sp.				0.39				0.15												
Unidentified Crustacea			1.55	2.83	9.96		19.71	1.70	6.90	7.16		5.00			6.25	19.40		2.27		7.11

Except for RRU, no crustaceans are consumed in the EqUp

Ostracoda are found only in NECC and SEC

Callinectes (swimming crab) is noticeable in the NECC

Stomatopoda and Enoplometopus are only found in the western Pacific

FISH

	BET				RRU				SKJ						YFT					
	N Float	Eq Float	S Float	W Float	N Float	Eq Float	S Float	W Float	N Float	N Free	Eq Float	S Float	W Float	W Free	N Float	N Free	Eq Float	S Float	W Float	W Free
Acanthuridae								0.46											2.73	
Chaetodontidae								0.34												
Zanclidae																			2.73	
Balistidae + Balistes sp.					0.65		1.82	0.18			14.29								0.26	
Bramidae + Pterycombus petersii	1.13	2.65	1.61					0.42										0.99		
Coryphaenidae + C. hippurus	1.56		1.25		0.58															
Engraulidae								2.72						5.27					2.73	8.74
Auxis sp.					1.31											2.04				
Auxis thazard					0.65				3.45						4.17		5.88			
Scombridae	2.70		1.18		1.31	0.78														
Thunnus albacares																		1.18		
Thunnus sp.		0.12			0.65	13.33											2.94			
Katsuwonus pelamis		4.00		12.96	1.31		5.43	2.39						6.55	0.90			1.52		
Oxyporhamphus micropterus					1.15							5.00			5.23		2.94			
Cheilopogon sp.					0.68															
Cypselurus callopterus																	2.94			
Exocoetidae					1.96		1.82			0.11					0.54		19.18			
Exocoetus monocirrhus		0.01	0.00												2.71		1.47	0.00		
Exocoetus volitans			1.25		4.71		1.81								10.37		0.00			
Parexocoetus brachypterus																		1.00		
Alepes sp.								1.47												
Carangidae				3.14	0.65			3.73											19.13	
Caranx sp.								1.42												
Decapterus sp. + D. macarellus					1.95		1.82	8.46											5.45	
Elagatis bipinnulatus																			2.73	
Selar sp.								1.25												
Seriola peruana						5.89														
Vinciguerria lucetia						6.67			13.79						1.20	2.03				
Benthosema panamense			0.00		1.33					59.87						15.88		0.00		
Myctophidae + Myctophum spinosum								2.78												
Other (9 items)				0.58	0.66		1.82	0.89				4.89		1.00						
Unidentified Fish	5.70	35.76	23.43	47.49	42.37	66.66	44.73	48.96	32.76	32.85	50.00	31.21	60.00	74.43	18.24	14.66	22.21	27.69	39.69	69.69

Juveniles of reef-associated species are only found in the WTP

Engraulidae (anchovies) are also specific to WTP

Large quantities of flying fish are found in the ETP only

Carangidae are found in all areas but they represent a higher percentage of the diet in WTP

A large choice of scombridae are consumed in the ETP while only SKJ was found in the WTP

Unidentified Fish % varied, tend to be lower in NECC and higher in WTP

MOLLUSCS	BET				RRU				SKJ						YFT					
	N Float	Eq Float	S Float	W Float	N Float	Eq Float	S Float	W Float	N Float	N Free	Eq Float	S Float	W Float	W Free	N Float	N Free	Eq Float	S Float	W Float	W Free
Carinaria sp.														0.33						
Cavolinia sp.								0.14						0.20						0.44
Bivalvia												5.00				0.98				
Gastropoda					0.02															
Argonauta cornutus	0.45				1.09		0.91		3.45						3.52	0.00	0.00			
Argonauta sp.	2.70		1.52		0.00										4.01	3.26		1.54		
Dosidicus gigas	39.50	4.26	11.17		5.48		2.73		5.17	0.01	14.29	12.50			15.73	5.13	17.17	9.23		
Onychoteuthis banksii	4.05				0.22										0.61					
Thysanoteuthis rhombus	4.60	0.00	0.00		1.31										1.04	0.00		0.00		
Sthenoteuthis oualaniensis	4.28	0.01	10.34		1.31	0.00								0.62	1.14		0.01	2.03		
Ancistrocheirus lesueurii	4.05														0.35			0.00		
Ommastrephidae	0.68		0.00	7.69														1.65		
Japetella diaphana	0.90	0.01	0.01		0.00										1.69	1.19	1.49	0.01		
Vitreledonella richardi		0.08	0.00									5.00			0.00		2.97	0.01		
Gonatus sp.	2.03	0.01	0.27												0.00		0.01	0.01		
Histioteuthis sp.	1.35	0.01	0.26														0.04	0.39		
Mastigoteuthis dentata	2.79	4.01	0.89									2.50			1.51	1.19	1.47	0.39		
Mastigoteuthis sp.															0.69					
Abraliopsis sp.																0.00				
Octopoda		0.26			0.22										0.00					
Octopodidae																0.87				
Teuthida	21.52	48.81	44.37	13.58	9.85		16.36	2.70	6.90		21.43	8.90		3.03	15.67	30.62	19.26	43.76	1.55	11.70

Few species identified in the WTP: *Carinaria* and *Cavolinia* (planktonic mollluscs) and Ommastrephidae (squid)

In the ETP, predators consume a large variety of squids, particularly *Dosidicus gigas*, *Sthenoteuthis oualaniensis*, *Argonauta*, *Mastigoteuthis*…

Teuthida (unidentified squids) represent a low% in WTP

Diet comparison – SUMMARY

-amount of food in WTP stomachs is 2 to 4 times higher than in ETP on average

- WTP predators, RRU from ETP and SKJ from NECC are mainly piscivorous

- All BET and YFT from ETP as well as SKJ from EqUp and SEC eat primarily cephalopods

- Unidentified preys, particularly fish, induce a high uncertainty on comparisons conducted at the level of prey items

-Some species are specific to some areas

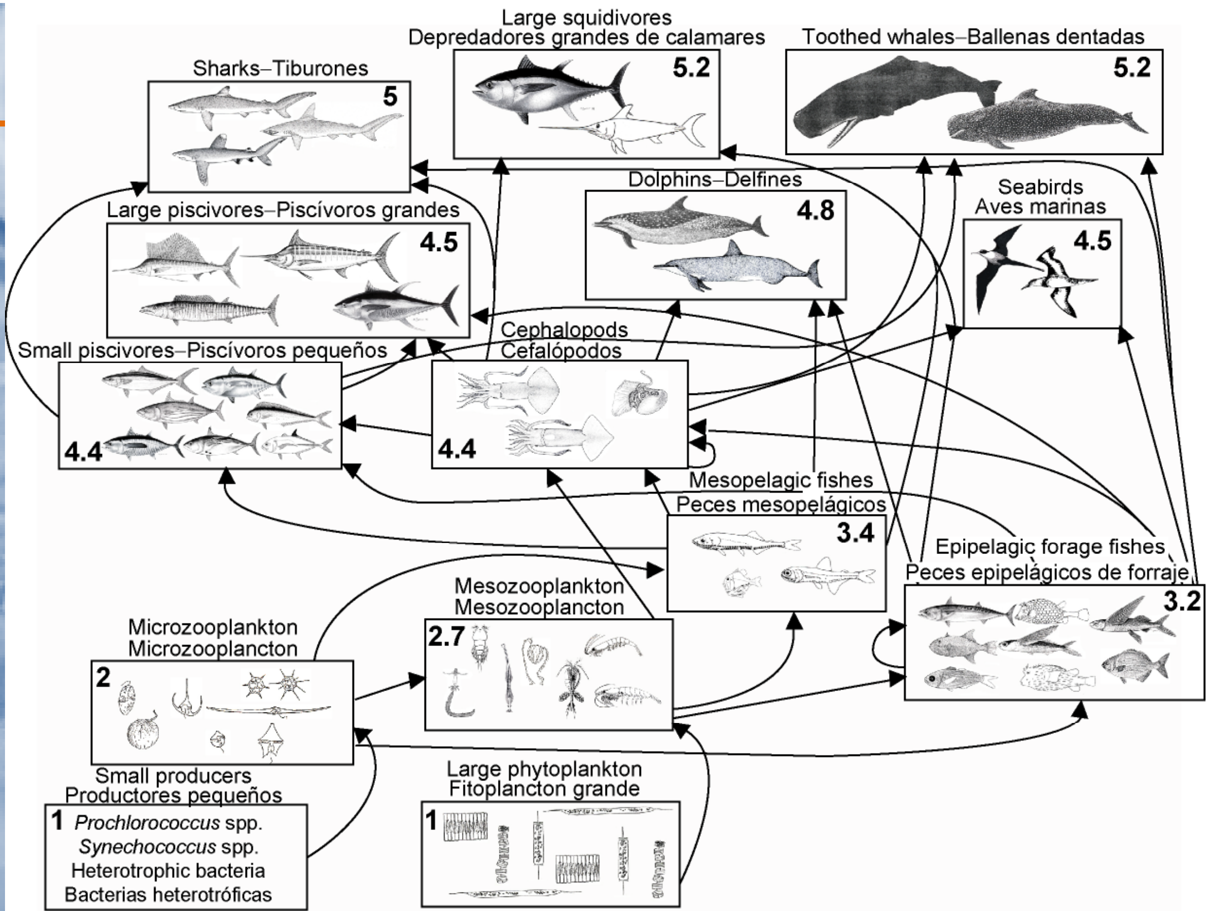
-reef-associated preys and probably island-related Engraulidae were specific to the WTP

-a variety of Scombridae were consumed in the ETP only SKJ was observed in the WTP

- squids are preponderant in the diet of ETP Tuna except SKJ (and RRU) with Dosidicus and a variety of squids while they represent a low% for WTP predators with planktonic molluscs

There is a clear difference between WTP and ETP while it is difficult to observe a clear trend between the different areas of the ETP

ECOSYSTEM modeling (ECOPATH)



<u>ETP (Olson & Watters 2003)</u>
"changes in the basic parameters for two components at middle trophic levels, Cephalopods and *Auxis spp., exert the greatest influence on the system.* "

<u>WTP (Allain et al. 2007)</u>
SKJ appear has a key role in the system (high biomass, high production, high consumption and important cannibalism)
A disagreement in the input data: the forage biomass estimates from the Seapodym model could not sustain the tuna biomass from the stock assessment model MULTIFAN-CL.
2 possible explanations:
-underestimation of forage
-a potential importation of forage from the East is not captured in the model.

Underestimation of forage in the WTP?

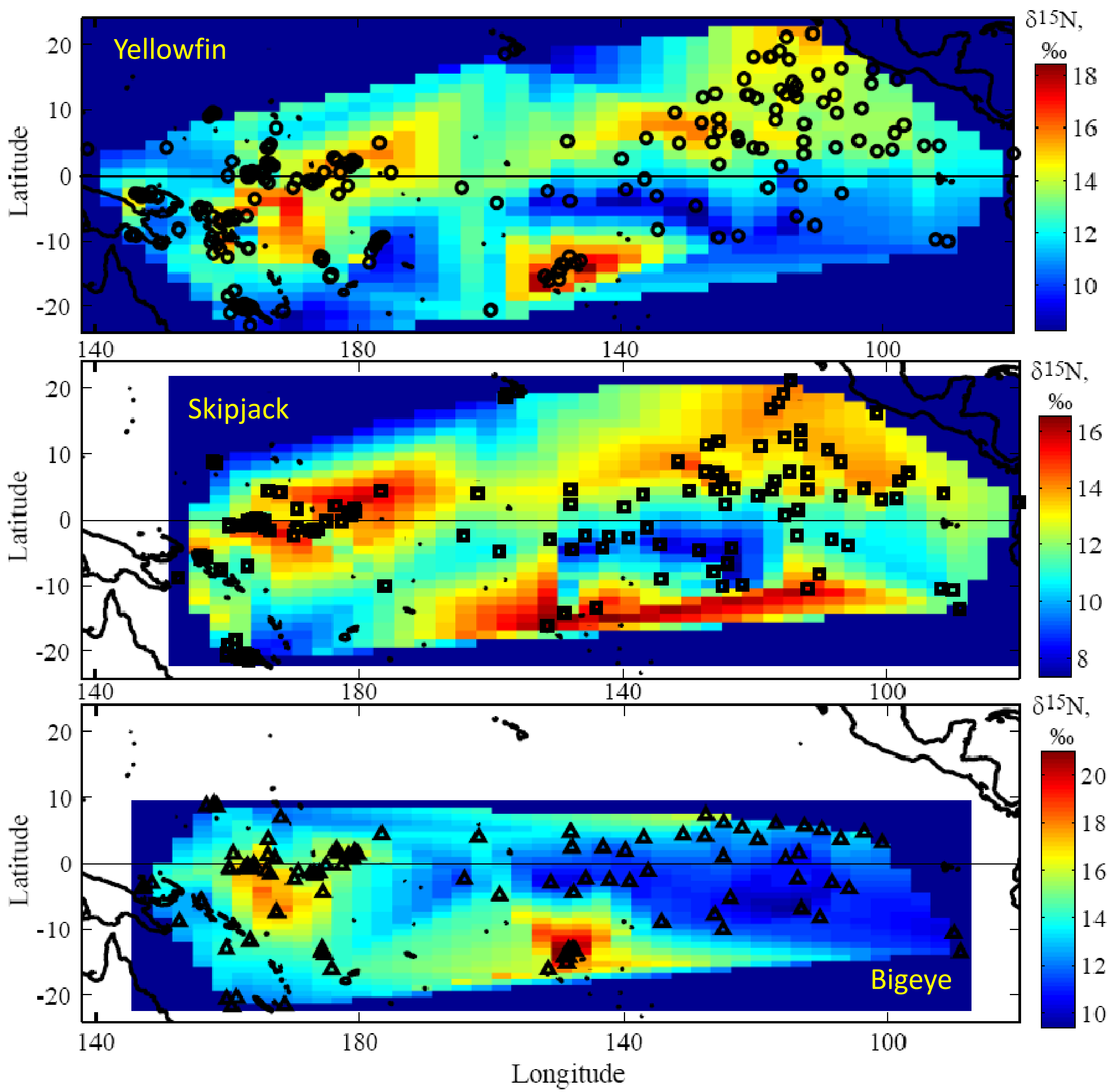
→ the importance of reef and islands associated fauna should be explored, Island effect in the WTP is probably underestimated particularly in forage biomass estimates

Importation of forage from the East not captured?

→ advection of forage

→ our study of isotopes at the scale of the whole Pacific exclude extensive movements of the tuna

Stable isotope analysis suggest limited movement behavior throughout the equatorial Pacific.



There is a strong need for forage biomass estimates both at global and regional scales and acquisition of better knowledge of its composition and movements (horizontal and vertical)