IMPACTS OF CLIMATE CHANGE-INDUCED ENVIRONMENTAL FLUCTUATIONS ON THE STRUCTURE OF MARINE ECOSYSTEM AROUND THE TAIWAN BANK

11 Nov., 2022

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Marine Primary production and energy flow

■ Primary Production(PP)

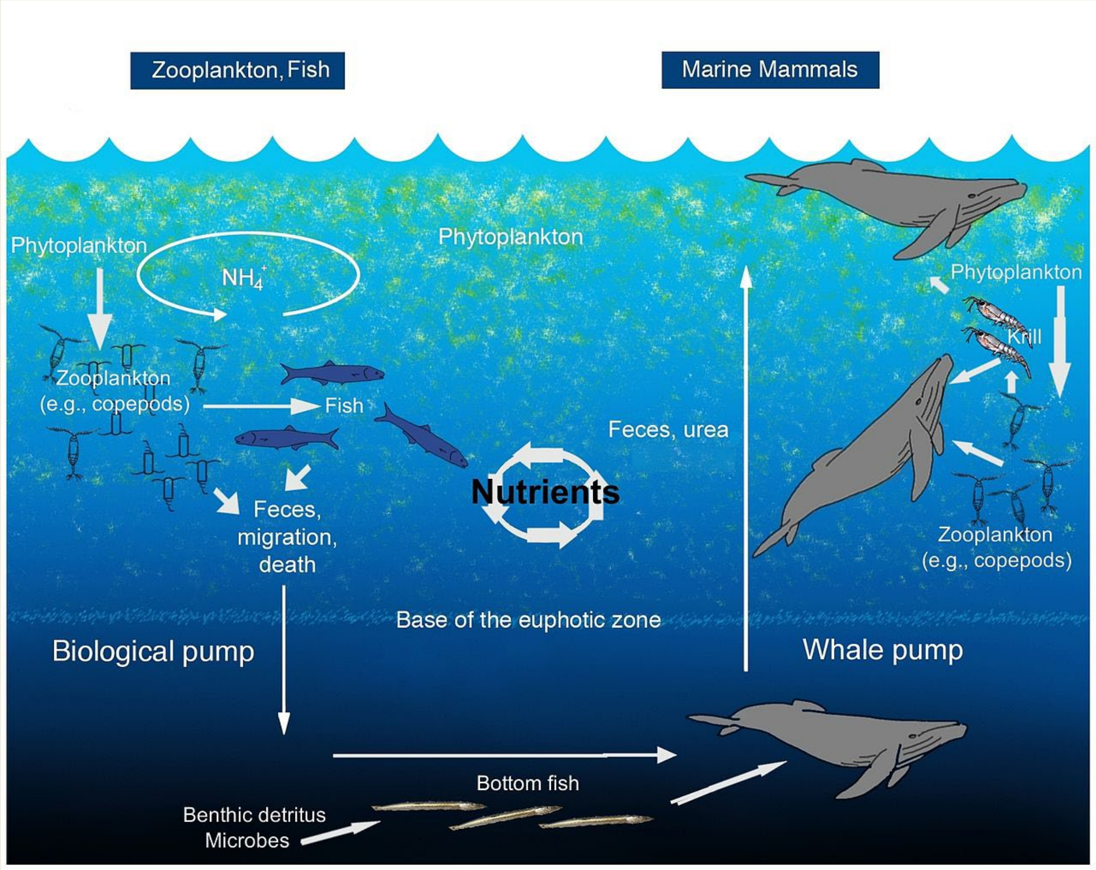
The basis for food chains, promotes the abundance of fishery resources by energy transfer between trophic levels.

■ Energy transfer and balance

A certain PP can support a certain mount of fish catch. On the contrary, a certain catch requires a certain PP to support it in order to balance the operation of the ecological food chain.

■ Benthic-pelagic coupling

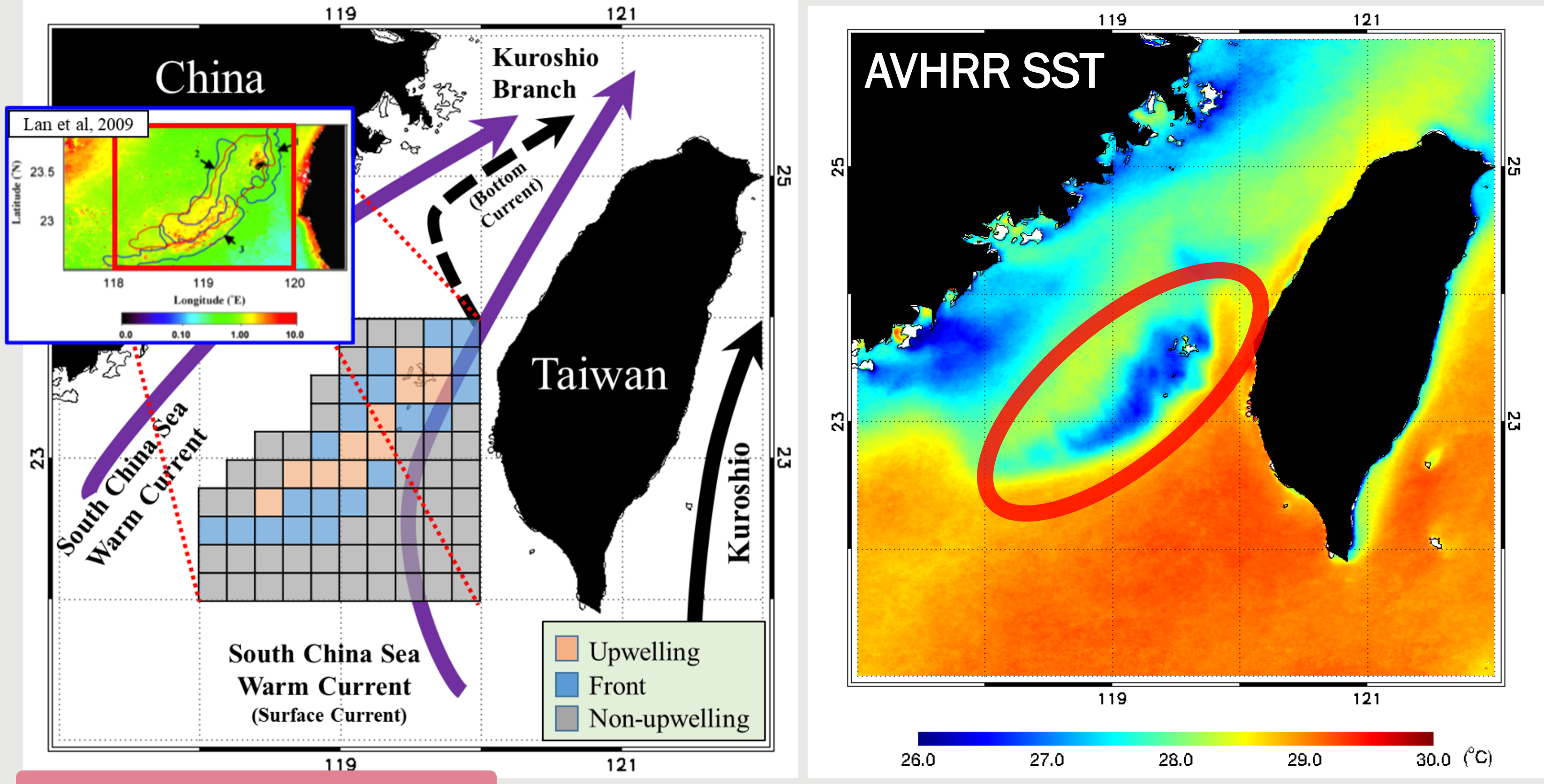
The benthic-pelagic coupling plays a pivotal role in marine ecosystems by allowing nutrient cycling and energy transfer between the benthic and pelagic domains.



Cite from Roman et al, 2010

Environmental Characteristics of Taiwan Bank (TB)

Taiwan Bank upwelling area



Cited from Hsiao et al., 2021

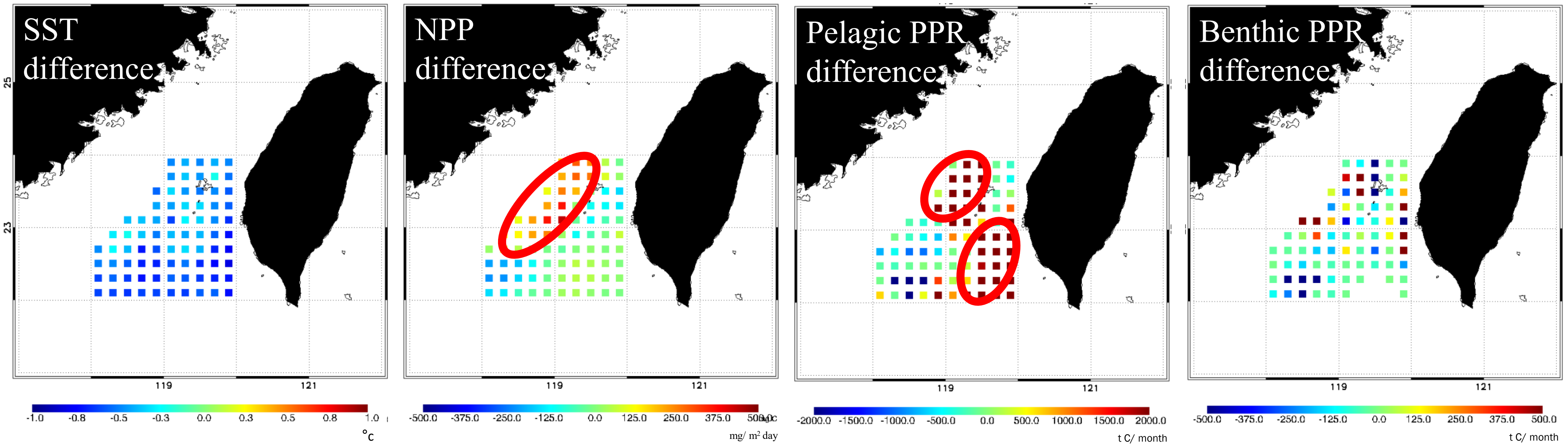
Taiwan Bank (TB)

TB upwelling

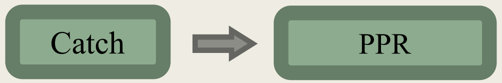
■Located in the southwestern Taiwan Strait (TS), the Taiwan Bank (TB) is characterized by sand dunes and shallow water. (<30M)

■The bottom water flows upward along the edge of the continental shelf, forming an upwelling region that is an essential high-productivity fishing ground.

Differences between La Niña (2011) and El Niño (2016) events



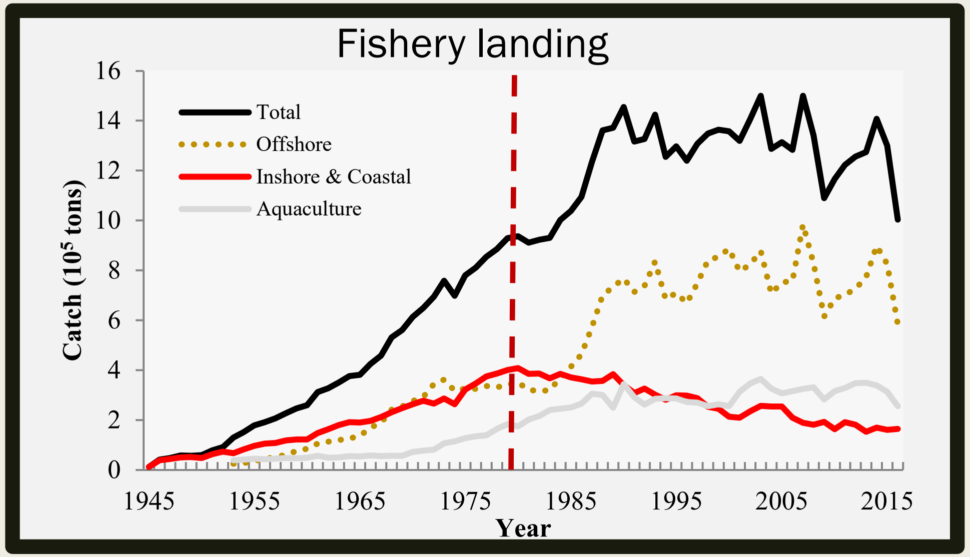
- Higher average PPRs were noted of pelagic species in the northwest and southeast parts of the frontal habitat, northern parts of the upwelling habitat, and southern parts of the non-upwelling habitat, with lower SST and higher NPP in La Niña years.
- Variations in the spatial distribution of the benthic PPR (benthic species) were less associated with environmental factors during ENSO events.

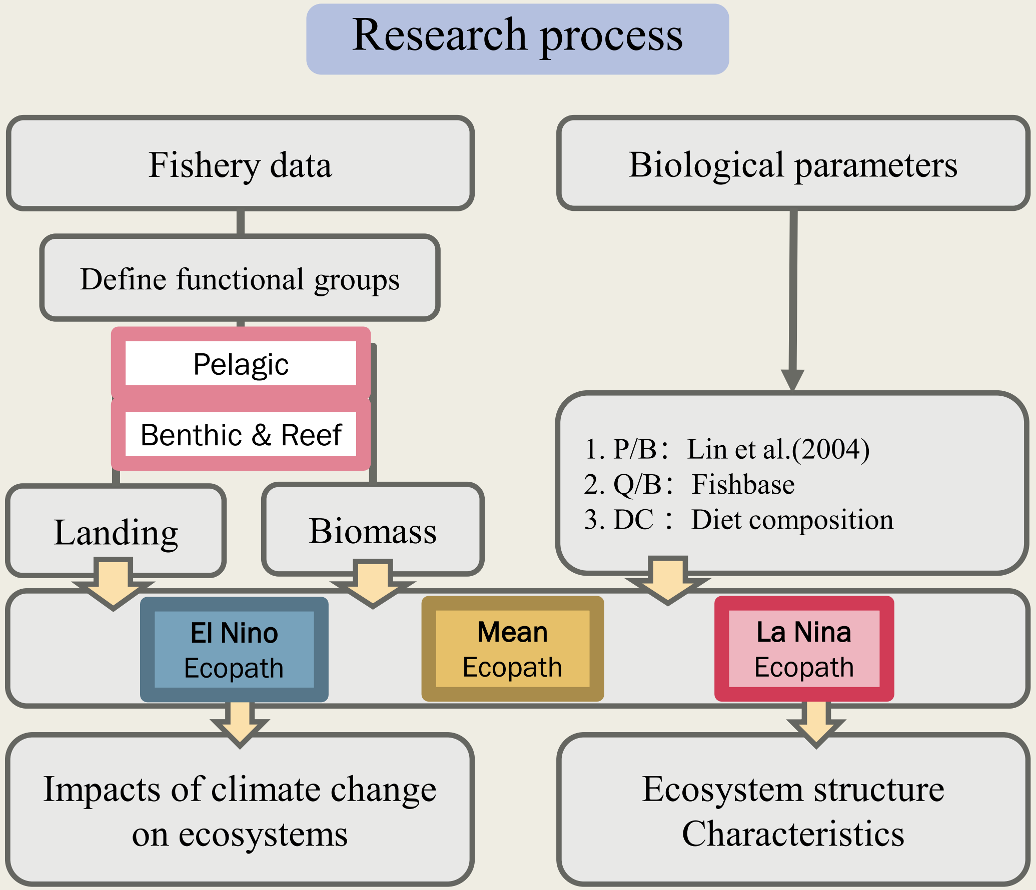


PPR

Primary Production Required(PPR)- Converting catches to equivalent PP which can be regarded as an indicator of environmental tolerance.

Purpose of study





Purpose

■The complexity of hydrological cycling and upwelling system provided high nutrient, provide high richness of benthic and pelagic species in the TB.

■But there are no detailed analysis and available information within ecosystem structure and trophic relationships changed by climatic events has been carried out in the TB.

■Also, the inshore fishery in Taiwan have been declining year by year since the 1980s, and the relationship between climate change affecting the marine environment and fishery production is unclear.

Ecosystem Model

Ecopath with Ecosim (EwE)

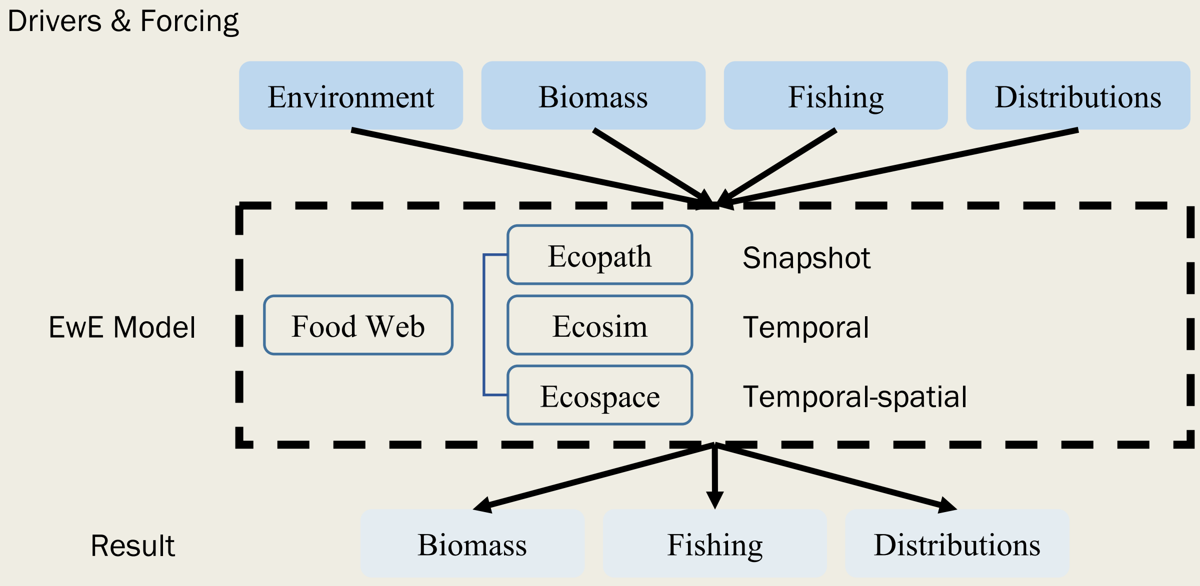
Ecopath, a snapshot food web model

1. Basic Ecopath input parameters (B, P/B, Q/B, EE)
2. Diet composition data
3. Fishery Landing data

$$Q_i = P_i + R_i + GS_i \times Q_i$$

consumption (Q_i), production (P_i), respiration (R_i), unassimilated food ($GS_i \times Q_i$)

$$(P/B)_i \times B_i = Y_i + \sum_j B_j \times (Q/B)_j \times DC_{ji} + E_i + BA_j + (P/B)_i \times B_i(1 - EE_i)$$



- (P/B)i - the production to biomass ratio for a certain functional group i
- Bi - the biomass of a group i
- Yi - the total fishery catch rate of group i
- (Q/B)j - the consumption to biomass ratio for each predator j
- DCji - the proportion of group i in the diet of predator j
- Ei - the net migration rate (emigration − immigration)
- BAi - the biomass accumulation rate for the group i
- EEi - the ecotrophic efficiency
- (1 − EEi) - mortality other than predation and fishing.

Data collection

Function groups

According to the top 30 species based on fishery logbook and the important commercial species by expert opinion, 32 function groups was being selected.

Biomass & Landing

■Biomass data was transform from fishery logbook data, through the CPUE and catch, biomass was being derived.
■Landing data from fishery logbook data aggregate in ton/km^2 per year unit.

$$B = \frac{\sum_i^n C_i}{\sum_i^n G_i \times \sum_i^n D_i}$$

where Ci is the fishery catch of group i, Gi is the numbers of grids in group i, Di is the numbers of data in group i

Basic parameter resource

	No.	Function Groups		Biomass	p/b	q/b	landing	dc
Predator fish	1	*Thunnus albacares*	Yellow fin tuna	-	Fishbase	Fishbase	-	
	2	*Katsuwonus pelamis*	Skipjack tuna	-	Fishbase	Fishbase	-	
	3	*Coryphaena hippurus*	Dolphinfish	-	Fishbase	Fishbase	-	
	4	*Scomberomorus commerson*	Spanish mackerel	-	Fishbase	Fishbase	-	
Pelagic fish	5	*Scomber australasicus*	Spotted mackerel	-	Duan (2005)	Fishbase	-	
	6	*Scomber japonicus*	Chub mackerel	-	Duan (2005)	Fishbase	-	
	7	*Trachurus japonicus*	Japanese jack mackerel	-	Duan (2005)	Fishbase	-	
	8	other mackerels	other mackerels	-	Duan (2005)	Fishbase	-	
	9	*Auxis rochei rochei*	Bullet tuna	-	Duan (2005)	Fishbase	-	
Small pelagic fish	10	*Etrumeus micropus*	Pacific round herring	-	Duan (2005)	Fishbase	-	
	11	*Sardinella spp.*	Sardinella spp.	-	Duan (2005)	Fishbase	-	Fishbase, SeaLife Base, The Fish Datebase of Taiwan. Duan (2005) Lin (2013) Wang (2005
	12	*Decapterus maruadsi*	Round scad	-	Lin (2013)	Fishbase	-	
Benthic and Reef fish	13	*Seriola dumerili*	Amberjack	-	Lin (2013)	SeaLife Base	-	
	14	*Mene maculata*	Moonfish	-	Lin (2013)	Fishbase	-	
	15	*Decapterus kurroides*	Mackerel scad	-	SeaLife Base	Fishbase	-	
	16	*Polydactylus sextarius*	Polynemid fish	-	Duan (2005)	SeaLife Base	-	
Cephalopod	17	*Uroteuthis chinensis*	Mitre squid	-	Lin (2013)	Lin (2013)	-	
	18	Loliginidae	Squids	-	Lin (2013)	Lin (2013)	-	
Crustaceans	19	*Portunus sanguinolentus*	Portunus sanguinolentus	-	Lin (2013)	Lin (2013)	-	
	20	*Penaeus japonicus*	Penaeus japonicus	-	Wang (2005)	Wang (2006)	-	
	21	*Penaeus penicillatus*	Penaeus penicillatus	-	Wang (2005)	Wang (2006)	-	
	22	*Metapenaeopsis barbata*	Metapenaeopsis barbata	-	Wang (2005)	Wang (2006)	-	
	23	*Metanephrops thomsoni*	Metanephrops thomsoni	-	Wang (2005)	Wang (2006)	-	
Zooplankton	24	Zooplankton_P	Zooplankton_P	-	Wang (2005)	Wang (2006)	-	
	25	Zooplankton_B	Zooplankton_B	-	Wang (2005)	Wang (2006)	-	
Phytoplankton	26	Phytoplankton_P	Phytoplankton_P	-	Wang (2005)	Wang (2006)	-	
	27	Phytoplankton_B	Phytoplankton_B	-	Wang (2005)	Wang (2006)	-	
Detritus	28	Detritus	Detritus	Ye (2007)				

Calculating surrogates for ecosystems

System attributes

- Mean trophic level (**MTL**)
- Mean trophic level of catch (**MTLc**)
- Total system throughput (**TST**)
- Connectance
- Omnivory index

When the **OI** value is **zero**, the consumer in question is **specialized**.

$$TL_i = 1 + DC_{ij} \cdot TL_i$$

$$OI_i = \sum_{j=1}^{n} \left(TL_j - (TL_i - 1)^2 \cdot DC_{ij}\right)$$

TL_j and TL_i are trophic level of predator *j* and prey *i* respectively, and DC_{ij} is the proportion of prey *i* in the diet of predator *j*.

Mixed Trophic Impact analysis

$$\varepsilon_i = \sqrt{\sum_{j=1}^{n} m_{ij}^2}$$

The mixed trophic impact (MTI) analysis quantifies the negative or positive impact that an increase in the biomass of a group would have on the other groups in the ecosystem.

Keystoness Index (KSi)

(Libralato et al., 2006)

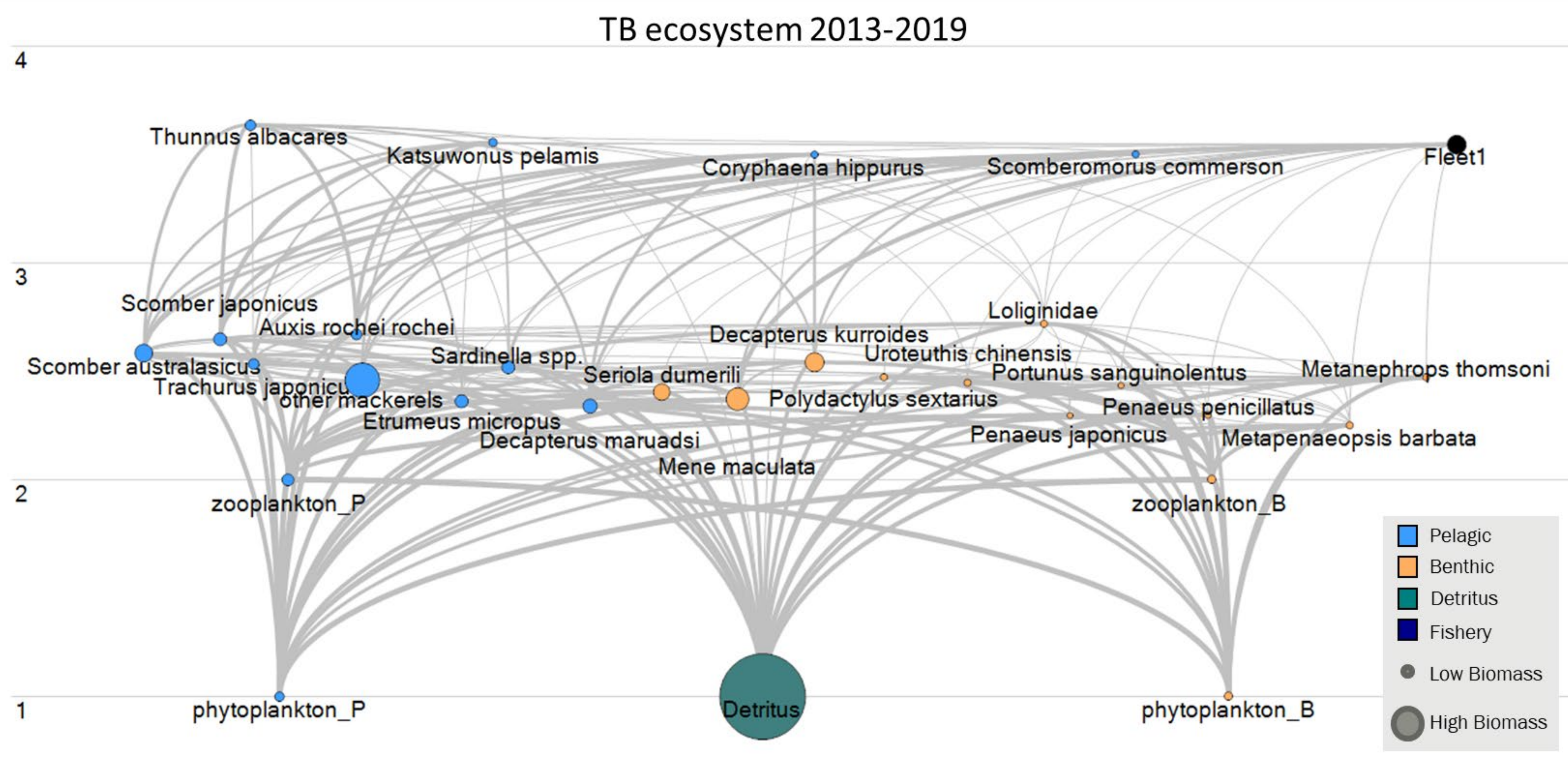
$$KS_i = \log[\varepsilon_i(1 - p_i)]$$

Top-down effect (td)

$$td = \frac{\sum_{j \neq i}^{n} m_{ij}^2 (m_{ij} < 0)}{\sum_{j \neq i}^{n} m_{ij}^2}$$

ε_i is the overall effect
m_{ij} being the relative impact of a slight increase in biomass of impacting group i on biomass of impacted group j
p_i is the contribution of the functional group to the total biomass of the food web.

TB ecosystem



Ecosystem emergent properties

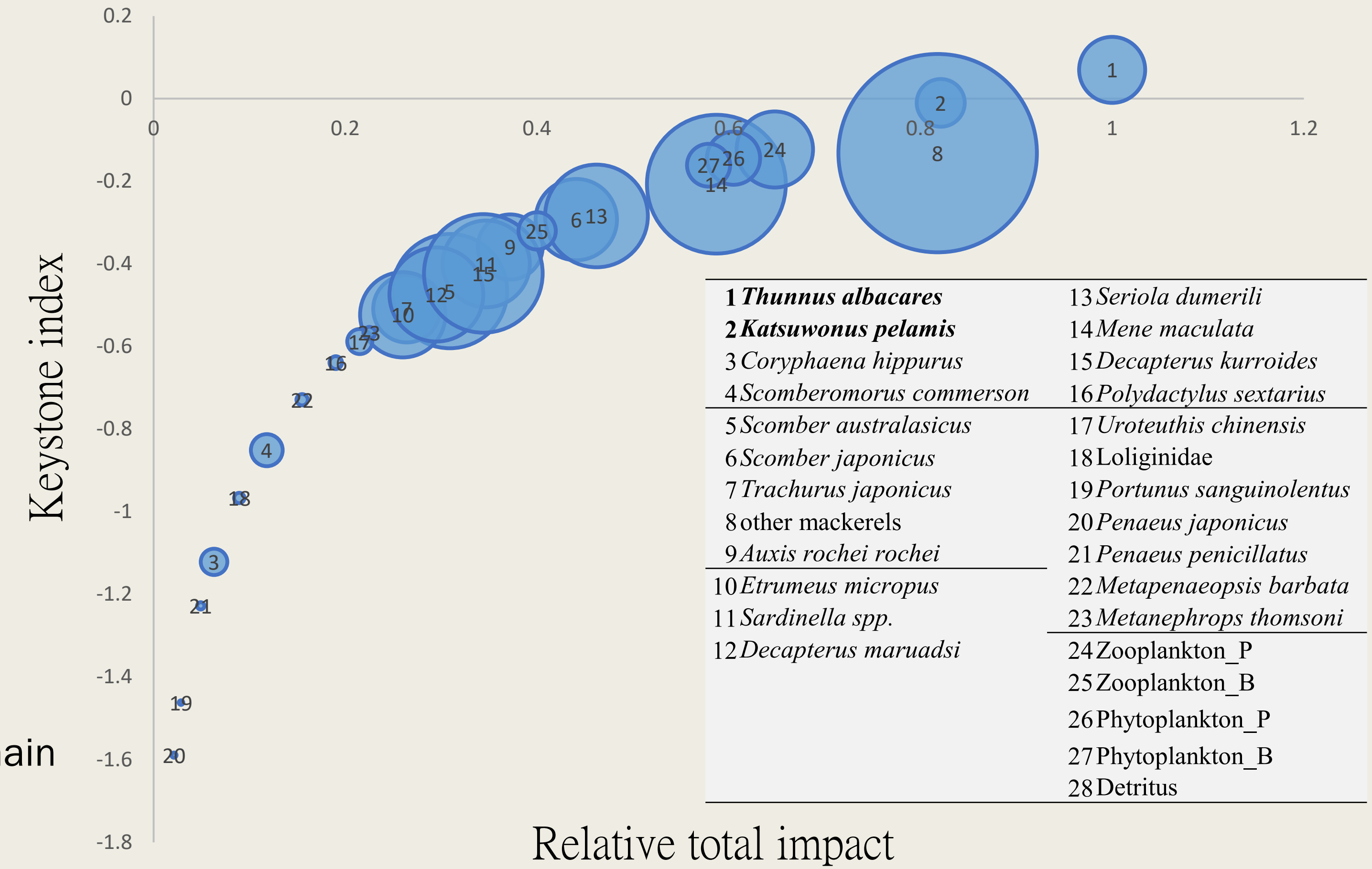
	Parameter	Mean	Unit
Ecosystem Structure	Total number of pathways	340	
	Mean length of pathways	6.932	
	Omnivory index	0.257	
	Shannon diversity index	2.544	
	Connectance Index	0.261	
	Maximum trophic level	3.639	
Ecosystem productivity	Total system throughput	3391.35	t/km^2/year
Cycles & Flows	Transfer efficiency	18.69%	
	Cycling index(Finn's)	1.888	% of throughput
Consumption/Respiration	Sum of all consumption	1544.446	t/km^2/year
	Sum of all export	456.282	t/km^2/year
	Sum of all respiratory	809.067	t/km^2/year
	Sum of all flows into detritus	581.554	t/km^2/year
Fishery	Total catch	8.204	t/km^2/year
	Mean trophic level of catch	2.546	

System structure

System total throughput (**TST**) is about 3391 (t km-2yr-1), average energy transfer efficiency is 18.69%.

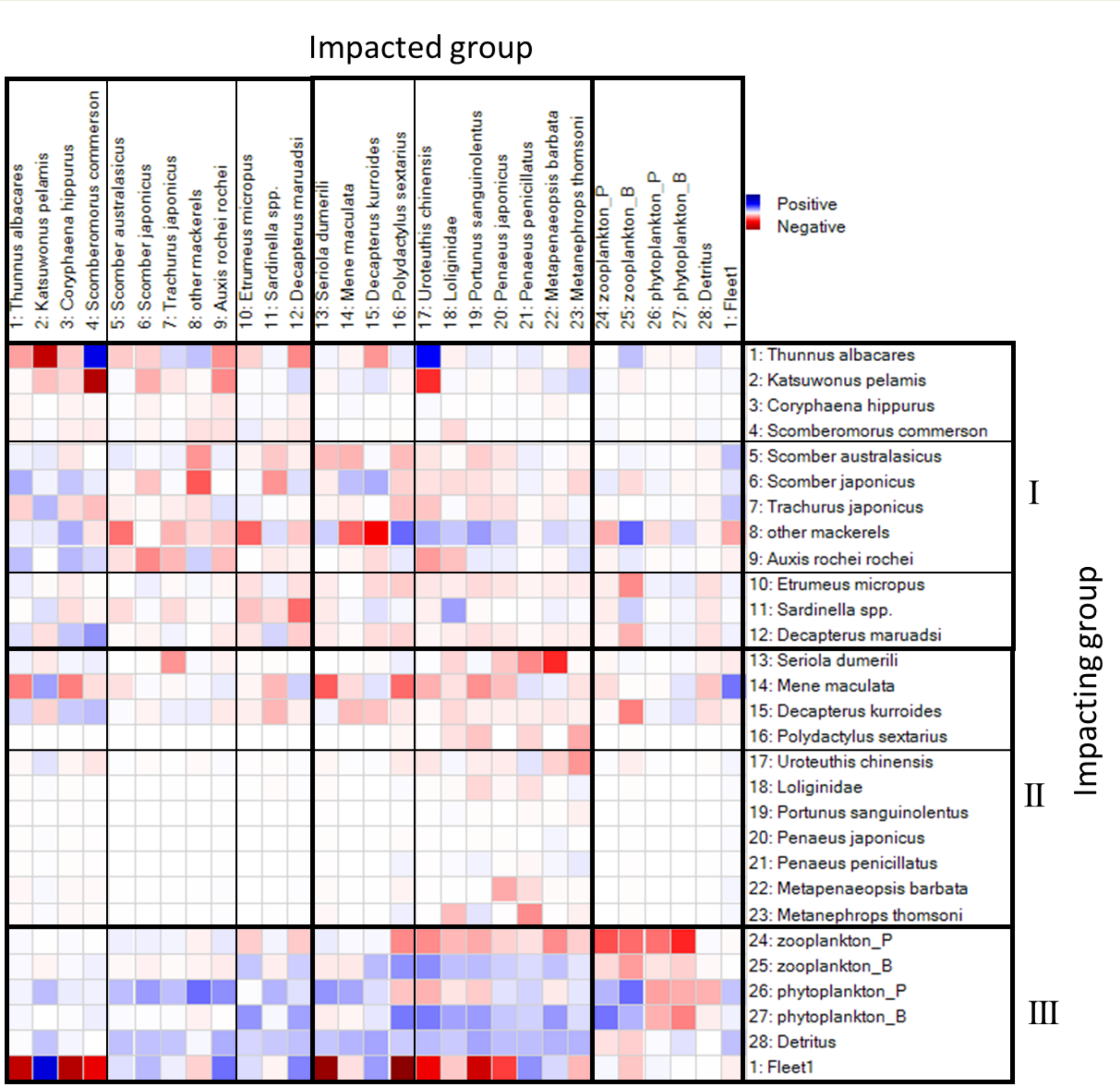
Trophic Level

Maximum TL is 3.639, mean TL of catch is 2.546



Key species

Yellowfin tuna and skipjack tuna are the main keystone species.



	No.	Group name	
Predator fish	1	*Thunnus albacares*	Yellow fin tuna
	2	*Katsuwonus pelamis*	Skipjack tuna
	3	*Coryphaena hippurus*	Dolphinfish
	4	*Scomberomorus commerson*	Spanish mackerel
Pelagic fish	5	*Scomber australasicus*	Spotted mackerel
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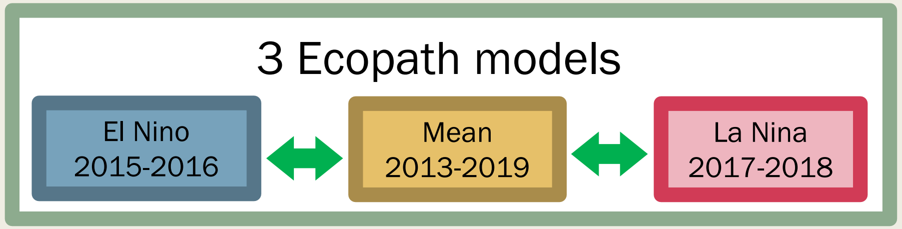
TB ecosystem



Ecosystem emergent properties

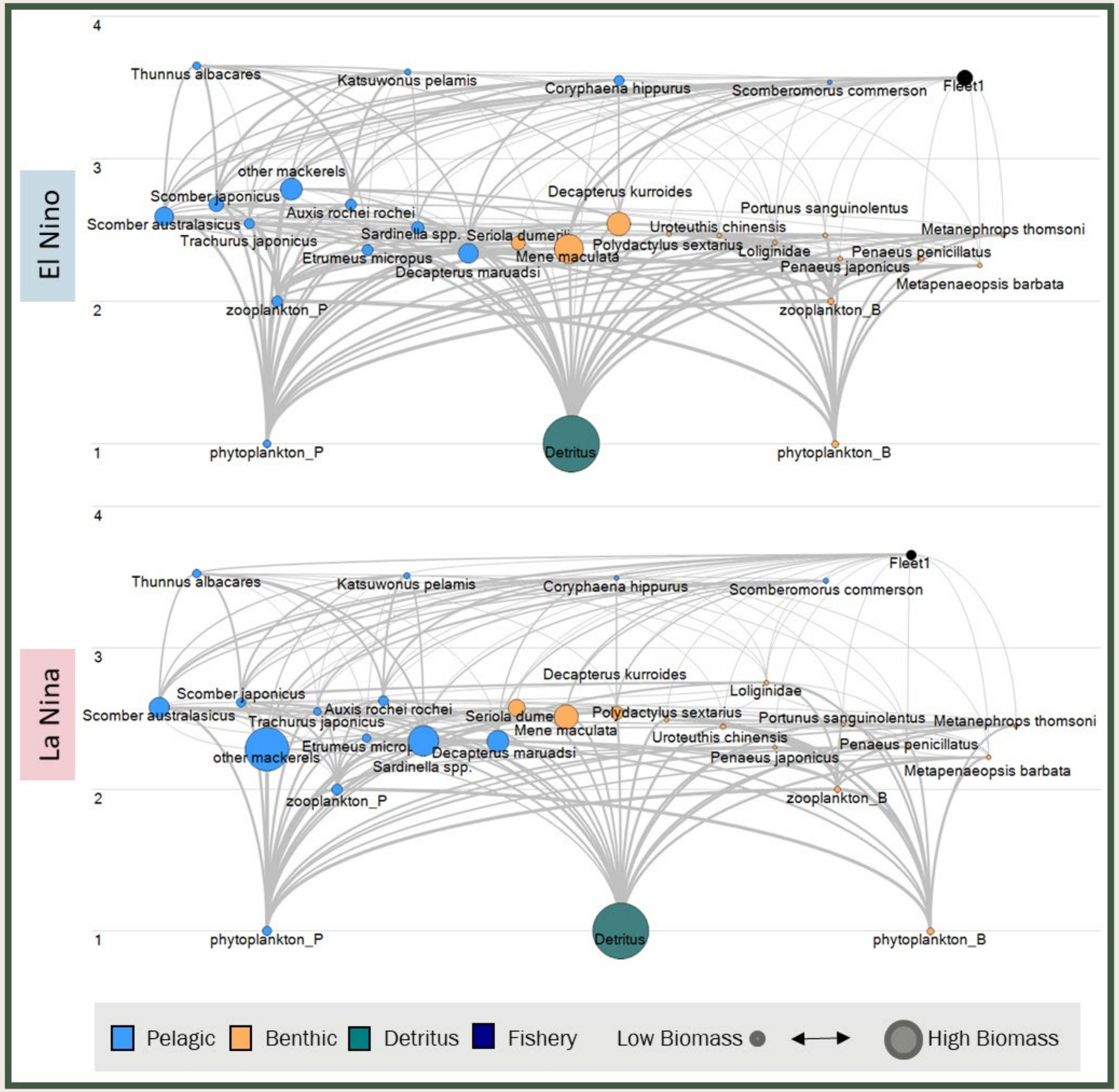
	Parameter	La Nina	Mean	El Nino	Unit
Ecosystem Structure	Total number of pathways	80	340	393	
	Mean length of pathways	4.138	6.932	6.883	
	Omnivory index	0.247	0.257	0.271	
	Shannon diversity index	2.238	2.544	2.596	
	Connectance Index	0.255	0.261	0.263	
	Maximum trophic level	3.523	3.639	3.653	
Ecosystem productivity	Total system throughput	8619.54	3391.35	6991.377	t/km^2/year
Cycles & Flows	Transfer efficiency	13.65%	18.69%	19.35%	
	Cycling index(Finn's)	0.554	1.888	0.393	% of throughput
Consumption/Respiration	Sum of all consumption	3864.955	1544.446	3213.948	t/km^2/year
	Sum of all export	1196.821	456.282	923.4526	t/km^2/year
	Sum of all respiratory	1968.79	809.067	1647.023	t/km^2/year
	Sum of all flows into detritus	1588.974	581.554	1206.953	t/km^2/year
Fishery	Total catch	5.473	8.204	12.425	t/km^2/year
	Mean trophic level of catch	2.659	2.546	2.568	

Climate impact

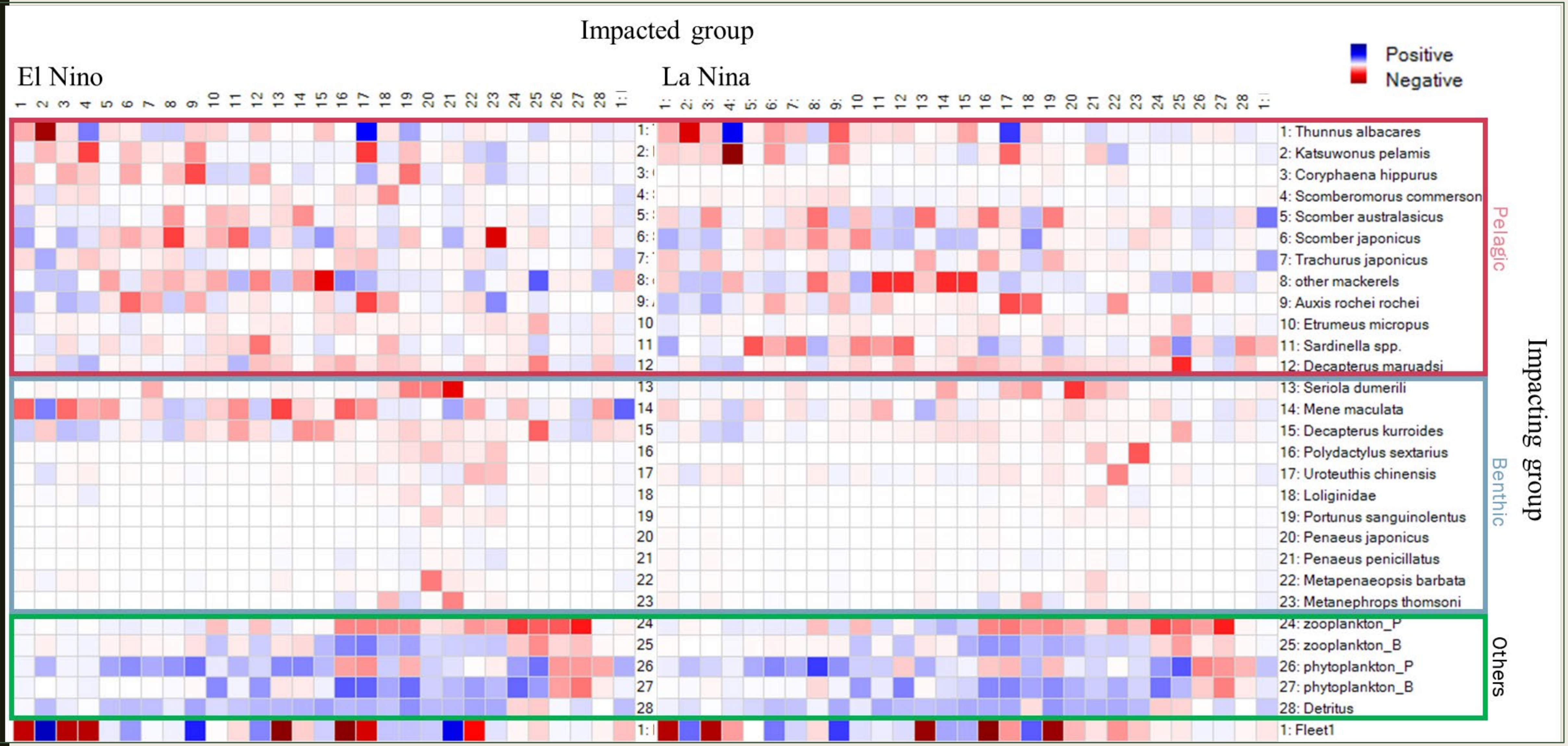
- Total biomass, TST, consumption and respiration **increased** during the El Nino and La Nina years, La Nina is **higher** than El Nino.
- However, the diversity index, Omnivory index and connectance index were relatively low during La Nina years, and the two periods had different variation in ecosystem structure.
- In La Nina years, total catch was lower but Mean trophic level of catch was slightly higher than El Nino years.

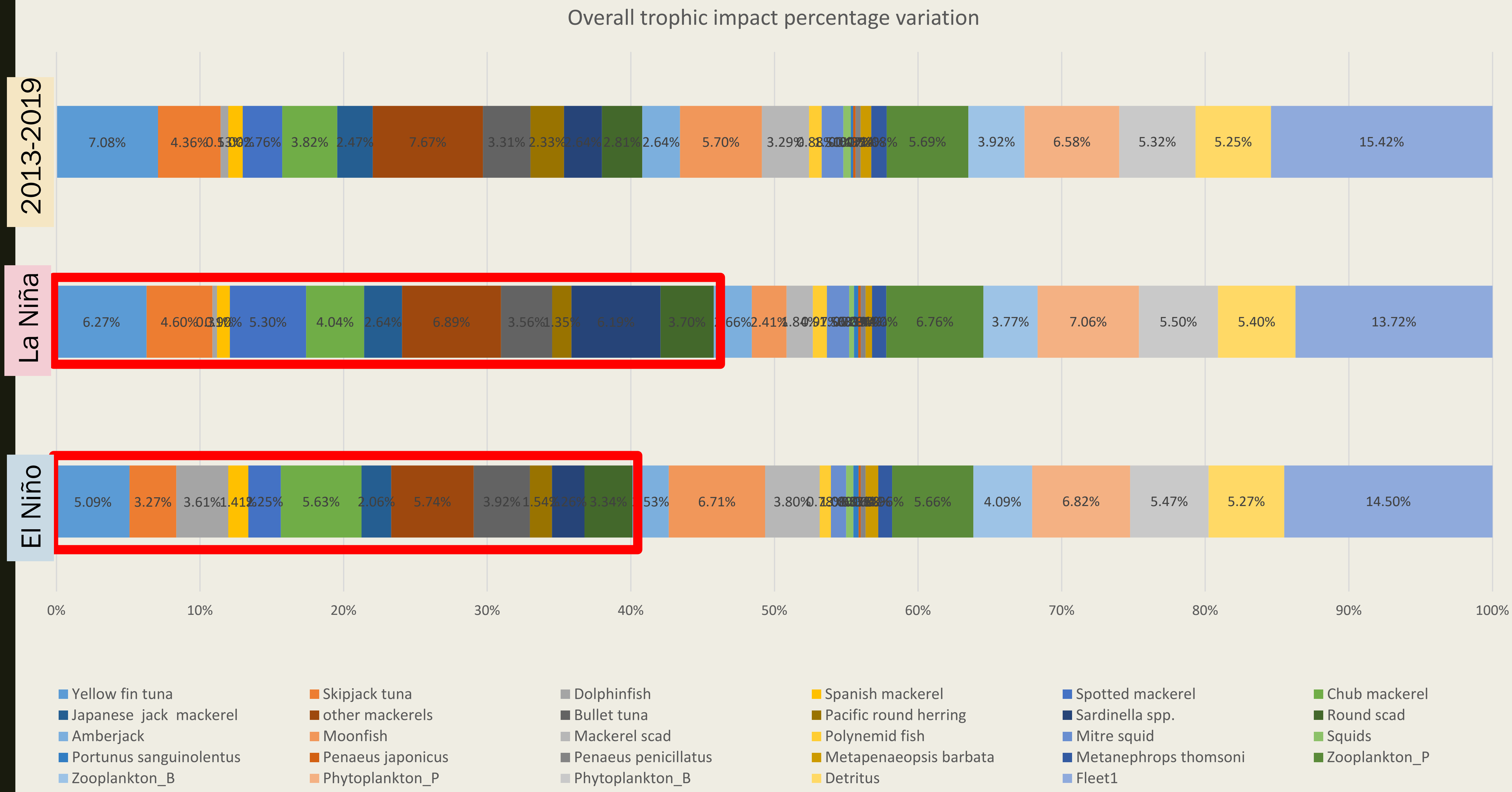
El Nino and La Nina models

No.	Group name	Trophic level (El Nino)	Trophic level (La Nina)	Trophic level (Mean)	Biomass (t/km²) El Nino	Biomass (t/km²) La Nina	Biomass (t/km²) Mean
1	**Yellow fin tuna**	3.653	3.523	3.639	3.305	4.098	2.480
2	**Skipjack tuna**	3.610	3.511	3.554	1.828	2.084	1.304
3	Dolphinfish	3.552	3.494	3.500	5.495	0.185	0.386
4	Spanish mackerel	3.537	3.473	3.502	0.307	0.892	0.574
5	Spotted mackerel	2.595	2.580	2.582	16.592	19.741	7.544
6	Chub mackerel	2.679	2.615	2.646	10.724	4.622	3.788
7	Japanese jack mackerel	2.548	2.551	2.537	5.846	3.227	2.579
8	other mackerels	2.788	2.285	2.462	22.271	87.573	22.813
9	Bullet tuna	2.679	2.629	2.674	6.140	5.985	2.417
10	Pacific round herring	2.360	2.360	2.360	6.201	4.087	4.180
11	Sardinella spp.	2.517	2.341	2.517	7.914	40.954	4.351
12	Round scad	2.340	2.340	2.340	17.933	22.076	5.093
13	Amberjack	2.410	2.576	2.405	9.977	14.607	6.051
14	Moonfish	2.371	2.510	2.370	37.111	26.295	11.113
15	Mackerel scad	2.543	2.544	2.543	24.312	9.012	8.133
16	Polynemid fish	2.473	2.492	2.474	0.128	0.106	0.087
17	Mitre squid	2.462	2.441	2.448	0.513	0.770	0.345
18	Squids	2.413	2.755	2.721	0.146	0.083	0.055
19	Portunus sanguinolentus	2.464	2.462	2.438	0.039	0.016	0.010
20	Penaeus japonicus	2.300	2.300	2.300	0.022	0.018	0.012
21	Penaeus penicillatus	2.300	2.300	2.300	0.075	0.041	0.026
22	Metapenaeopsis barbata	2.252	2.227	2.252	0.127	0.087	0.065
23	Metanephrops thomsoni	2.467	2.451	2.474	0.185	0.100	0.073
24	Zooplankton_P	2.000	2.000	2.000	6.764	6.737	3.342
25	Zooplankton_B	2.000	2.000	2.000	1.999	1.488	0.786
26	Phytoplankton_P	1.000	1.000	1.000	3.173	4.547	1.615
27	Phytoplankton_B	1.000	1.000	1.000	2.228	2.104	1.044
28	Detritus	1.000	1.000	1.000	163.500	163.500	163.500



Interspecies relationship





Overall trophic impact percentage variation
2013-2019
La Niña
El Niño
7.08%
4.36%
3.82%
7.67%
5.70%
5.69%
3.92%
6.58%
5.32%
5.25%
15.42%
6.27%
5.30%
4.04%
6.89%
3.70%
6.76%
3.77%
7.06%
5.50%
5.40%
13.72%
5.09%
3.27%
5.63%
5.74%
6.71%
5.66%
4.09%
6.82%
5.47%
5.27%
14.50%
0%
10%
20%
30%
40%
50%
60%
70%
80%
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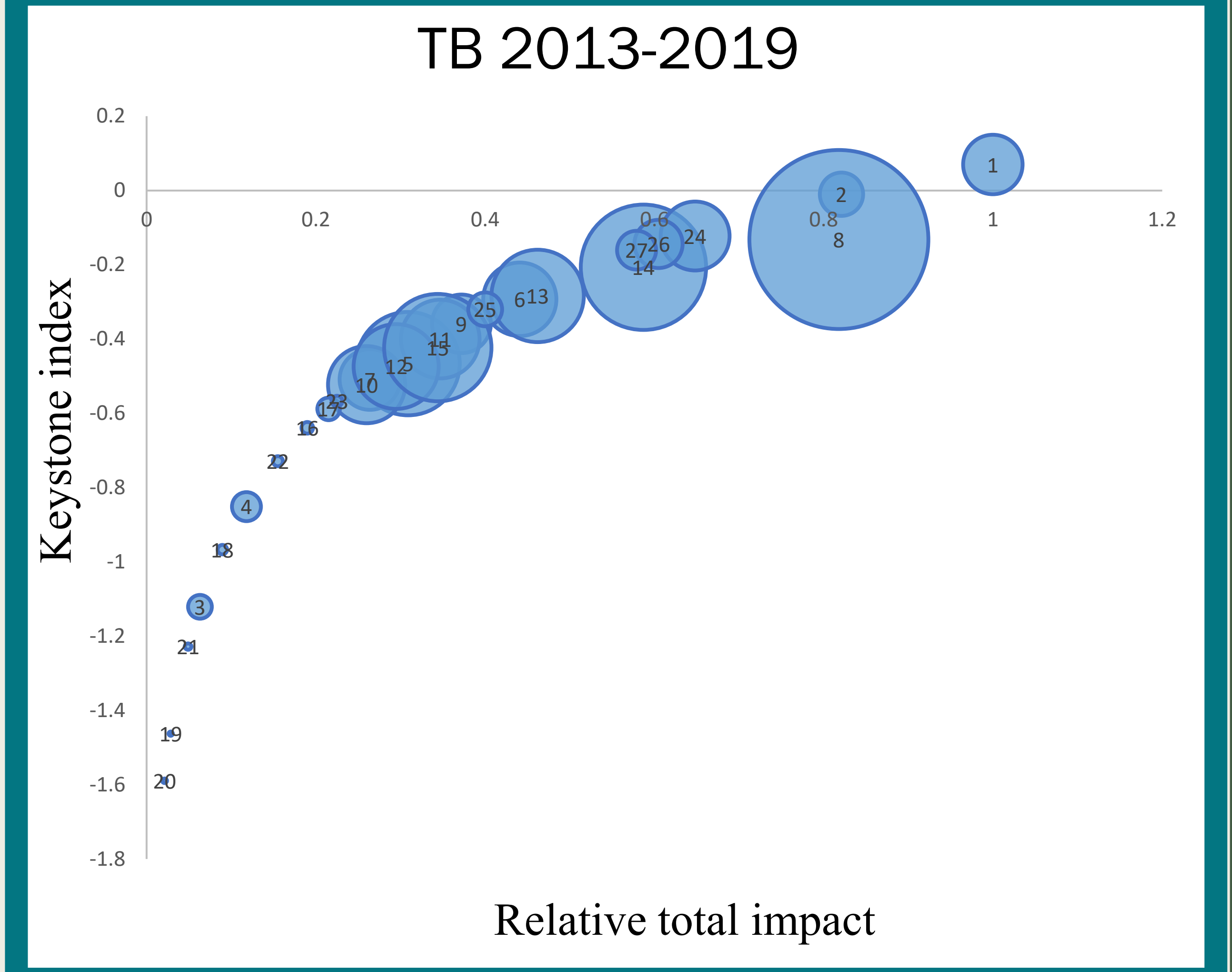
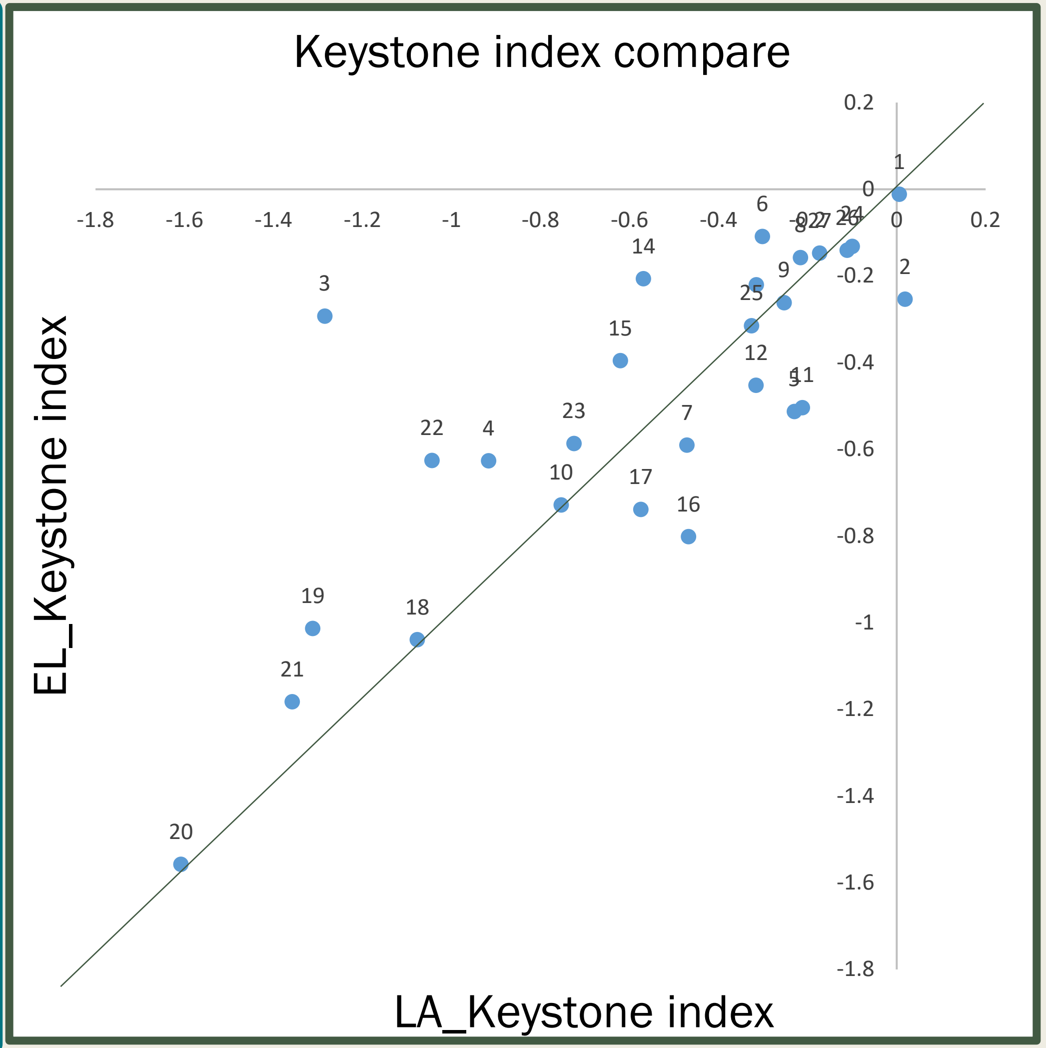
Zooplankton_P
Zooplankton_B
Phytoplankton_P
Phytoplankton_B
Detritus
Fleet1

Key species

The keystoneness index reveals *Thunnus albacares* and *Katsuwonus pelamis* are the main key species, and top-down control has a relatively high impact on the ecosystem.





The variation of TB ecosystem

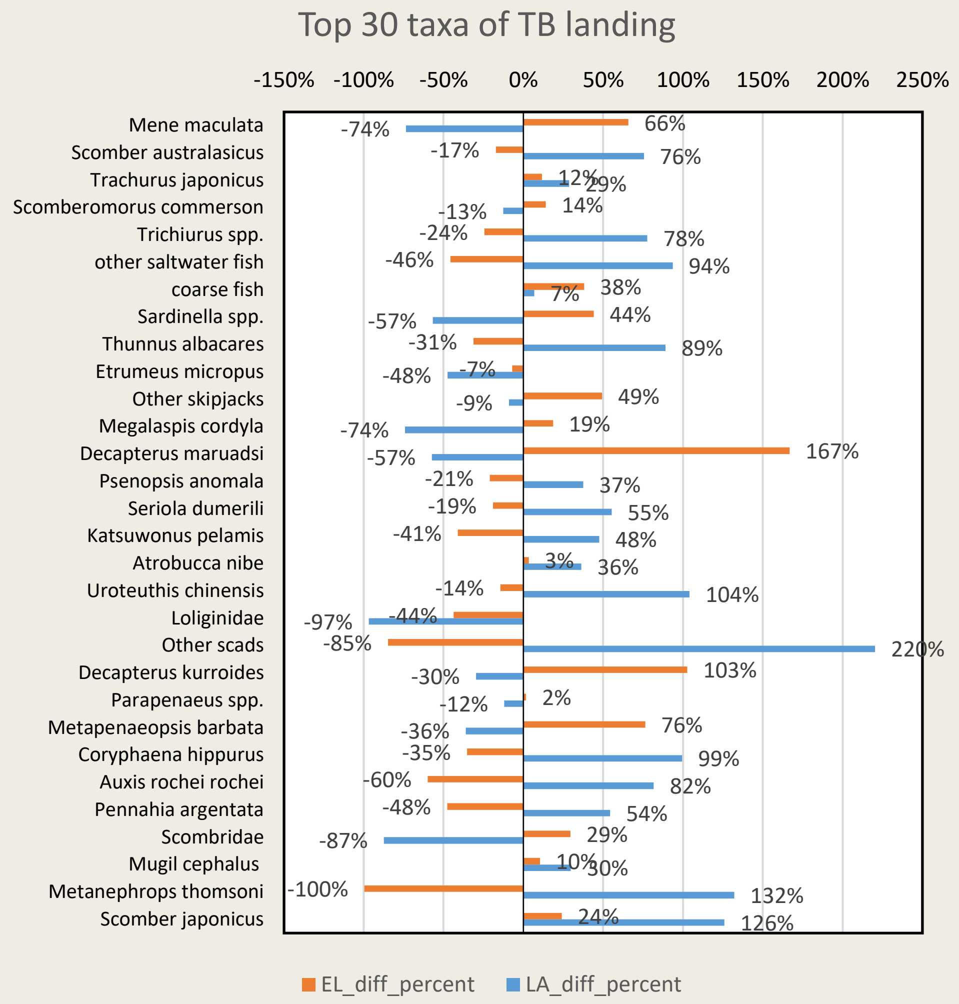
Key species

The other mackerels functional groups also has the high Relative total impact and Keystone index value, but due to the huge mount of biomass, suggest it wasn't the key species in TB ecosystem

Climate impact

- In La Nina years, due to the other mackerels and sardinella spp. were high biomass
- TST is higher than El Nino

- In El Nino years, almost all of benthic species was increased, lead to the Omnivory index, Shannon diversity index, Connectance Index increased.
- And TL of catch and TST decreased.



Conclusion

- The key species index shows that yellowfin tuna and skipjack tuna are the main key species, and no effect by the climate change. Beside, downward control influence has a relatively high impact on the ecosystem.
- In La Nina year, due to the high mount of Sardinella spp. and top predator, the TST increased but system connection was decreased.

	Parameter	La Nina	Mean	El Nino	Unit
Ecosystem Structure	Total number of pathways	80	340	393	
	Mean length of pathways	4.138	6.932	6.883	
	Omnivory index	0.247	0.257	0.271	
	Shannon diversity index	2.238	2.544	2.596	
	Connectance Index	0.255	0.261	0.263	
	Maximum trophic level	3.523	3.639	3.653	
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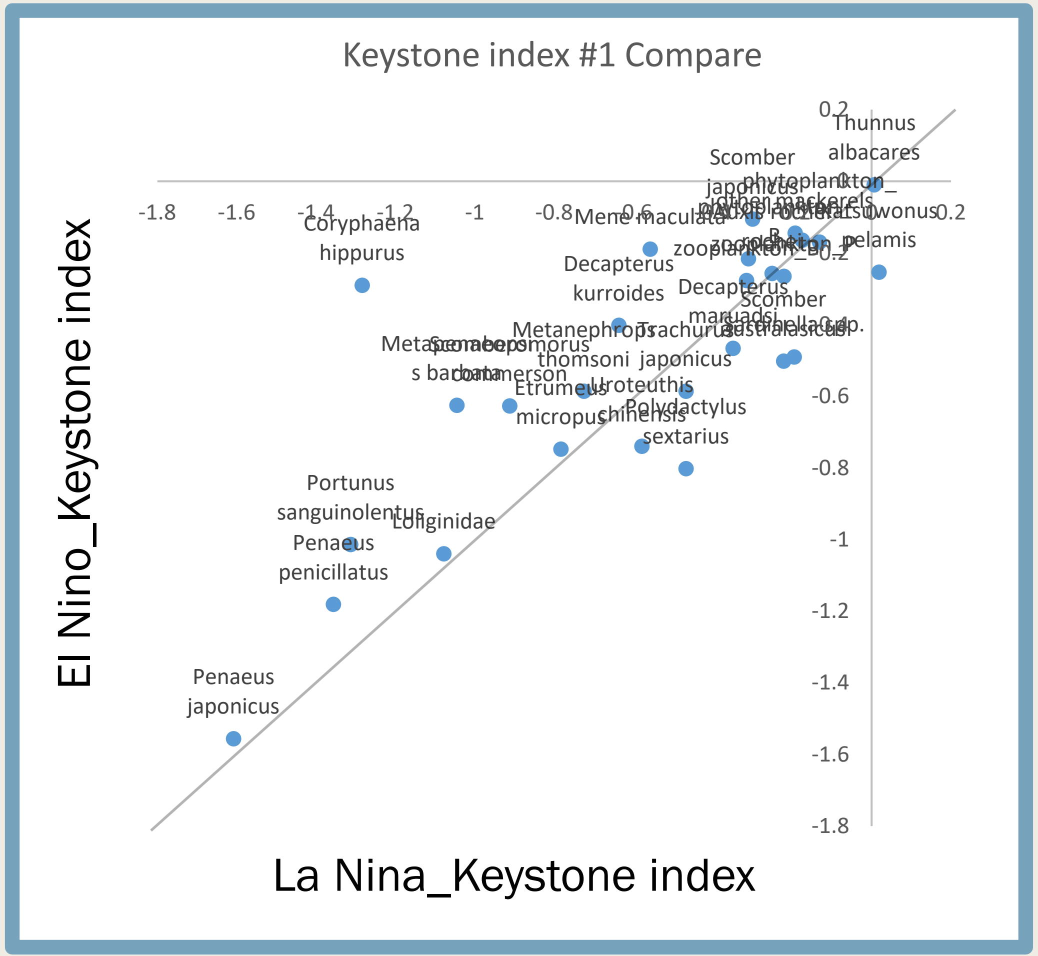

THANKS FOR LISTENING