Species-Specific ENSO Responses of Commercial Fish in the Northern South China Sea under Climate Warming Scenarios

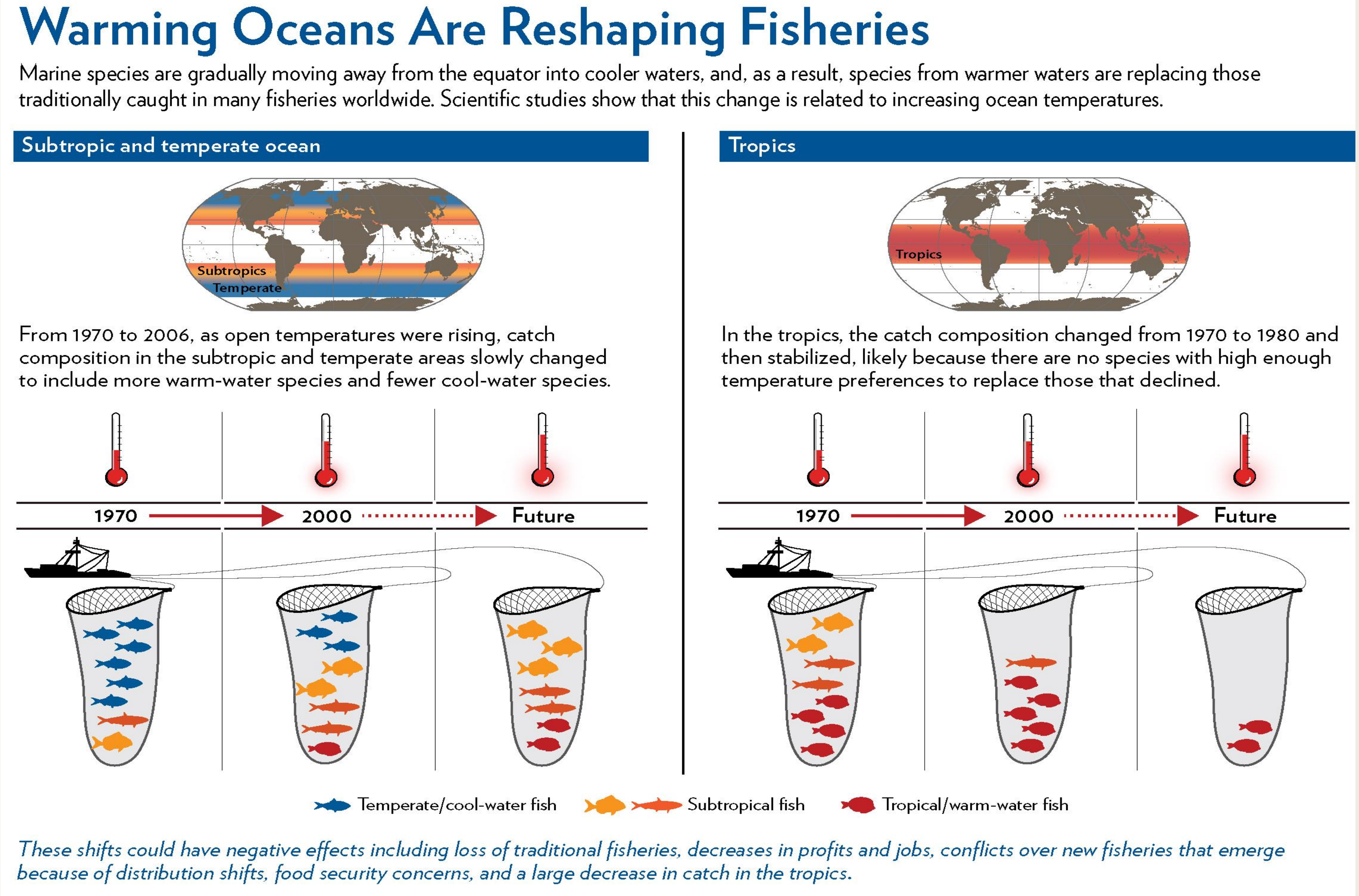
Po-Yuan Hsiao, Kuo-Wei Lan, William W.L. Cheung

Department of Environmental Biology and Fisheries Science
National Taiwan Ocean University
University of British Columbia, Vancouver, BC, Canada

2025/11/11

CHANGING OCEAN RESEARCH UNIT
THE UNIVERSITY OF BRITISH COLUMBIA

Climate change impact on oceans and Fisheries



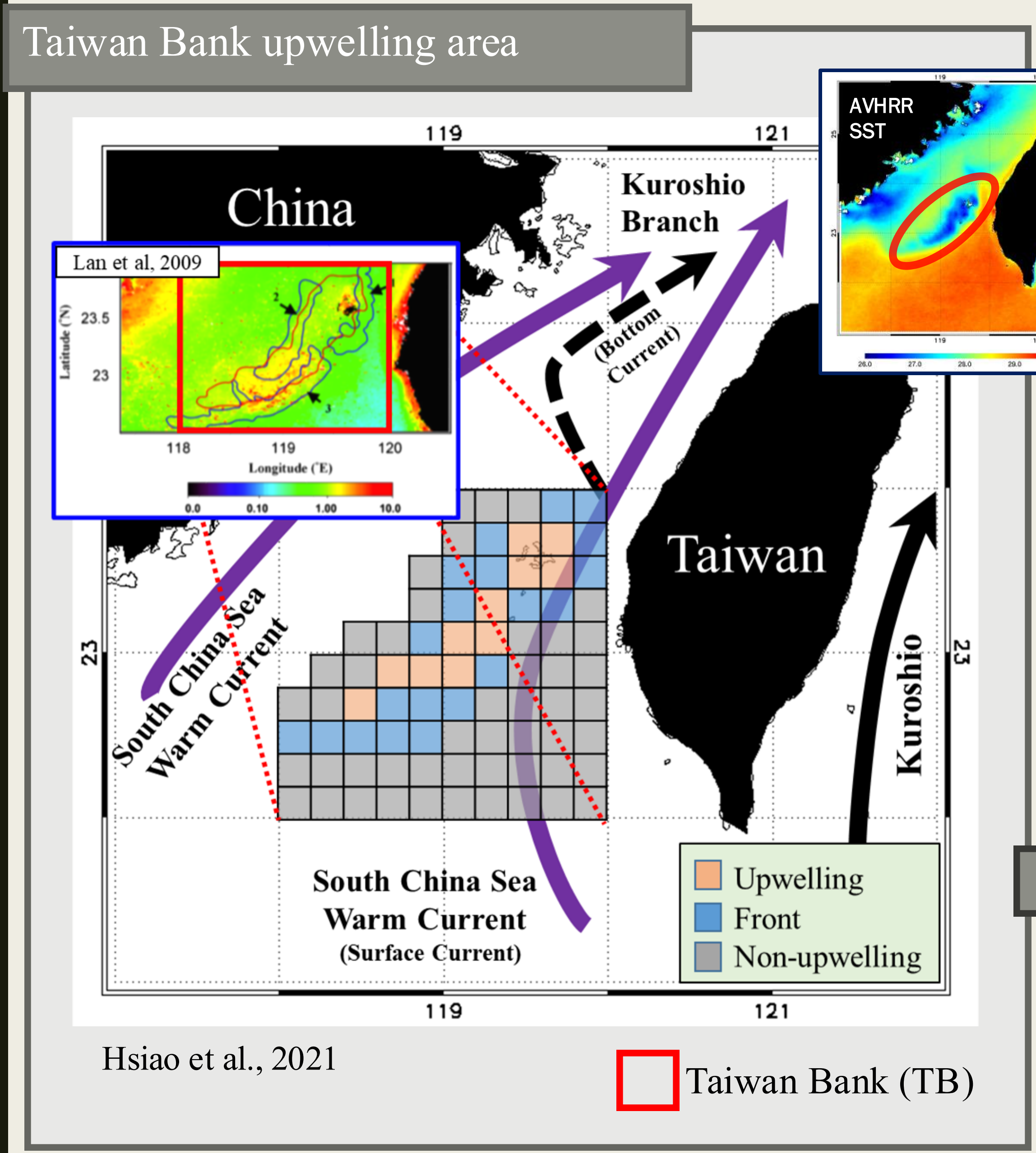
Species are migrating away from the equator

economic losses

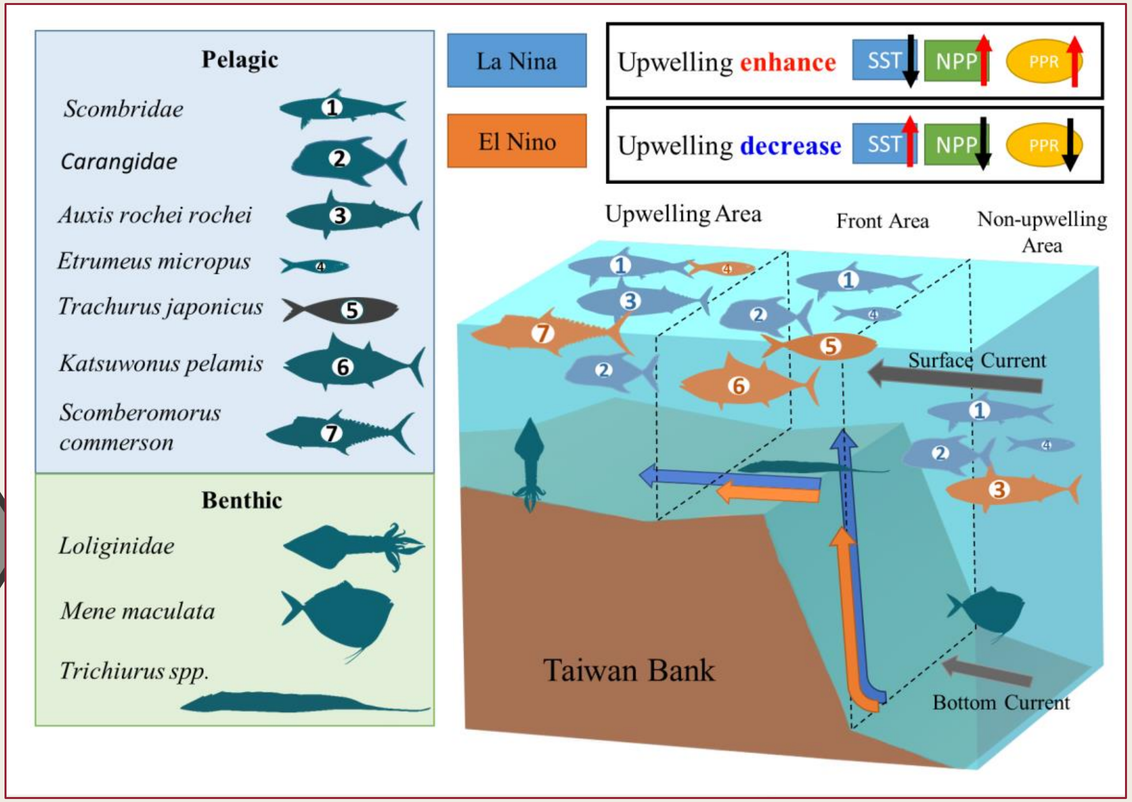
impacting food security.

Graphic by The Pew Charitable Trusts' ocean science division, Concepts from: Cheung, W.W.L.. R. Watson and D. Pauly. 2013. Signature of ocean warming in global fisheries catch. Nature. DO!:10.1038/nature 12156.

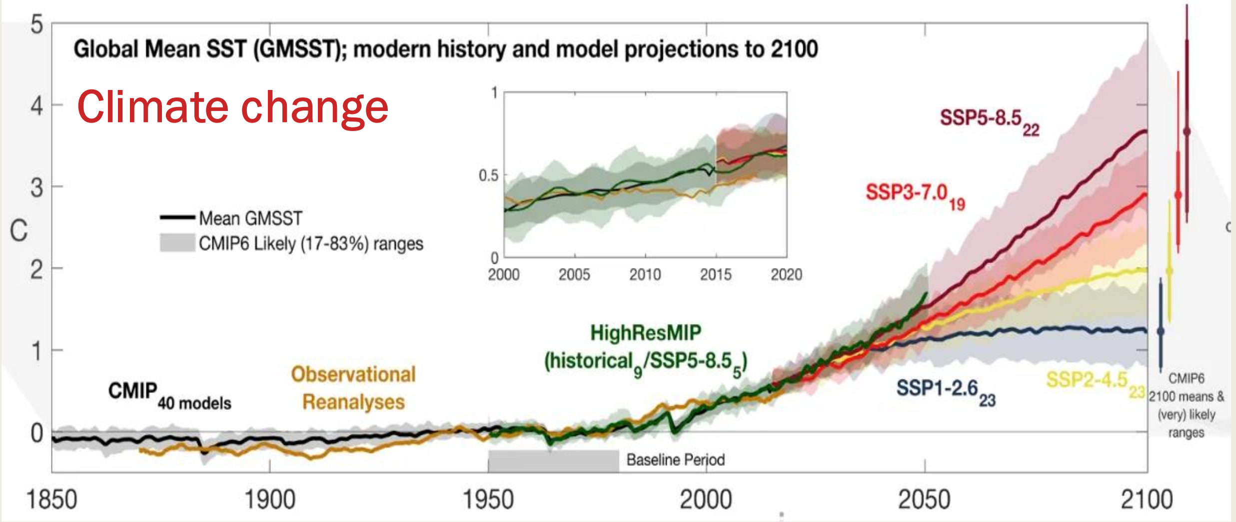
ENSO effect on the TB ecosystem



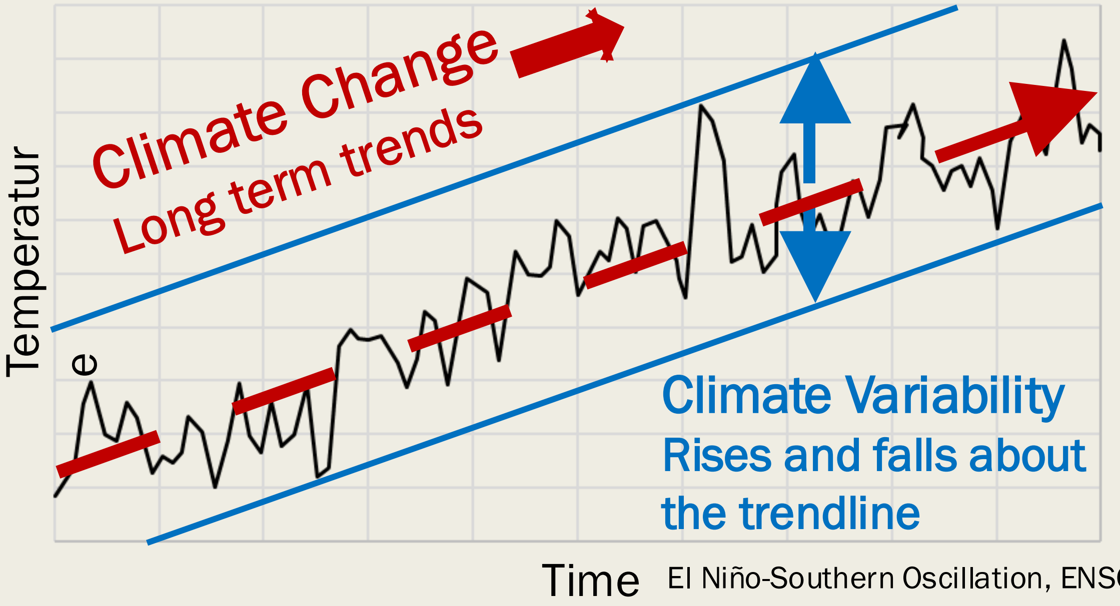
- In La Nina events, the upwelling enhance leading the Pelagic species abundance increased (through the environments factors).
- In the other hand, El Nino periods upwelling getting weaker, the pelagic species composition also shifting.



Climate Change and Variability

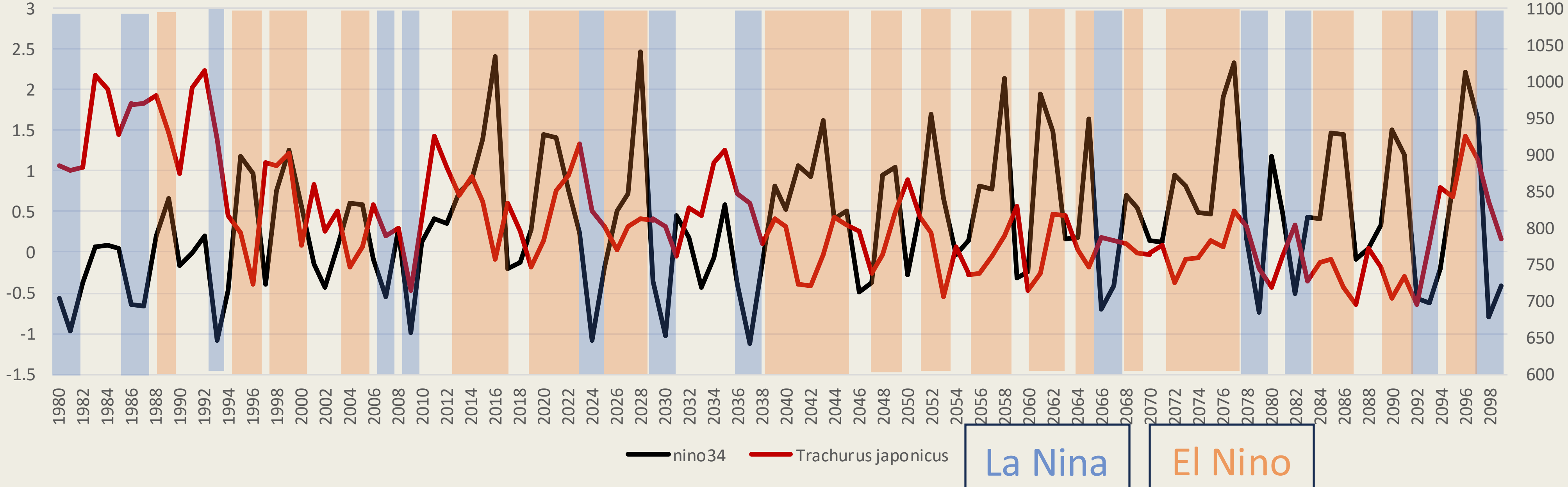


(Cites : Carbonbrief. Source: IPCC (2021) Figure 9.3.)

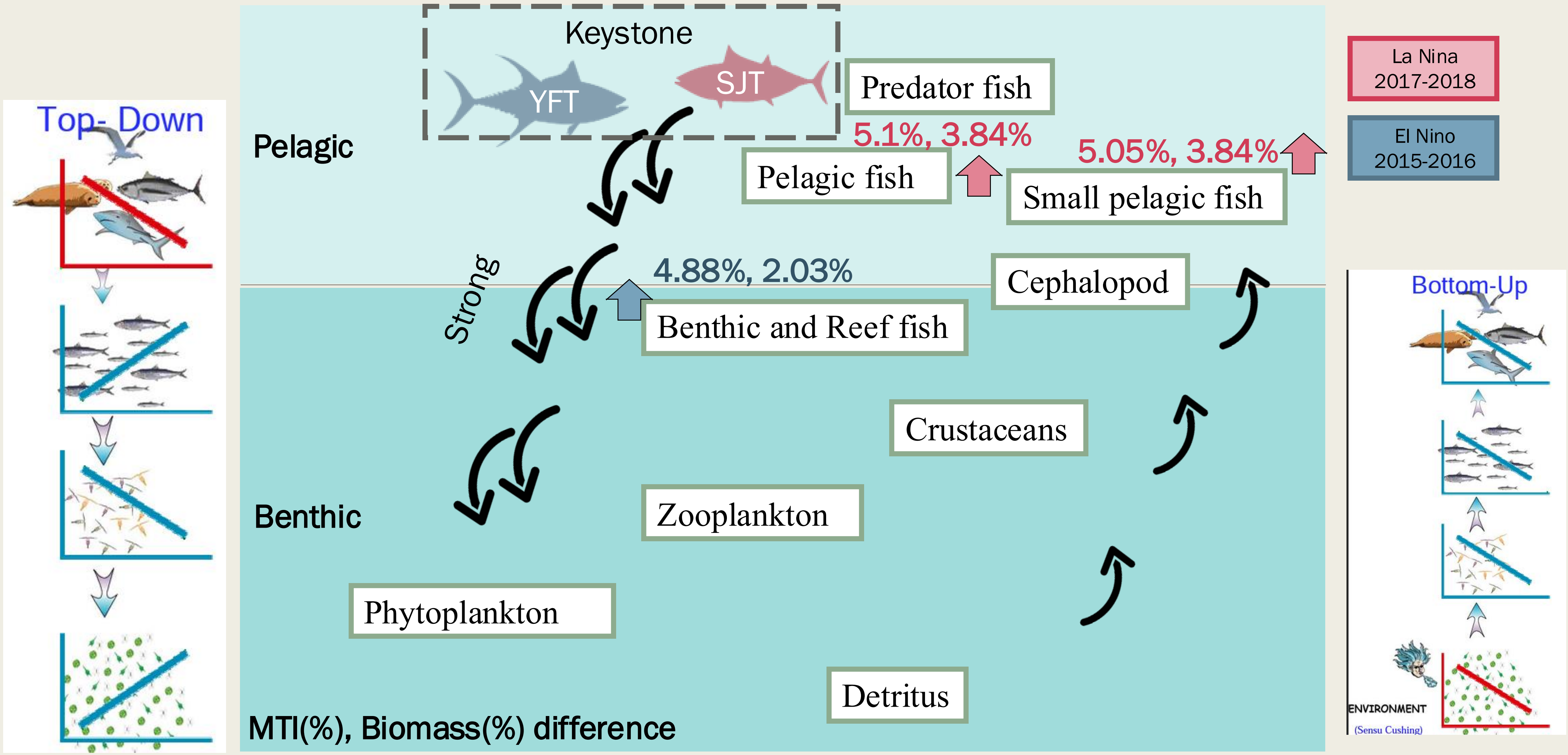


El Niño-Southern Oscillation, ENSO
Pacific Decadal Oscillation, PDO
Western Pacific Oscillation, WPO
North Pacific Gyre Oscillation, NPGC

- Forcing drivers: Long-term Trend (GMSST) and Short-term Variability (ENSO)
- How will ENSO's impact on fish change under this future warming scenario?



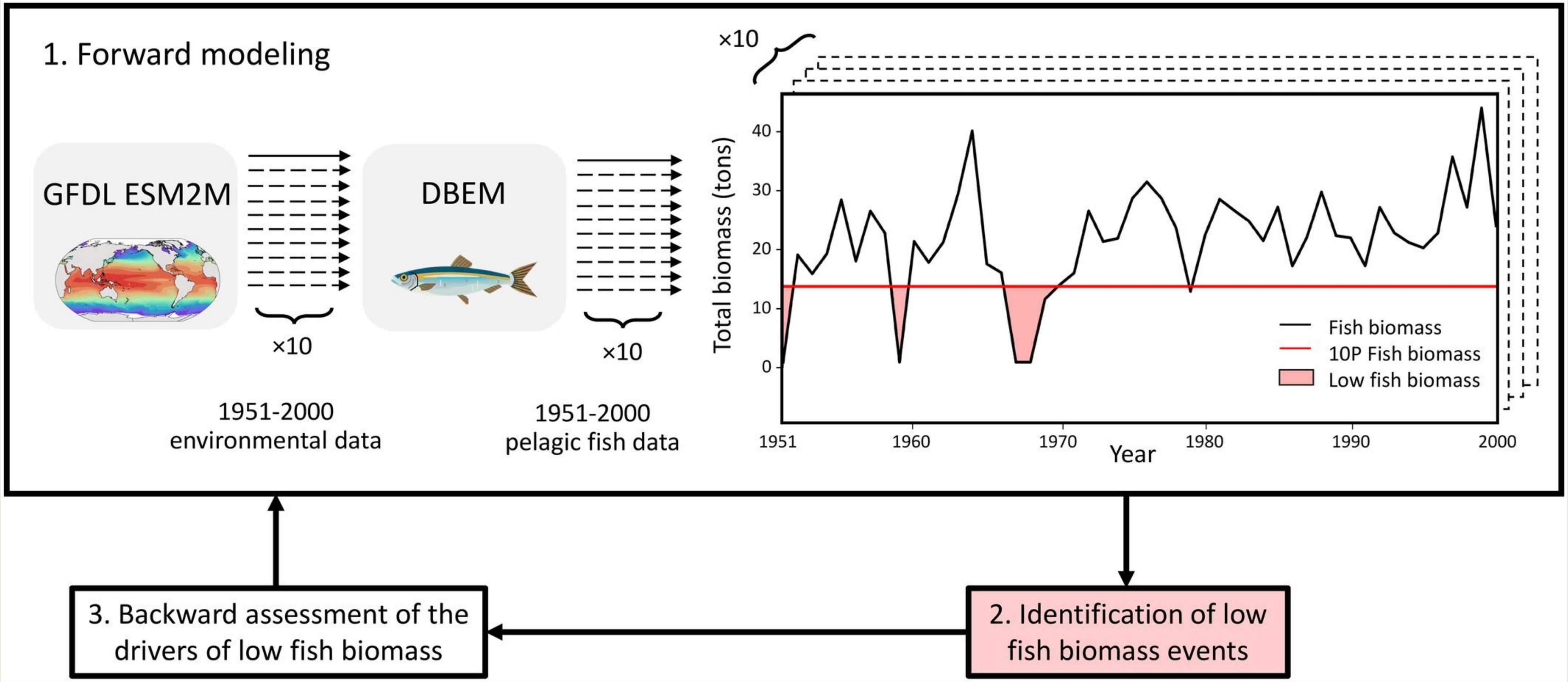
ENSO effect on the TB ecosystem



Conceptual Hypothesis: A Food Web Perspective

- We hypothesize that ENSO impacts the ecosystem through complex food web dynamics (e.g., Top-Down vs. Bottom-Up)
- Responses are likely "species-specific" and will differ based on ecological groups: Predator, Pelagic, SPF, Benthic and Reef

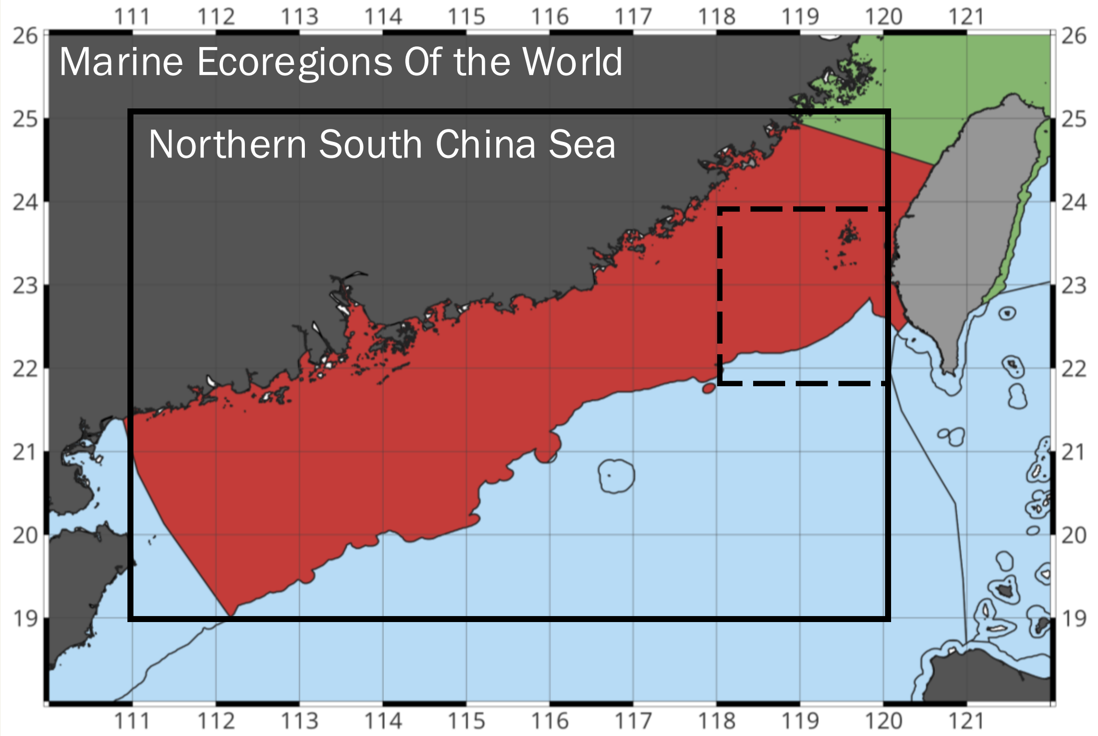
Extreme and compound ocean events are key drivers of projected low pelagic fish biomass



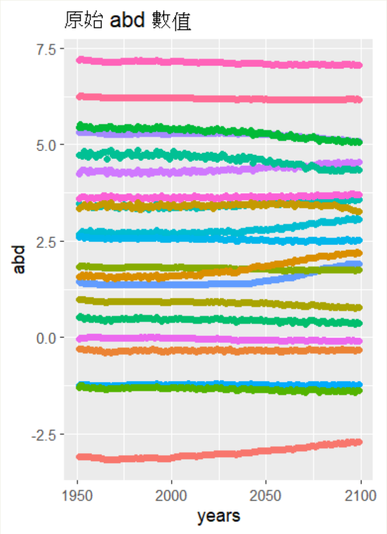
Le Grix, N., Cheung, W. L., Reygondeau, G., Zscheischler, J., & Frölicher, T. L. (2023). Extreme and compound ocean events are key drivers of projected low pelagic fish biomass. Global Change Biology, 29, 6478–6492. https://doi.org/10.1111/gcb.16968

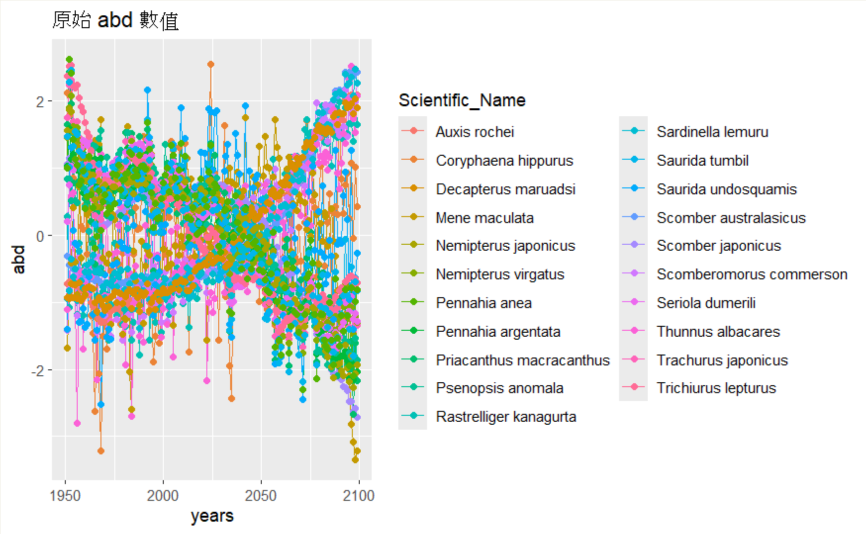
Data & Pre-processing

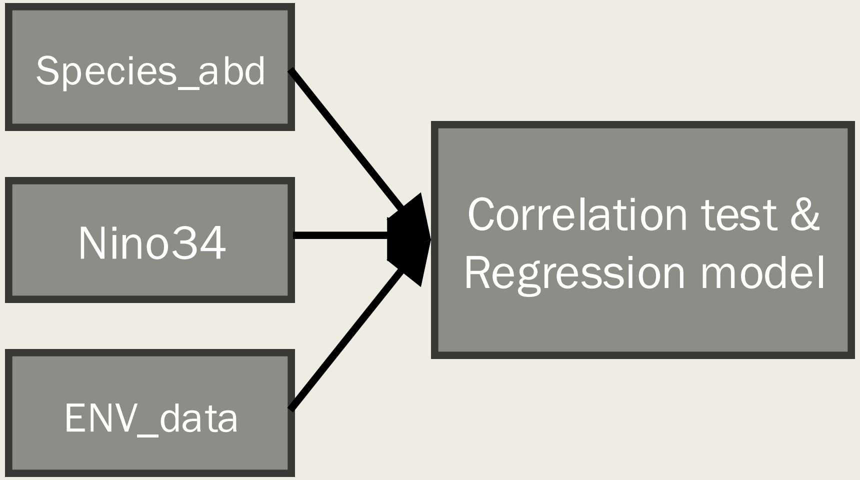
Data collection



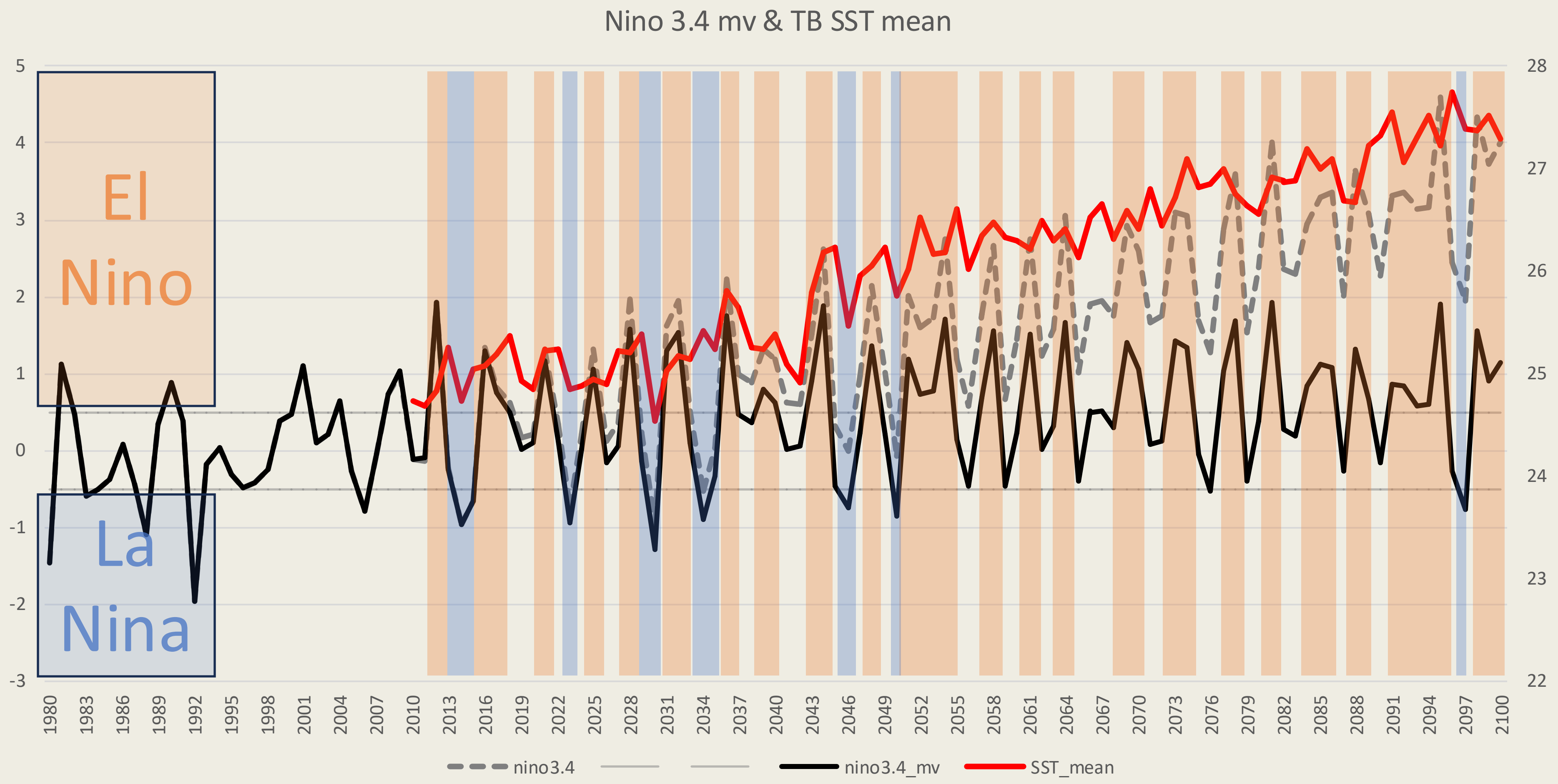
- 1950-2100, resolution 0.5*0.5
- Environment data from Earth System Model GFDL ESM2M
- Biomass data were simulated using a species-based Dynamic Bioclimate Envelope Model (DBEM)
- 10 Ensemble members
- 21 species in 4 groups
- Log transform and z-score normalization







Define ENSO like events



- Annual SST anomalies in the Niño3.4 area over the past 30 years
- Shift the baseline every 5 years

moving average

Check other papers

Detrending

Ensemble models

ENSO under climate scenario

2.2. Methods

In this study, El Niño and La Niña events were selected by using the SST anomaly averaged over the Niño3 region (5°S-5°N, 150°W-90°W, Niño3 index). In each observation and model, the El Niño and La Niña events were selected as periods when the Niño3 index exceeded half of its standard deviation (SD) for over six months (Levine et al., 2016). For

Contents lists available at ScienceDirect
Deep-Sea Research Part II
journal homepage: www.elsevier.com/locate/dsr2
ELSEVIER

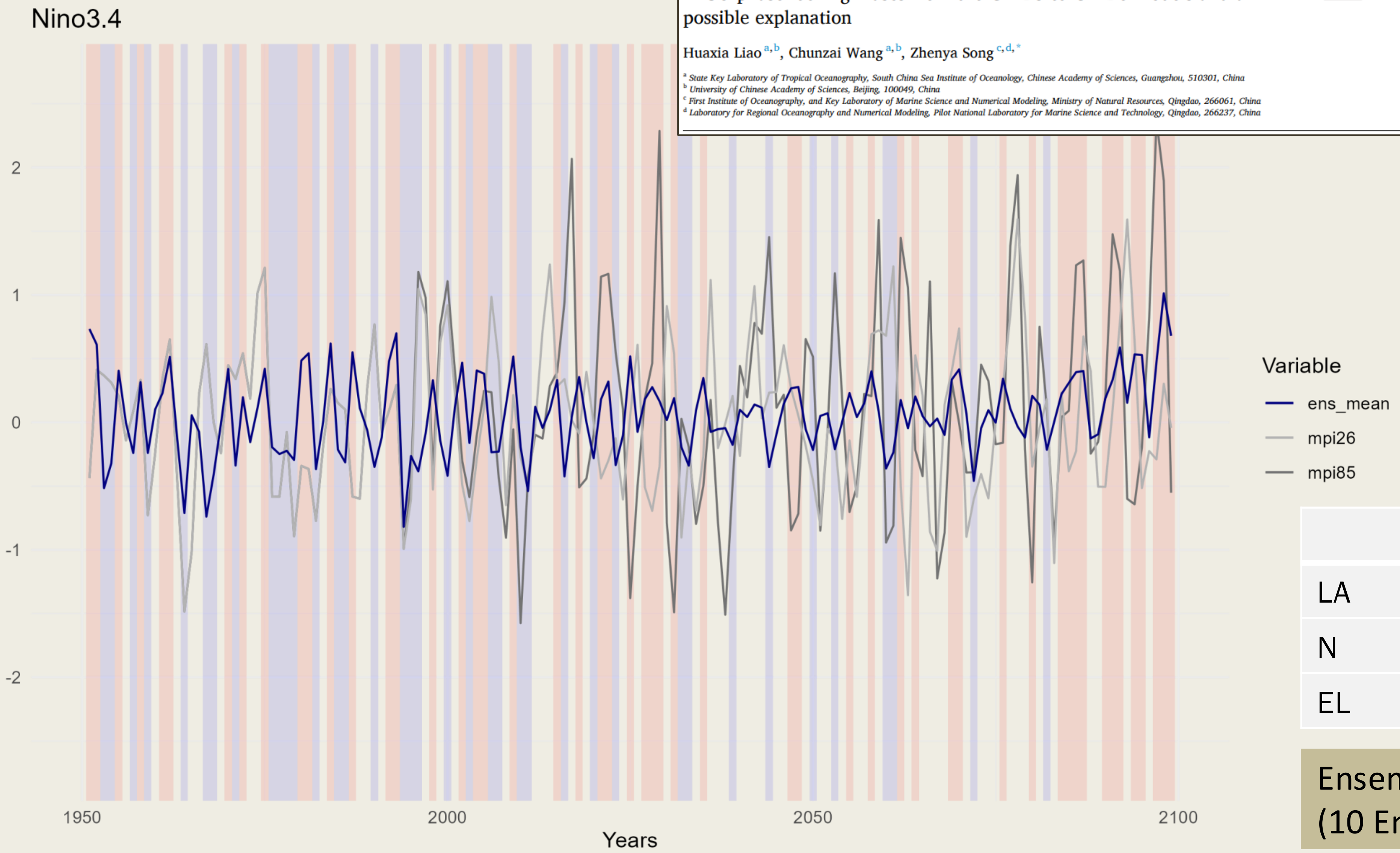
ENSO phase-locking biases from the CMIP5 to CMIP6 models and a possible explanation

Huaxia Liao [a,b], Chunzai Wang [a,b], Zhenya Song [c,d,*]

[a] State Key Laboratory of Tropical Oceanography, South China Sea Institute of Oceanology, Chinese Academy of Sciences, Guangzhou, 510301, China
[b] University of Chinese Academy of Sciences, Beijing, 100049, China
[c] First Institute of Oceanography, and Key Laboratory of Marine Science and Numerical Modeling, Ministry of Natural Resources, Qingdao, 266061, China
[d] Laboratory for Regional Oceanography and Numerical Modeling, Pilot National Laboratory for Marine Science and Technology, Qingdao, 266237, China

ENSO like events

Thresholds, +- 0.5 Standard Deviation (Liao et al., 2021) (SD, 0.3053365)

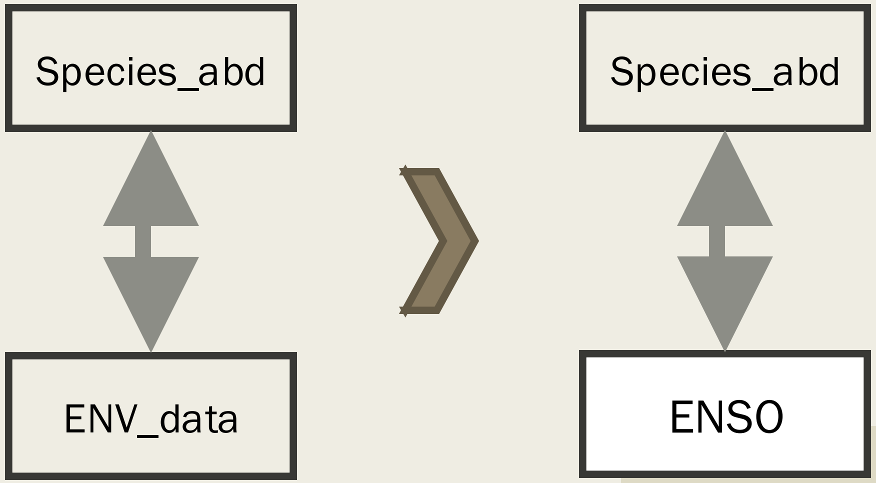


1950-2100 (150)
ENSO 90
La Nina 38
El Nino 52

	p1	p2	p3
LA	20	13	5
N	14	21	24
EL	16	16	20

Ensemble models
(10 Ensemble members)

Research structure



Quantitative:
Nino3.4

Categorical:
El, La, Nu

Q1: Is there a species-specific difference in ENSO response?

Q2: Is there a group-level difference?

We know ENV_data impacts Species_abd.
Our goal is to understand ENSO's role.

- GFDL ESM2M
- DBEM
    - 10 ENS

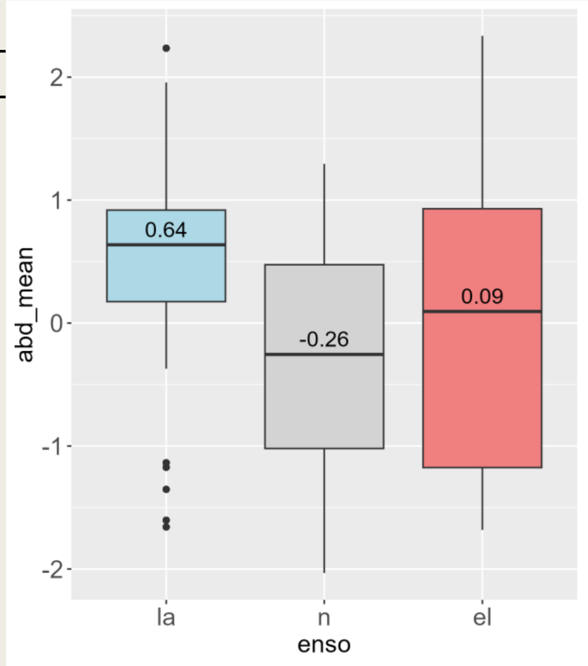
Q3: Are these findings robust across all 10 Ensemble (ENS) members?

Result 1 – Initial Look

Species

		Scientific_Name	common_name	taxa_code
1	Predator	Thunnus albacares	Yellowfin Tuna	600143
2	fish	Coryphaena hippurus	Dolphinfish	600006
3		Scomberomorus commerson	Spanish mackerel	600121
4	Pelagic	Scomber australasicus	Blue mackerel	600116
5	fish	Scomber japonicus	Chub mackerel	600117
6		Auxis rochei	Bullet tuna	600093
7		Decapterus maruadsi	Japanese scad	601939
8		Trachurus japonicus	Japanese jack mackerel	600366
9		Rastrelliger kanagurta	Indian mackerel	600111
10	Small pelagic fish	Sardinella lemuru	Bali sardinella	601510
11	Benthic	Seriola dumerili	Amberjack	601005
12	and Reef	Mene maculata	Moonfish	600390
13	fish	Psenopsis anomala	Pacific rudderfish	600497
14		Pennahia argentata	Silver croaker	600434
15		Pennahia anea	Donkey croaker	613664
16		Trichiurus lepturus	Hairtail	601288
17		Priacanthus macracanthus	Red bigeye	600356
18		Saurida tumbil	Lizardfish	606479
19		Saurida undosquamis	Brushtooth lizardfish	601055
20		Nemipterus virgatus	Golden threadfin bream	600396
21		Nemipterus japonicus	Japanese threadfin bream	604559

Overall Abundance



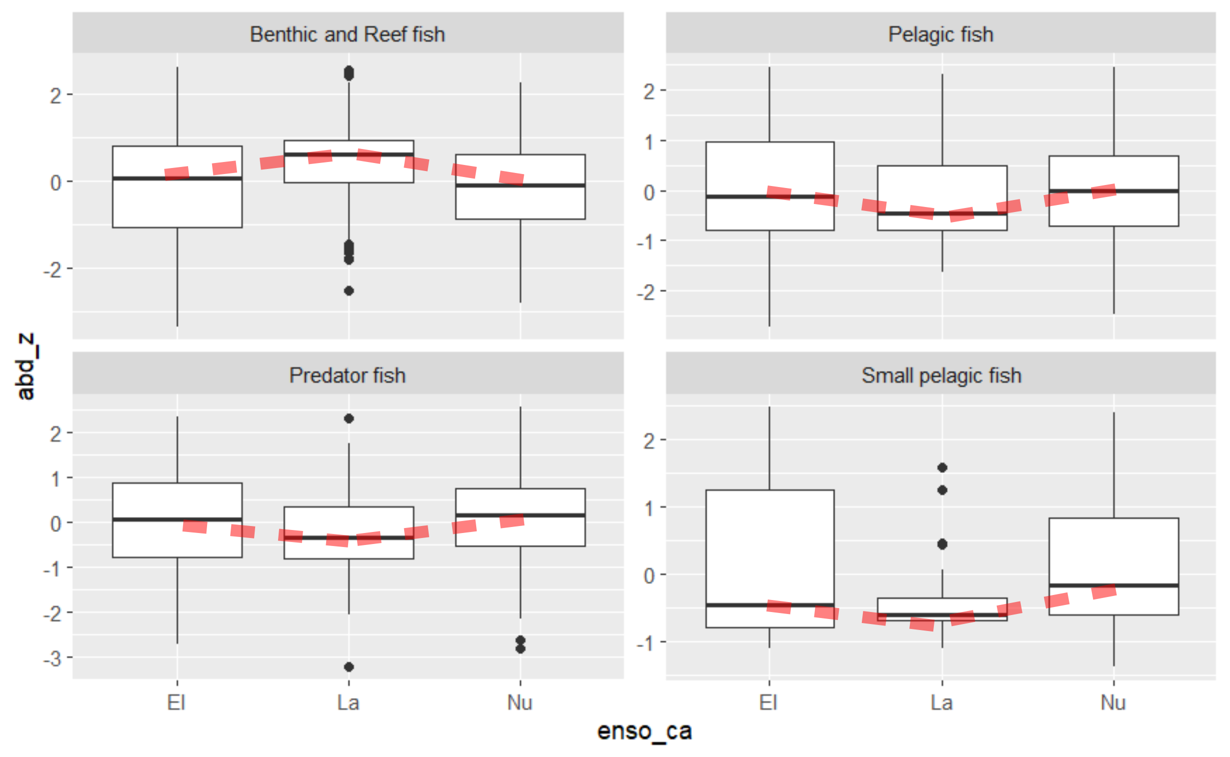
anova

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
enso_group	2	204.8	102.39	5.283	0.0062	**
Residuals	132	2558.1	19.38			

- Mean abundance is highest during La Niña (0.64) and lowest during Neutral periods (-0.26).
- overall abundance shows a significant difference between ENSO states (ANOVA, p = 0.0062).

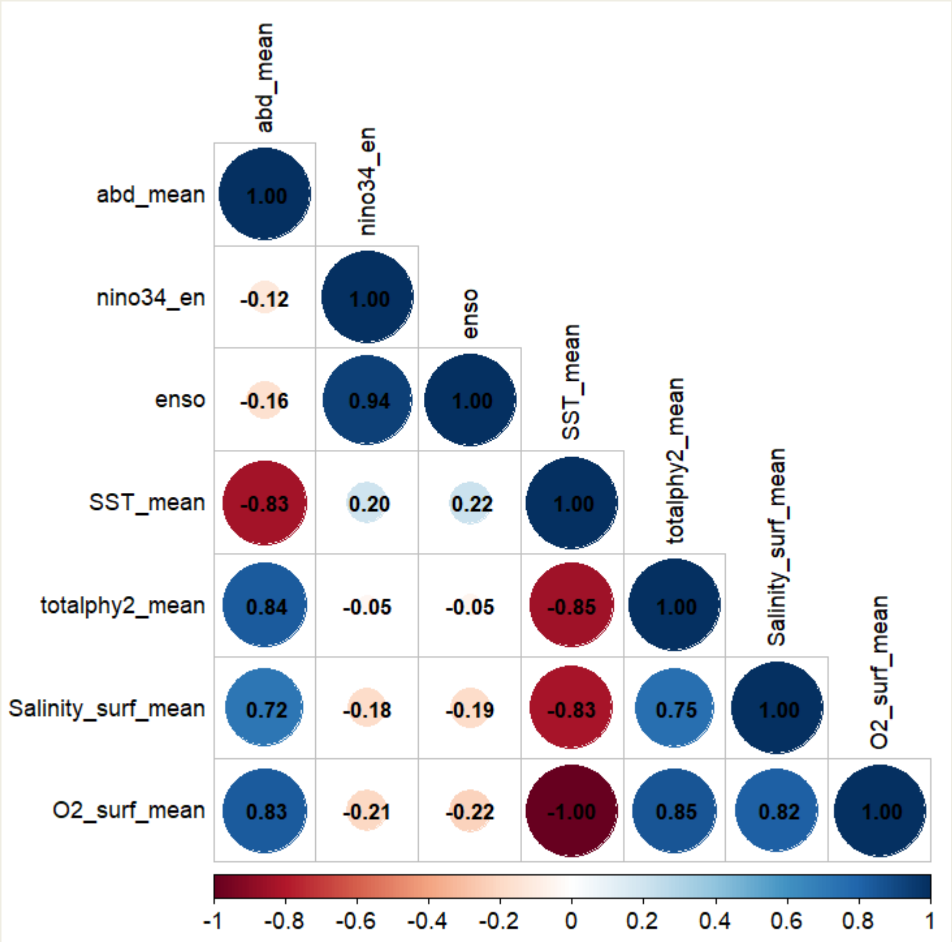
Result 2Group-Level Patterns

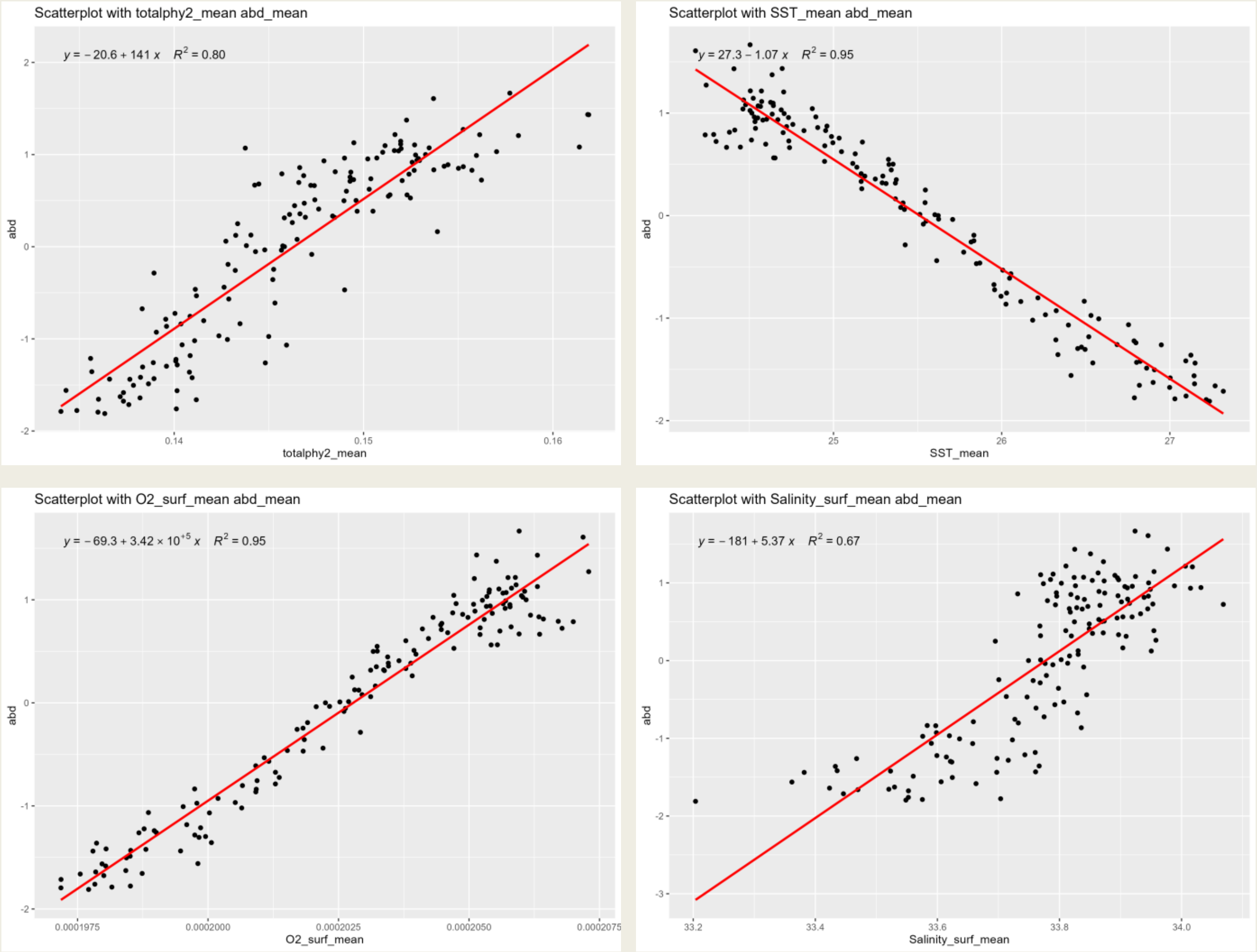
Groups



- When we disaggregate by group, the pattern changes.
- The "Benthic and Reef fish" group shows a different response pattern compared to the other groups, suggesting aggregation is hiding details.

Correlation



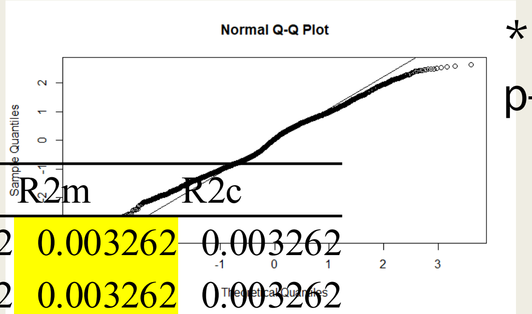


- ENSO and the Nino3.4 index exhibit low correlations with yearly mean species abundance and the environmental factors, with correlation coefficients (r) mostly ranging between 0.2 and 0.3.
- The environmental factors themselves show high correlations with each other.
- Strong negative correlation with SST, and positive correlations with NPP, O2, and salinity.
- Linear relationship between yearly mean species abundance and the four environmental factors.

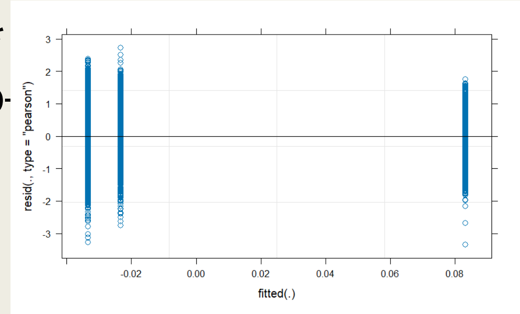
LMM & LM

LMM

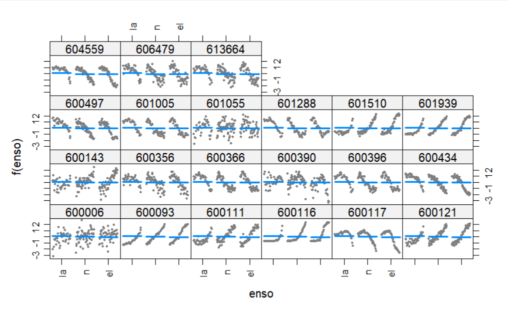
Abd ~ ENSO + (1|species)



* p-



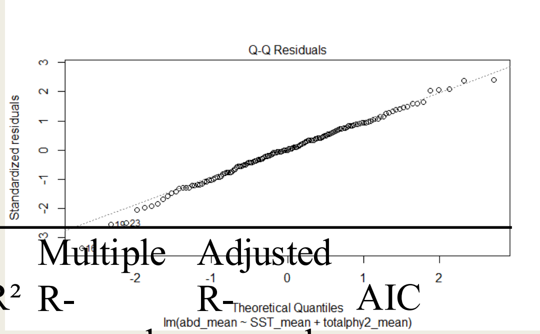
	Estimate	Std. Error	df	t value	Pr(>|t|)	AIC	R2m	R2c
(Intercept)	0.09544	0.03524	3126	2.708	0.0068 **	8873.732	0.003262	0.003262
enson	-0.1402	0.04519	3126	-3.103	0.00193 **	8873.732	0.003262	0.003262
ensoel	-0.11439	0.04636	3126	-2.467	0.01366 *	8873.732	0.003262	0.003262
SST_mean	-0.18488	0.01938	3127	-9.538	<2e-16 ***	8789.213	0.02826	0.02826
totalphy2_mean	29.9727	2.7649	3127	10.84	<2e-16 ***	8753.594	0.036209	0.036209
Salinity_surf_mean	0.8823	0.1159	3127	7.612	3.54E-14 ***	8817.901	0.018188	0.018188
O2_surf_mean	59674.23	6184.349	3127	9.649	<2e-16 ***	8761.789	0.028905	0.028905

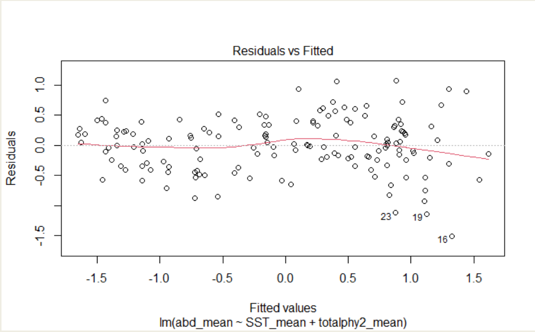


The model Abd ~ ENSO has near-zero explanatory power (R^2 = 0.003262)

LM

lm(abd_mean ~ SST_mean + totalphy2_mean)





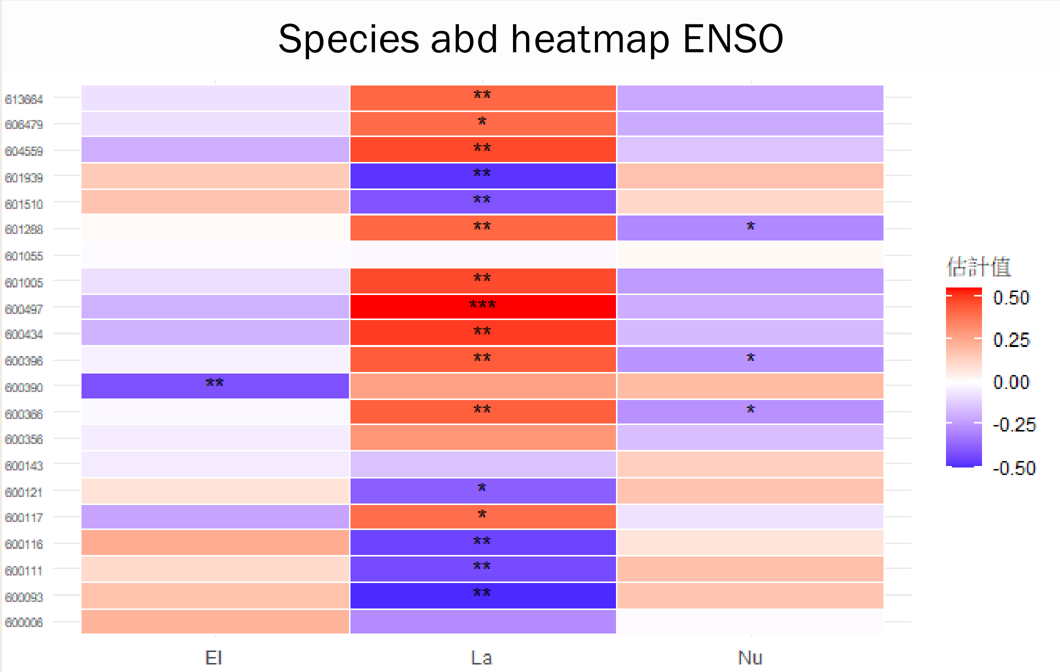
	Estimate	Std. Error	t value	Pr(>|t|)	Partial R^2	Multiple R-squared:	Adjusted R-squared:	AIC
(Intercept)	-1.14E-14	3.72E-02	0	1				
SST_mean	-5.34E-01	6.98E-02	-7.65	2.49E-12 ***	0.286			-184.37
totalphy2_mean	3.95E-01	6.98E-02	5.65	8.12E-08 ***	0.179			-205.13
total						0.797	0.7942	-232.59

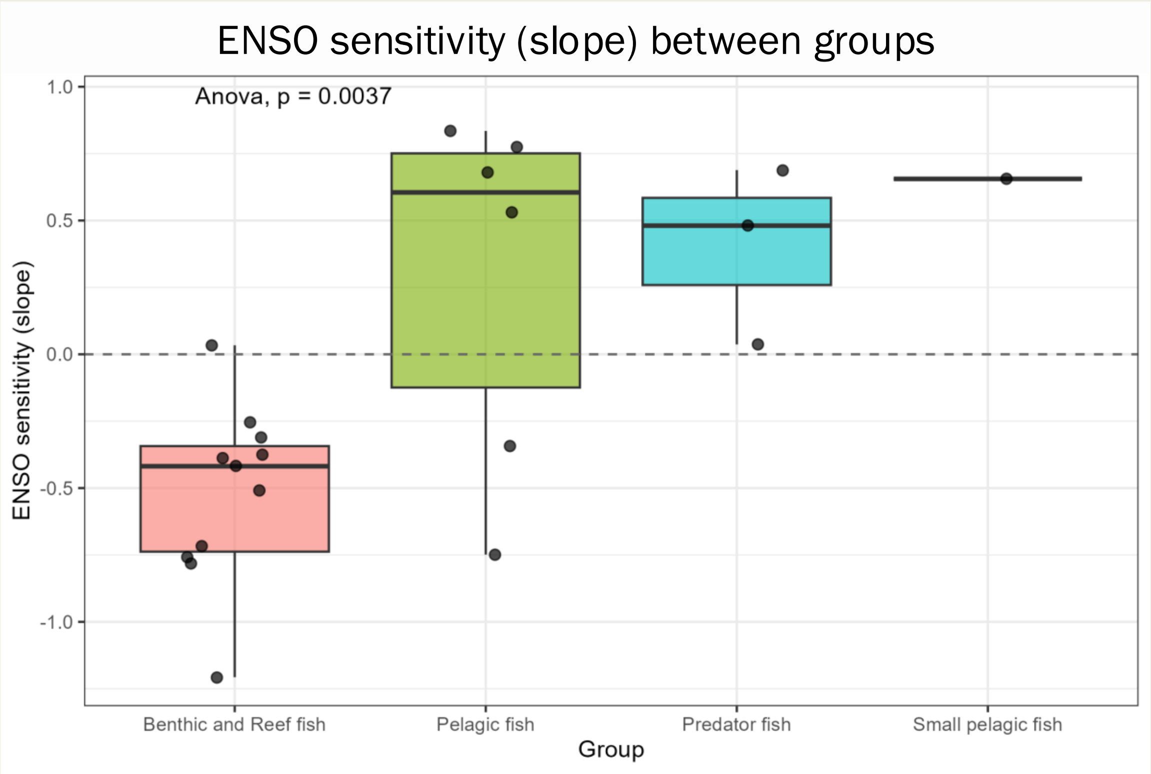
Coefficient for SST of -0.5341 and for NPP of 0.3945. The overall R^2 was 0.79

- ENSO
- Log trans
- Z-score
- Stepwise

Does this mean ENSO is irrelevant?

Opposing Effects





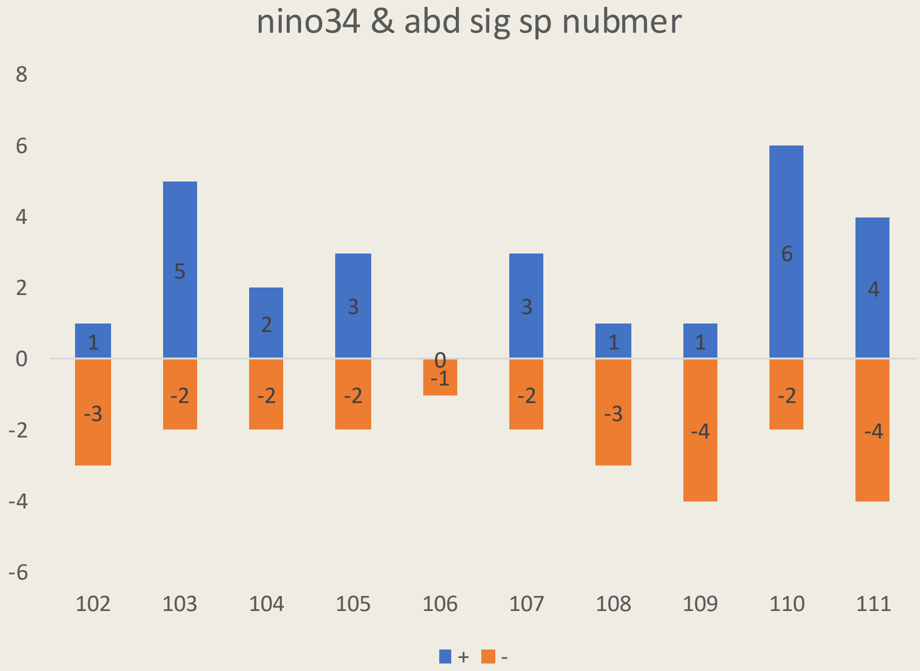
- The La Niña state has a stronger influence (compared to the Neutral state), affecting most species (17 out of 21) with an overall positive tendency (11 out of 17, 65%).
- The El Niño state affects only one species, showing a negative impact (–0.61), specifically the benthic and reef fish species (ID: 600390).

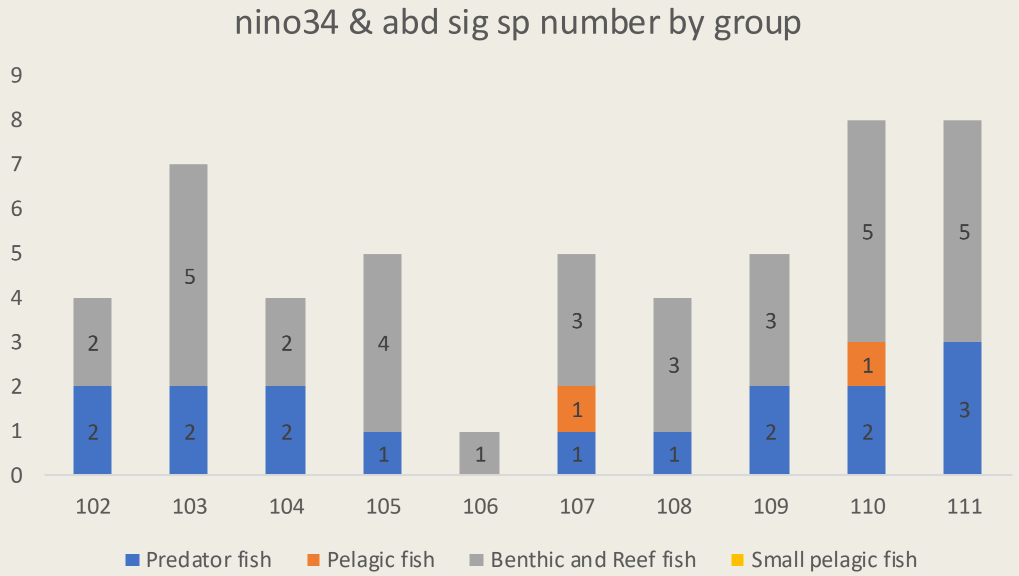
Benthic/Reef fish show a negative response to ENSO (stronger La Niña = higher abundance).
Pelagic/Predator fish show a positive response (stronger El Niño = higher abundance)

The low R^2 in the overall model is because these strong positive and negative effects cancel each other out.

The ENSO signal is not weak; it's hidden by opposing responses.

Ensemble Robustness Check





- In every single ensemble (102-111), we observe a robust co-existence of species with significant positive (blue) and negative (orange) responses .
- This confirms the "opposing effects" phenomenon is robust.
- The opposing pattern—Benthic/Reef fish (grey) vs. Predator/Pelagic fish (blue/orange)—is consistently observed across all 10 ensemble members.
- ENS 110 & 111 show the strongest signals.

Species difference

Q: species difference?

Yes. Responses are highly species-specific, with both positive and negative effects. Species 600390 (Benthic) is most impacted.

Q: groups difference?

Yes. There are significant opposing responses (ANOVA, p=0.0037).

Q: relationship between sp_abd & ENSO

The relationship is hidden. La Niña state has the largest impact, but its effect is positive for Benthic fish and negative for Pelagic fish .

Q: ENS difference?

The "opposing effects" pattern is robust across all 10 ensembles. ENS 110 & 111 show the strongest signals.

Preliminary Summary

•**ENSO and Abundance Changes**: El Niño events increase, with higher species abundance during La Niña; ENSO's impact is overshadowed by environmental factors, making it non-significant.
•**Environmental Factors**: Species abundance is negatively correlated with SST and positively correlated with NPP, O_2, and salinity.
•**Model Performance**: Species as a random effect has little influence; R^2 of the model without random effects is 0.79, but autocorrelation and multicollinearity affect explanatory power.
•**Future Direction**: ENSO effects may be nonlinear; using a GAM is recommended for further analysis.

Model performance

Shapiro-Wilk	Residual normality	W = 0.99244，p-value = 0.6193
Durbin-Watson	Residual autocorrelation?	D-W = 1.058929，p-value = 0
VIF	Multicollinearity?	

nino34_en	SST_mean	totalphy2_mean	Salinity_surf_mean	O2_surf_mean
1.238329	580.936482	4.339453	5.495035	548.713333

- NPP may be influenced by SST or O2, causing it to capture part of their effects in the model and appear more significant.
- The absence of significant results for species as a random effect may stem from interactions and collinearity among variables.
- While ENSO, SST, O2, and salinity do affect species abundance, their influence is less pronounced than that of NPP.

Working on……

Improve currents LM,LMM:

Stepwise Comparison → Multimodel Comparison

Or

LM → GAM

The limitations of LM/LMM (non-linearity, autocorrelation, collinearity) must be addressed.
Future Direction: Use a Generalized Additive Model (GAM).
GAMs can handle non-linear relationships and can incorporate correlation structures (e.g., AR(1)) to solve autocorrelation, providing a more robust estimate of the true effects.

THANKS FOR LISTENING