# Application of time series analysis to detect the effect of multi-scale climate indices on global yellowfin tuna population

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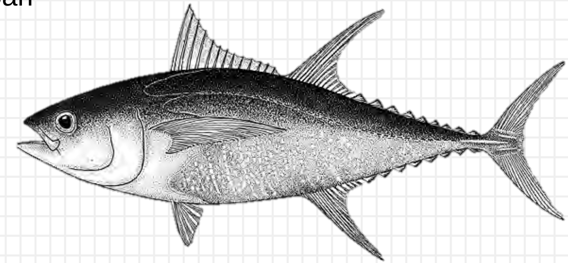
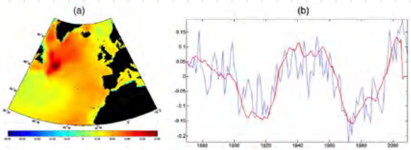


Introduction

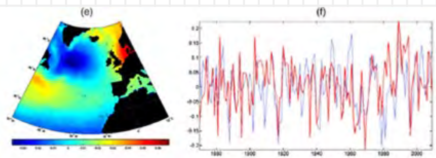
# Climate change

**Harris, et al.(2014) indicates the Atlantic Multi-decadal Oscillation is a driver of diatom abundance.**

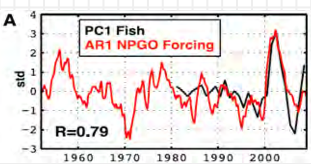


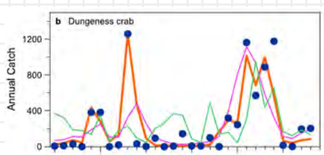

The AMO accounts for 51.89% of the variation in the first PC.

The NAO accounts for 24.38% of the variation in the first PC.




**Shows that synchronous shifts in climate patterns and community variability are related to changes in oceanic environment.**




**Cloern, et al.(2010)**

Climate change

Climate variability

Atlantic Multidecadal Oscillation (AMO)

Indian Ocean Dipole (IOD)

North Pacific Gyre Oscillation (NPGO)
Pacific Decadal Oscillation(PDO)
Oceanic Nino Index (ONI)

Marine environment

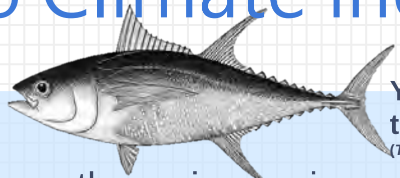
Extreme climate

Global warming
Greenhouse effect

Rising sea level
Heat wave
Desertification

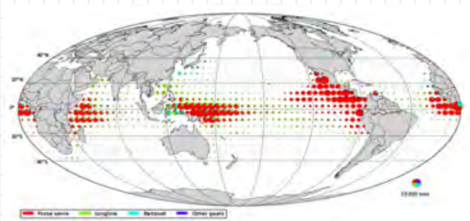
Introduction

# Tuna Fisheries Related to Climate index

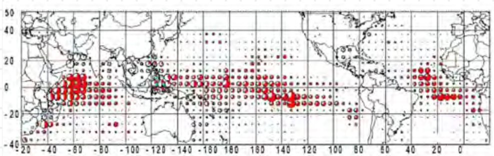


**Yellowfin tuna**
***(Thunnus albacares***

1. Purse seiners and industrial longline dominated.
2. Albacore、bigeye、skipjack and **yellowfin tuna** are the main species.
3. Yellowfin tuna is the second largest tuna fishery in the world.

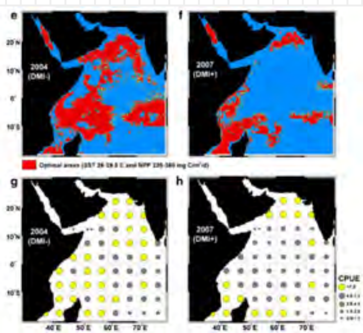


Mean annual distribution of global yellowfin tuna catch by fishing gear type from 1950 to 2013, Pecoraro, C., et al.(2014)

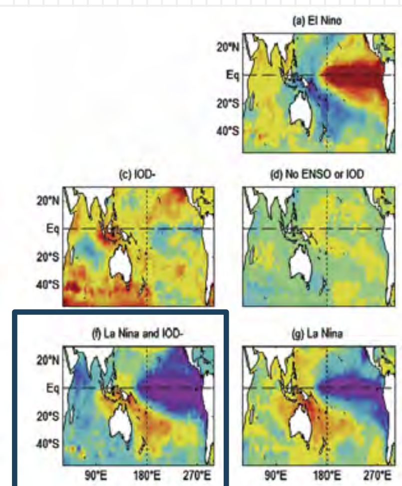


Average catches of tropical tunas caught by longliners(1997-2006), Fonteneau and Halliear,( 2014)

**The environmental processes associated with the Indian Ocean Dipole that drive variability in tuna populations** **(Lan, 2013)**

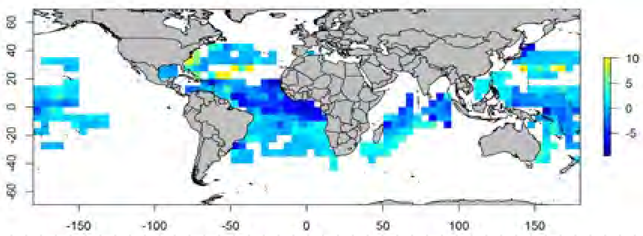


**(Meyers G, 2007)**

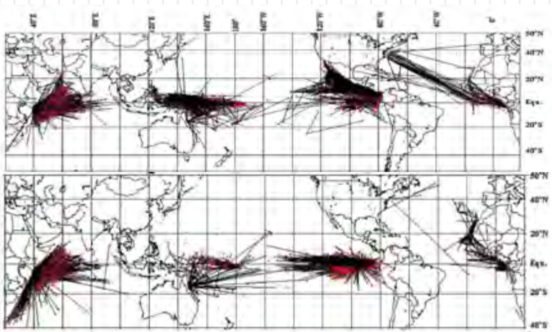


# Global scale distribution and habitat preference research

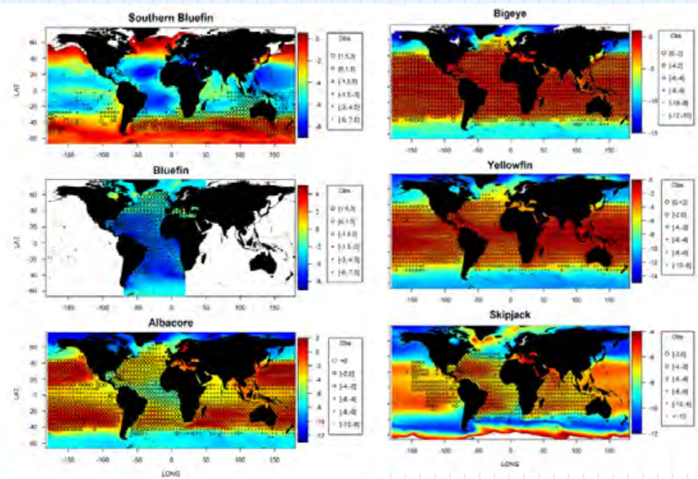
**Monllor-Hurtado, et al.(2016) shows the shift of tuna catches in subtropical latitudes on a global scale.**




**Fonteneau (2014) collected and analyzed the big-eye and yellowfin tuna tagged data.**



**Arrizabalaga, et al,(2015) analyses the habitat pre-ferences of six tuna species around the world.**



Introduction

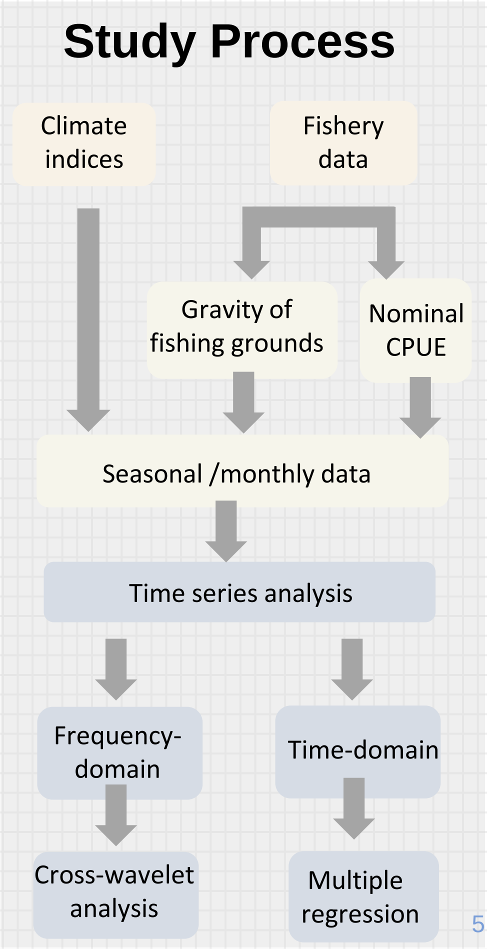
# Purpose of Study

1. Synchronous shifts in climate patterns and community variability are related to changes in oceanic environment.

2. Variations in the abundance and distribution of pelagic tuna populations have been associated with large-scale climate indices.

3. Fluctuations in tuna populations might not simply be determined by single climate indices.

4. In our study, we will use a global scale sight to investigate the relationship between climate indices and tuna populations.



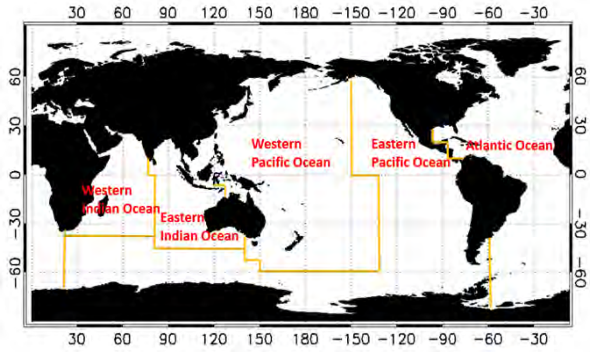
Materials and methods

# Fishery data

## Selection

We removed the data from TRFMOs which didn’t include fishing positions(latitude and longitude), fishing effort (number of hooks), fishing date, and catch (in number).

| | Period | Resolution | Taiwanese data | Other countries data | Data source |
|---|---|---|---|---|---|
| **Atlantic Ocean** | | | | Japan, USA | ICCAT |
| **Eastern Pacific** | | | | Japan | IATTC |
| **Western Pacific** | 1986-2010 | 5°x5° | Overseas Fisheries Development Council of the Republic of China | All convention members | WCPFC |
| **Eastern Indian** | | | | Japan | IOTC |
| **Western Indian** | | | | | |




## Analysis

### Catch rates

$$C_j = \frac{\sum_{i=1}^{n} N_{ij}}{\sum_{i=1}^{n} E_{ij}}$$

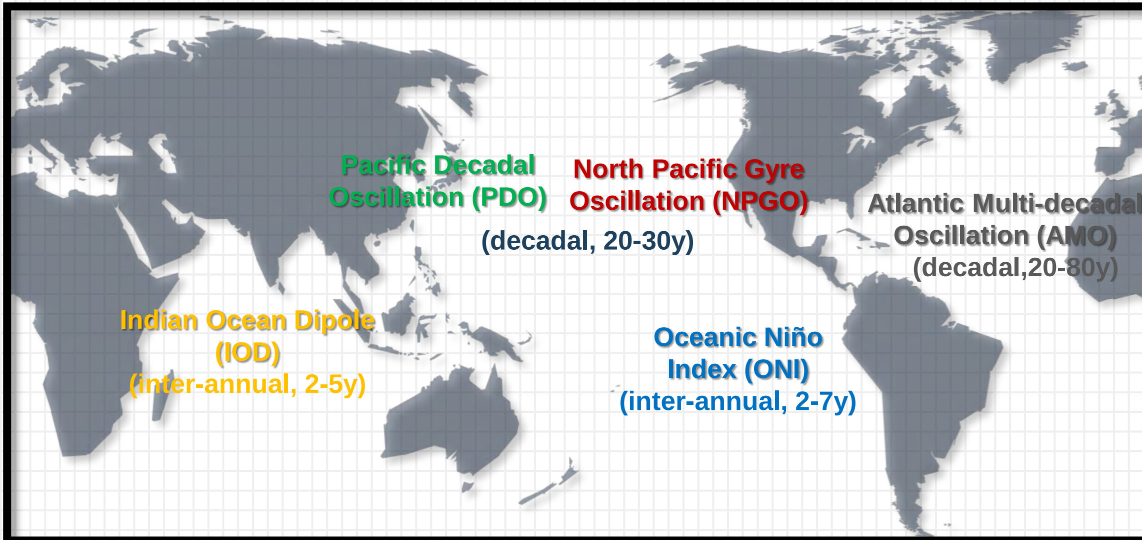
C : catch rates
$N_{ij}$ : catch (in number)
$E_{ij}$ : number of hooks
*i* and *j* : fishing positions

### Gravity of fishing grounds

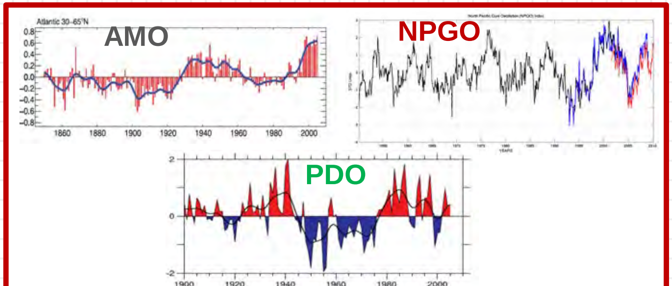
$$G_{ymi} = \frac{\sum L_{ymi} \times CPUE_{ymi}}{\sum CPUE_{ymi}}$$

*y*: year
*m*:month
*G* : longitudinal gravity of fishing grounds

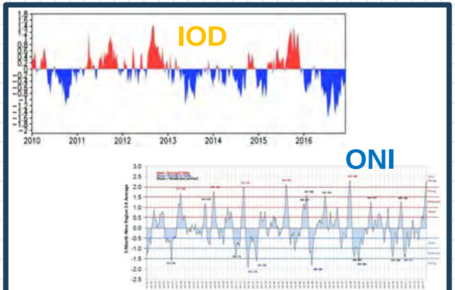
# Climate indices




Decadal(long-term)




Inter-annual (short-term)

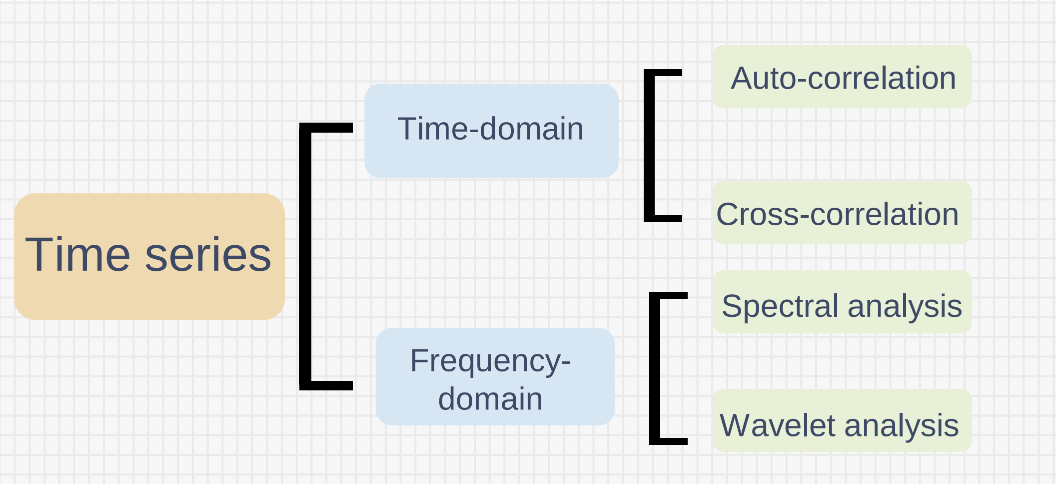


# Time series analysis

**Definition：a series of data points indexed or listed in time order.**

1. Time series analyses are valuable tools for investigating long-term fluctuations in fish populations and relationships between populations and environmental variables.

2. There are several types of motivation and data analysis available for time series which are appropriate for different purposes and etc.



# Time-domain

## Multiple regression

We used stepwise multivariate regression to obtain the best-fit model.

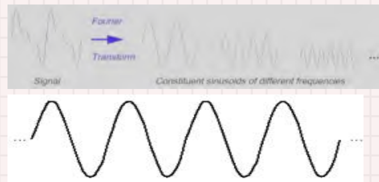
$$y_i = \beta_0 + \sum_{j=1}^{n} \beta_j X_{ij} + \varepsilon_i$$

## Cross correlation

Cross-correlation function was used to examine the time lag relationships be-tween the population of yellowfin tuna and climatic indices corresponding to the Pearson correlation.

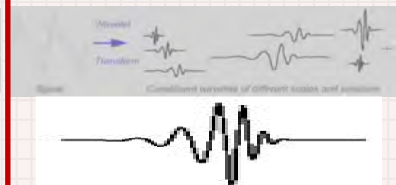
# Frequency-domain

## Fourier transform




**Suit for stationary signal only**

## Wavelet transform



**Could apply to non-stationary signal analysis**

## Morlet mother wavelet

$$\psi_0(\eta) = \pi^{-1/4} e^{i\varpi o} e^{-\eta^2/2}$$

$\eta$ : a dimensionless time parameter

$\omega_0$ : a dimensionless frequency

## Wavelet coherency

$$W^{XY} = W^X W^{Y*}$$

(The cross-wavelet transformation of the two series)

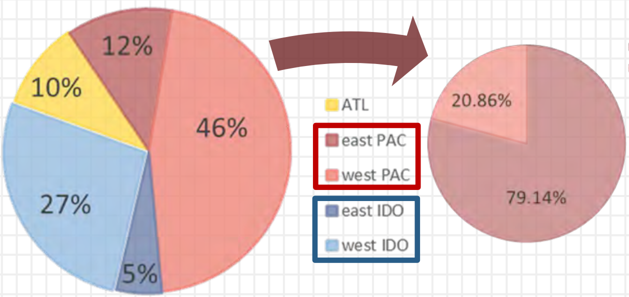
$$R_n^2(s) = \frac{\left| S(s^{-1} W_n^{XY}(s)) \right|^2}{S(s^{-1} W_n^X(S))^2 \cdot S(s^{-1} W_n^Y(S))^2}$$

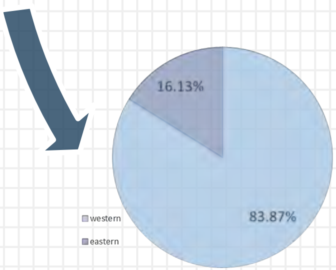
*S*: a smoothing operator by a running average

Results

# Spatial distribution

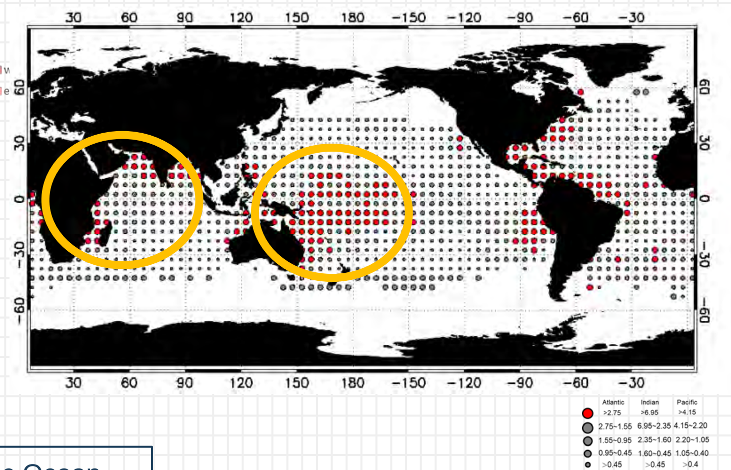
**Catch number of global YFT**




ATL : Atlantic Ocean
PAC : Pacific Ocean
IDO : Indian Ocean

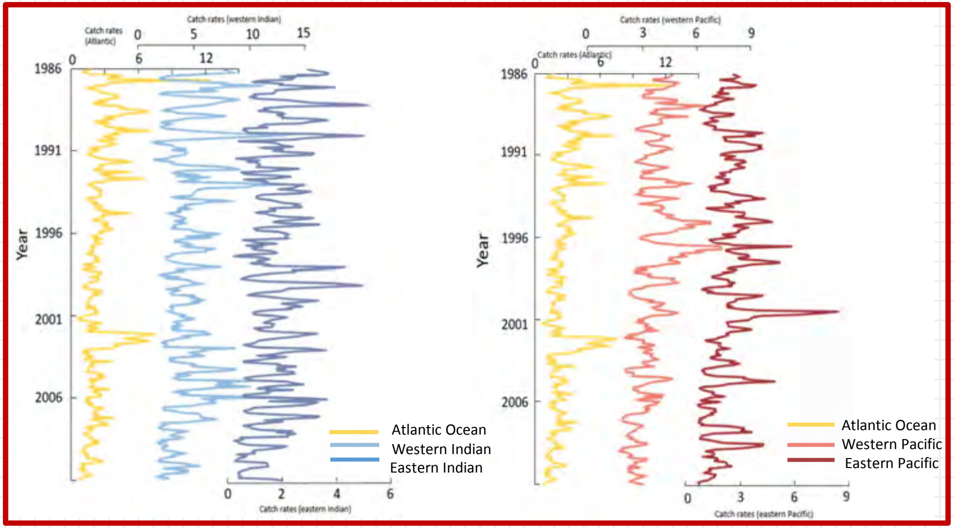
**1986-2010 global YFT catch rates**



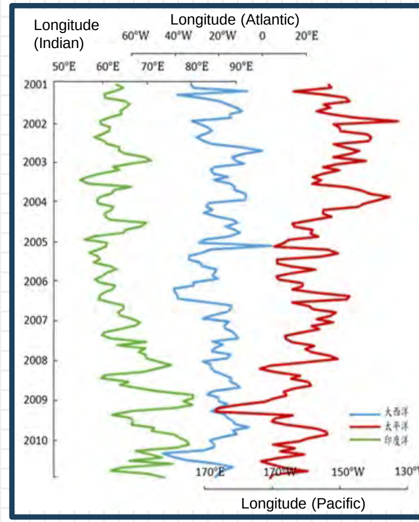
Results

# Catch rates and gravity of fishing grounds

## Time series of catch rates




## Time series of gravity of fishing grounds




### Results of Pearson correlation (catch rates)

| | ATL | Western PAC | Eastern PAC | Western IDO | Eastern IDO |
|---|---|---|---|---|---|
| ATL | ---- | | | | |
| Western PAC | 0.25* | ---- | | | |
| Eastern PAC | 0.11 | 0.42* | ---- | | |
| Western IDO | -0.09 | 0.03 | -0.29* | ---- | |
| Eastern IDO | -0.08 | 0.04 | -0.19* | 0.51* | ---- |

### Results of Pearson correlation (gravity of fishing grounds)

| Longitudinal / Latitudinal | ATL | IDO | PAC |
|---|---|---|---|
| ATL | ---- | -0.43* | 0.04 |
| IDO | 0.47* | ---- | 0.1 |
| PAC | 0.17 | 0.48* | ---- |

ATL : Atlantic Ocean
PAC : Pacific Ocean
IDO : Indian Ocean

Results

# Multiple regression

## Results of regression analysis of YFT catch rates against climate indices

| Climate indices | Time scale | Atlantic | | | | Eastern Pacific | | | | Western Pacific | | | | Eastern Indian | | | | Western Indian | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Multiple regression | | Time lag | | Multiple regression | | Time lag | | Multiple regression | | Time lag | | Multiple regression | | Time lag | | Multiple regression | | Time lag | |
| | | beta | p value | lag | R | beta | p-level | lag | R | beta | p-level | lag | R | beta | p-level | lag | R | beta | p-level | lag | R |
| AMO | Decadal | -0.46 | 0.00 | 7 | -0.37 | -0.22 | 0.00 | ----- | | -0.37 | 0.00 | 0 | -0.48 | -0.20 | 0.00 | 0 | -0.2 | -0.05 | 0.42 | ---- | |
| NPGO | | 0.16 | 0.01 | ---- | | 0.04 | 0.52 | ----- | | -0.17 | 0.00 | 1 | -0.36 | 0.15 | 0.02 | ---- | | -0.09 | 0.17 | ---- | |
| PDO | | -0.14 | 0.04 | 7 | 0.27 | -0.09 | 0.20 | ----- | | 0.13 | 0.04 | 9 | 0.4 | 0.21 | 0.00 | ---- | | 0.22 | 0.00 | 1 | 0.3 |
| DMI | Inter-annual | -0.14 | 0.04 | ---- | | 0.09 | 0.22 | ----- | | -0.11 | 0.06 | 20 | -0.23 | -0.05 | 0.50 | ---- | | -0.17 | 0.01 | 19 | 0.25 |
| ONI | | 0.21 | 0.01 | ---- | | 0.04 | 0.66 | ----- | | -0.06 | 0.37 | ---- | | -0.12 | 0.12 | ---- | | 0.05 | 0.49 | ---- | |

## Results of regression analysis of Taiwanese YFT gravity of fishing grounds against climate indices

| Climate indices | Time scale | Atlantic | | Eastern Pacific | | Western Pacific | | Eastern Indian | | Western Indian | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | beta | p-level | beta | p-level | beta | p-level | beta | p-level | beta | p-level |
| AMO | Decadal | 0.48 | 0.00 | 0.02 | 0.78 | 0.12 | 0.03 | -0.41 | 0.00 | -0.46 | 0.00 |
| NPGO | | -0.17 | 0.00 | 0.17 | 0.01 | 0.28 | 0.00 | 0.05 | 0.34 | 0.04 | 0.45 |
| PDO | | -0.07 | 0.22 | 0.17 | 0.01 | -0.14 | 0.02 | 0.18 | 0.00 | -0.06 | 0.32 |
| DMI | Inter-annual | 0.10 | 0.07 | -0.06 | 0.34 | 0.11 | 0.05 | 0.22 | 0.00 | -0.15 | 0.01 |
| ONI | | 0.08 | 0.17 | 0.10 | 0.16 | 0.17 | 0.01 | -0.15 | 0.01 | 0.09 | 0.13 |

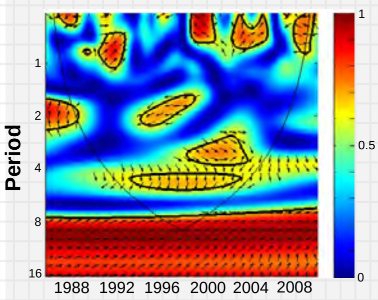
Results

# Wavelet analysis

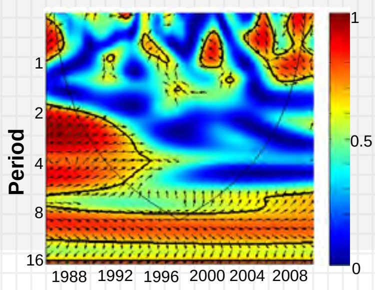
## Cross-wavelet coherence between climatic indices and yellowfin tuna catch rates

| Climate indices | Area | Correlation | 1-2y | 2-4y | 4-8y |
|---|---|---|---|---|---|
| AMO | ATL | + | | 2000-2006 | |
| | Western PAC | + | 1986-1990<br>1994-2000 | | |
| NPGO | ATL | + | 1986-1992 | | 1986-1996 |
| | Western PAC | - | 1992-2000 | | |
| | Eastern IDO | + | 1992-1998 | | |
| PDO | ATL | - | 1986-1996 | | |
| | Western PAC | + | 1990-1994 | 1998-2006 | |
| | Eastern IDO | - | 1986-1990 | | 1986-2010 |
| | Western IDO | + | 2004-2010 | 1986-1996 | |
| DMI | ATL | + | 2002-2010 | | |
| | Western PAC | - | 1994-2002<br>2006-2010 | | 1986-2010 |
| | Western IDO | - | 2004-2010 | 1998-2000 | |

PDO v.s west PAC catch rates




PDO v.s west IDO catch rates



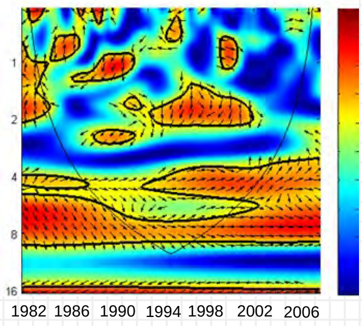
Results

# Wavelet analysis

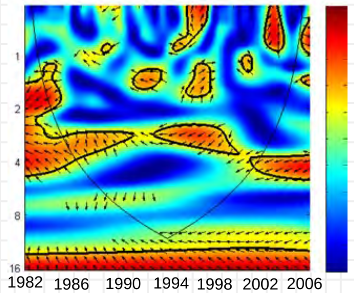
## Cross-wavelet coherence between fishing grounds and yellowfin tuna catches rates

| Climate indices | Area | Correlation | 1-2y | 1-4y | 2-4y | 4-8y | 8-16y |
|---|---|---|---|---|---|---|---|
| AMO | ATL | + | | | 1998-2006 | | |
| | Eastern IDO | - | | | 1982-1996 | | |
| | Eastern PAC | + | | | 2002-2010 | | |
| NPGO | ATL | - | | | 1998-2002 | | |
| | Eastern IDO | + | | 1981-1988 | | | 1981-2010 |
| | Western IDO | - | | 2004-2010 | 1981-1995<br>1990-1994 | | 1981-2010 |
| | Eastern PAC | + | | | 1981-1985 | | 1981-2010 |
| PDO | ATL | - | 1996-2006 | | | | 1981-2002 |
| | Eastern PAC | - | 1996-1999 | | | 1986-2010 | 1981-2010 |
| | Western PAC | - | | | 1998-2002 | 1981-2010 | |
| DMI | Western IDO | - | 2002-2010 | | 1988-2006 | | 1981-2010 |
| | Western PAC | - | | 1981-1990 | 1992-2002 | 2002-2010 | |

**PDO v.s. eastern Pacific**



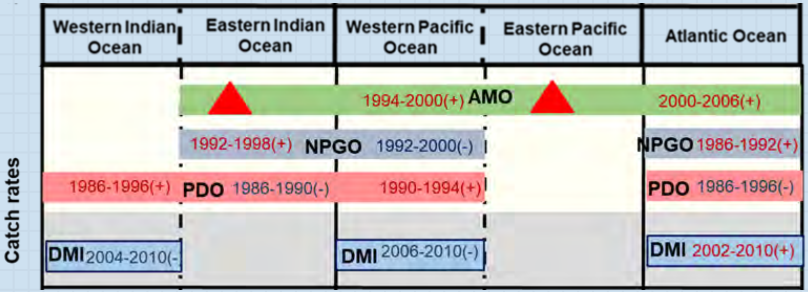

**DMI v.s. western Pacific**

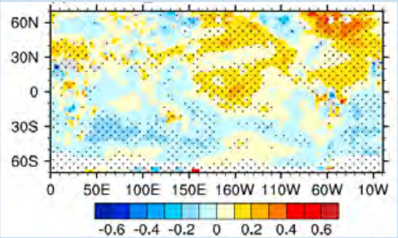


Discussion

# The relationship between climate indices, catch rates and gravity of fishing grounds.

## The population abundances were effected by the long term climate indices.



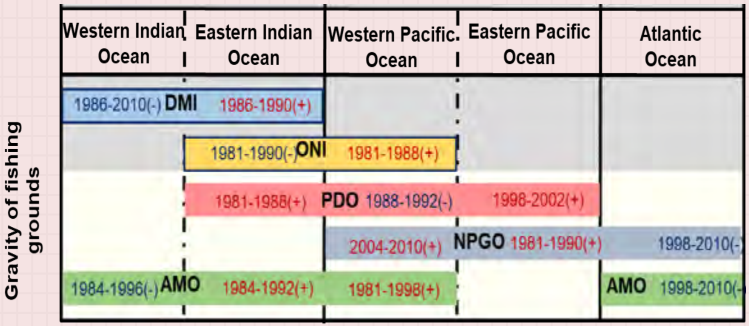




The wavelet analysis results of AMO is consistent with the Dong and Zhou (2014).

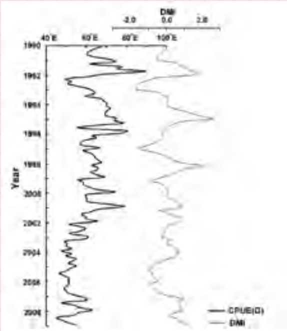
Dong and Zhou(2014)

## The fishing locations were effected by the short term climate indices.

(Lan,2012)

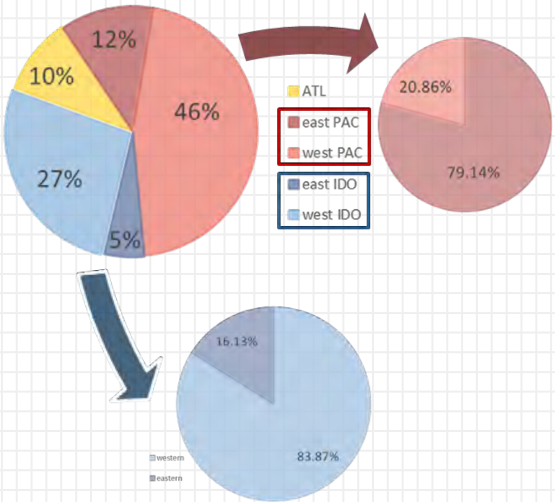



1. Lan (2012) indicated the gravity of YFT fishing grounds showed similar variations with DMI.
2. Wavelet analysis showed a significant negative correlation between DMI and CPUE with a periodicity of 2-3yr.



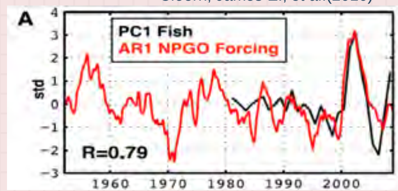
Discussion

# Research gap in the Eastern Indian Ocean and Eastern Pacific Ocean?

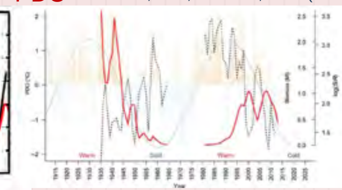


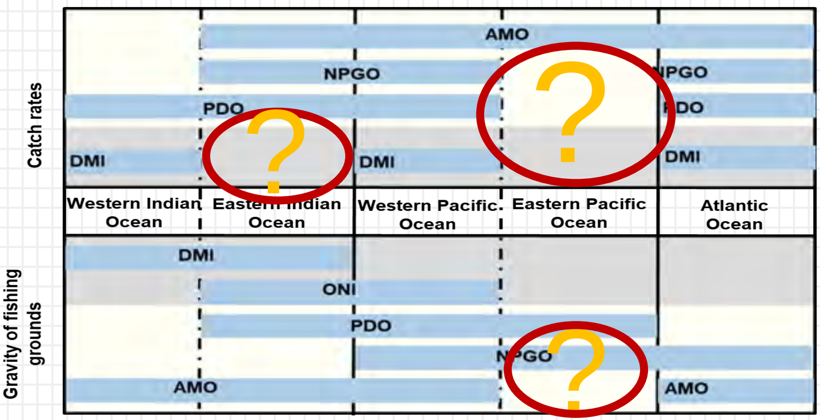

## Eastern Pacific Ocean

NPGO Cloern, James E., et al.(2010)



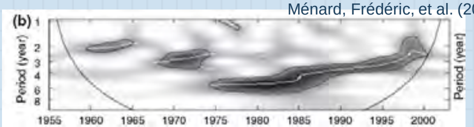

PDO Zwolinski, J. P., & Demer, D. A. (2013).






## Eastern Indian Ocean Climate indices

Ménard, Frédéric, et al. (2007)



# Summary

1. The population abundances were effected by the long term climate indices (AMO, NPGO and PDO).

2. The fishing locations were effected by the short term climate indices (DMI, OMI).

3. Future programs should be provide the basic parameters of yellowfin tuna predicated spatial model.

# Thank you for your attention!!