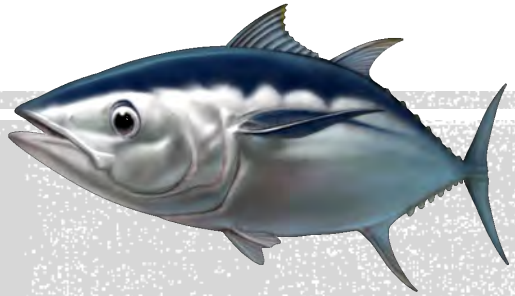

Spatial distributions and catch rates variability of Bigeye tuna (*Thunnus obesus*) cohorts related to oceanographic and climatic indices in the Pacific Ocean

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National Taiwan Ocean University

PICES – 2018 Annual Meeting

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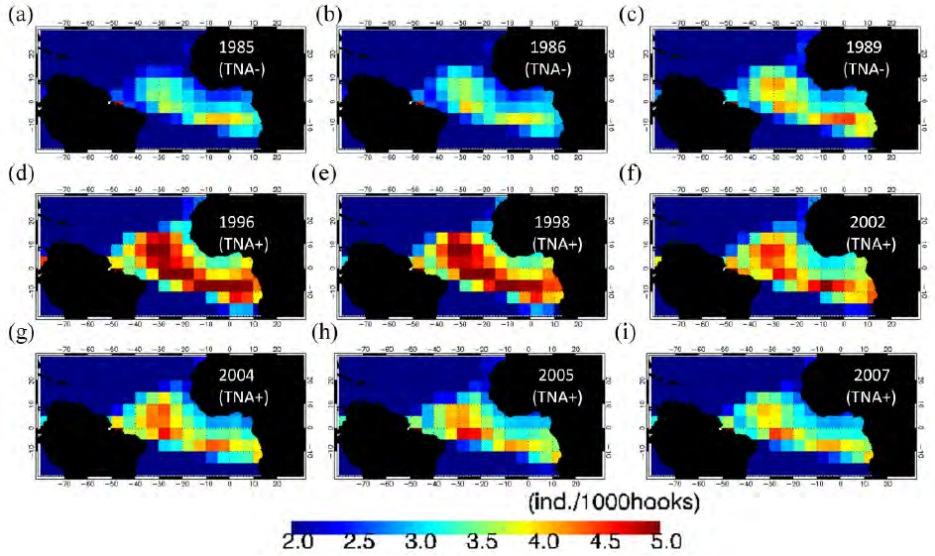
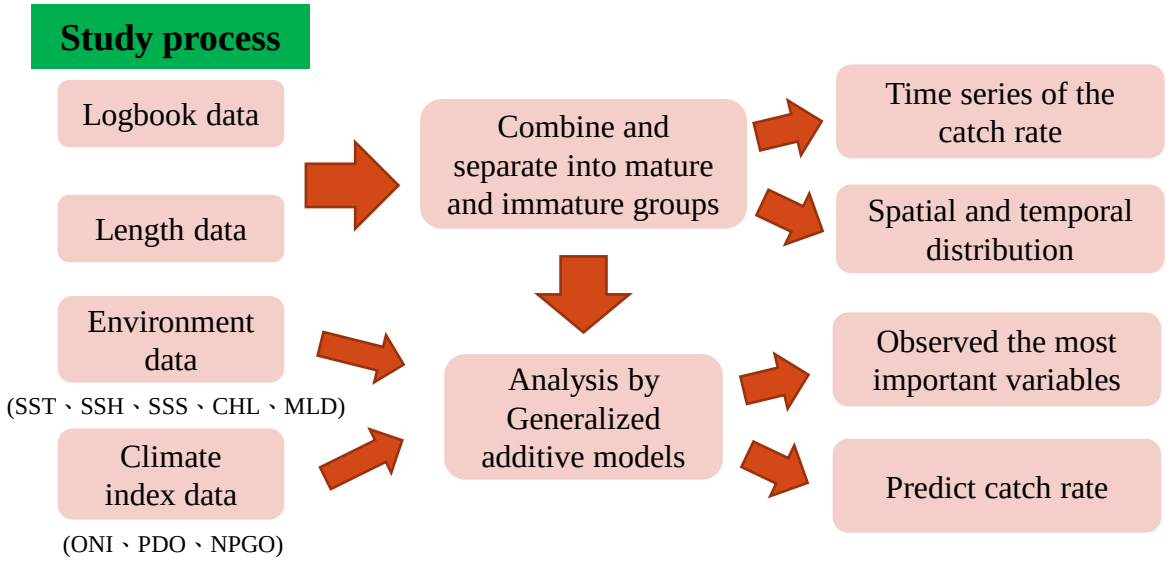
Research motivation and the purpose of present study

- Pelagic tuna species likely track suitable habitats for feeding and spawning migrations. However, Climatic oscillations, anomalies, and changes clearly influence oceanographic variability and affect fishing grounds and catch rates of BET further.
- According to previous research indicated that the bigeye tuna catch rate and distributions of BET would affected by environment variables. However, the spatial and temporal distribution of catch rates on different life stage of BET are unexplored.
- This research more focus on the analysis of oceanographic variability related to immature and mature groups.



The spatial distribution catch rate prediction of bigeye tuna during negative (Fig. a,b,c) and positive (Fig. d-i) Tropical Northern Atlantic (TNA) (source : Chou et al., 2015)



Materials and Methods

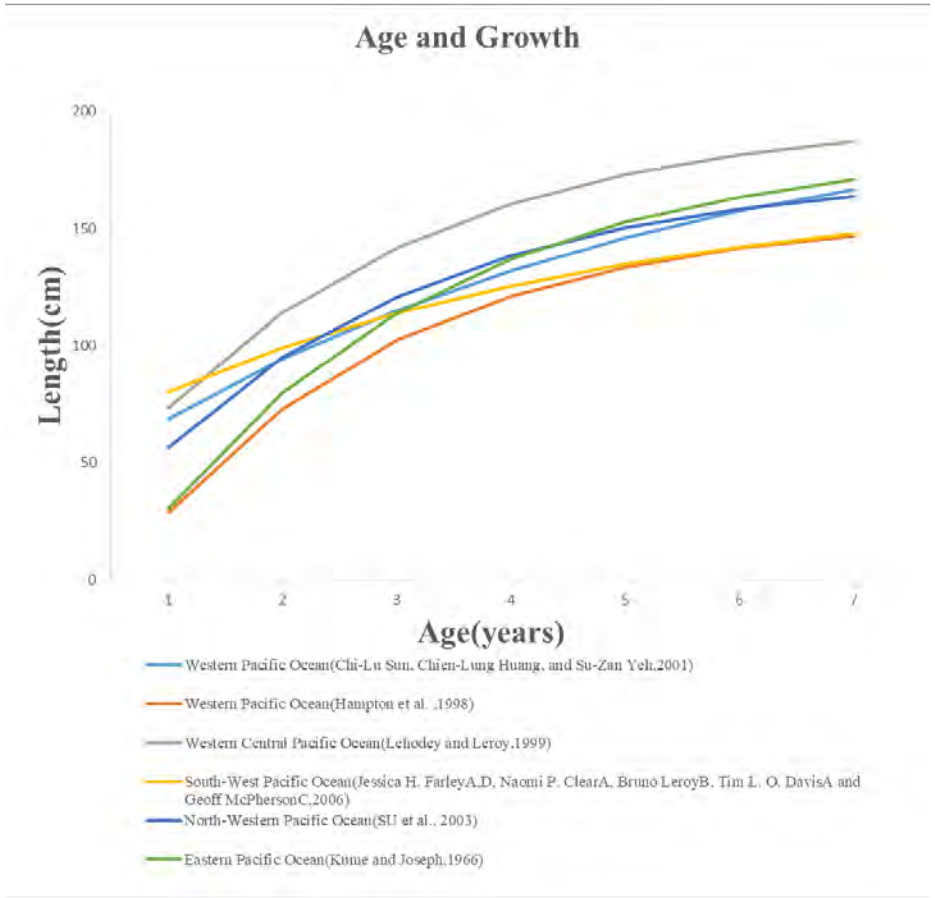
Name	Fishery data			
Including	Latitude、Longitude Catch、Length(cm)			

Using Von Bertalanffy Growth Equation(VBGE) formula to estimate average length of BET.

Age cohorts	Length
Age<1	<56cm
Age1	56-92cm
Age2	92-117cm
Age3	117-135cm
Age4	135-148cm
age≥5	>148cm

Base on Calkins research in 1980,we divided age cohorts into mature and immature group.

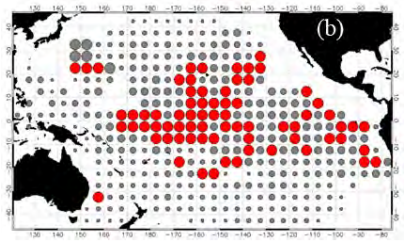
Immature groups	Mature groups
Age<1~Age<3	Age3~Age≧5



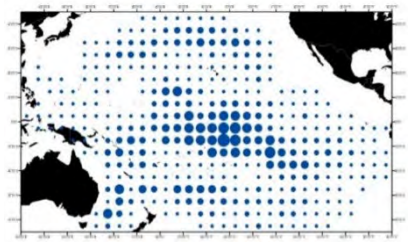
Materials and Methods

Name		Length data		
Including		Latitude、Longitude NHB、Hooks Fish species and numbers		

Fishery Data

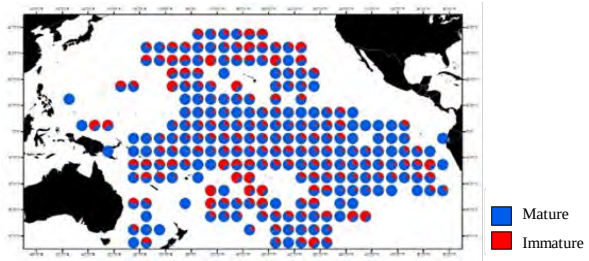


The spatial distribution catch rates



The spatial distribution Taiwanese tuna longline efforts

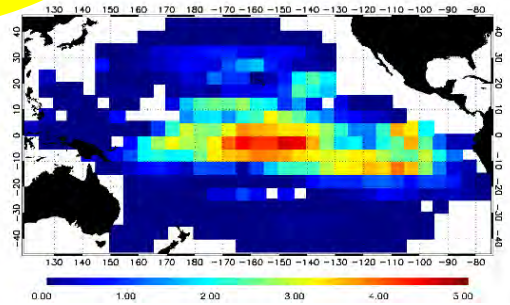
Length Data



The spatial distribution catch percentage

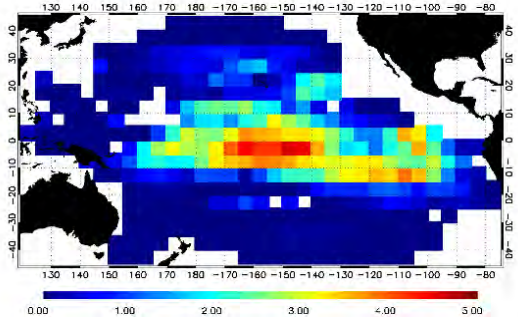
catch percentage of mature and immature group.

Immature cohort



The spatial distribution the catch rate of immature cohort

Mature cohort



The spatial distribution the catch rate of mature cohort

The catch rate formula of BET

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

C_{ij} ： Monthly average catch rate of BET.
N_{ij} ： Monthly average catch unmber of BET.
E_{ij} ： Monthly average effort.
i, j ：The location of fishman.

Materials and Methods

Materials and Methods

Name			Oceanographic environmental data	climate index data
Including			Sea surface temperature (SST) Chlorophyll-a concentration (CHL) Sea surface salinity (SSS) Sea surface height (SSH) Mixed layer depth (MLD)	Oceanic Nino Index(ONI) Pacific Decadal Oscillation(PDO) North Pacific Gyre Oscillation(NPGO)

Oceanographic environmental data

Environmental Data	Time	Resolution	Source
Sea surface temperature (SST)	2002~2014 Monthly data	1°	HadISST
Chlorophyll-a concentration (CHL)	2002~2014 Monthly data	0.05°	MODIS aqua ocean color
Sea surface salinity (SSS)	2002~2014 Monthly data	1°	NECP GODAS
Sea surface height (SSH)	2002~2014 Monthly data	1°	NECP GODAS
Mixed layer depth (MLD)	2002~2014 Monthly data	1°	NECP GODAS

Climate index data

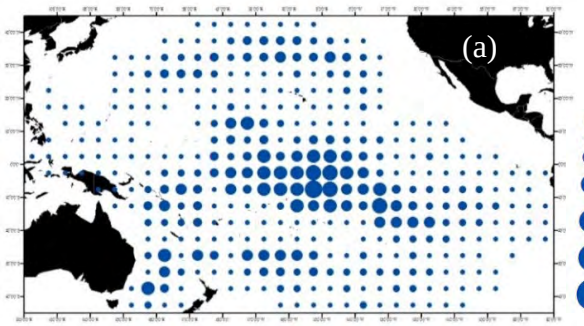
Climate index	Time	Source
Oceanic Nino Index(ONI)	2002~2014 Monthly data	National Oceanic and Atmospheric Administration,NOAA
Pacific Decadal Oscillation(PDO)	2002~2014 Monthly data	
North Pacific Gyre Oscillation(NPGO)	2002~2014 Monthly data	

Result

The spatial distribution of fishery and length data

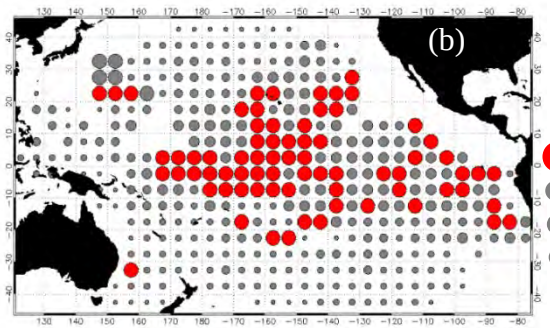
Fishery data

The distribution of Taiwan longline effort



1.40E+03 -7.80E+05
7.80E+05 - 2.25E+06
2.25E+06 - 4.38E+06
4.38E+06 - 8.63E+06
8.63E+06 - 1.74E+07
1.74E+07 - 3.61E+07
3.61E+07 - 4.83E+07

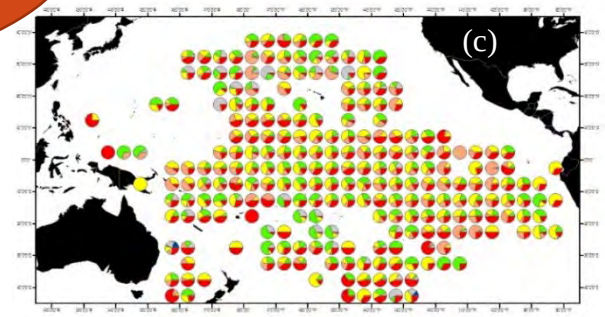
The distribution of BET catch rate



>5.5
3.3~5.5
1.4~3.2
0.7~1.3
0~0.6

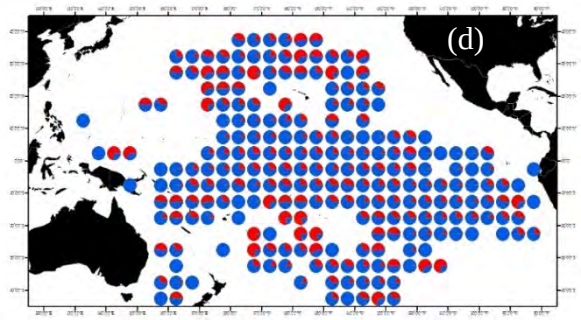
Distribution

The distribution proportion of each age cohorts



Age<1
Age1
Age2
Age3
Age4
Age≥5

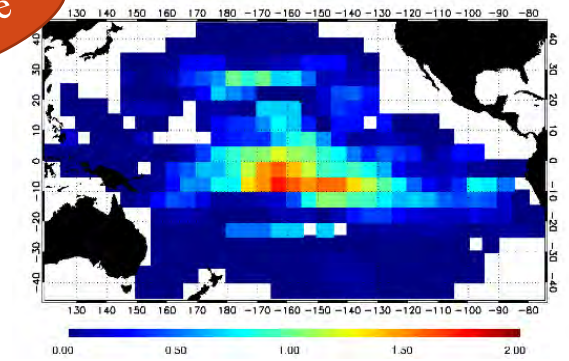
The distribution proportion of immature and mature groups



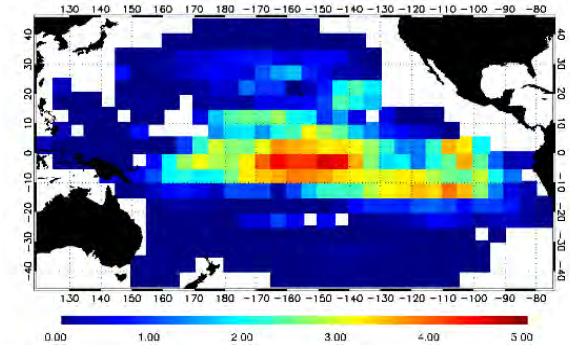
Mature
Immature

Catch rate

The spatial distribution of the catch rate of immature groups



The spatial distribution of the catch rate of mature groups



- Effort concentrated in Central Pacific, and high catch rate appeared in Equator and Eastern Pacific.
- Immature groups show high distribution in mid-high latitude , and mature groups were more concentrated in Central and Eastern Pacific Ocean.
- The distribution of catch rate of immature groups were distributed in Central and North Pacific Ocean , and mature groups were more concentrated in Central and Eastern Pacific Ocean.

Result

GAM result of the immature groups

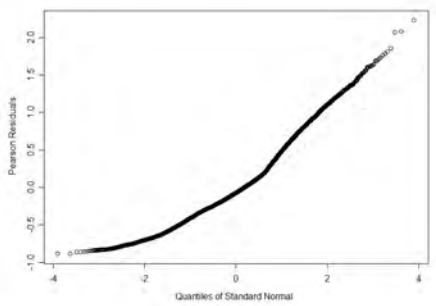
- The optimal interval for immature group of SST in the range 26-28℃, 0.4-0.5 m of SSH, 34.5-35.5 psu of SSS, 60-90 m of MLD and 0.1-0.2 mg/m^3 of CHL.
- The stepwise GAM procedure was used to select the best predictors. All variables in the GAM model for the catch rate of 5 degree were significant. The most important factor of influence were MLD(16.2%) and SST(14.2%) for immature groups.
- The catch rate of immature groups has significant influence on PDO and ONI.

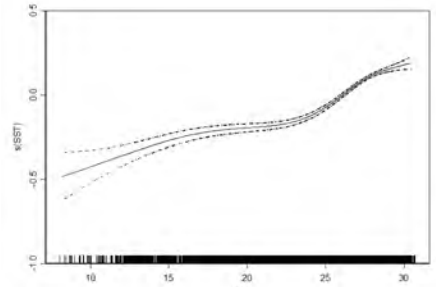
Deviance explained, and AIC of immature group catch rate explain in a GAM with sequentially added variables.

Variable	R.eq.	Deviance explained	AIC
log(CPUE+c)~s(SST)	0.141	14.20%	35380.53
log(CPUE+c)~s(SST)+s(SSH)	0.163	16.40%	35126.98
log(CPUE+c)~s(SST)+s(SSH)+s(SSS)	0.209	21.10%	34561.56
log(CPUE+c)~s(SST)+s(SSH)+s(SSS)+s(MLD)	0.262	26.40%	33867.97
log(CPUE+c)~s(SST)+s(SSH)+s(SSS)+s(MLD)+s(CHL)	0.272	27.50%	33733.44
log(CPUE+c)~s(SST)+s(SSH)+s(SSS)+s(MLD)+s(CHL) +s(PDO)	0.276	27.90%	33683.11
log(CPUE+c)~s(SST)+s(SSH)+s(SSS)+s(MLD)+s(CHL) +s(PDO)+s(NPGO)	0.28	28.30%	33627.4
log(CPUE+c)~s(SST)+s(SSH)+s(SSS)+s(MLD)+s(CHL) +s(PDO)+s(NPGO)+s(ONI)	0.287	29.10%	33541.65

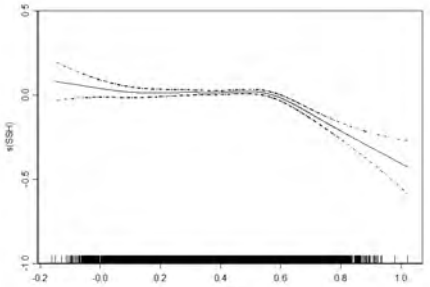
Deviance explained, and AIC of immature group catch rate explain in a GAM with each added variables

Variable	edf	Ref.df	F	P	Deviance explained
s(SST)	8.364	8.889	186.2	<0.001	14.20%
s(SSH)	8.349	8.887	112.1	<0.001	9.05%
s(SSS)	8.61	8.955	81.27	<0.001	6.78%
s(MLD)	8.663	8.967	246.7	<0.001	16.20%
s(CHL)	8.604	8.954	151.8	<0.001	11.90%
s(PDO)	8.28	8.861	7.46	<0.001	0.69%
s(NPGO)	1	1	6.076	<0.05	0.06%
s(ONI)	8.429	8.906	14.8	<0.001	1.32%

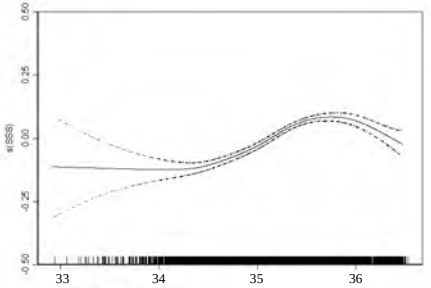




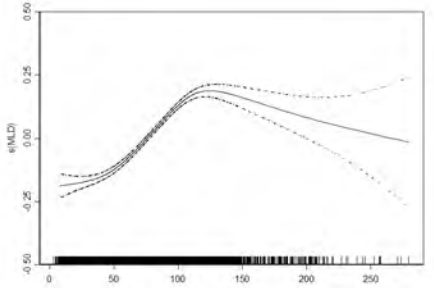
SST



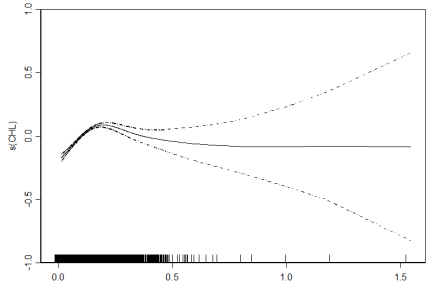
SSH



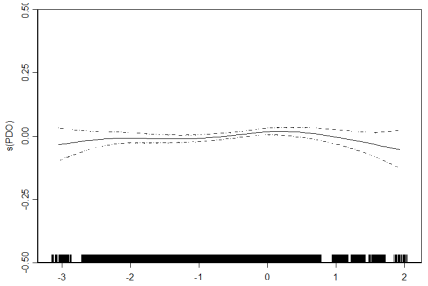
SSS



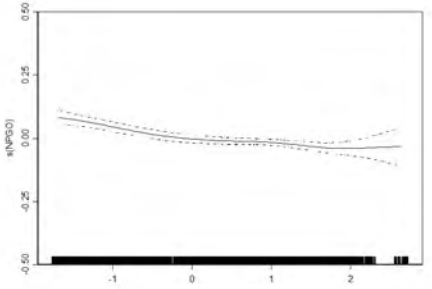
MLD



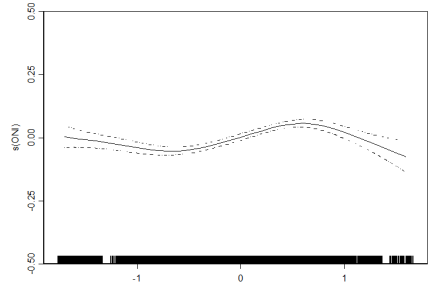
CHL



PDO



NPGO



ONI

Result

GAM result of the mature groups

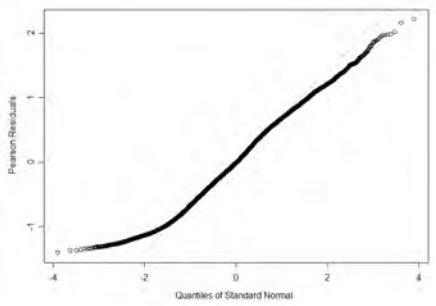
- The optimal interval for mature group of SST in the range 25-28℃, 0.4-0.5 m of SSH, 34.5-35.5 psu of SSS, 50-100 m of MLD and 0.1-0.2 mg/m^3 of CHL.
- The stepwise GAM procedure was used to select the best predictors. All variables in the GAM model for the catch rate of 5 degree were significant. The most important factor of influence were CHL(17%) and SST(16.9%) for mature groups.
- The catch rate of mature groups has significant influence on PDO and ONI.

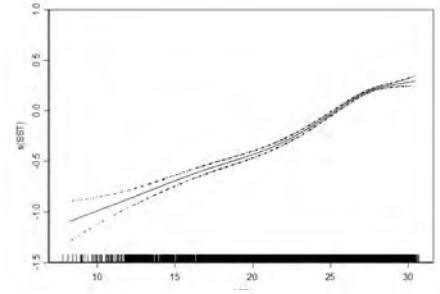
Deviance explained, and AIC of immature group catch rate explain in a GAM with sequentially added variables.

Variable	R.eq.	Deviance explained	AIC
log(CPUE+c)~s(SST)	0.168	16.90%	35417.49
log(CPUE+c)~s(SST)+s(SSH)	0.193	19.40%	35119.85
log(CPUE+c)~s(SST)+s(SSH)+s(SSS)	0.233	23.50%	34616.87
log(CPUE+c)~s(SST)+s(SSH)+s(SSS)+s(MLD)	0.294	29.60%	33785.36
log(CPUE+c)~s(SST)+s(SSH)+s(SSS)+s(MLD)+s(CHL)	0.314	31.70%	33499.74
log(CPUE+c)~s(SST)+s(SSH)+s(SSS)+s(MLD)+s(CHL) +s(PDO)	0.321	32.40%	33319.1
log(CPUE+c)~s(SST)+s(SSH)+s(SSS)+s(MLD)+s(CHL) +s(PDO)+s(NPGO)	0.323	32.70%	33374.15
log(CPUE+c)~s(SST)+s(SSH)+s(SSS)+s(MLD)+s(CHL) +s(PDO)+s(NPGO)+s(ONI)	0.336	34.00%	33196.42

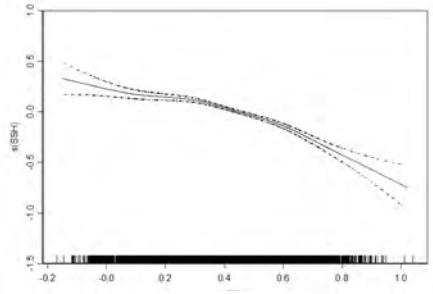
Deviance explained, and AIC of immature group catch rate explain in a GAM with each added variables

Variable	edf	Ref.df	F	P	Deviance explained
s(SST)	8.125	8.797	231.6	<0.001	16.90%
s(SSH)	8.271	8.859	91.95	<0.001	7.53%
s(SSS)	8.785	8.986	77.11	<0.001	6.47%
s(MLD)	8.47	8.921	213	<0.001	15.90%
s(CHL)	8.607	8.954	230.5	<0.001	17.00%
s(PDO)	8.59	8.953	14.54	<0.001	1.31%
s(NPGO)	3.33	4.164	2.843	<0.05	0.14%
s(ONI)	8.604	8.954	18.37	<0.001	1.63%

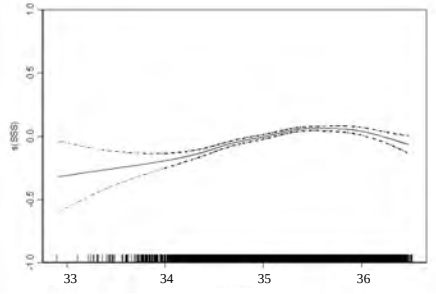




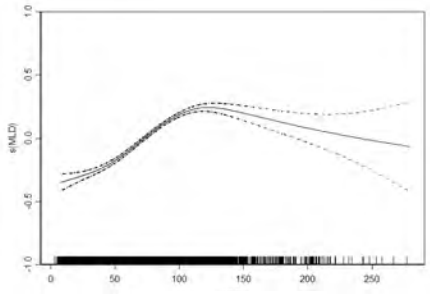
SST



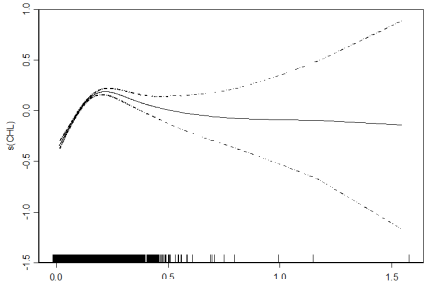
SSH



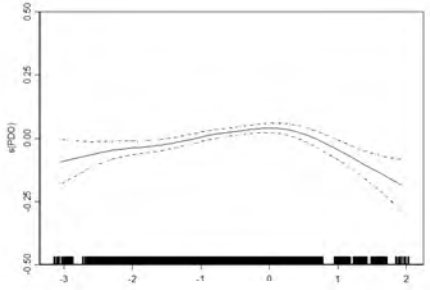
SSS



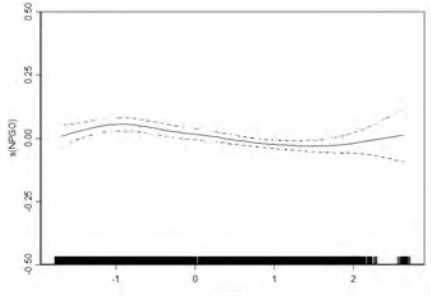
MLD



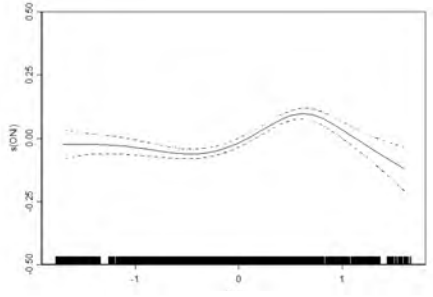
CHL



PDO



NPGO



ONI

Result

The prediction of BET during El Niño and La Niña

Season1 (Jan-Mar)

Season2 (Apr-Jun)

Season3 (Jul-Sep)

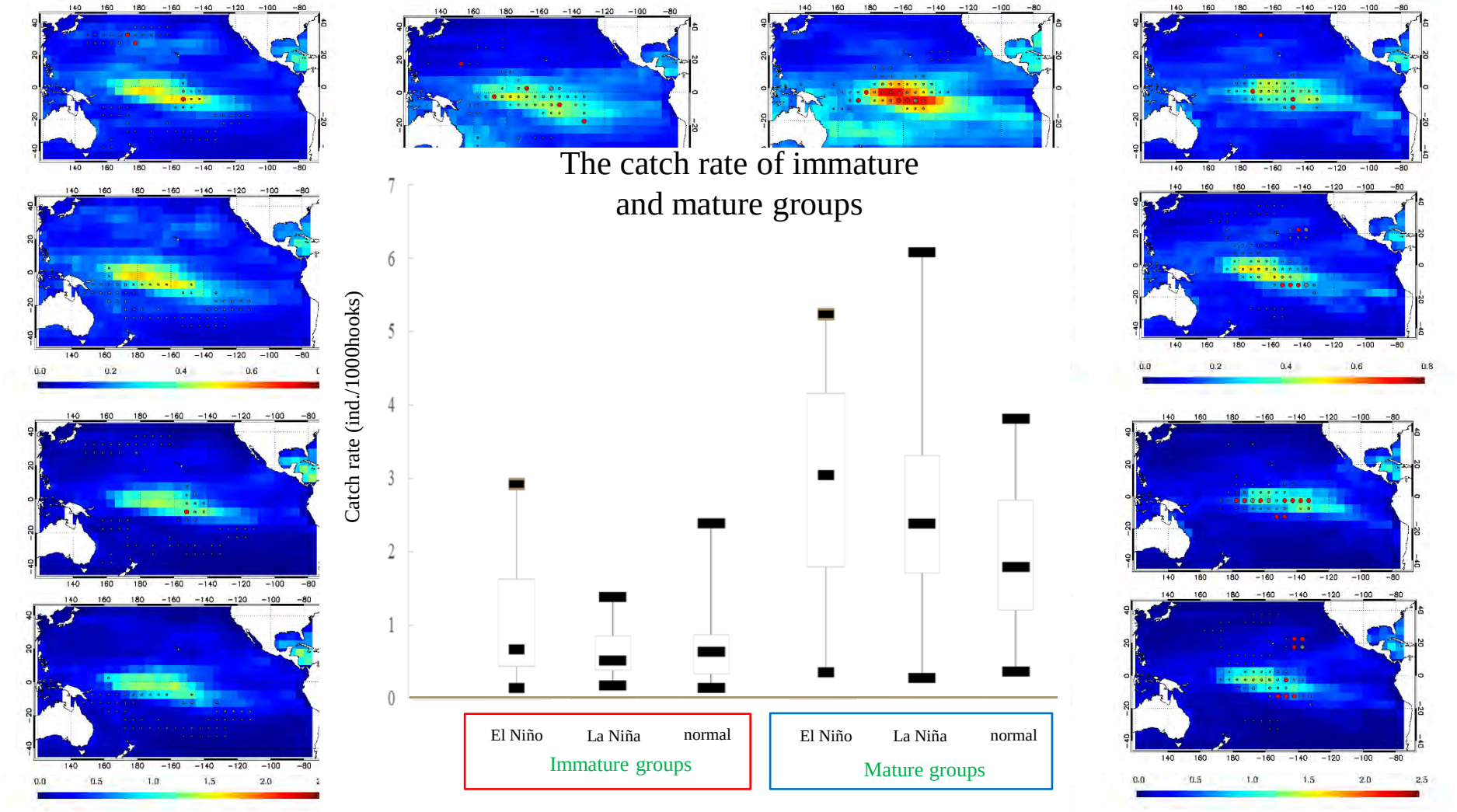
Season4 (Oct-Dec)

El Niño Immature

La Niña Immature

El Niño Mature

La Niña Mature



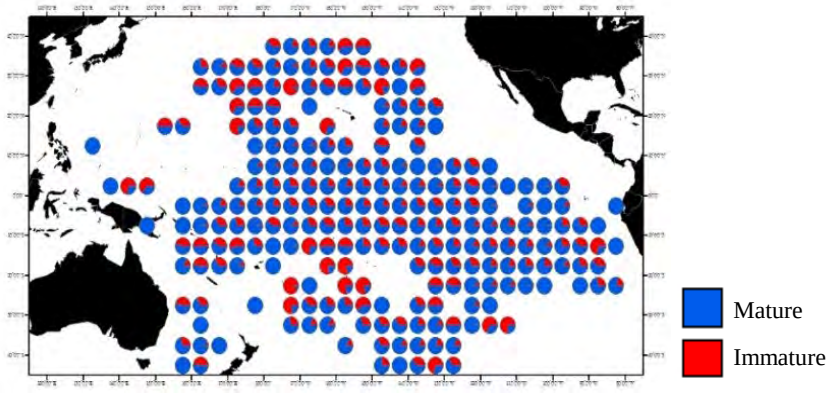
The catch rate of immature and mature groups

Discussion

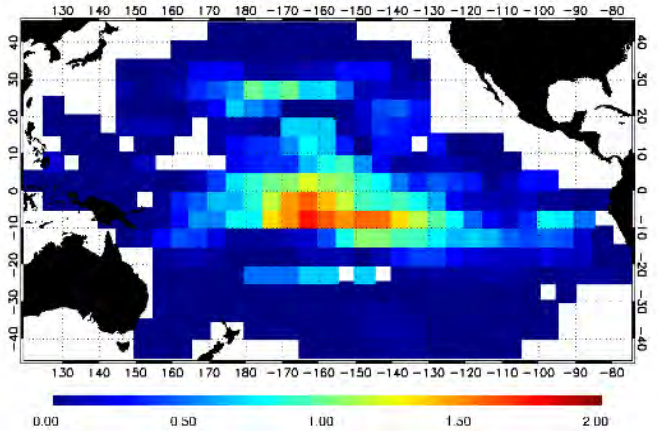
The Spatial distribution of immature and mature groups

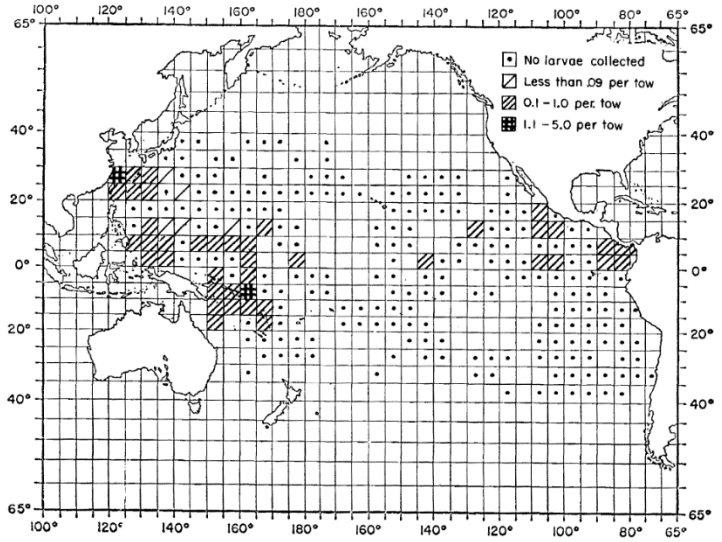
- The immature group accounted for a large proportion in the mid and high latitude , but the high catch rate occurred in the low latitude.

The distribution proportion of immature and mature groups

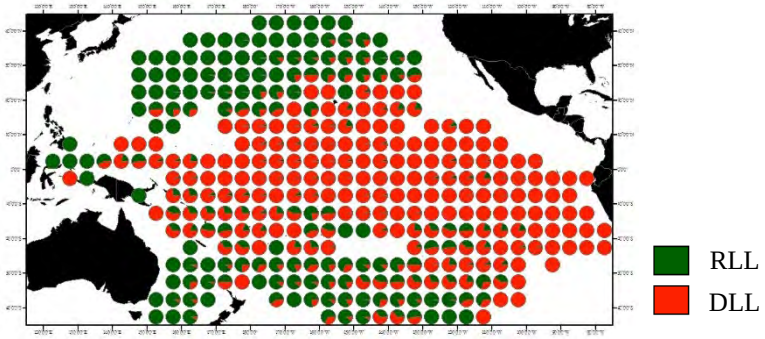


The spatial distribution of the catch rate of immature groups

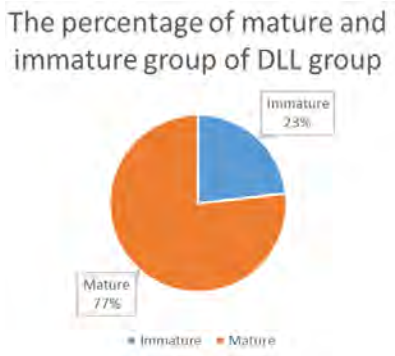


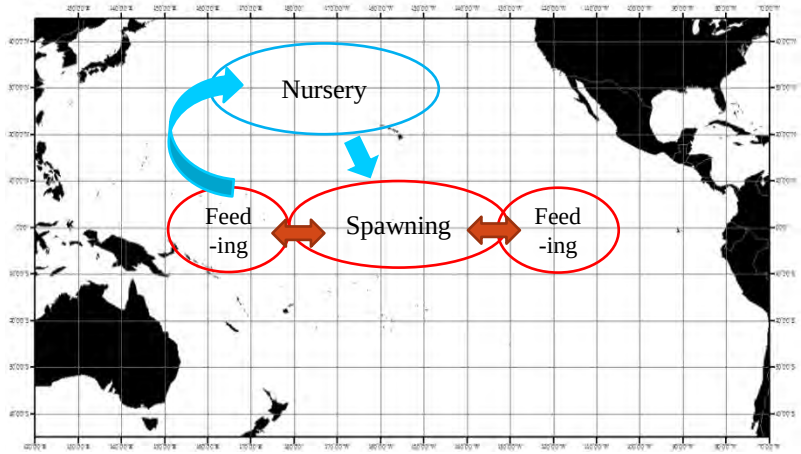


Distribution of bigeye larvae in the Pacific Ocean
(source : Nishikawa et al.,1978)



The proportion of fishery gear in Pacific Ocean





Conclusion

- The spatial distribution of the immature group accounted for a large proportion in the north and south Pacific Ocean , and the mature group more concentrated in the central and east Pacific Ocean.
- A similar pattern of the immature and mature group revealed positive correlations for the catch rates, and the MLD (16.2%) explained the greatest amount of deviance for the immature group, but the greatest amount of deviance was CHL (17%) for the mature group. The climatic indices wss more significantly related to ONI and PDO.
- When El Niño happened , the catch rate of immature and mature groups would increase. In contrast, When La Niña happened , the catch rate of immature and mature groups would decrease.
- Previous studies indicated that it has significant influence on PDO phase change , so the further study purpose is exploring the relationship between PDO and BET variability.

THANK YOU FOR ATTENTION!!