The influences of climatic variability on summertime environmental variations and ecosystem structures around the waters of Taiwan Bank

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PICES

Taiwan Bank

- The Taiwan Bank (TB) is located in the southern Taiwan Strait, the marine environments are affected by China Coastal Currents, South China Sea Warm Current and Kuroshio Branch Current.
- In summer, the surface current is predominantly by wind driven, and the bottom current flows upwards from the continental slope with four major upwelling regions.

Isobaths of the Taiwan Strait

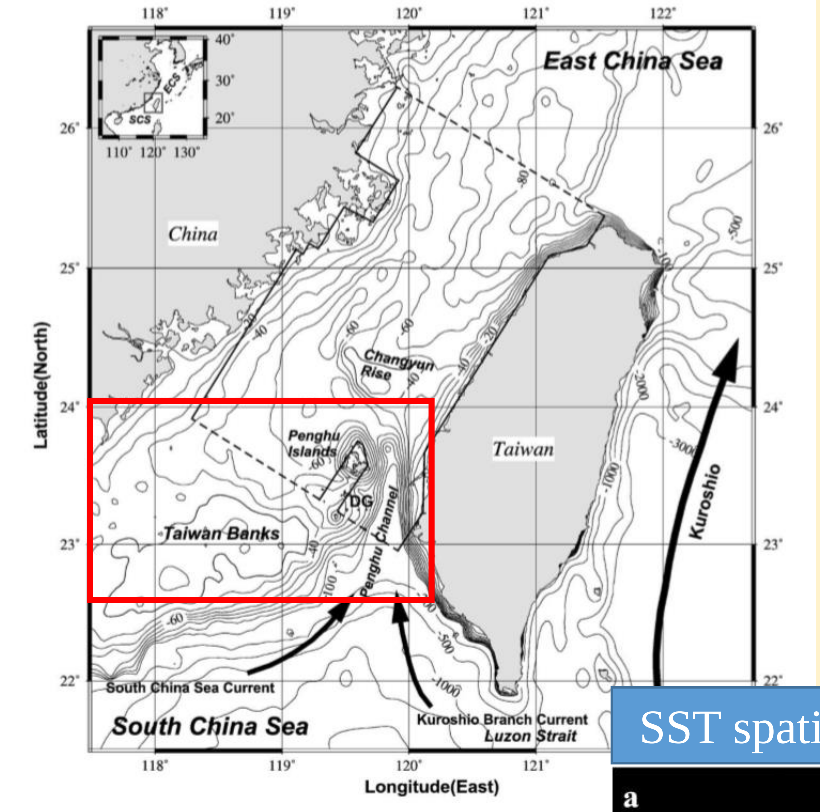
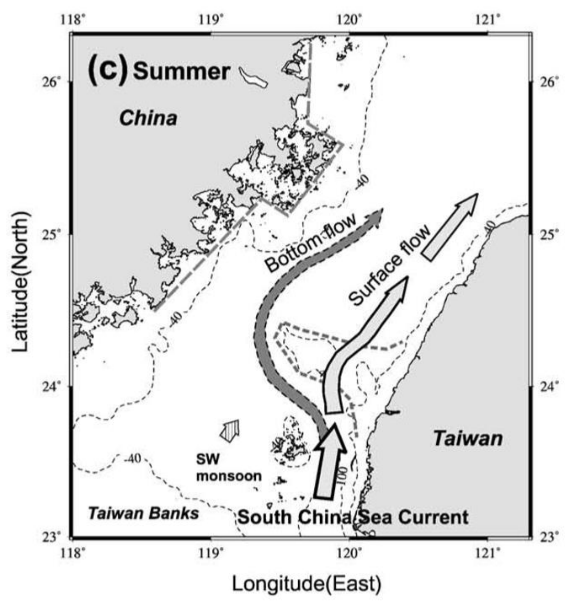
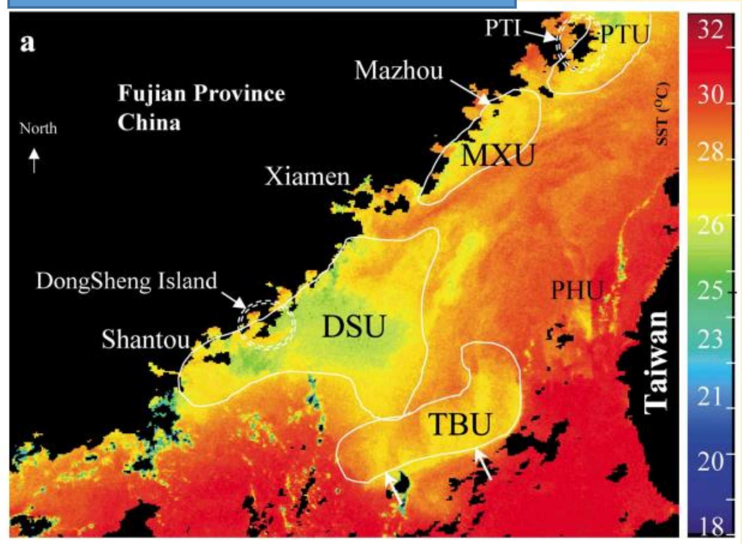


Fig. 1. Isobaths (in meters) in and around the Taiwan Strait. The small insert at the upper-left corner shows to the East China Sea (ECS) and the South China Sea (SCS). The dashed and solid lines indicate open-oc domain, respectively.

Jan 2002



SST spatial distribution



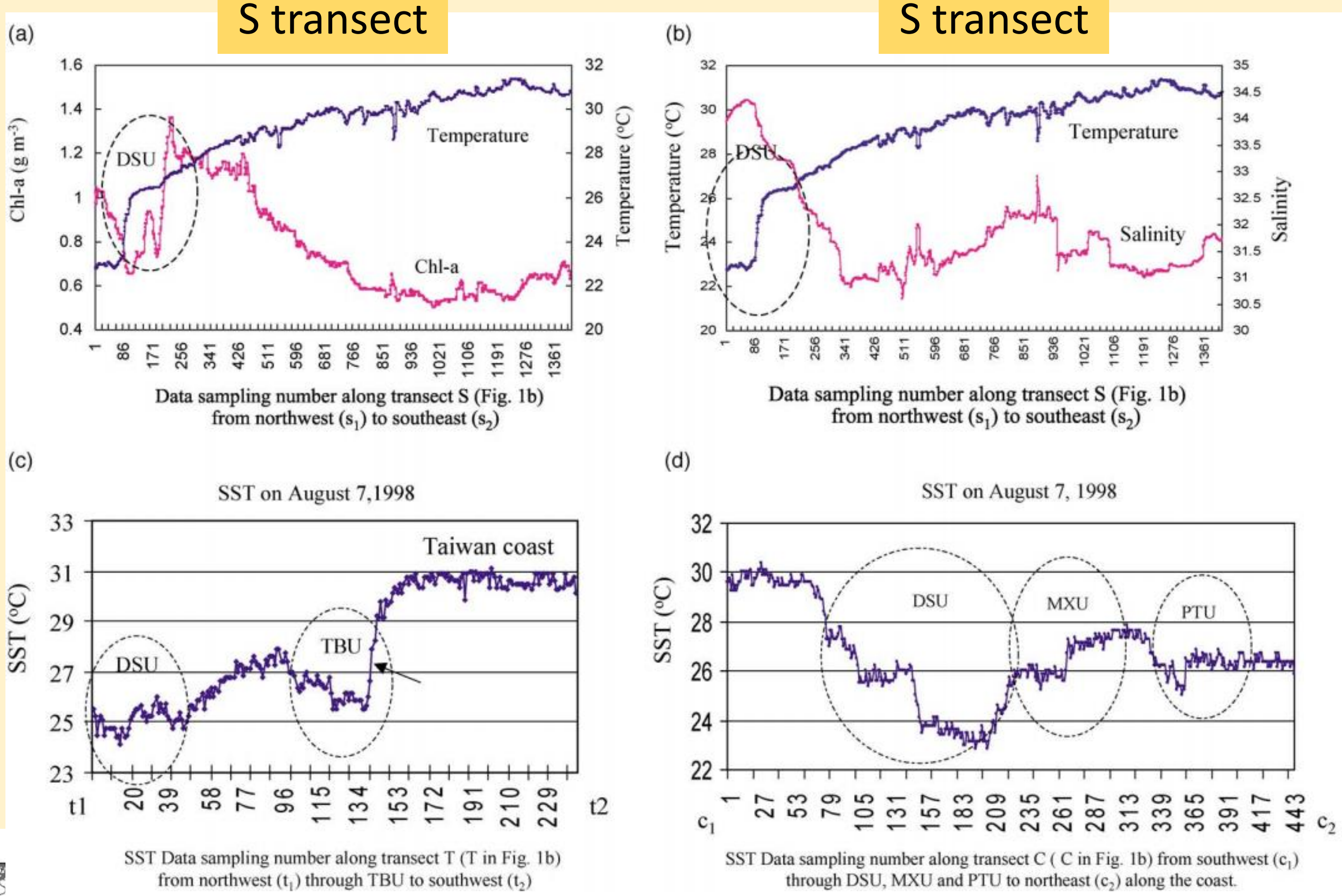
Tang, et al 2002

Upwelling character

- The upwelling area usually has low sea surface temperature (SST), high CHL-aorophyll-a (CHL-a) and high primary production (PP).
- There are lots of fishing ground at the upwelling area including TB upwelling.

S transect

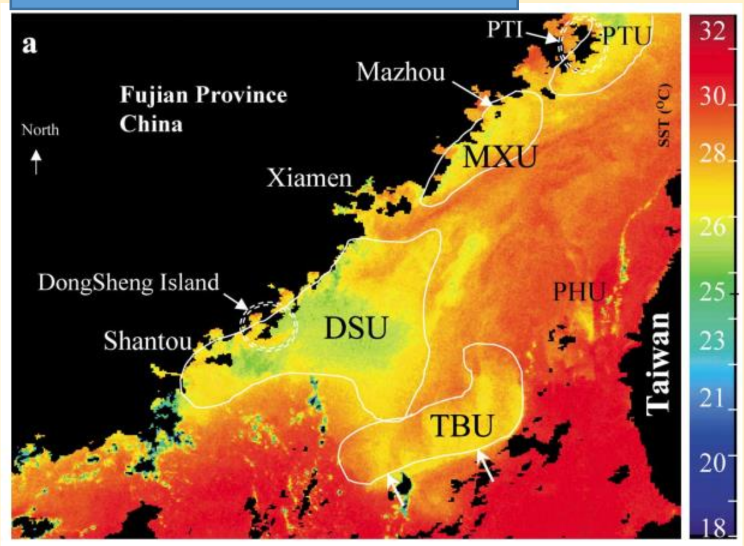
S transect



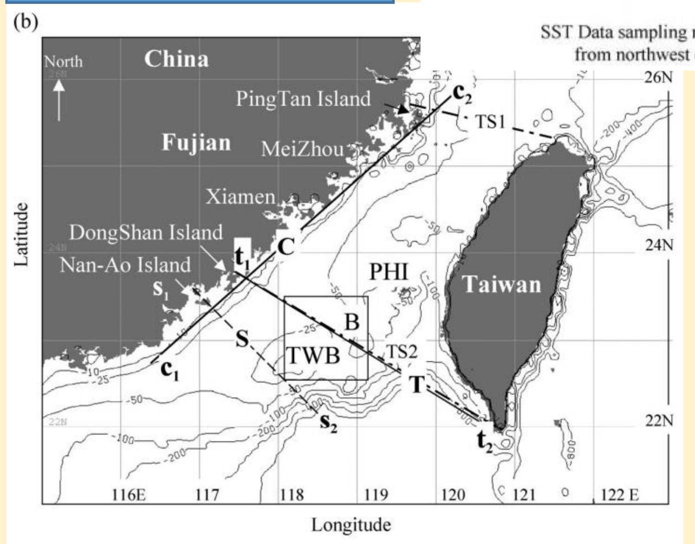
T transcet

C transcet

SST spatial distribution



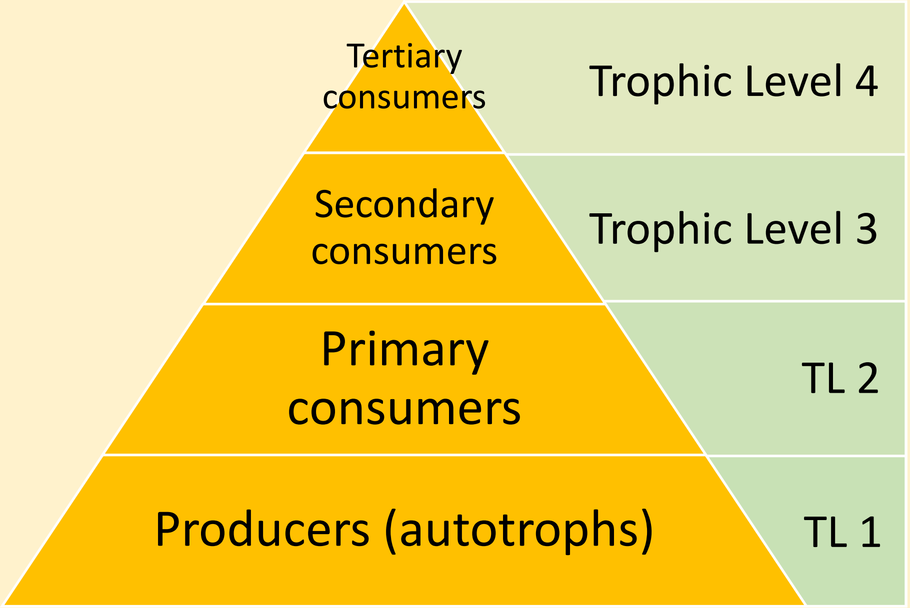
Taiwan straits



In summer, the temperature difference between the upwelling area and the general area is 1-3°C (Tang et al, 2002)

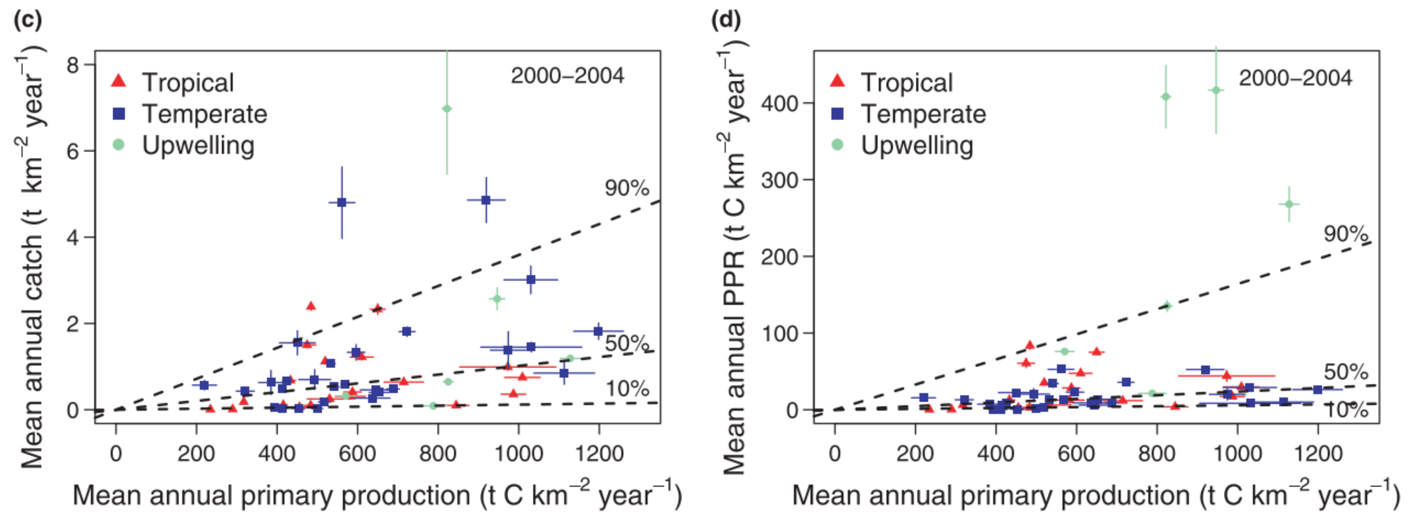
Cited from Tang, et al. 2002 Jun-Sep, 1998

Primary production & PPR



- Primary production (PP), produced by autotrophs organisms, supporting the most initial energy in the energy flow of the entire food web.
- Primary production required (PPR), convert the catch to the same value of primary productivity which is a comparable energy unit.

Previous study used PPR in large scale area (global) to analysis the character and variation by each ecosystems (LME).



Cited from Chassot, et al. 2010

Is it able to used the same concept on local small scale area?
How to define the each area in it and aggregate the fishery data?

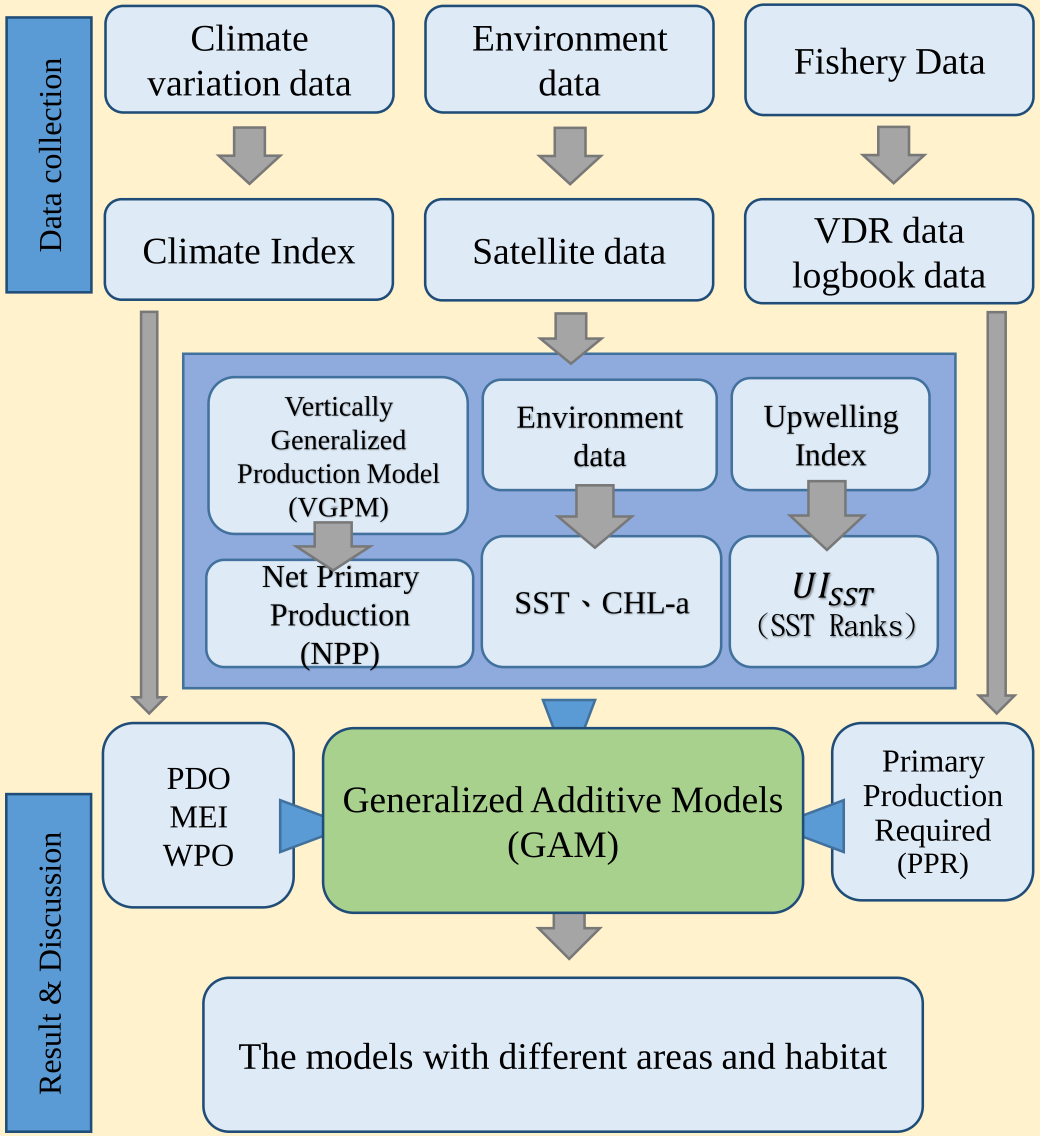
Purpose of Study

- Create models to express the PPR in different regions and habitat in local small scale area.

Hypothesis

1. The climate change will lead the environment variation effect the PPR of TB area.
2. Different regions in TB area has different environment characters, upwelling area is directly affected by upwelling straight.
3. The PPR of front area has most value and highly representative in TB area.

Flow chart



Data collection

- Environment data：Sea surface temperature (SST), Chlorophyll a (CHL-a) are daily data. Monthly Net Primary Production (NPP) data was calculated by Vertically Generalized Production Model (VGPM).
- Climate Index：Pacific Decadal Oscillation (PDO), Multivariate ENSO Index (MEI), Western Pacific Oscillation (WPO)
- Fishery data：VDR data and logbook data from 2011-2015.

DATA	Source	Resolution	Time
SST	NOAA AVHRR	0.01°	2002-2015
CHL-a	Aqua MODIS	0.01°	2002-2015
NPP	Ocean Productivity	9km	2002-2015
Fishery data	VDR and logbook	0.1°	2011-2015

Fishery data

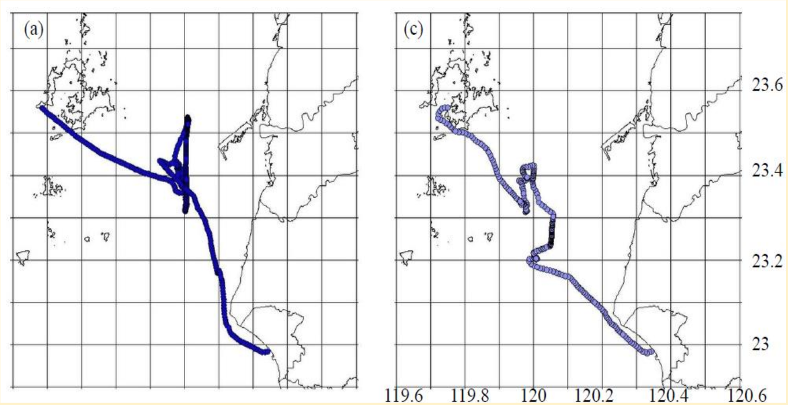
VDR DATA

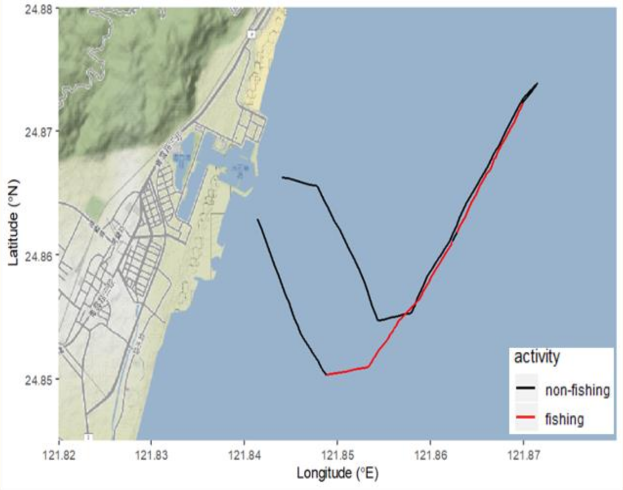
- Voyage Data Recorder, VDR, through it we can get the vessel number, work hour, work position, and speed.

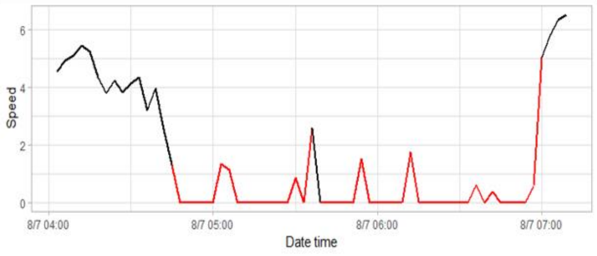
LOGBOOK

- Collect by Port inspector, including vessel number, catch species, catch weights, fishing area, fishing gears.

fishing boat dynamic







沿近海作業漁船漁獲情形紀錄表

年　月　日

船名		船長姓名		漁船編號	CT　—
出港	年　月　日　港	進港	年　月　日　港		
作業海域	東經：　°　′；北緯：　°　′	作業天數	天		

漁業種類（請依漁船作業種類勾選下列選項，未有適當選項，請填其它作業種類）

釣具類：☐鮪/鯖/雜魚/白帶魚/紅目鰱/鬼頭刀 延繩釣 ☐鯖/鎖管 立繩釣 ☐一支釣 ☐曳繩釣 ☐手釣 拖曳/定點 ☐其它：

作業紀錄：作業水深＿＿＿米；投放筐數＿＿＿筐、每筐鉤數＿＿＿鉤、計＿＿＿鉤

網具類：☐單船/赤尾青/櫻花蝦 拖網 ☐雙船/快速/底 拖網(配對漁船：CT　－　) ☐蝦桁曳網 ☐巾著網（配對漁船：CT　－　）☐張網/鰻 ☐流袋網/鰻 ☐叉手網/鰻/赤尾青/丁香 ☐大目袖網/鰻(配對漁船：CT　－　&CT　－　) ☐旋/烏魚流/土魠流/大目流/表層流/中層流/底流/底 刺網 ☐其它：

作業紀錄：作業水深＿＿＿米、下網次數＿＿＿次

其它作業種類：☐鳳螺/赤鯮/螃蟹 籠具 ☐潛水採集 ☐徒手採集蚵/蛤 ☐鏢旗魚 ☐捕魚苗/鰻 ☐強制陷阱/鰻 ☐定置網 ☐ 娛樂漁船 ☐其它：

本次投放漁具數：＿＿＿個

漁　獲　情　形

漁獲魚種	重量（公斤）	平均體長(公分)	單價(元)	總價(元)
本航次總計				

漁　獲　保　存　方　式　與　保　存　溫　度（℃）

☐冷凍機凍結(-20--10) ☐碎冰冷藏(0-5) ☐水冰(-5-5) ☐其它：＿＿＿

船長或漁業人：＿＿＿　縣市政府或區漁會：＿＿＿

填表人：＿＿＿　資料來源方式：＿＿＿

本航次卸魚聲明書流水號：＿＿＿　☐未填寫　☐無須填寫

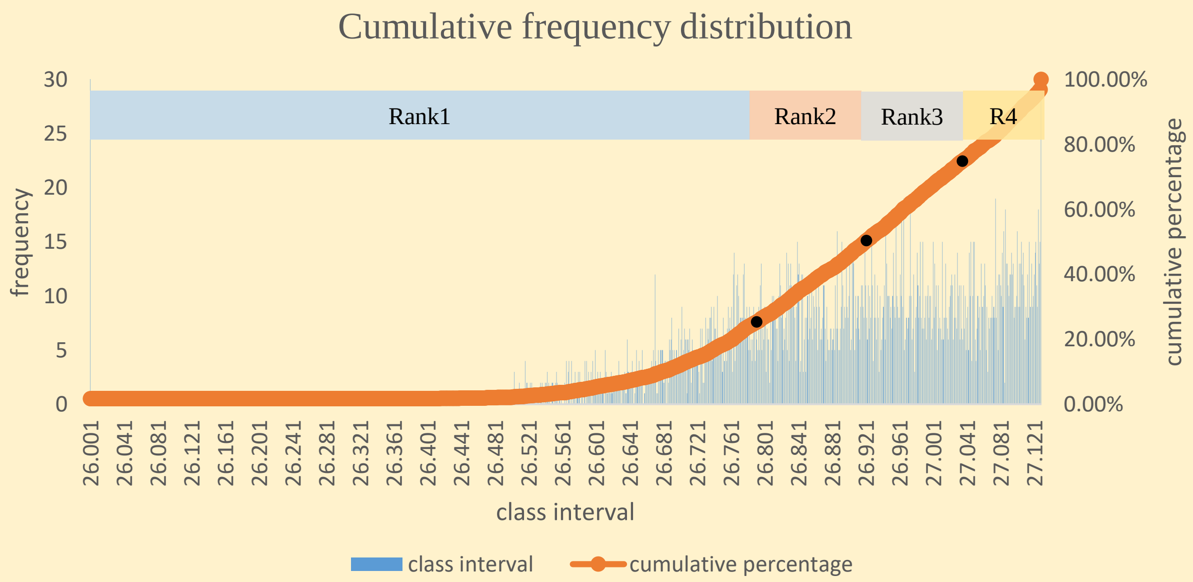
Vessel name | date | Species | Catch weights | gears

船名	年	月	日	spe	尾數	重量 kg	水深 m	漁業別
宏盈六號	2015	4	1	紅甘	2	3	3-18	刺網
宏盈六號	2015	4	1	煙仔	3	1.5	3-18	刺網
宏盈六號	2015	4	1	臭肚	2	1	3-18	刺網
宏盈六號	2015	4	1	黑毛	1	1	3-18	刺網
宏盈六號	2015	4	1	下雜魚	5	2.5	3-18	刺網
宏盈六號	2015	4	2	紅甘	1	1	3-20	刺網
宏盈六號	2015	4	2	煙仔	2	2	3-20	刺網
宏盈六號	2015	4	2	黃雞仔	5	2	3-20	刺網
宏盈六號	2015	4	2	黑豬哥	2	1	3-20	刺網
宏盈六號	2015	4	14	煙仔	2	2	3-17	刺網
宏盈六號	2015	4	14	石老	1	0.5	3-17	刺網
宏盈六號	2015	4	14	黃雞仔	3	1	3-17	刺網
宏盈六號	2015	4	14	軟絲	1	1	3-17	刺網
宏盈六號	2015	4	14	下雜魚	6	3	3-17	刺網
宏盈六號	2015	4	18	白毛	6	2	3-15	刺網
宏盈六號	2015	4	18	下雜魚	2	0.8	3-15	刺網
宏盈六號	2015	4	25	紅甘	2	2	3-15	刺網
宏盈六號	2015	4	25	煙仔	2	1.5	3-15	刺網
宏盈六號	2015	4	25	黑豬哥	2	2	3-15	刺網
宏盈六號	2015	4	25	下雜魚	5	3	3-15	刺網
宏盈六號	2015	4	27	石狗公	2	0.8	3-15	刺網
宏盈六號	2015	4	27	變身苦花	1	0.5	3-15	刺網
宏盈六號	2015	4	27	軟絲	2	1	3-15	刺網
宏盈六號	2015	4	27	下雜魚	4	1.5	3-15	刺網

Upwelling Index

UI_{SST}

- SST based upwelling index, UI_{SST}
- $UI_{SST} = SST_{(lon,lat)} - SST_{mean}$
- Use the cumulative frequency of the UI_{SST} to define the upwelling Ranks.



Primary Production Required

- Convert fishing catches to same value of primary productivity.

$$PPR = \sum_{i=1}^{n} \left(\frac{C_i}{9}\right) \times \left(\frac{1}{TE}\right)^{TL_i - 1}$$

C_i : catch weight (ton)
TE : Transfer efficiency
TL_i : Trophic level

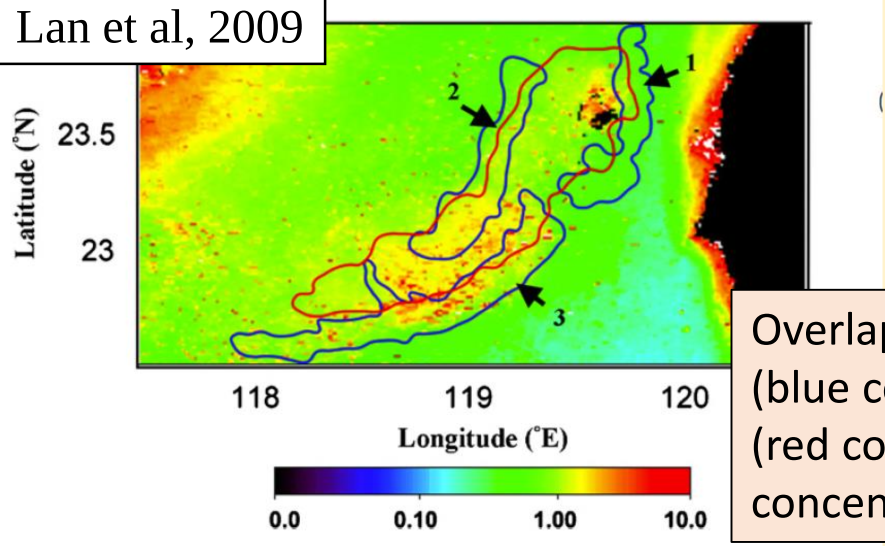
species	TL	weight %
Scombridae	3.75	44.70%
Carangidae	3.7	14.20%
Auxis rochei rochei	4.27	4.54%
Acetes intermedius	2.26	2.98%
Metanephrops thomsoni	2	1.32%
Trichiurus spp.	4.42	1.12%
Sepia esculenta	3.39	1.12%
Pennahia argentata	3.72	0.85%
Trachurus japonicus	3.4	0.79%
Loliginidae	4	0.74%

Dividing the PPR in Pelagic and Benthic with different character and habitat with species.

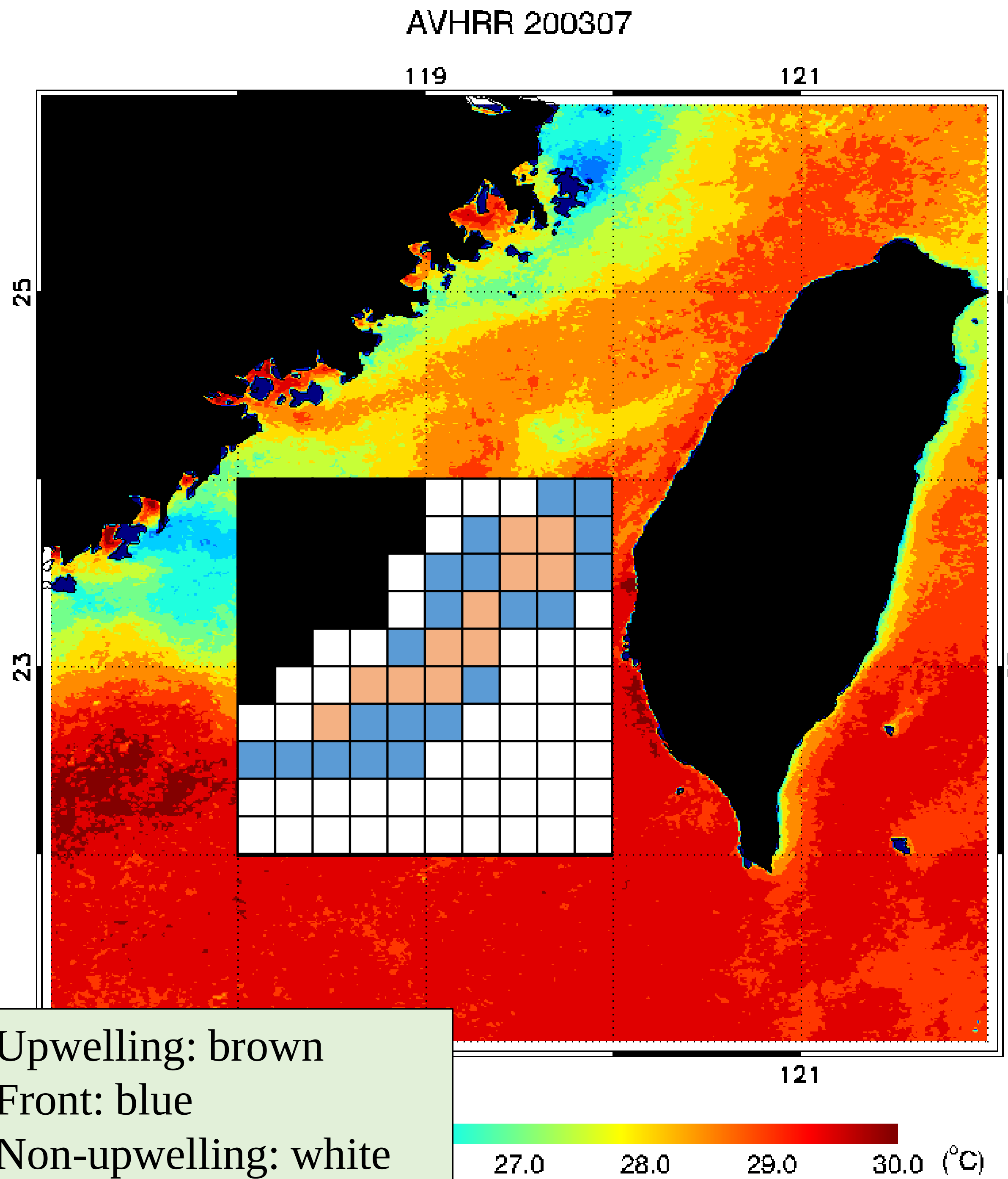
Define the areas

- Grid the study area (118-120E, 22-24N) at 0.2 degrees resolution monthly data.
- Define TB area and exclude Dong Sheng areas.
- Divided into Upwelling area, Front area, and Non-upwelling area according SST gradient and Chl-a concentration.

Lan et al, 2009



Overlap the SST gradient (blue contour), 26°C SST (red contour), and chl-a concentration (base).



Upwelling: brown
Front: blue
Non-upwelling: white

GAM (Generalized Additive Models)

- GAM model can represent highly nonlinear and nonmonotonic relationships between responses and sets of explanatory variables.
- To create the PPR model, the environmental factors (SST, NPP, Chl-a), upwelling index (SST ranks) and climate index (MEI, WPO, PDO) were used as the predictor variables. Formula as below,

$$\log(PPR + c) = a_0 + s(NPP) + s(CHL) + s(SST) + s(sst\ rank) + s(MEI) + s(\mathrm{WPO}) + s(PDO)$$

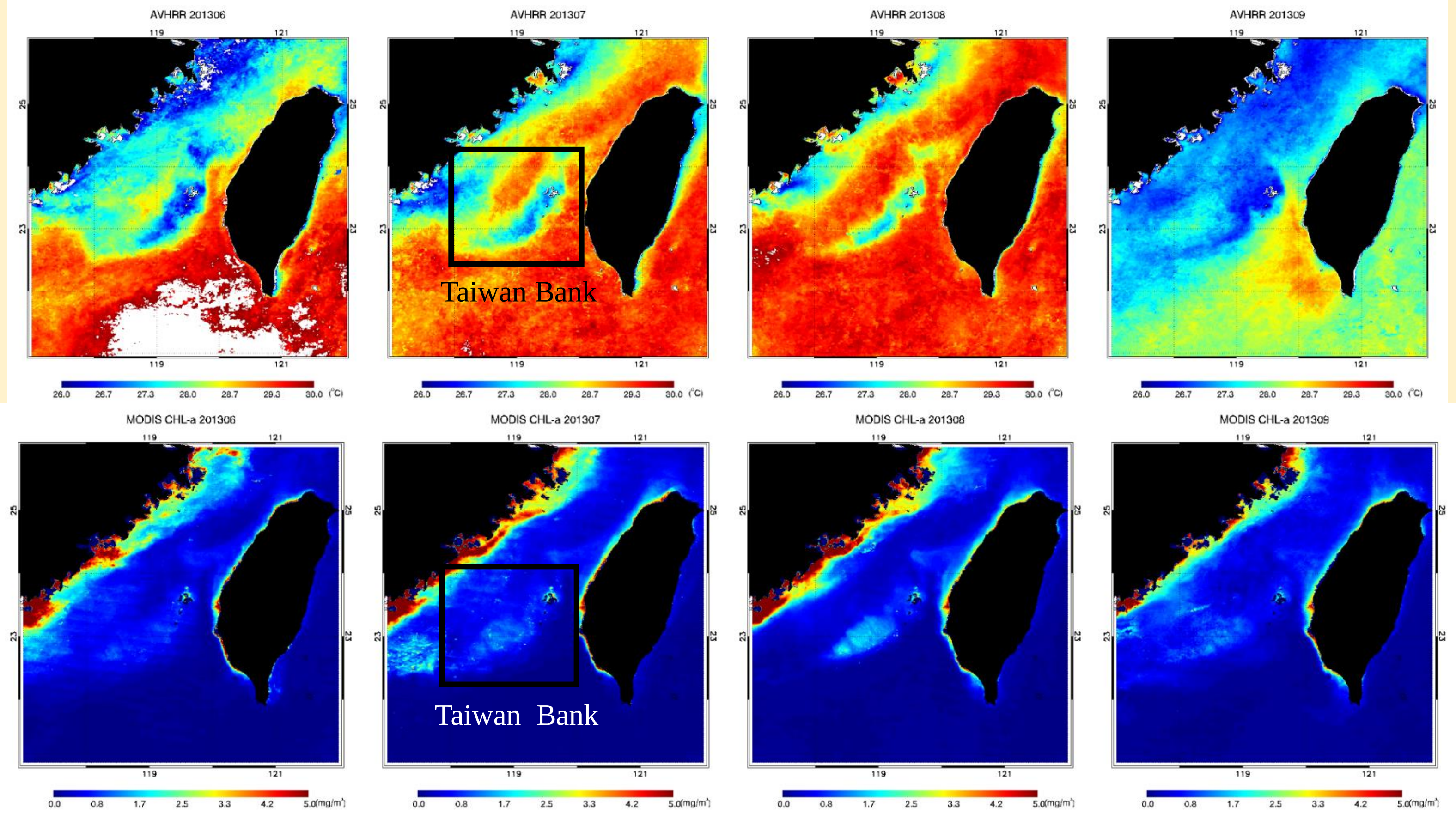
- The model with the optimal conformation was selected using a stepwise procedure that was based on the lowest value of Akaike's information criterion (AIC)

$AIC = -2\ln(L) + 2P$ L：Likelihood funtion P：number of factors

SST & CHL-a

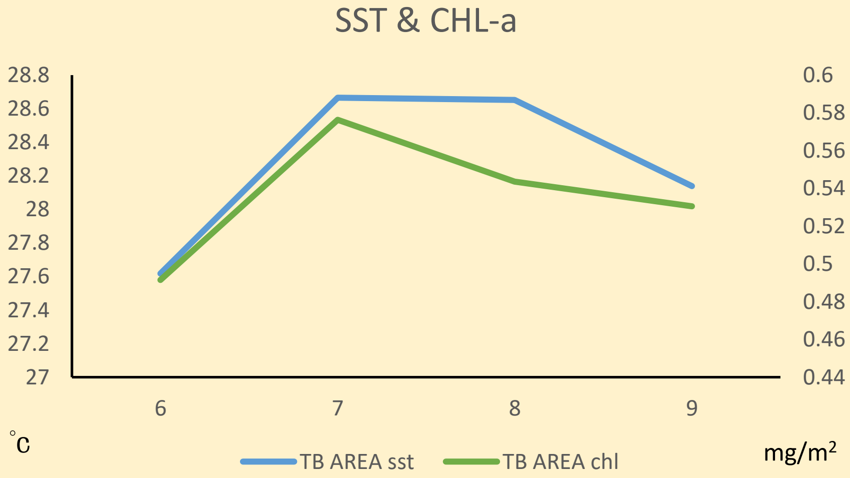
SST & CHL-a spatial distribution of Summertime (Jun-Sep)

2002-2015



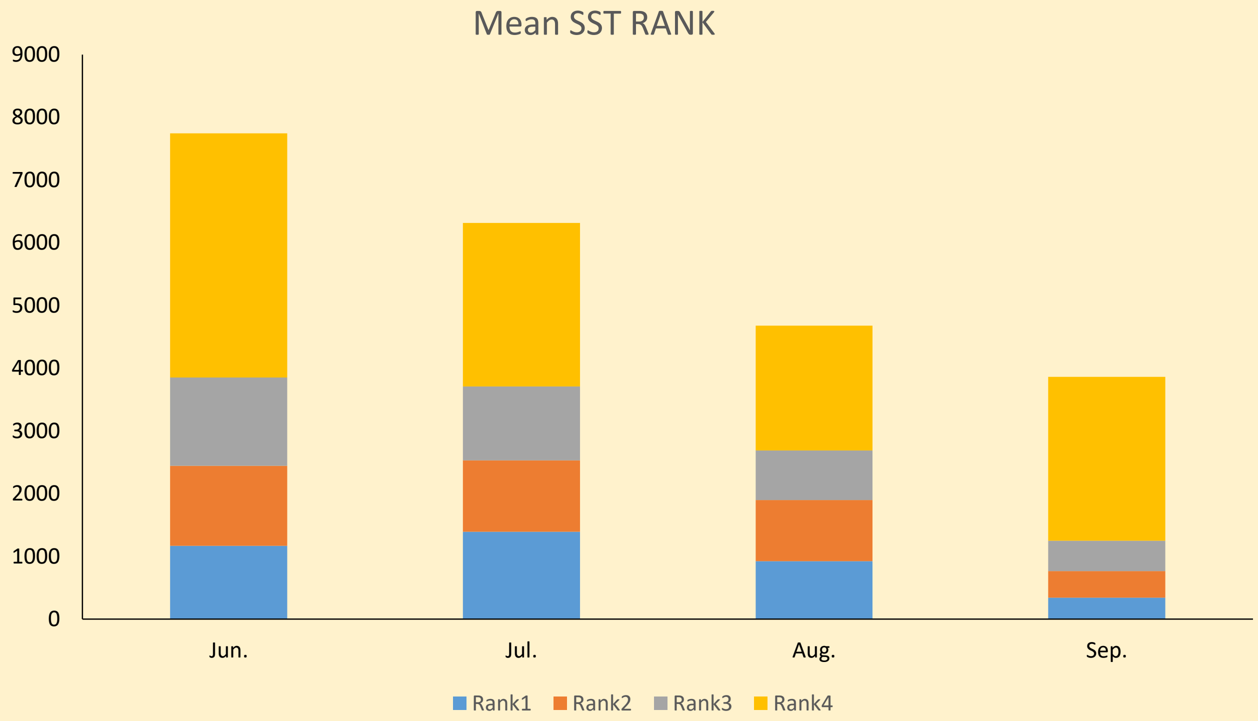
2003

- The average SST is 28.27°c, lowest in June highest in August.
- The averages CHL-a is 0.53mg/m², lowest in June.

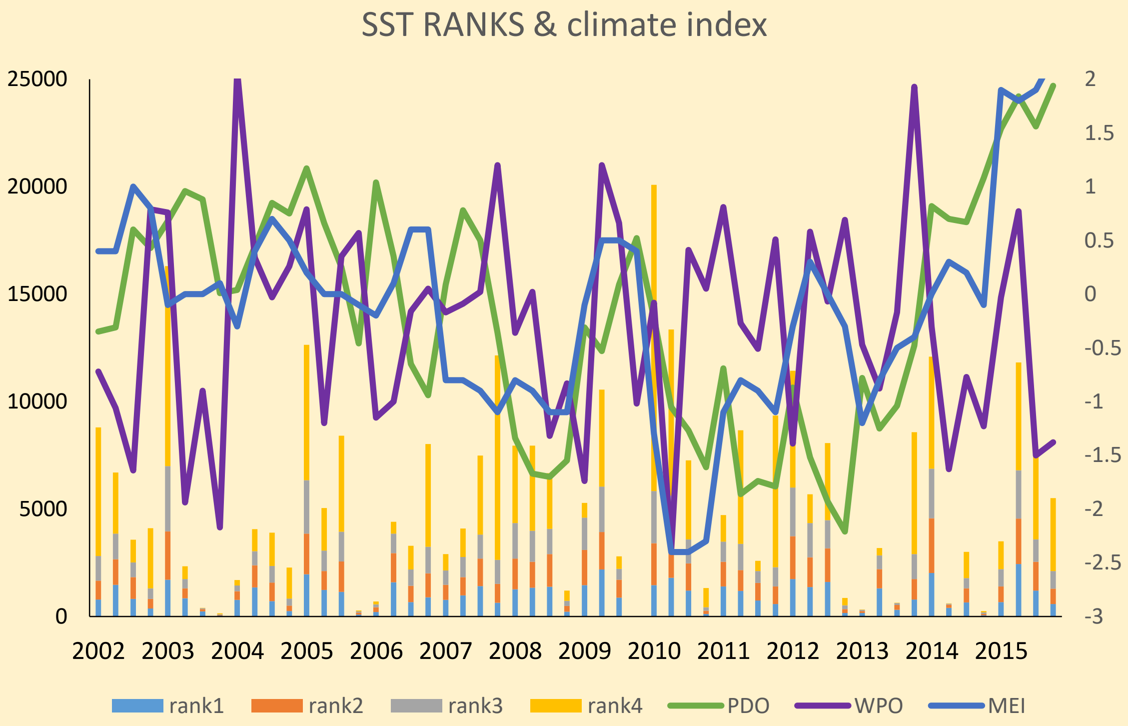


UI_{SST} RANK

2002-2015



Time series diagram of UI_{SST} RANK and climate index

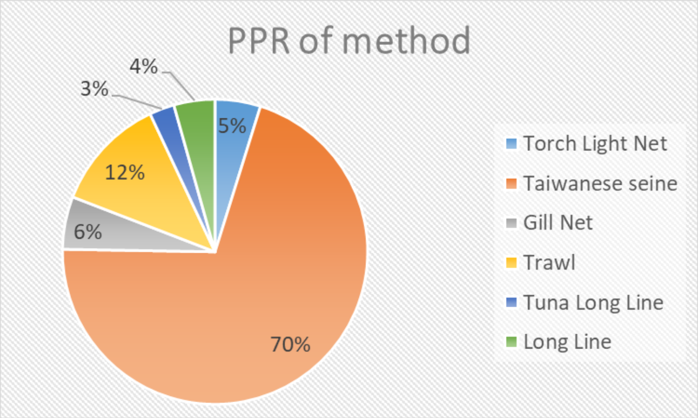


Upwelling is strongest in June and weakest in August.

Upwelling has variation with WPO and MEI index

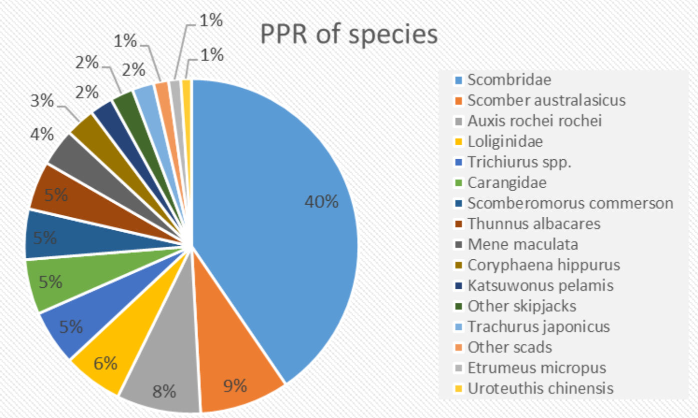
Result

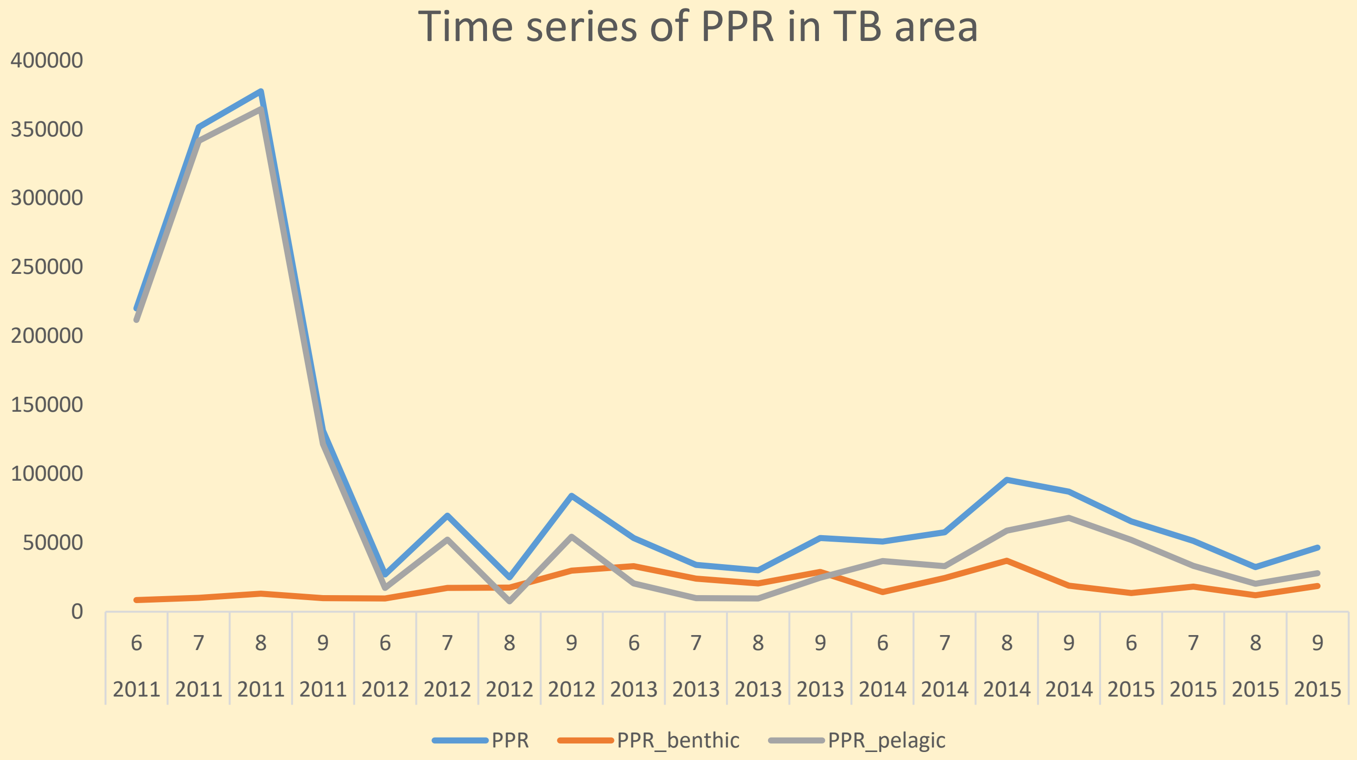
Fishery data - Method Species distribution



Pelagic	Benthic
Scombridae	*Loliginidae*
Scomber australasicus	*Trichiurus* spp.
Auxis rochei rochei	*Mene maculata*
Etc…	*Etc…*

The pelagic PPR has the similar pattern with PPR.





Dividing the PPR with different methods and species.

Result

NPP & PPR

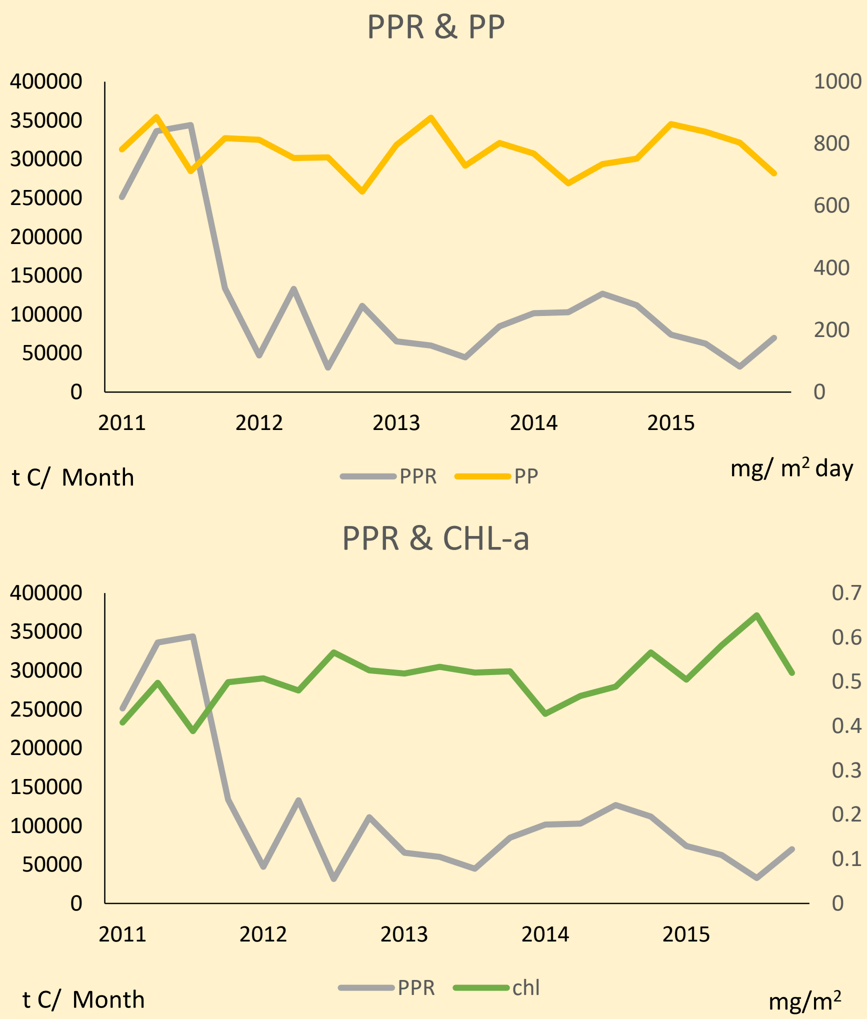
Correlations
Marked correlations are significant at p < .05000 N=20

	SST	Chl	NPP	Total Rank	PPR	MEI	WPO	PDO
SST	1.00	0.17	-0.33	-0.75	0.09	-0.06	-0.29	-0.11
Chl	0.17	1.00	0.08	-0.06	-0.49	0.38	-0.36	0.30
NPP	-0.33	0.08	1.00	0.21	0.21	-0.07	0.14	0.08
Total Rank	-0.75	-0.06	0.21	1.00	-0.08	0.23	0.32	0.12
PPR	0.09	-0.49	0.21	-0.08	1.00	-0.49	0.19	-0.49
MEI	-0.06	0.38	-0.07	0.23	-0.49	1.00	-0.24	0.79
WPO	-0.29	-0.36	0.14	0.32	0.19	-0.24	1.00	-0.35
PDO	-0.11	0.30	0.08	0.12	-0.49	0.79	-0.35	1.00

The PPR has the negative correlation with Chl-a, MEI, PDO.

Dividing the PPR with different areas and species to further analysis.

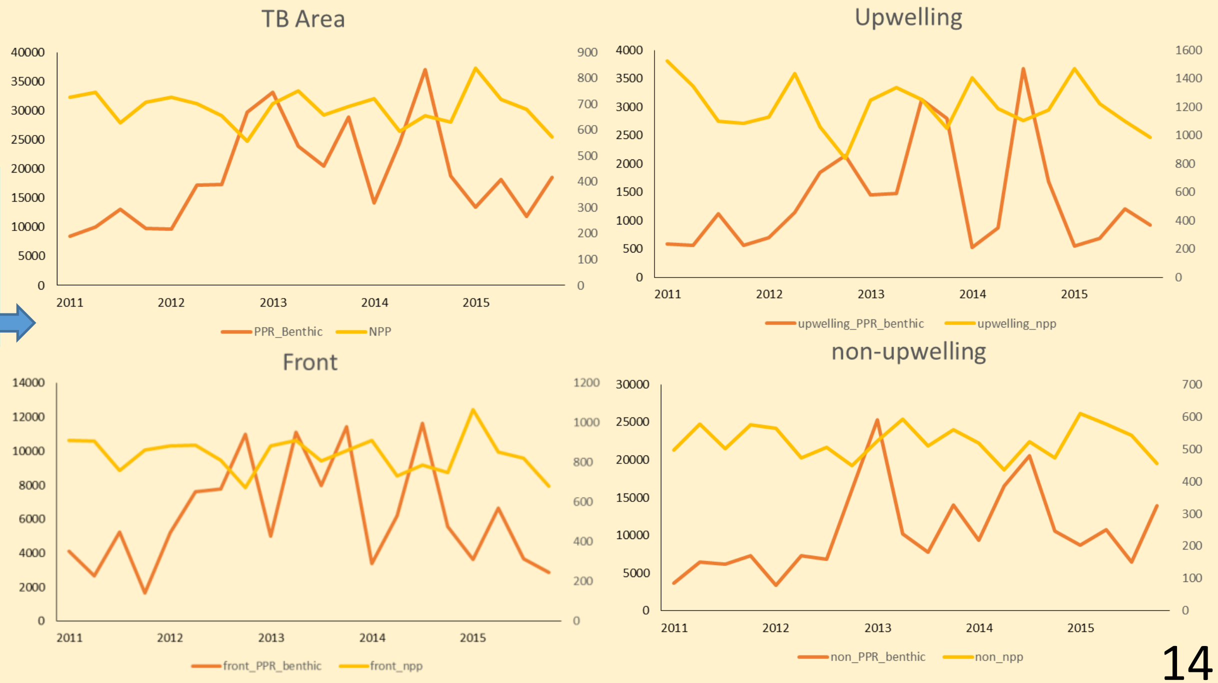
Time series of PPR from 2011-2015



Benthic PPR and PP have the opposite pattern in 3 area.

There is no obvious correlation between PPR and PP in whole area.

Time series of Benthic PPR & NPP



GAM

Deviance explained

*Red means p value less the 0.05

		s(SST)	s(CHL)	s(NPP)	s(total_rank)	s(WPO)	s(MEI)	s(PDO)
Upwelling	PPR	0.79%	4.13%	7.83%	1.49%	0.57%	3.37%	2.23%
	PPR_Benthic	0.43%	7.06%	20.60%	0.48%	2.66%	2.83%	0.75%
	PPR_Pelagic	1.56%	2.74%	2.92%	1.73%	3.91%	3.51%	8.11%
Front	PPR	4.93%	14.90%	25%	6.41%	0.12%	0.90%	1.14%
	PPR_Benthic	2.84%	18%	25.70%	3.47%	0.84%	2.06%	0.17%
	PPR_Pelagic	4.58%	10.90%	18.90%	5.11%	0.08%	0.65%	4.87%
Non-Upwelling	PPR	2.93%	0.08%	0.04%	0.02%	1.49%	3.39%	4.02%
	PPR_Benthic	0.30%	11.40%	8.05%	0.66%	0.00%	0.27%	0.12%
	PPR_Pelagic	4.04%	2.61%	2.58%	0.13%	1.83%	5.26%	6.04%

- Benthic species are affected by NPP and CHL, which is larger than the Pelagic species.
- Overall, Pelagic PPR seems more related with total PPR.

SERVERAL MODELS

		Optimal models	R-sq.(adj)	Deviance explained
Upwelling	PPR	s(NPP)+s(MEI)+s(PDO))	0.174	23.10%
	PPR_Benthic	s(NPP)+s(CHL))	0.191	22.80%
	PPR_Pelagic	s(WPO)+s(MEI)+s(NPP)+s(total_rank))	0.109	15.50%
Front	PPR	s(NPP)+s(CHL)+s(total_rank)+s(SST)+s(MEI))	0.37	39.60%
	PPR_Benthic	s(NPP)+s(CHL)+s(total_rank)+s(SST)+s(MEI))	0.379	40.60%
	PPR_Pelagic	s(NPP)+s(CHL)+s(total_rank)+s(PDO)+s(SST))	0.315	34.30%
Non-Upwelling	PPR	s(PDO)+s(MEI)+s(SST))	0.0648	8.27%
	PPR_Benthic	s(CHL)+s(NPP)+s(total_rank))	0.106	11.40%
	PPR_Pelagic	s(PDO)+s(MEI)+s(SST)+s(NPP)+s(CHL))	0.106	12.70%

- Front area are effect by NPP, CHL, SST Rank and SST, the explained are most higher.
- Non-upwelling area is more affected by climate index than other area.

Discussion- the front area

cited from Chang, 2004

- The model of Front area has most highest deviance explained.
- SST front have a influence on primary productivity and vertical mixing of nutrients.
- The fishing distribution of squids (Chang, 2004) has highly correlated. There are several study show the same result. (Scales et al, 2014)

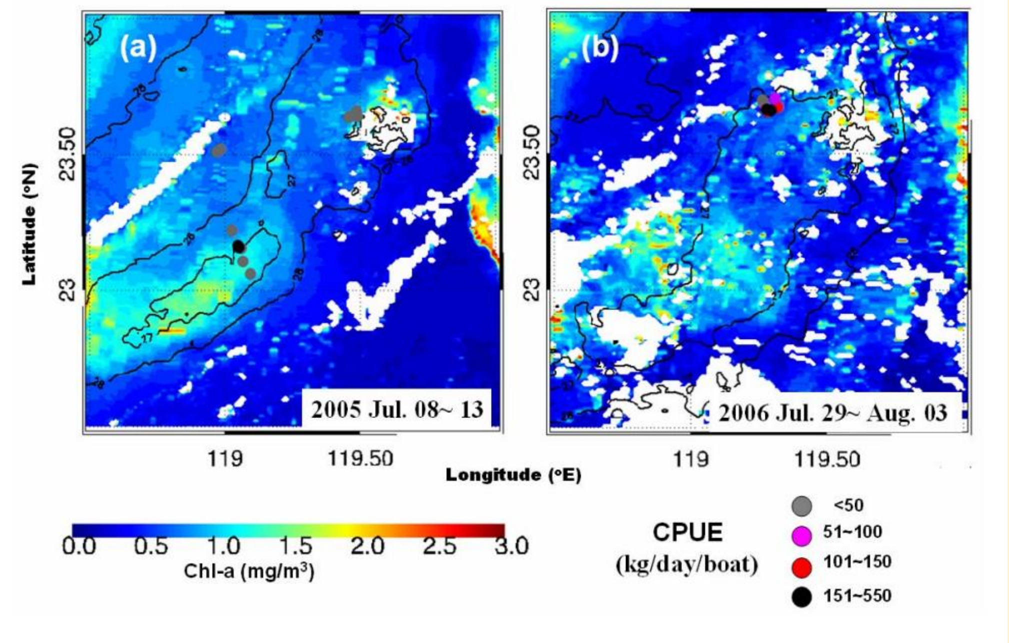
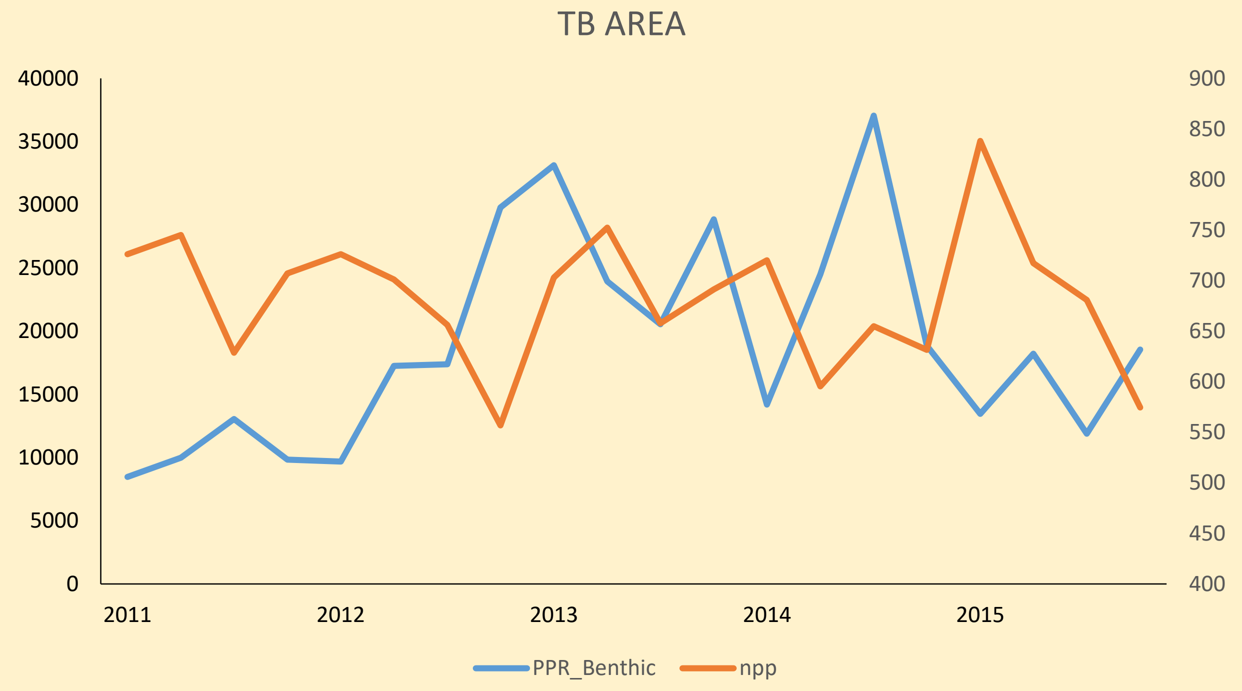


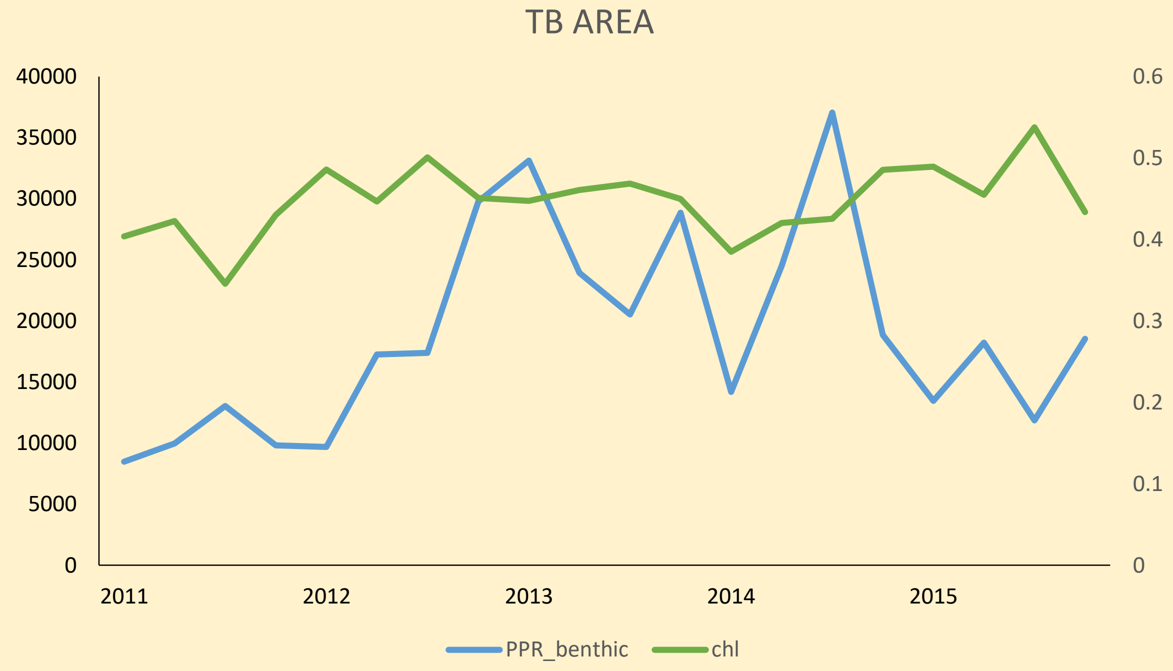
Figure 20. High CPUE locations superimposed on weekly Chl-a composite maps in July of 2005(b) and 2006(c).

- PPR of front area has effected by upwelling index, which means the straight of upwelling has the correction with PPR variation in front area.
- And through the oceanography, fish will gathering in front area.

Discussion

Benthos and Pelagic





- Benthic species are more affected by NPP and CHL than by climate index, which means the variation of Benthic species are stay in the area with constant PP and CHL.
- Pelagic PPR is related to climate index show the climate change will lead the environment factor change, then lead pelagic species variation.

Summary

- In the summer of Taiwan Bank upwelling, which strongest in June and weakest in August.
- The variation of Pelagic PPR has similar pattern with Total PPR, Benthic PPR has opposite pattern with NPP and Chl-a.
- Model of Front PPR has high Deviance explained and the straight of TB upwelling lead the PPR of Front area.

Future work

- Join more factors to enhance the deviance explained and used some fishery data to predict the pattern of models for further analysis.
- To compare each gird data to know the energy conversion efficiency be different in 3 area and the influence of it.

Thanks for listening.