Estimating spatial non-stationary environmental effects on the distribution of Pacific saury in the Northwest Pacific Ocean

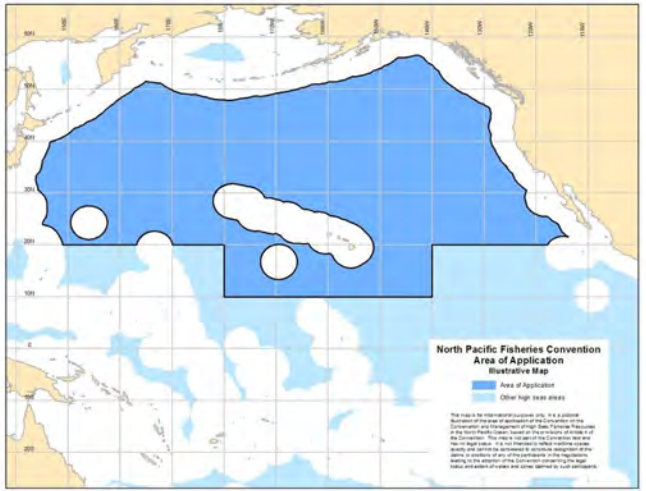
Presenter: Bai Li (bai.li@maine.edu)
North Pacific Fisheries Commission (NPFC)

1. Introduction

- North Pacific Fisheries Commission
  - Inter-governmental organization
  - Canada, China, Japan, the Republic of Korea, the Russian Federation, Chinese Taipei, the United States of America, and Vanuatu

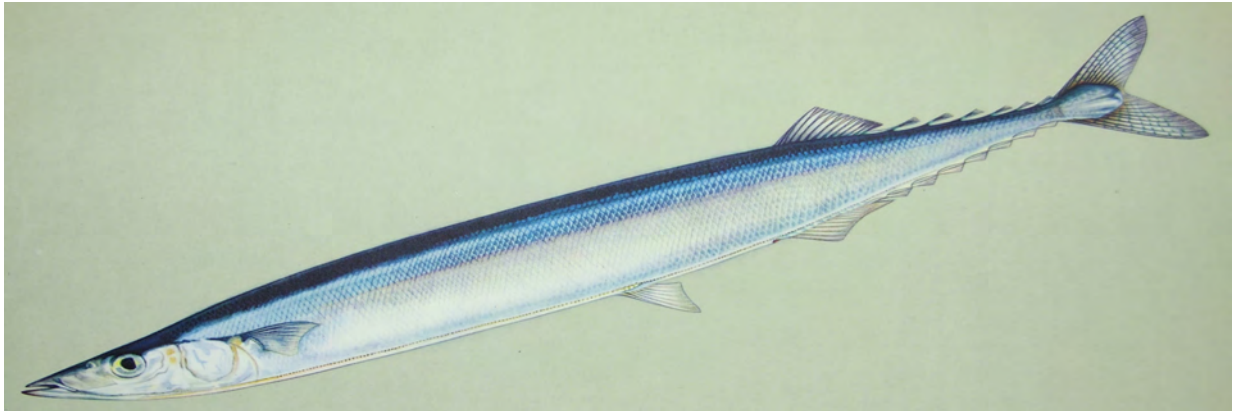
1. Introduction

- North Pacific Fisheries Commission
  - Ensures long-term conservation and sustainable use of the fisheries resources
  - Protects the marine ecosystems of the North Pacific Ocean



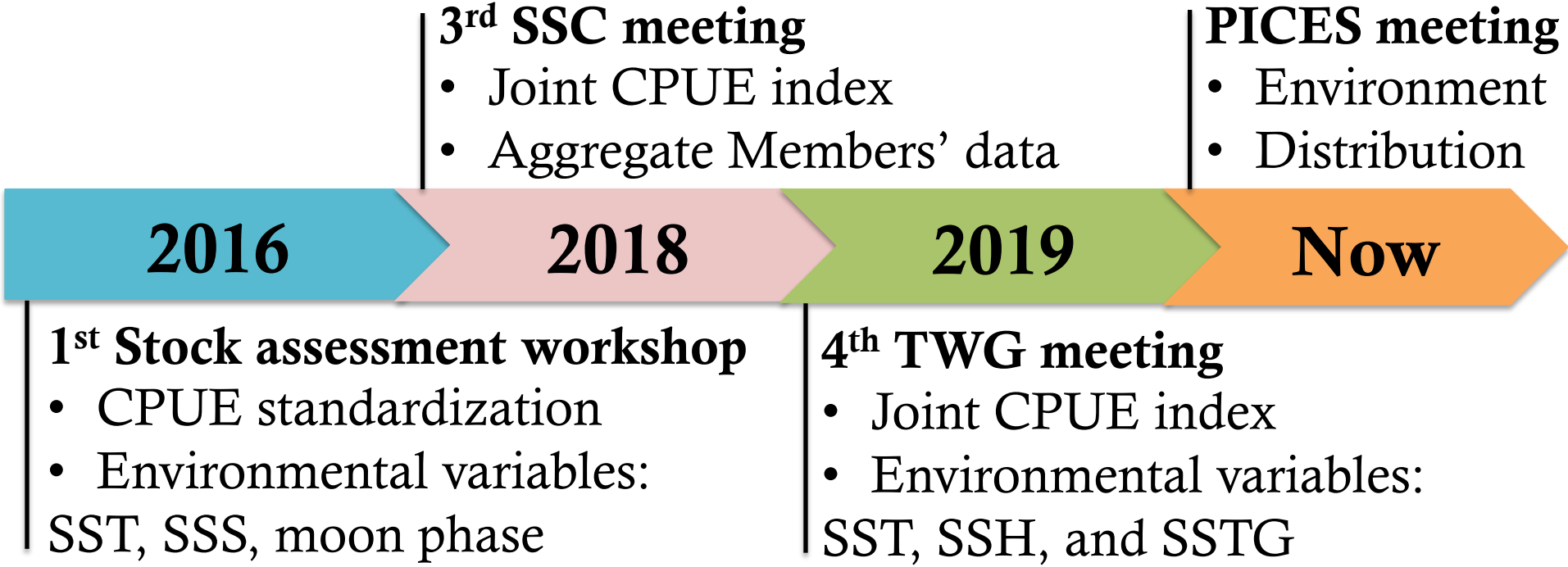
1. Introduction

- North Pacific Fisheries Commission
  - Pacific saury (*Cololabis saira*)
  - High priority
  - China, Japan, Korea, Russia, Chinese Taipei, and Vanuatu



1. Introduction

- Timeline of the work



1. Introduction

- Potential environmental effects
  - Top-down effect
    - Competition and predation

N

1. Introduction

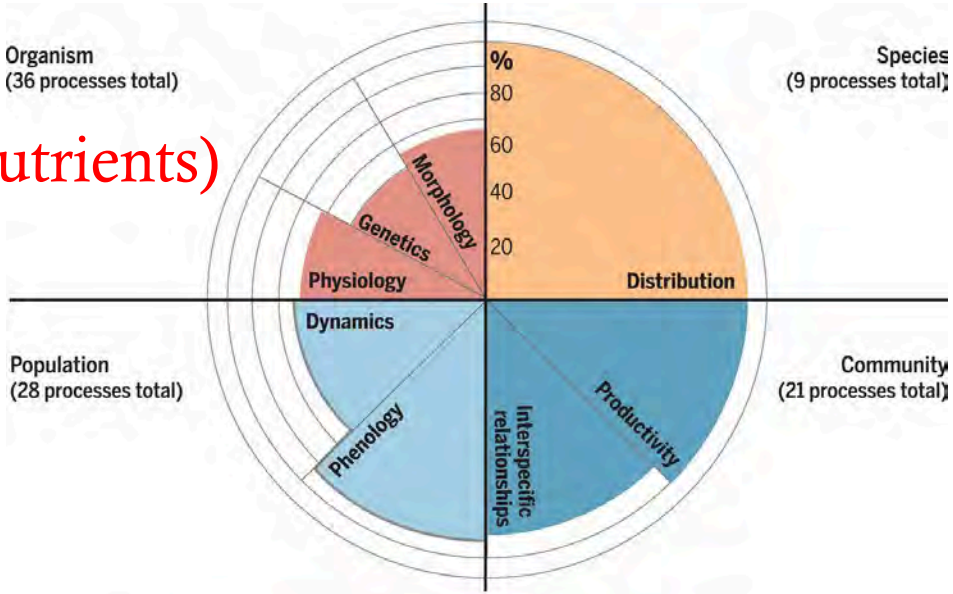
- Potential environmental effects
  - Bottom-up effect
    - Resource availability

(e.g. temperature and nutrients)

Examples:

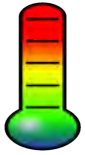
Range size and location
Habitat quantity and quality

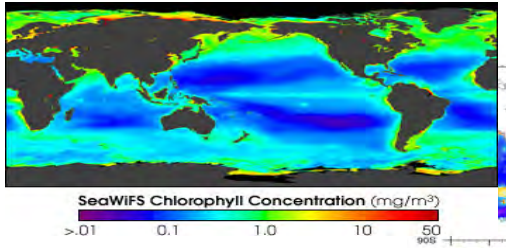
(Scheffers et al., 2016)

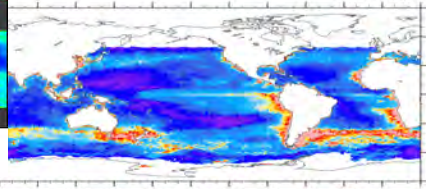


1. Introduction

- Previous studies on saury distribution and environmental effects
  - Sea surface temperature
    - 10 – 20 °C; 14 - 16 °C
  - Sea surface height anomaly
    - 5 – 17 cm
  - Eddy kinetic energy
    - 700 – 1200 cm^2s^{-2}
  - Chlorophyll a
    - 0.4 – 1.8 mg m^{-3}
  - Net primary production
    - 600 – 800 mg C $m^{-2}d^{-1}$



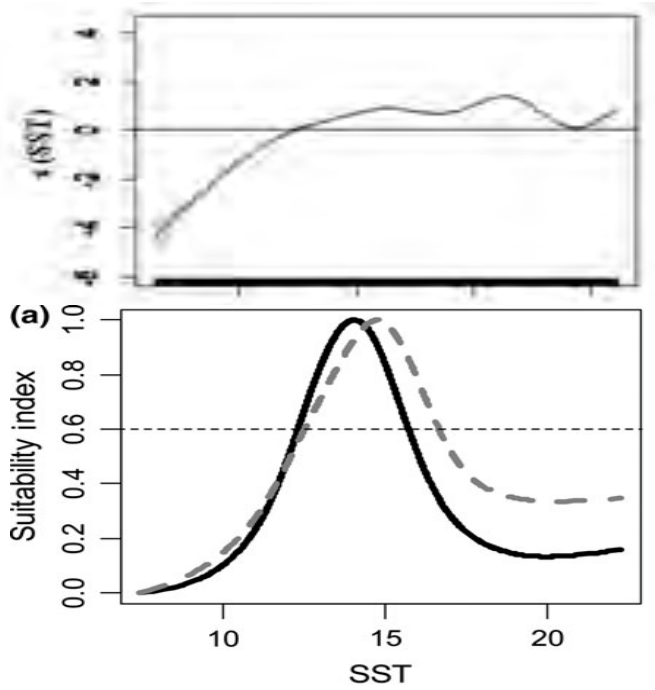




(Watanabe et al., 2006; Huang et al., 2007; Tseng et al., 2011, 2013 & 2014; Syah et al., 2016 & 2017)

1. Introduction

- Previous studies on saury distribution modeling
  - Data from single Member
  - Generalized linear model (GLM)
  - Generalized additive model
  - Habitat suitability index model



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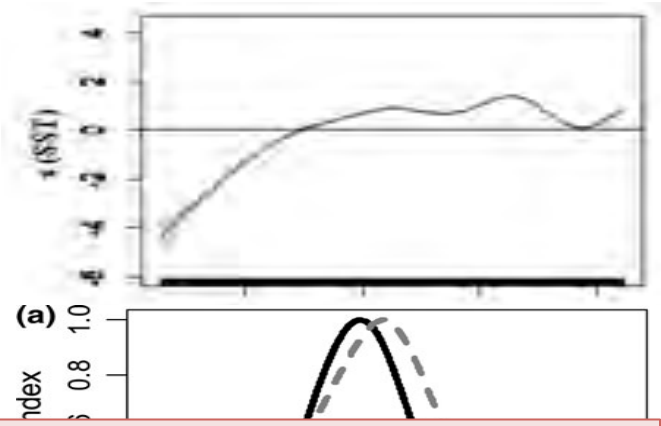


Elucidate important correlations between factors

Mask geographic varied (non-stationary) relationship

1. Introduction

- Stationarity and non-stationarity

Stationarity:

- **Relationships between environmental factors and saury CPUE are constant throughout the study region**
- **Parameters (mean and variance) of a process are independent of location or direction**

1. Introduction

- Stationarity and non-stationarity

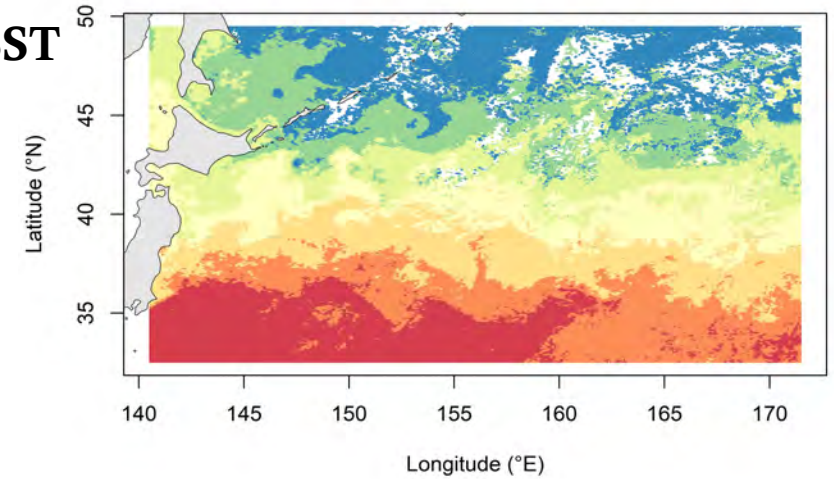
Non-stationarity:

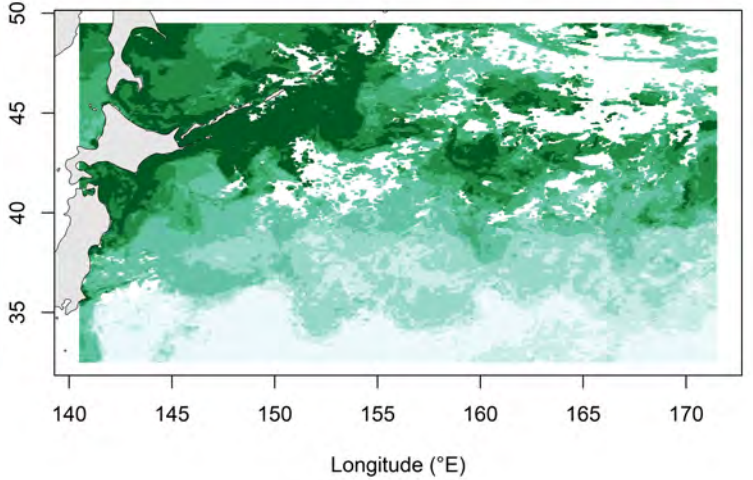
- **"Everything is related to everything else, but near things are more related than distant things". –Tobler's 1st law of geography**
- **Relationships between environmental factors and saury CPUE vary over the large study region**

1. Introduction

- Objective
  - Estimating spatial non-stationary environmental effects on the distribution of Pacific saury CPUE at a finer spatial scale

SST

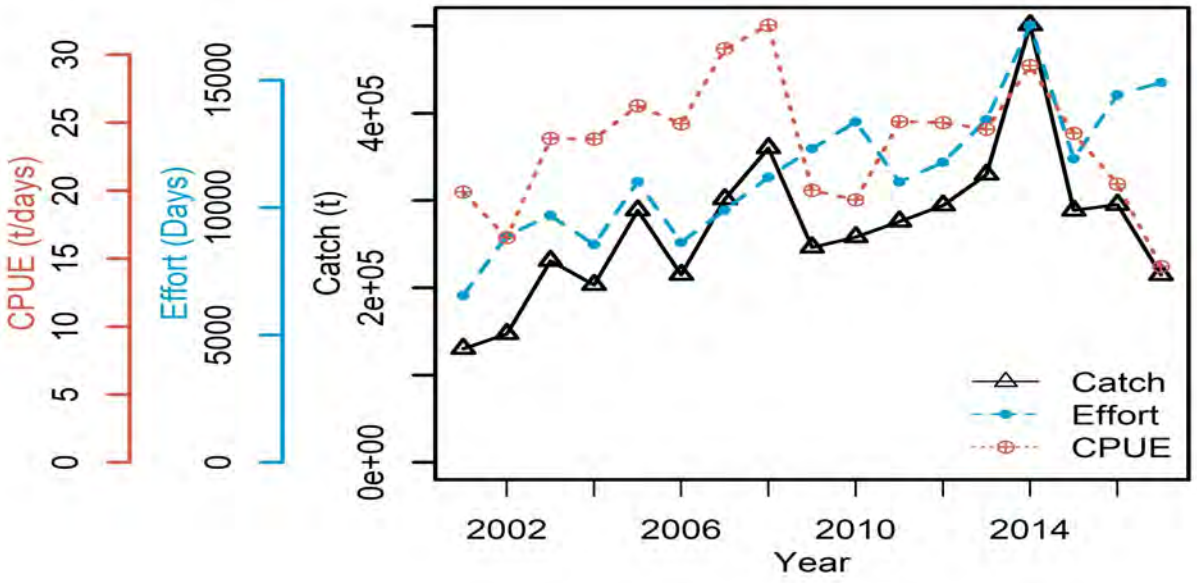




CHL

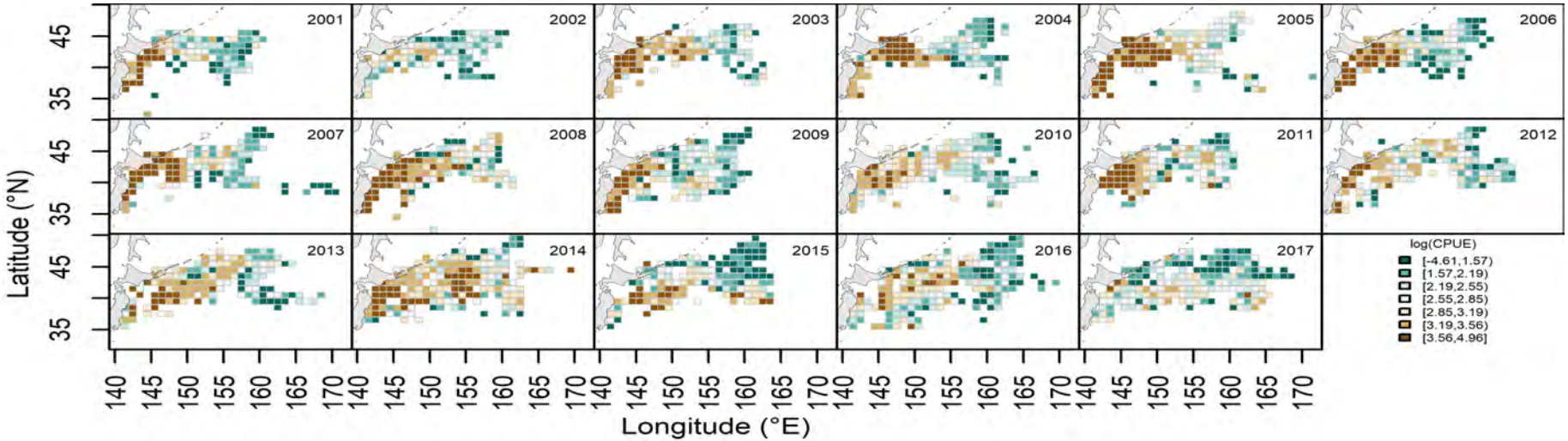
2. Materials and methods

- Fishery data
  - Catch (tons)
  - Effort (fishing days)
  - Catch per unit effort (t/days)
  - 2001 – 2017 (May – Dec)



2. Materials and methods

- Fishery data
  - Catch per unit effort
  - 1° × 1° grid



2. Materials and methods

- Environmental data
  - Sea surface temperature
  - Sea surface height
  - Sea surface temperature gradient
  - Chlorophyll a
  - 2003 – 2017; Month
  - 1° × 1° grid

2. Materials and methods

- Geographically weighted regression model
  - Extension of the traditional GLM
  - Incorporate a set of geographic locations for GLM development at each observation point

$$CPUE_i(x_i, y_i) = \beta_0(x_i, y_i) + \beta_1(x_i, y_i)\,SST + \beta_2(x_i, y_i)\,SSH + \beta_3(x_i, y_i)\,SSTG + \beta_4(x_i, y_i)\,CHL + \varepsilon_i$$

x_i and y_i: longitude and latitude coordinates

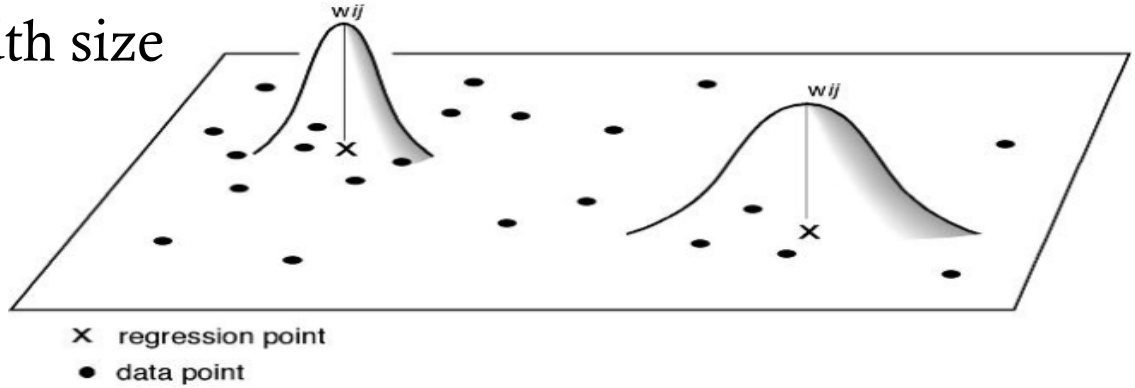
2. Materials and methods

- Geographically weighted regression model
  - Moving window
  - Fixed Gaussian weight

$W_{ij} = \exp(-d_{ij}^2 / \theta^2)$

d_{ij}: distance between regression point i and data point j

θ : fixed bandwidth size



3. Results

- Global regression results vs. GWR results

	GLM	GWR
Number of points	3259	3259
R square	0.037	0.27
SST coefficient	0.05	-1.38 ~ 1.77
SSH coefficient	0.05	-5.00 ~ 5.34
SSTG coefficient	0.16	-8.02 ~ 1.56
CHL coefficient	0.13	-15.98 ~ 25.73

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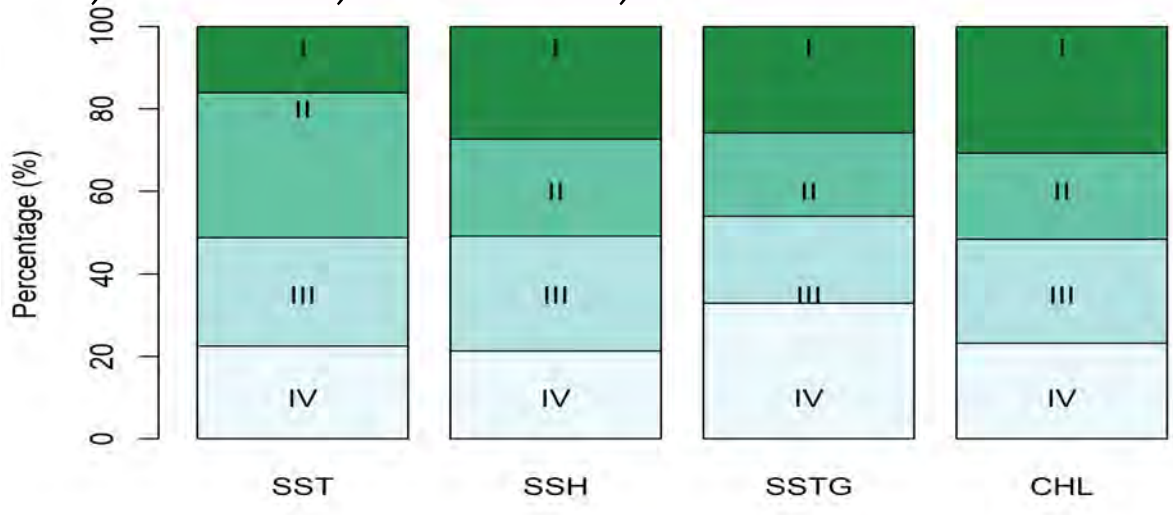
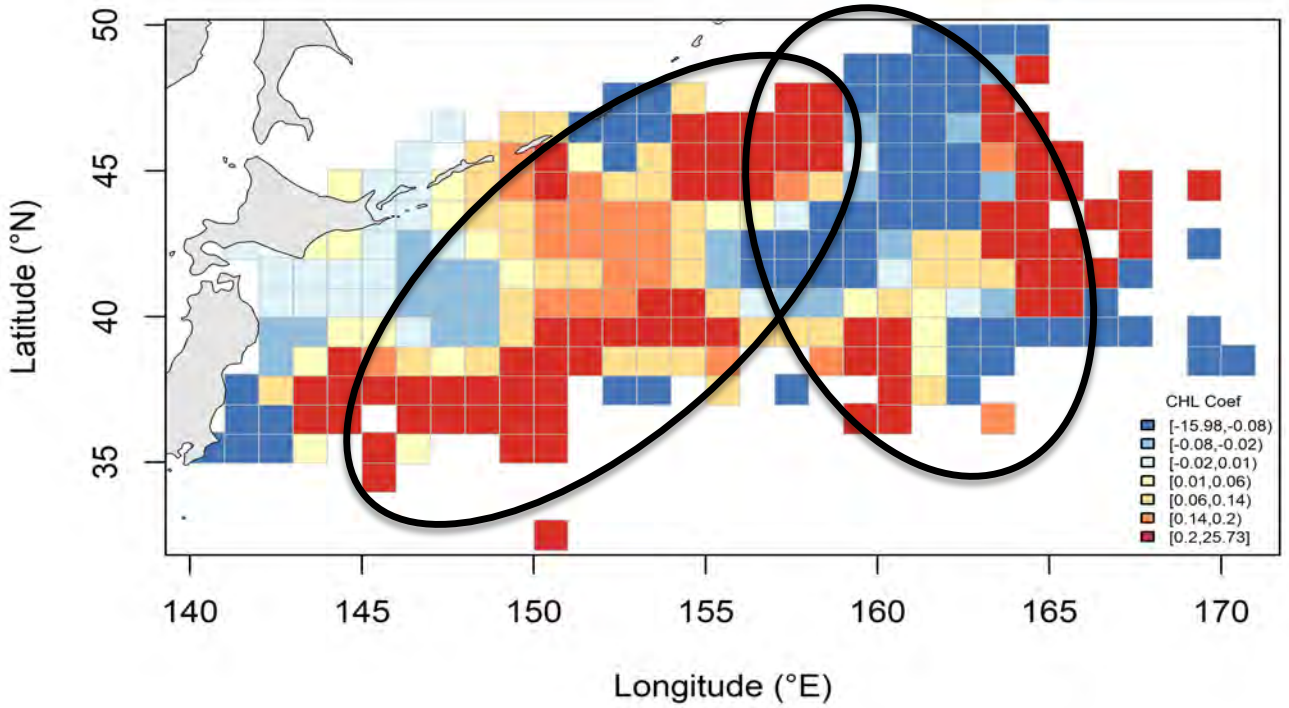
3. Results

- Rank of importance
  - I means most important and IV means least important
  - I: CHL; II: SST; III: SSH; IV: SSTG



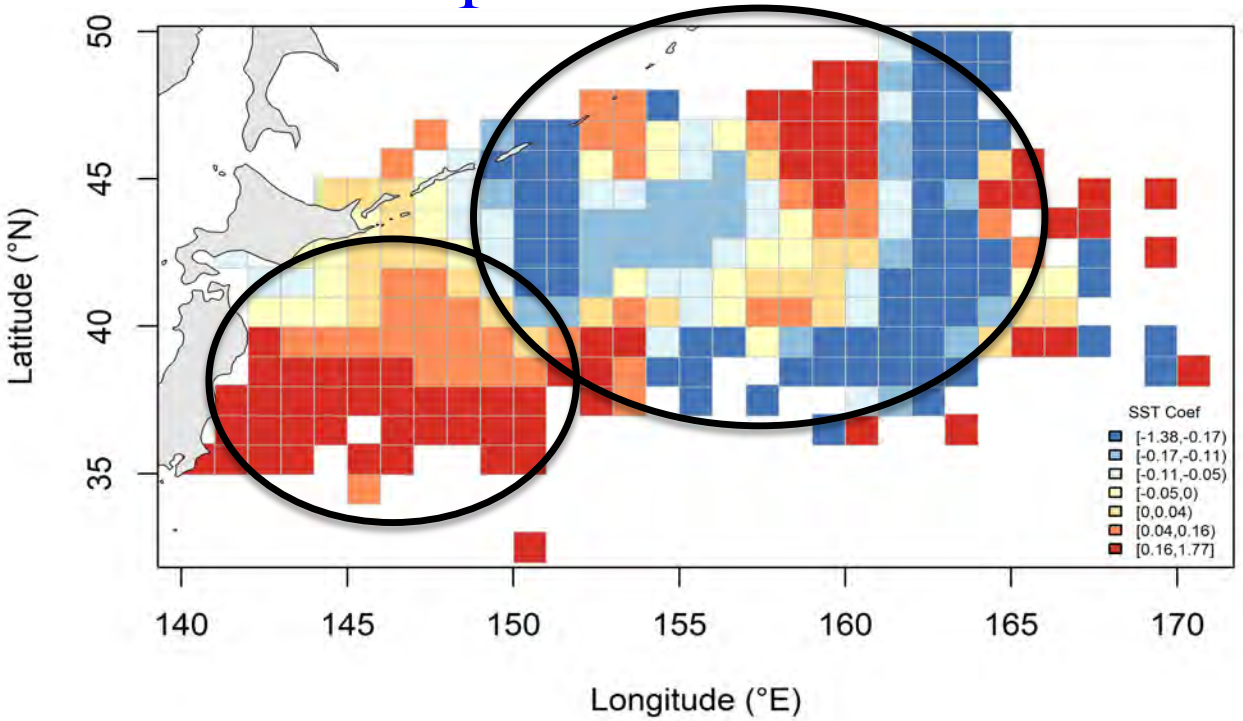
3. Results

- Chlorophyll a coefficients



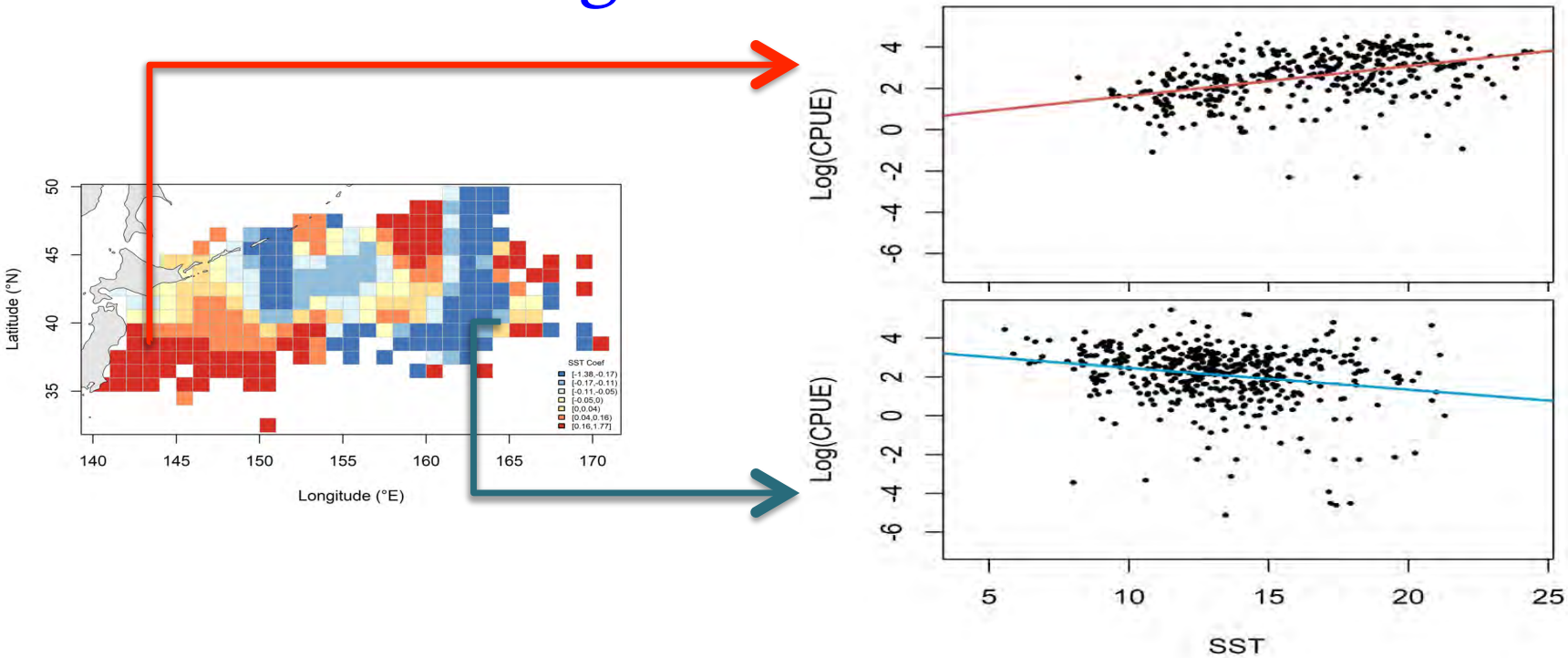
3. Results

- Sea surface temperature coefficients



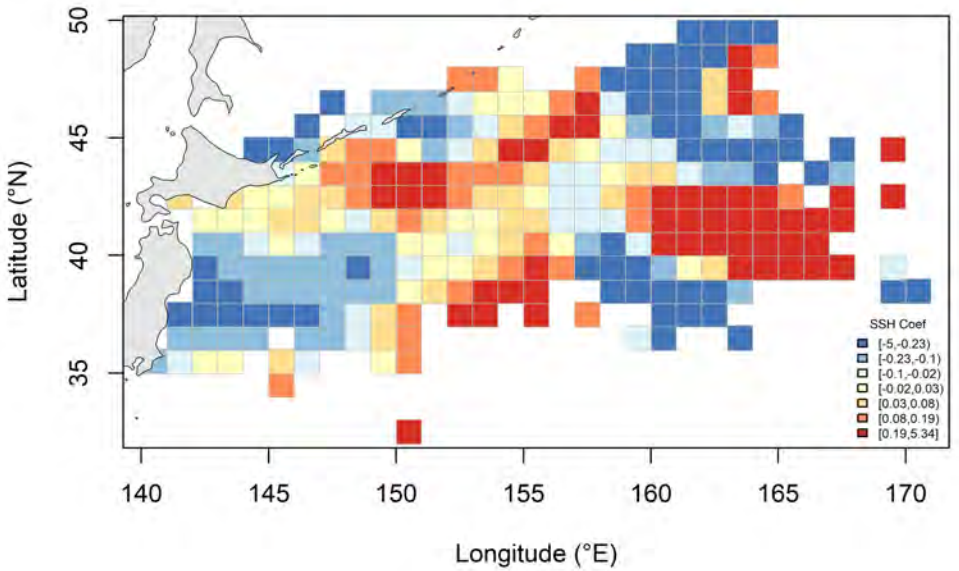
3. Results

- Positive and negative SST coefficients



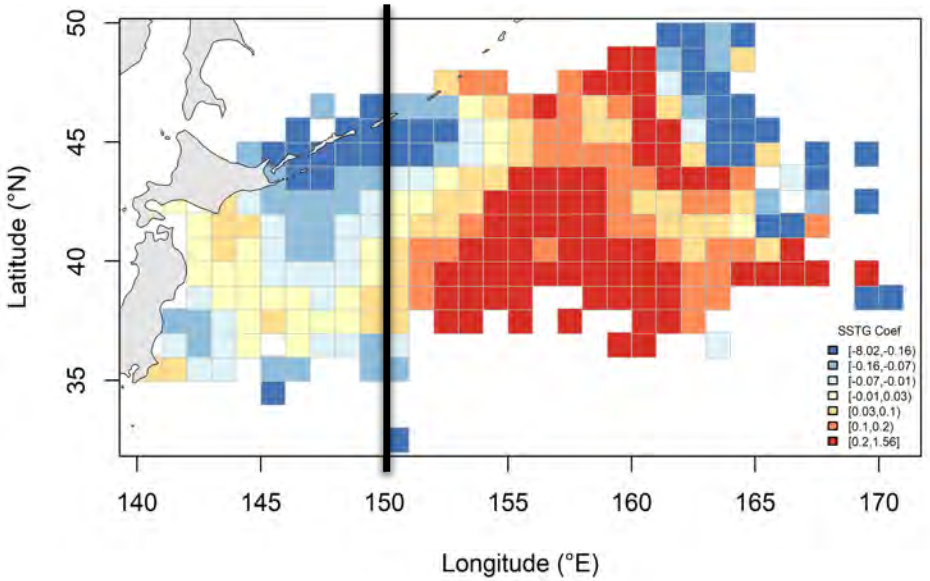
3. Results

- Sea surface height coefficients
  - Spatially varied relationships
  - Similar pattern of clusters with SST



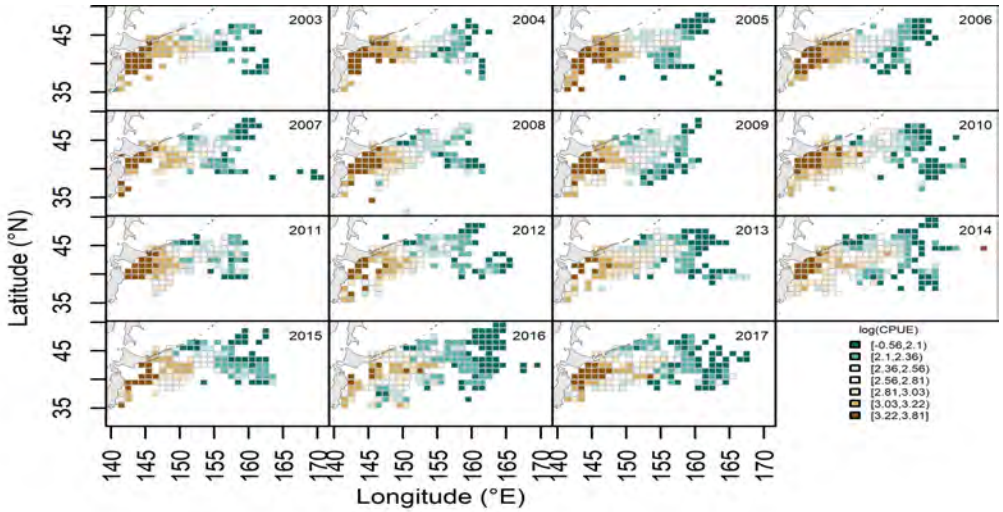
3. Results

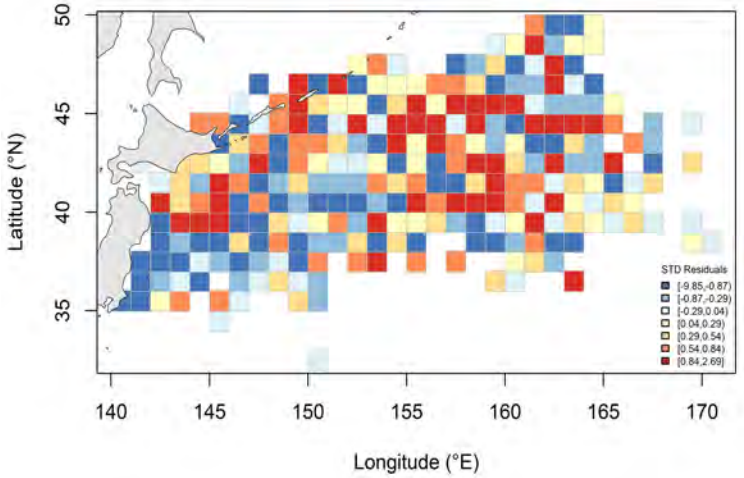
- Sea surface temperature gradient coefficients
  - East and west of 150°E



3. Results

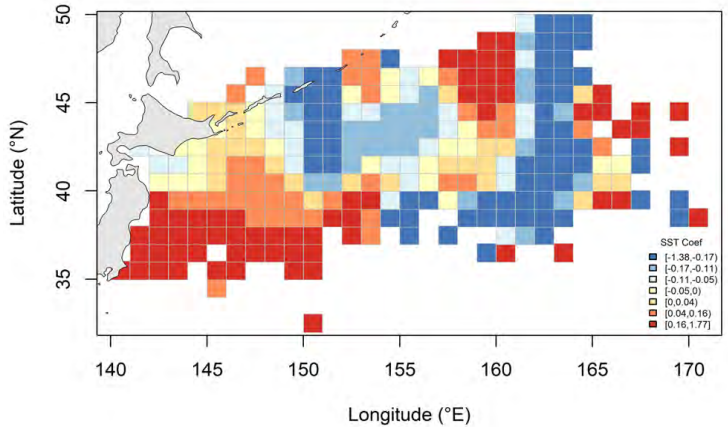
- Predicted CPUE and Moran' I test
  - No spatial autocorrelation in residuals (p=0.214)
- Cross validation (Train: 63.4%; 100 simulations)
  - Mean root mean square error is 2.94 t/days





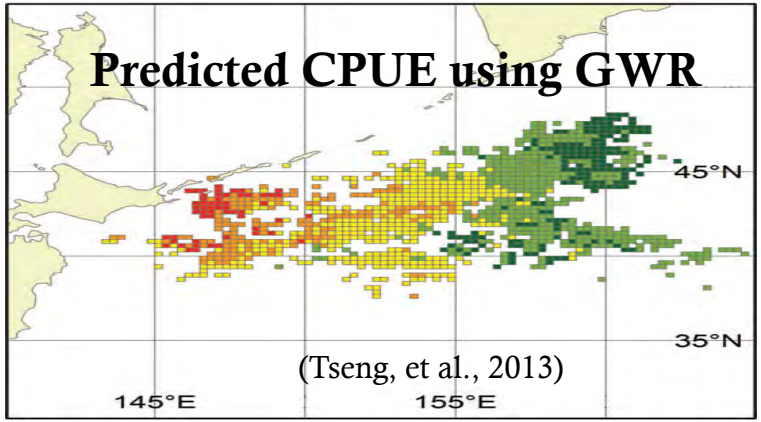
4. Summary and future work

- Biology perspective
  - Chlorophyll a was the most important predictor of distribution
  - Spatially-varied environmental effects were found



4. Summary and future work

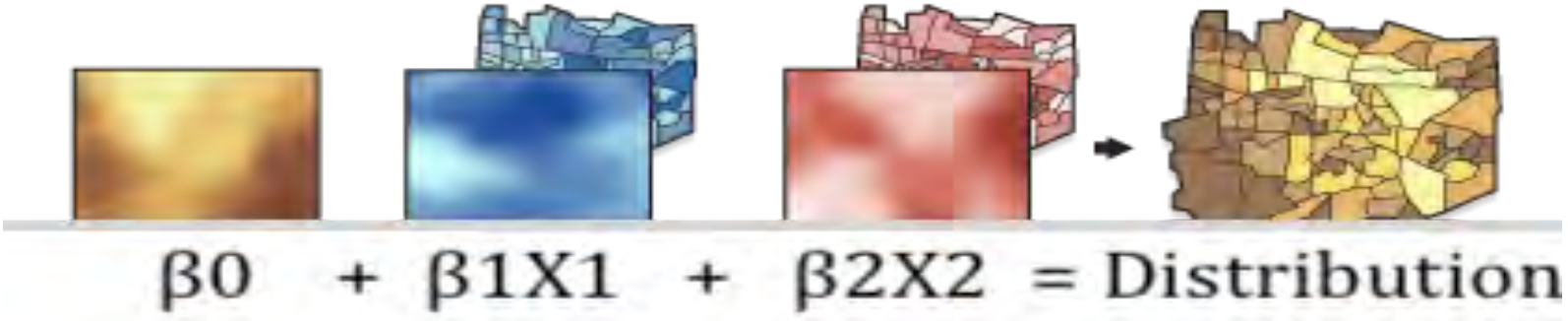
- Biology perspective
  - Chlorophyll a was the most important predictor of distribution
  - Spatially-varied environmental effects were found
  - East and west of 150°E/155°E exhibited different relationships



(Tseng, et al., 2013)

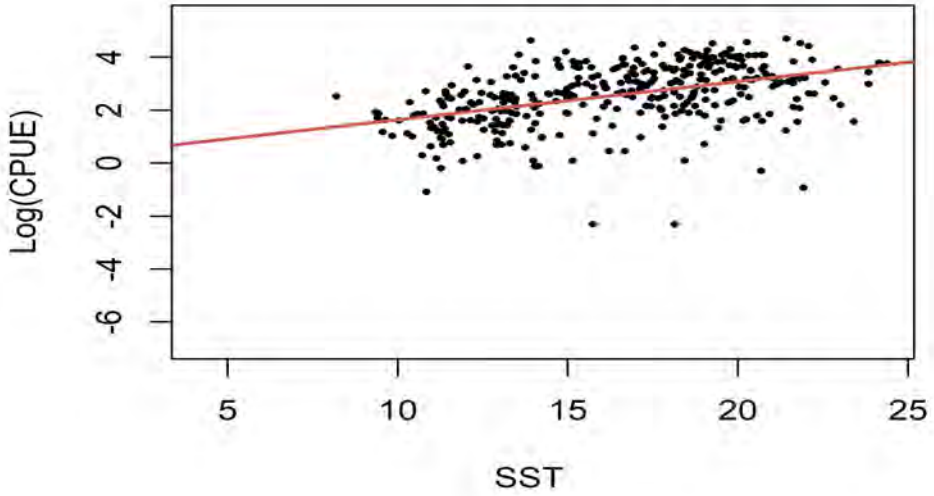
4. Summary and future work

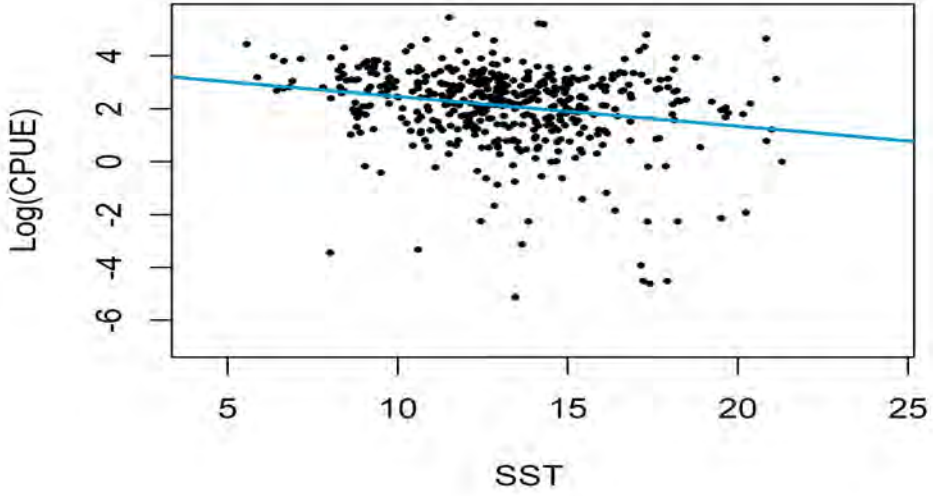
- Modeling perspective
  - R^2 Improvement from global GLM to GWR
  - Averaged environmental relationships (global models) within large marine ecosystem may mask processes operating at different scales (Pacific saury, Atlantic cod, American lobster, Snow crab, shrimp…)



4. Summary and future work

- Management perspective
  - Regional differences and climate change
  - Reliable prediction with better understanding of environment and saury distribution at a finer scale





4. Summary and future work

- Can CPUE represent the abundance distribution of saury?
  - Use effort in this study
  - Apply the method to other fishery-independent survey data
- Significance of the estimated relationship
  - Consider other factors (Chub mackerel, front…)
  - Higher data resolution (<1° × 1°)
- Future distribution under climate change
  - Predictions under different SST warming scenarios

Acknowledgements

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