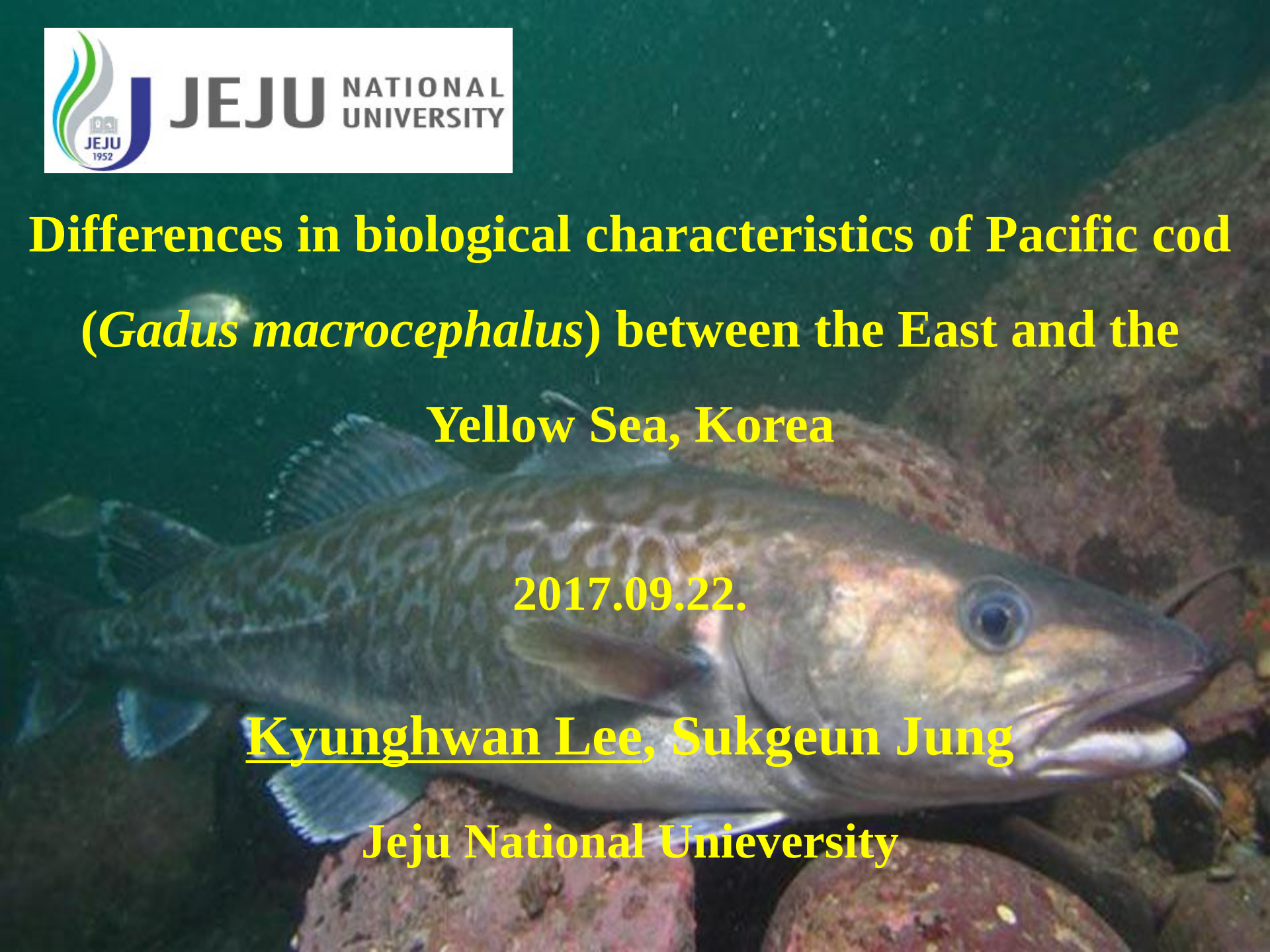

# Differences in biological characteristics of Pacific cod (*Gadus macrocephalus*) between the East and the Yellow Sea, Korea

2017.09.22.

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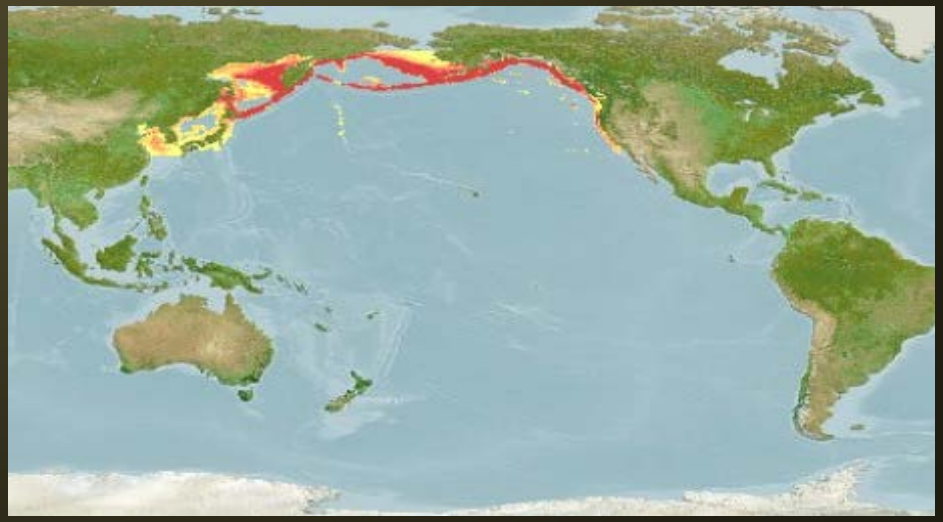
# Pacific cod

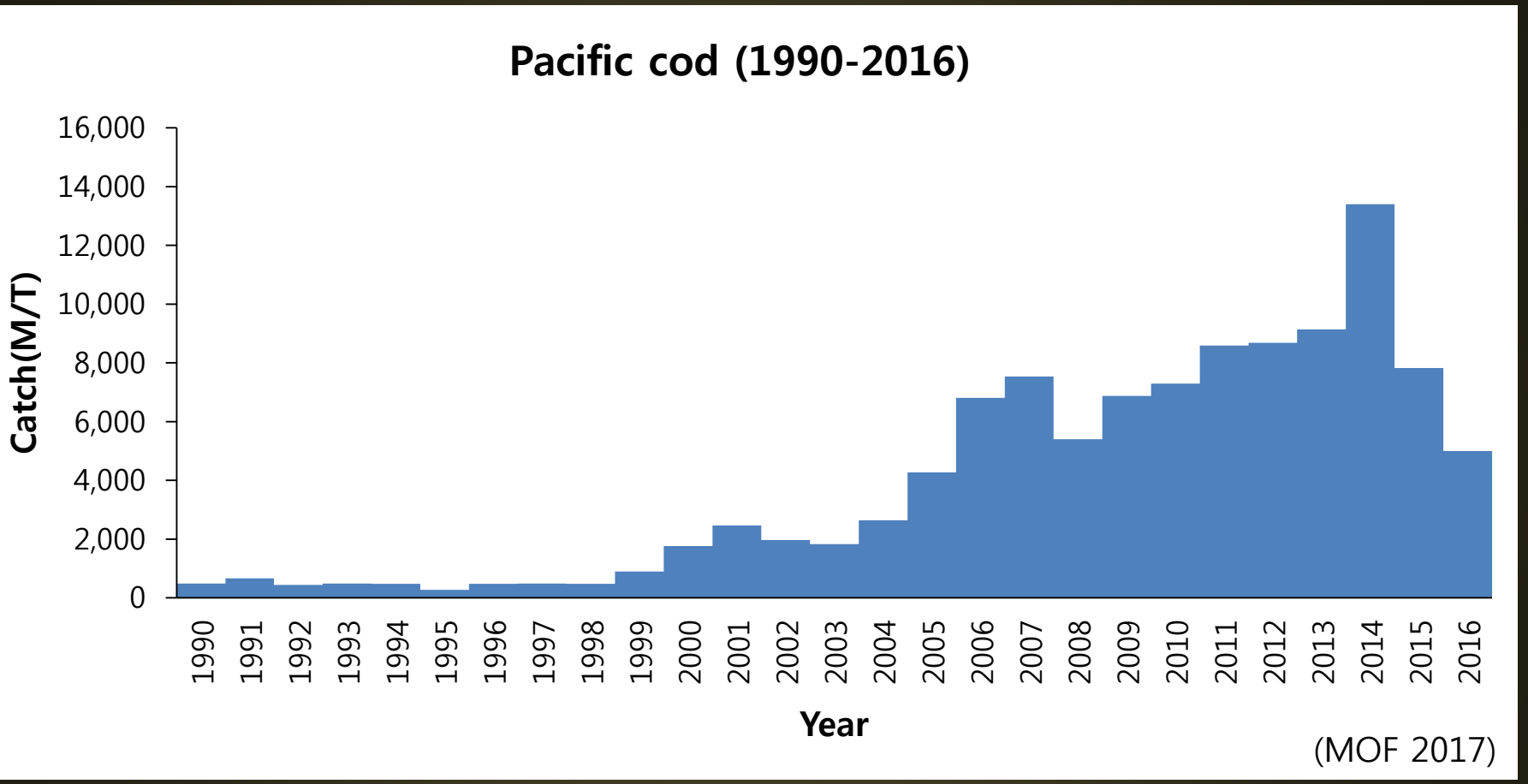
- Korean: 대구(大口)
- English: Pacific cod
- Russian: треска́
- Japanese: タラ(鱈)
- Chinese: 鳕鱼

# Ecology of Pacific cod

- Pacific cod have a broad habitat range from the Yellow Sea of Korea to the northwest coast of north America.
- Habitat depths: 10–550 m
- Habitat temperatures: 5–12 ℃
- Its major spawning season is from January to February in Korean waters.



# Catch biomass




- Catch have increased since the 2000s.

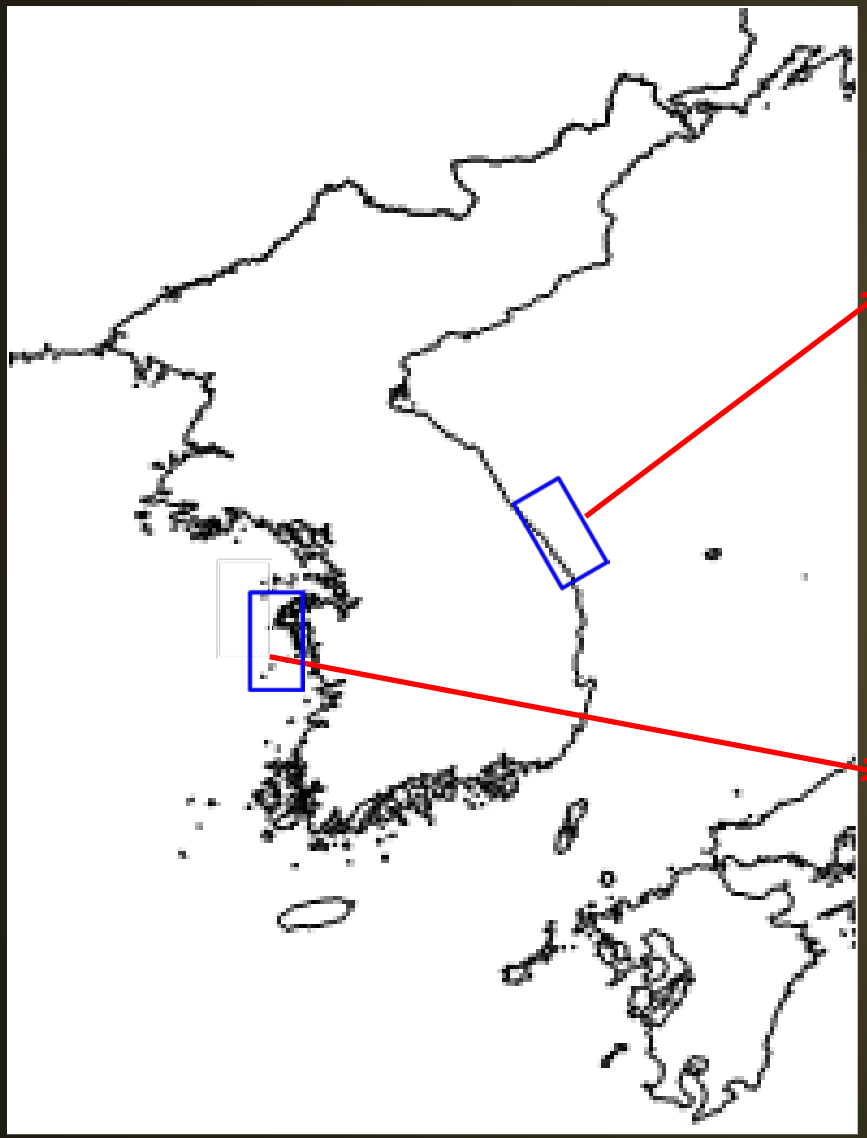
# Problems

- Most studies on Pacific cod have been conducted in the Eastern North Pacific.
- Past studies on Pacific cod in Korea were conducted in the East Sea and the Korea Strait.
- However, few studies have been conducted in the Yellow Sea.
- No comparative study between the East and the Yellow Seas.

# Objectives of the study

- Compare the growth and maturity of Pacific cod between the East and the Yellow Sea cod.
- Identify factors causing the regional differences.

# Data



## Growth

- Kangwon-do
- January to December 2003
- **Lee *et al.* (2005)**

## Group maturity

- Kangwon-do
- January and February 2007
- **Cha *et al.* (2007)**

## Growth and group maturity

- The Yellow Sea of Korea
- January to December 2007
- **Kim *et al.* (2013)**

# Age determination for growth equation

- To increase the accuracy of age determination, we excluded the data of the otoliths from the cod caught sampled during the period when the annual ring is formed, which can generate an error of +/- 1 yr:
  - ✓ East Sea: November–March
  - ✓ Yellow Sea: December–March (Im *et al.*, 2013)

# Determination of age in days

- **All cod were assumed to be hatched on January 1.**
- **Based on the catch date and the number of annual rings, the age was determined in days.**
- Example:
  - Number of rings = 3
  - Catch date = May 15, 2003
  - Age = 3 yr + (May 15) – (January 1)
  = 3 yr + 134 days
  = 3 yr + 134/365 yr
  = 3.367 yr

# Regional difference in the condition index of cod

- Regional difference in length-weight relationship was tested by ANCOVA.

# Regional difference in growth

- Non-linear regression was applied to estimate the growth parameters. → von Bertalanffy growth equation
- Regional difference in the growth equation was tested by Wald test and Kimura's likelihood ratio test.

# von Bertalanffy growth equation

$$L_t = L_\infty(1 - \exp(-K(t - t_0))$$

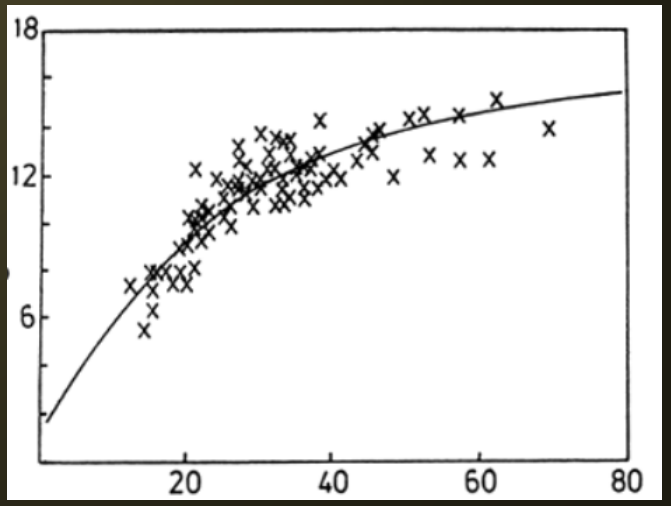
$L_t$: Body length of cod at t age

$L_\infty$: Theoretical maximum body length of cod

$K$: von bertalanffy growth coefficient

$t$ : Age of cod

$t_0$: Age of cod at 0 length



## To decrease the number of parameters of the von Bertalanffy equation from 3 to 2

- $t_0$ was directly determined from the length at hatch ($L_0$).

$$L_0 = L_\infty(1 - \exp(-K(0 - t_0)))$$

$$t_0 = \frac{1}{K} \cdot \log(1 - \frac{0.41}{L_\infty})$$

- $t$ = 0 , $L_0$ is Length of cod at 0 age (0.41 cm, Seo et al. 2007)

# Modified von Bertalanffy growth equation

Three parameters($L_\infty$, $K$, $t_0$)

$$L_t = L_\infty(1 - \exp(-K(t - t_0))$$

Two parameters ($L_\infty$, $K$)

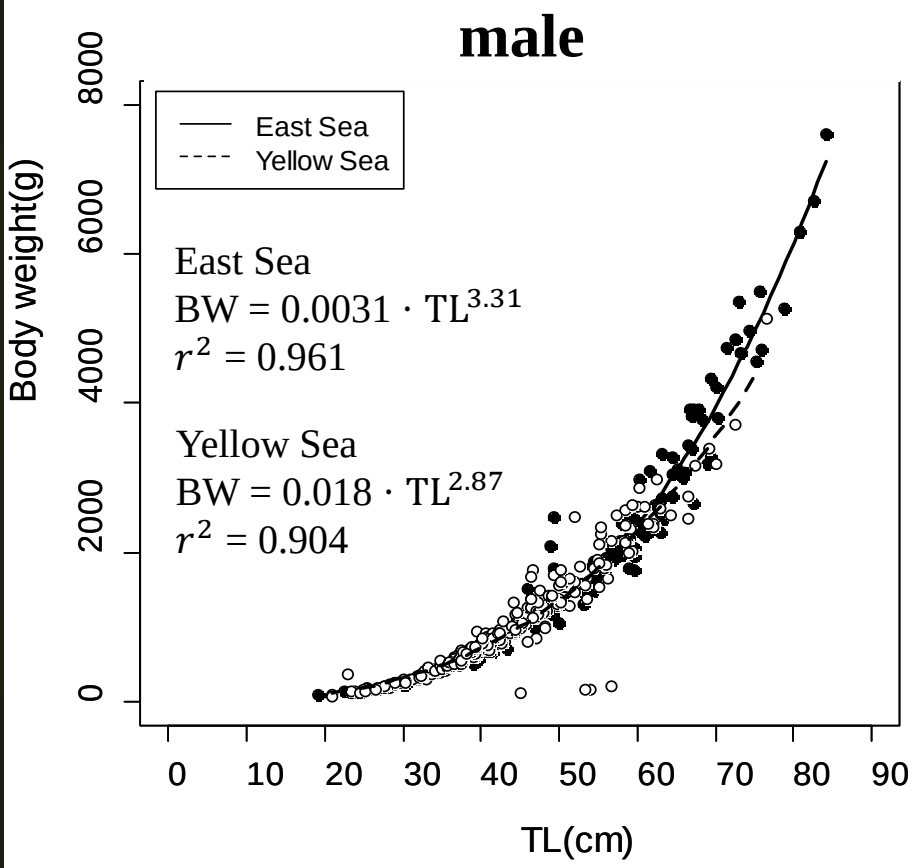
$$L_t = L_\infty[1 - \exp(-K(t - (1/K \cdot \log(1 - 0.41/L_\infty))))]$$

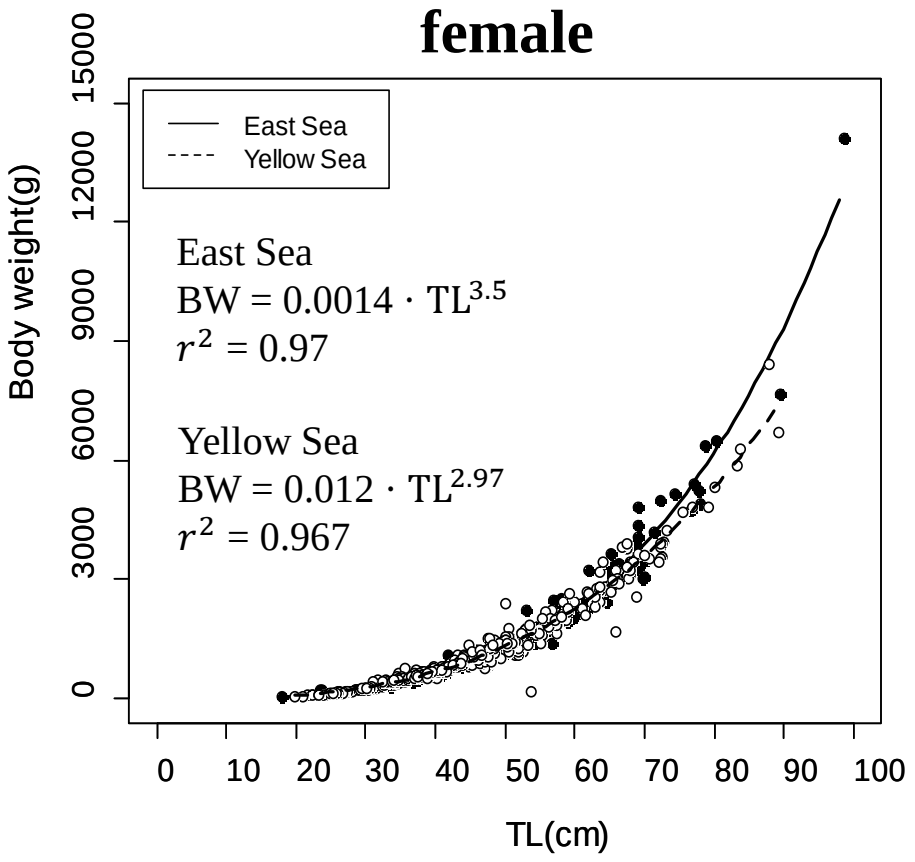
# Group maturity length

- Reported spawning season.
  - ✓ The East Sea: January – February (Chae *et al.* 2007)
  - ✓ The Yellow Sea: December – February (Kim *et al.* 2013)
- Parameters of the ogive were estimated by the generalized linear model. → Logistic regression
- Difference in mean group maturity length ($L_{50}$).
  - ✓ Welch-Aspin t-test

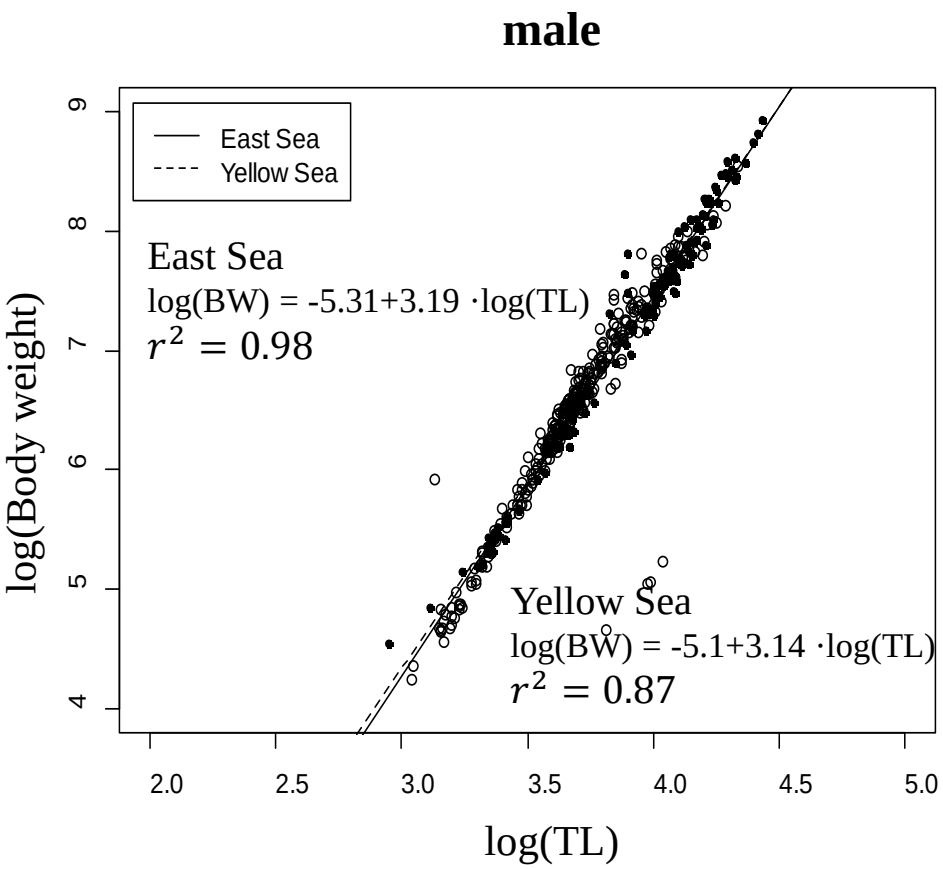
# Result

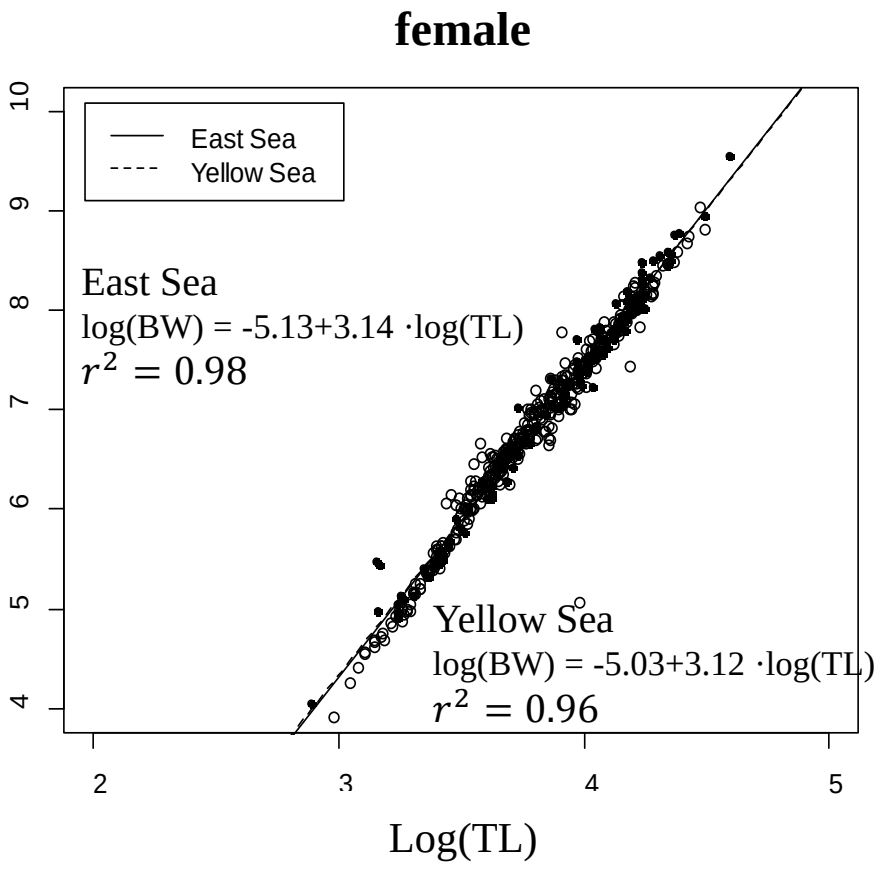
# Growth - Length-weight relationship



# ANCOVA for testing regional difference

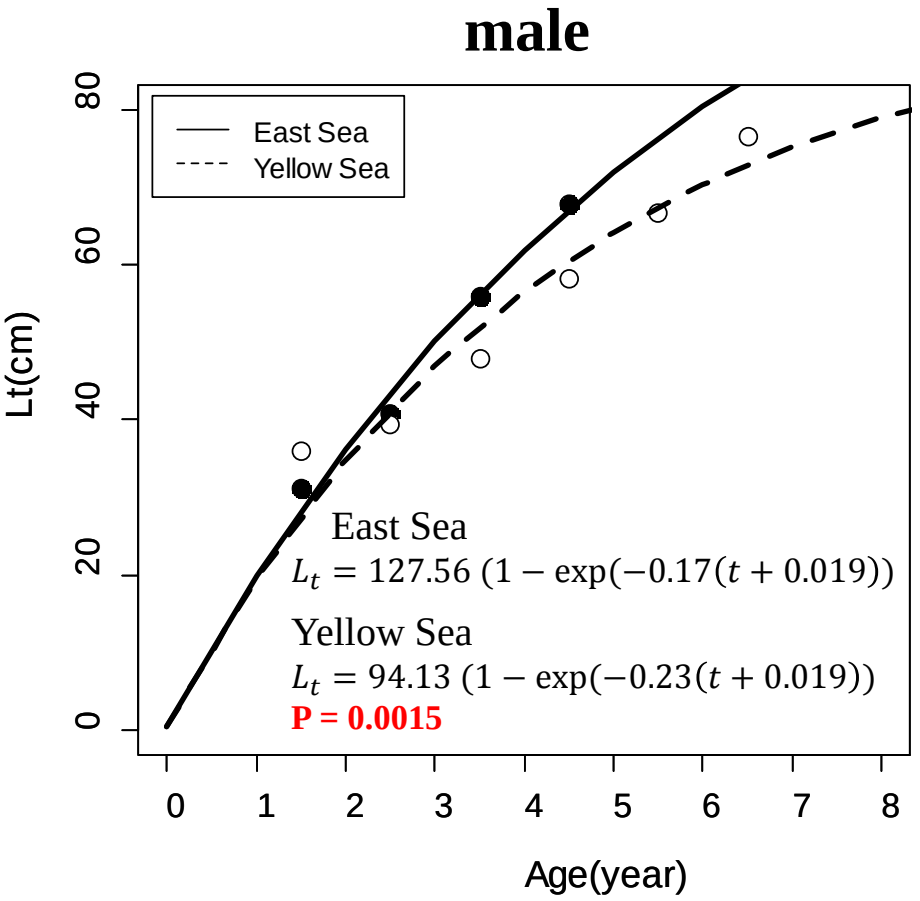


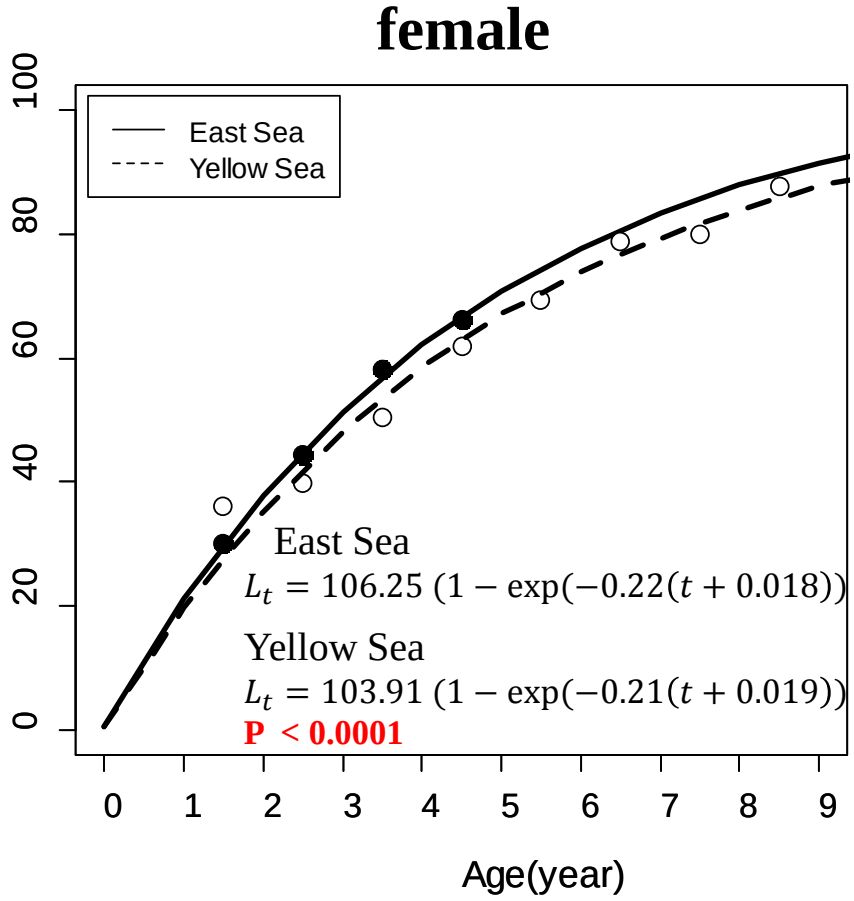




| F value | P value |
|---|---|
| 4680.57 | < 0.00001 |

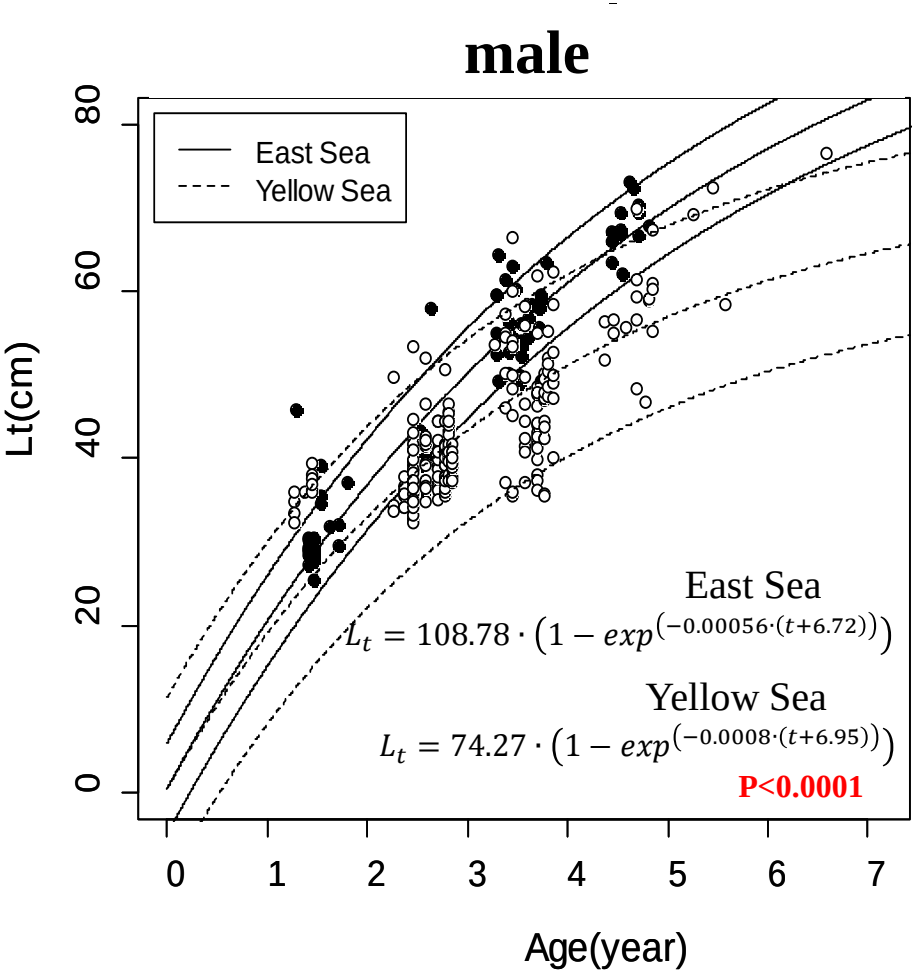
| F value | P value |
|---|---|
| 7354.988 | < 0.00001 |

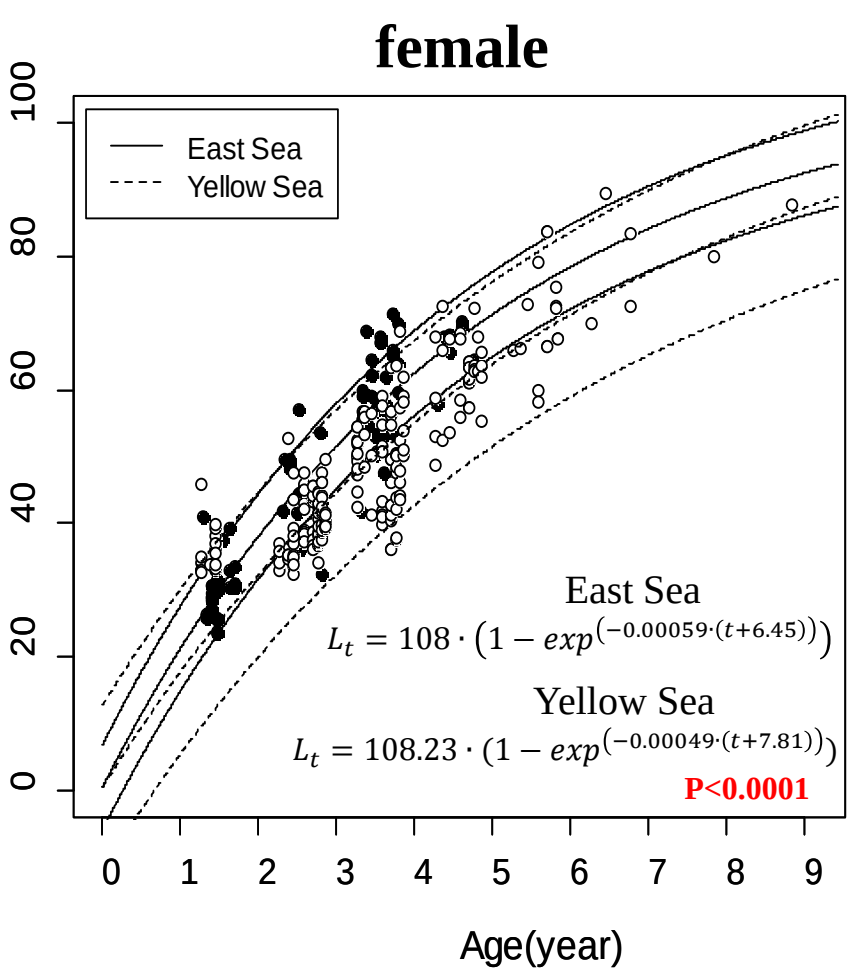
# Kimura's likelihood ratio test of regional difference

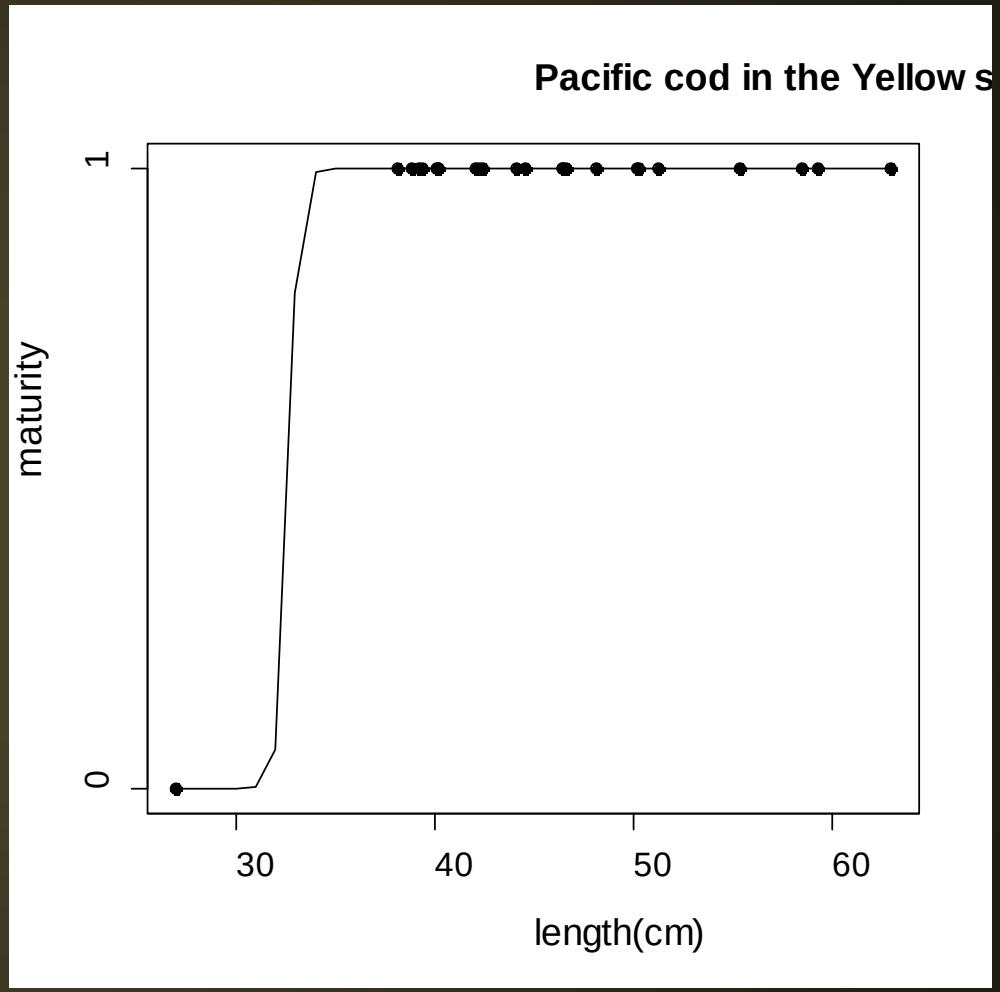


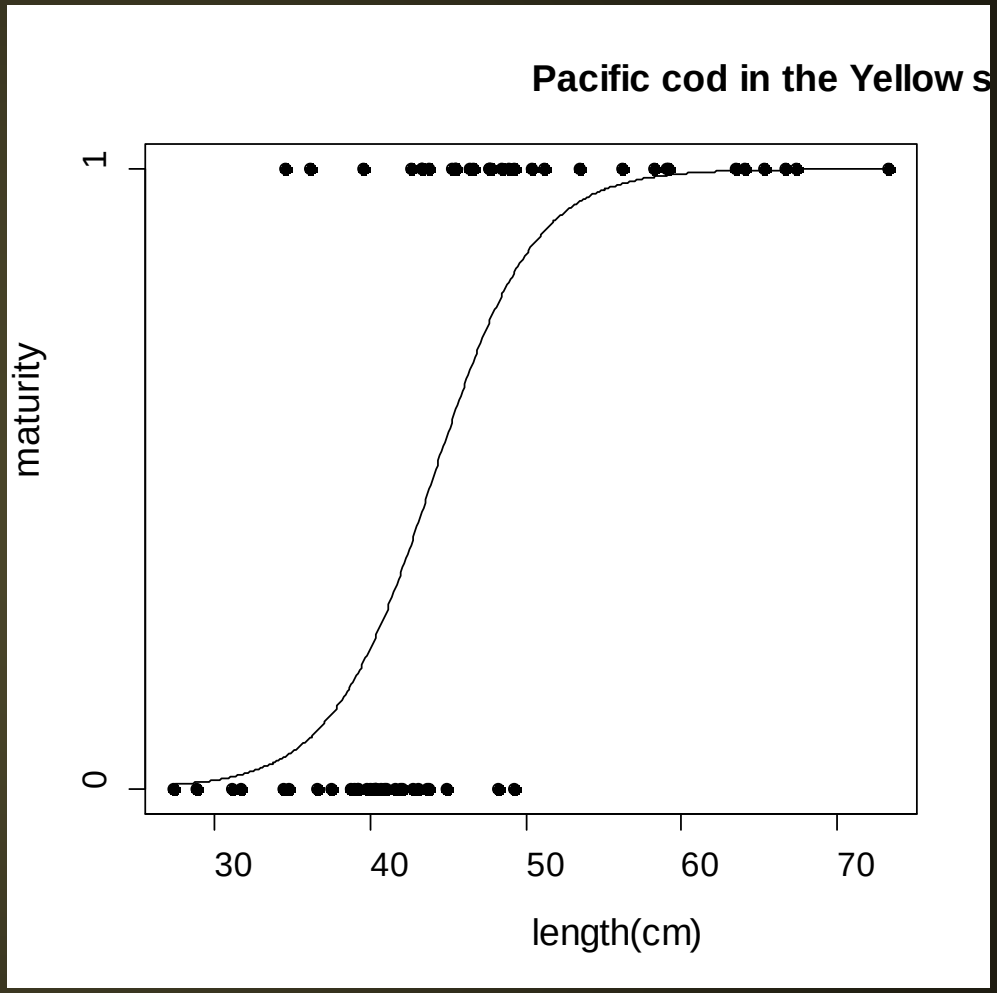



# Wald test of regional difference




Pacific cod in the Yellow s
maturity
1
0
30
40
50
60
length(cm)


Pacific cod in the Yellow s
maturity
1
0
30
40
50
60
70
length(cm)

# Regional difference in the variance of $L_{50}$ (Ashton, 1972)

| | East Sea | | Yellow Sea | |
|---|---|---|---|---|
| | male | female | male | female |
| $L_{50}$ | 58.82 | 58.27 | 32.66 | 44.02 |
| Var($L_{50}$) | 1.73 | 4.69 | - | 1.97 |
| N | 172 | 150 | 52 | 62 |

## F-test ( $H_0$: $\sigma_1^2 = \sigma_2^2$ )

| | The East and the Yellow Sea females |
|---|---|
| $F$ | 0.4 |
| P | < 0.0001 |
| df | 61 / 149 |

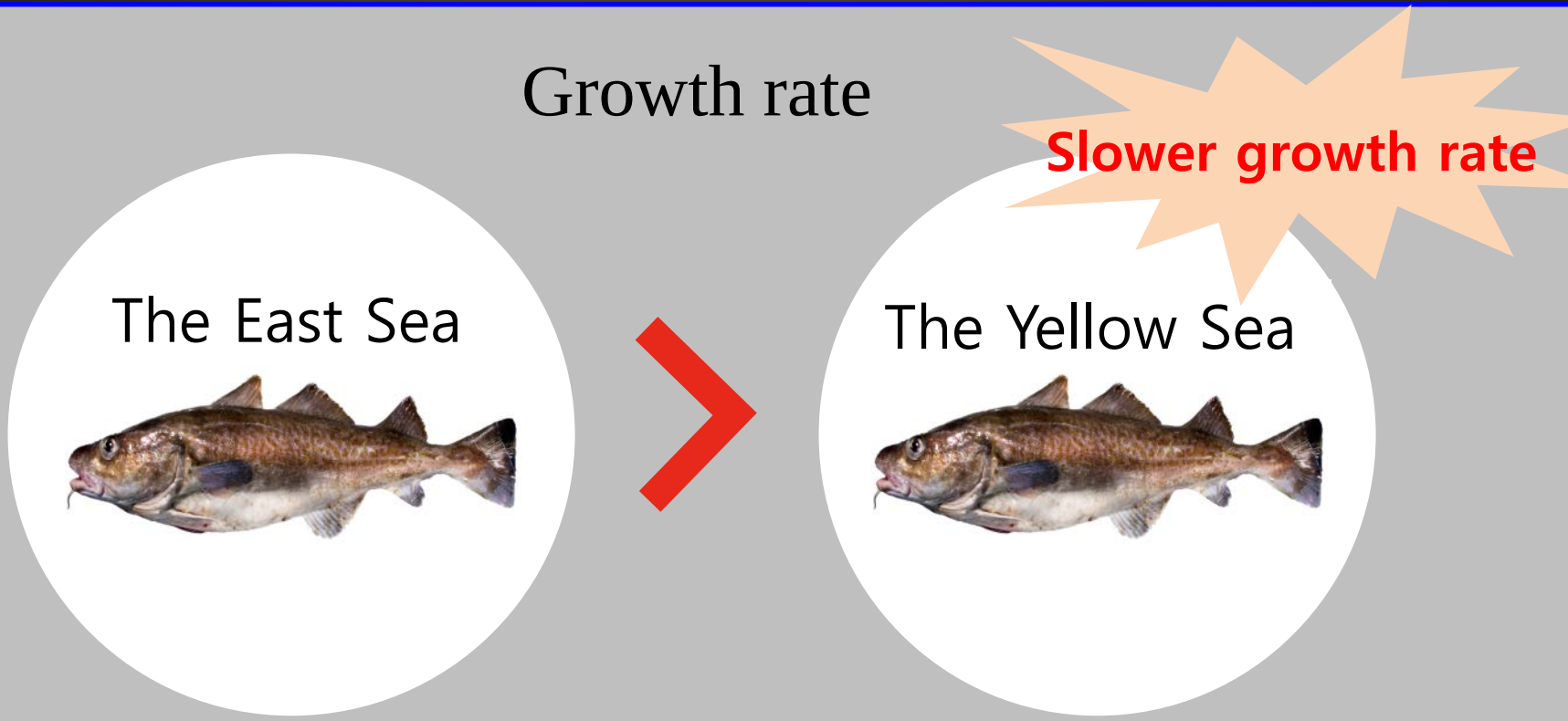
# Regional difference of $L_{50}$

$\sigma_1^2 \neq \sigma_2^2$

| | The East and the Yellow Sea females |
|---|---|
| Standard error (SE) | 0.25 |
| Degree of freedom (df) | 171 |
| t value | 56.77 |
| p-value | < 0.0001 |

# Regional differences in growth

- **Growth**
  - ✓ **The Yellow Sea cod showed slower growth rate than the East Sea cod.**



# Regional difference in maturation

- **Maturation**
  - ✓ **The Yellow Sea cod matured earlier than the East Sea cod by one year.**

Maturation

**Earlier maturation**

The East Sea

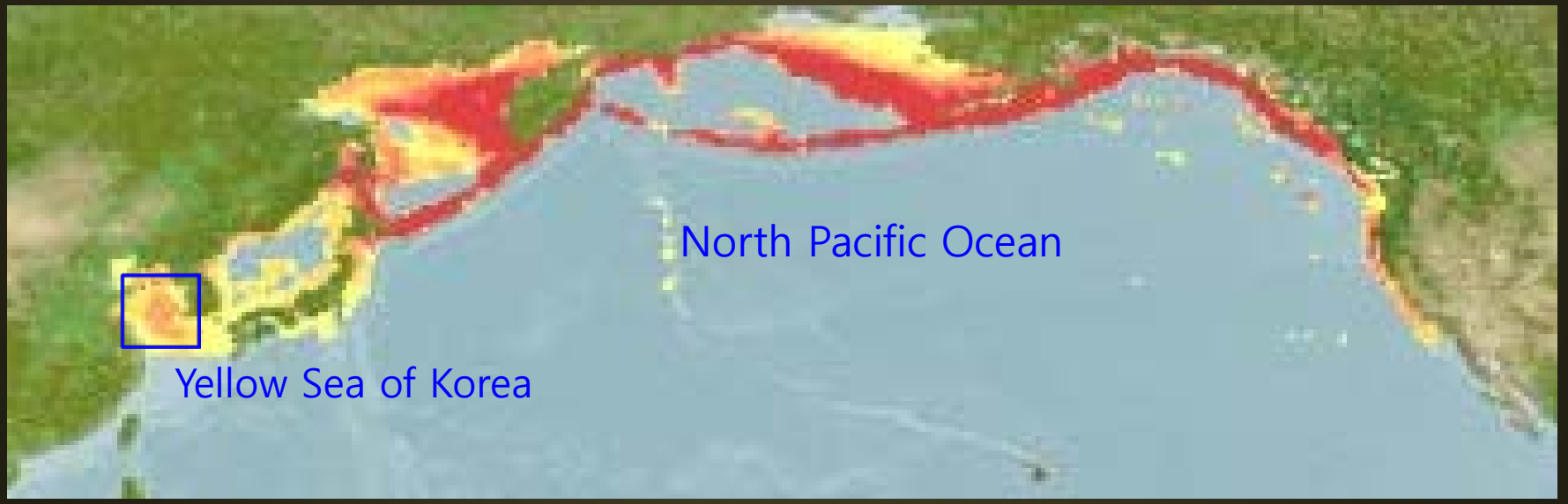
4 years

The Yellow Sea

3 years

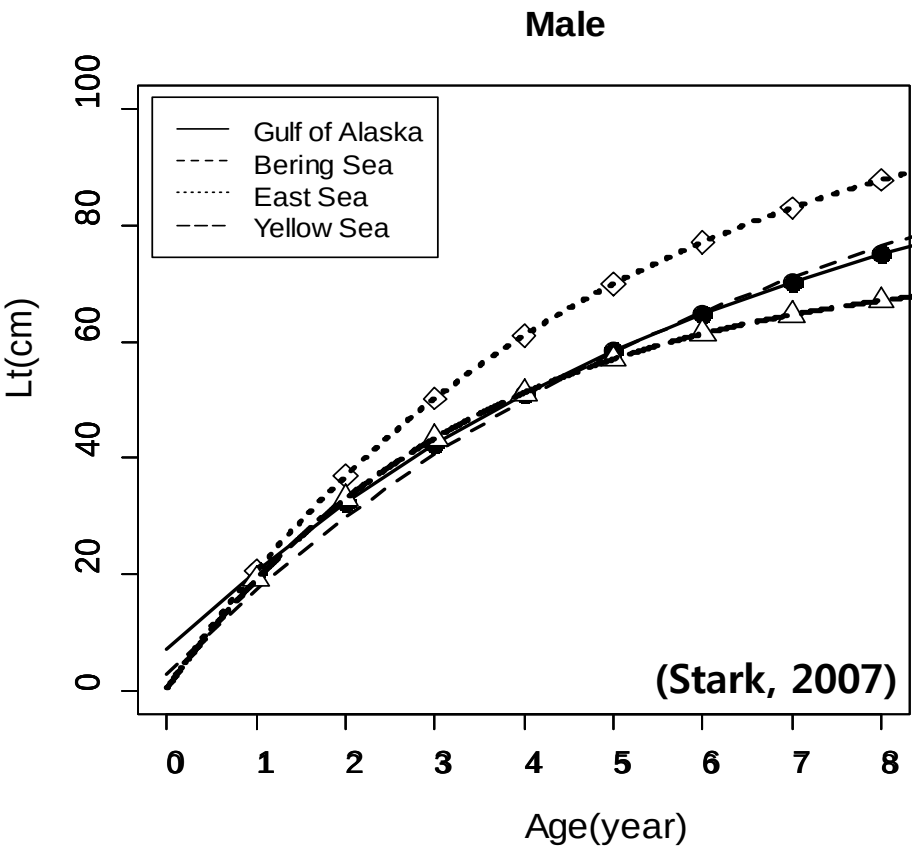
# Cause of regional differences in growth and maturity

- The Yellow Sea is the westernmost marginal area where cod can reside, and its environmental and feeding conditions are harsh compared with the East Sea.



# Basin-wide comparison of cod growth

- Korean waters vs Bering Sea vs Gulf of Alaska
  - ✓ Bering Sea cod grow faster than the cod in the Korean waters cod both male and female.




# Future studies

- Extended cod samples from the Yellow Sea and the Korea Strait.
- Environment and ecosystem comparisons between the Yellow and the East Sea.
- Effect of environment and feeding conditions on growth and maturation of Pacific cod.
- Additional comparative studies with other seas.

# Acknowledgement