Influence of ocean environment on a reduction of Japanese chum salmon (*Oncorhynchus keta*) body size

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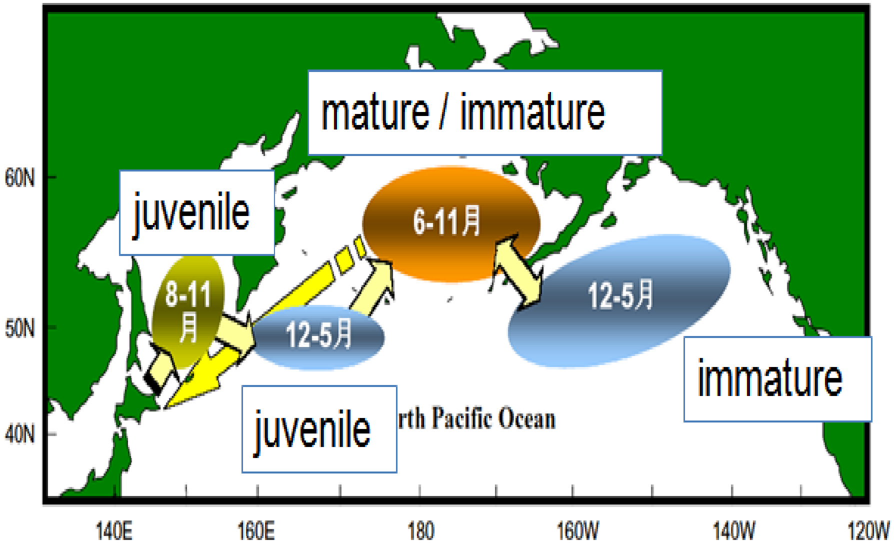
Introduction
Japanese chum salmon

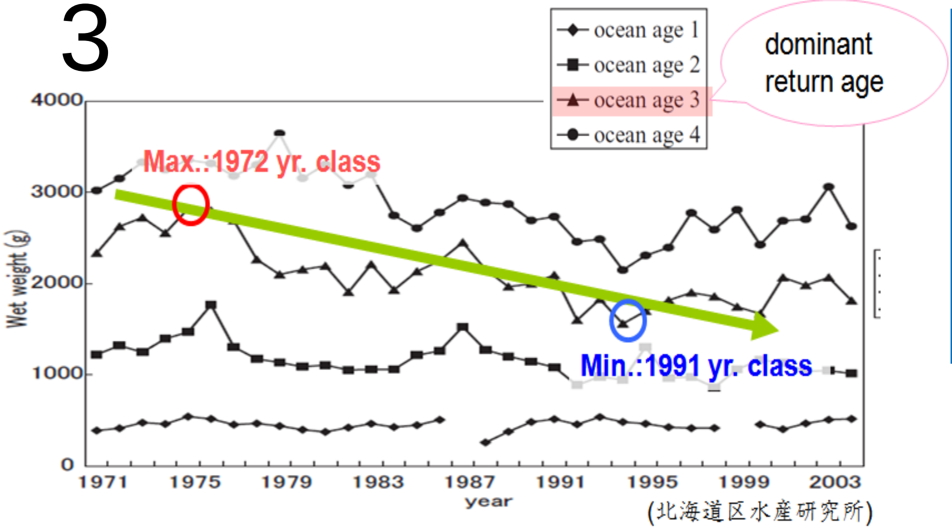
Migration route



(Urawa,2001)

●The Japanese chum salmon migrated from their natal rivers to the western North Pacific by way of the Okhotsk Sea.

● They migrates seasonally between the Bering Sea and the eastern North Pacific until they matures well.

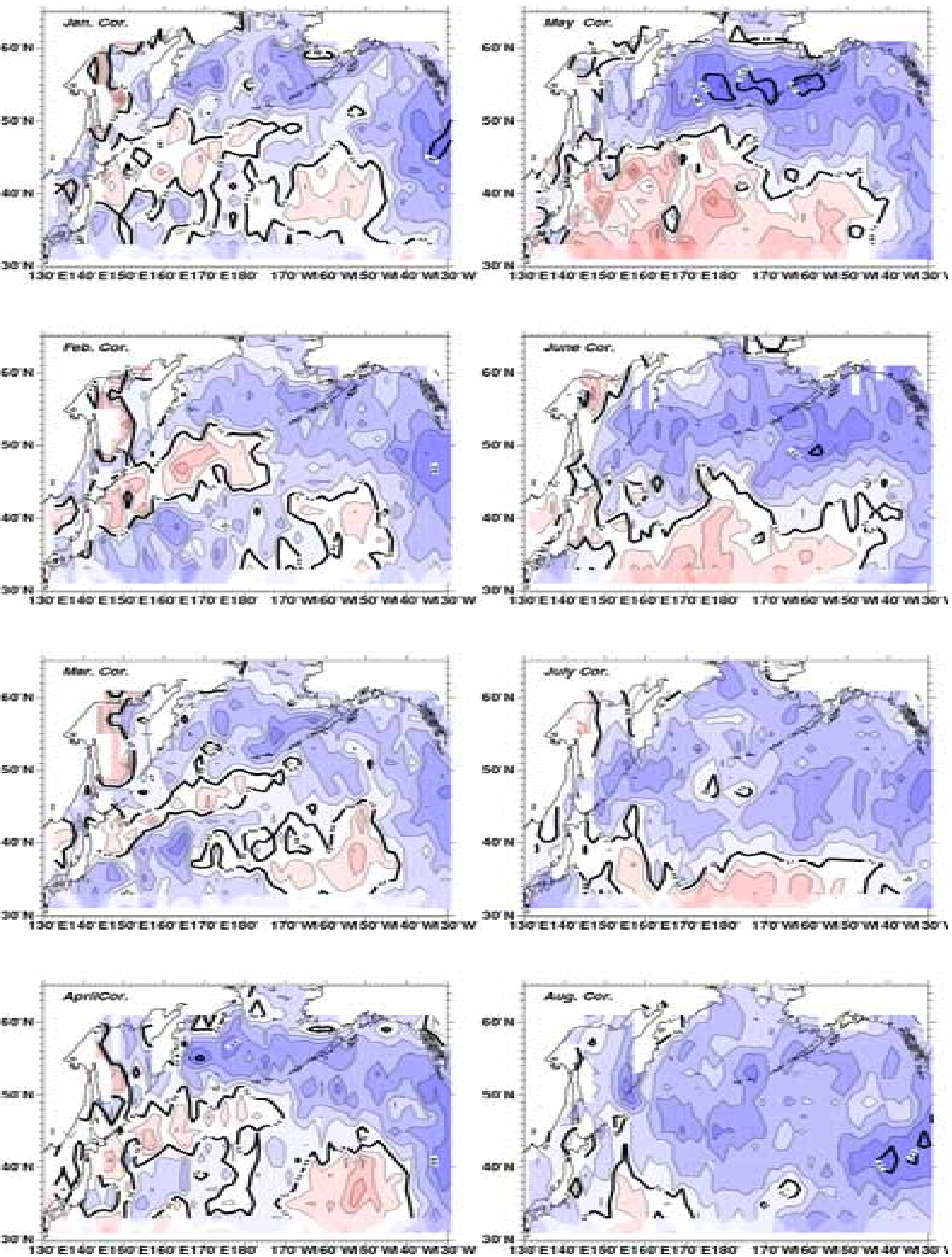


Historical change of body size

- The reduction of their body size was observed. Many studies pointed out that the fluctuation of climate and primary production effected them.

Objective

1. **When and Where did the size reduction occur?**
2. **What was the cause of size reduction?**

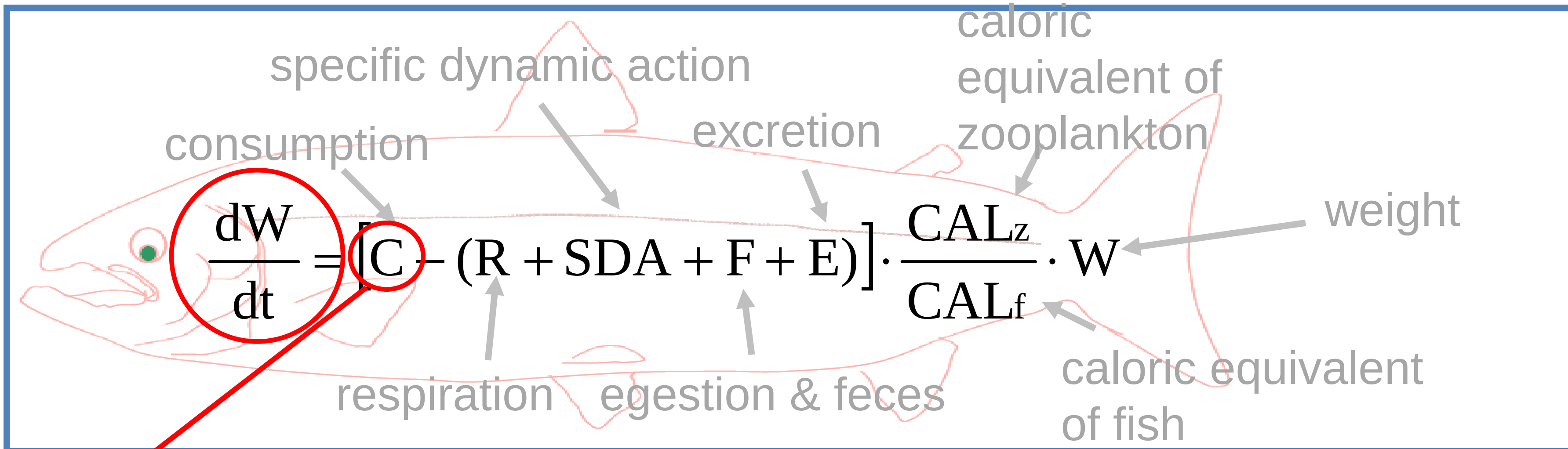


Horizontal distribution of correlation coefficient between SST and growth of chum salmon (from ocean age 2 to ocean age 3) from 1972 to 2004.
Red and blue regions show positive and negative correlation coefficient, respectively.

Temperature decrease (increase)
Growth of chum salmon increase (decrease)
Negative correlation

However, mechanism ?

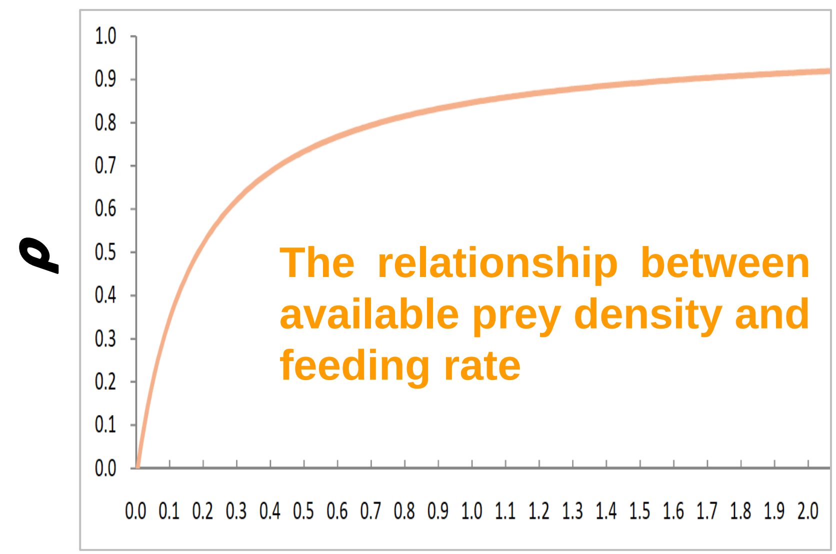
Governing equation of the bioenergetics model



$$\frac{dW}{dt} = [C - (R + SDA + F + E)] \cdot \frac{CAL_z}{CAL_f} \cdot W$$

$$C = C_{MAX} \cdot \rho \cdot f_c(T)$$

- C_{MAX} : maximum consumption rate ($C_{MAX} = ac \cdot W^{bc}$).
- ρ : prey density dependent function **(0< ρ < 1).**
- $f_c(T)$: temperature dependent function (**0<** f_c**(T) < 1**).



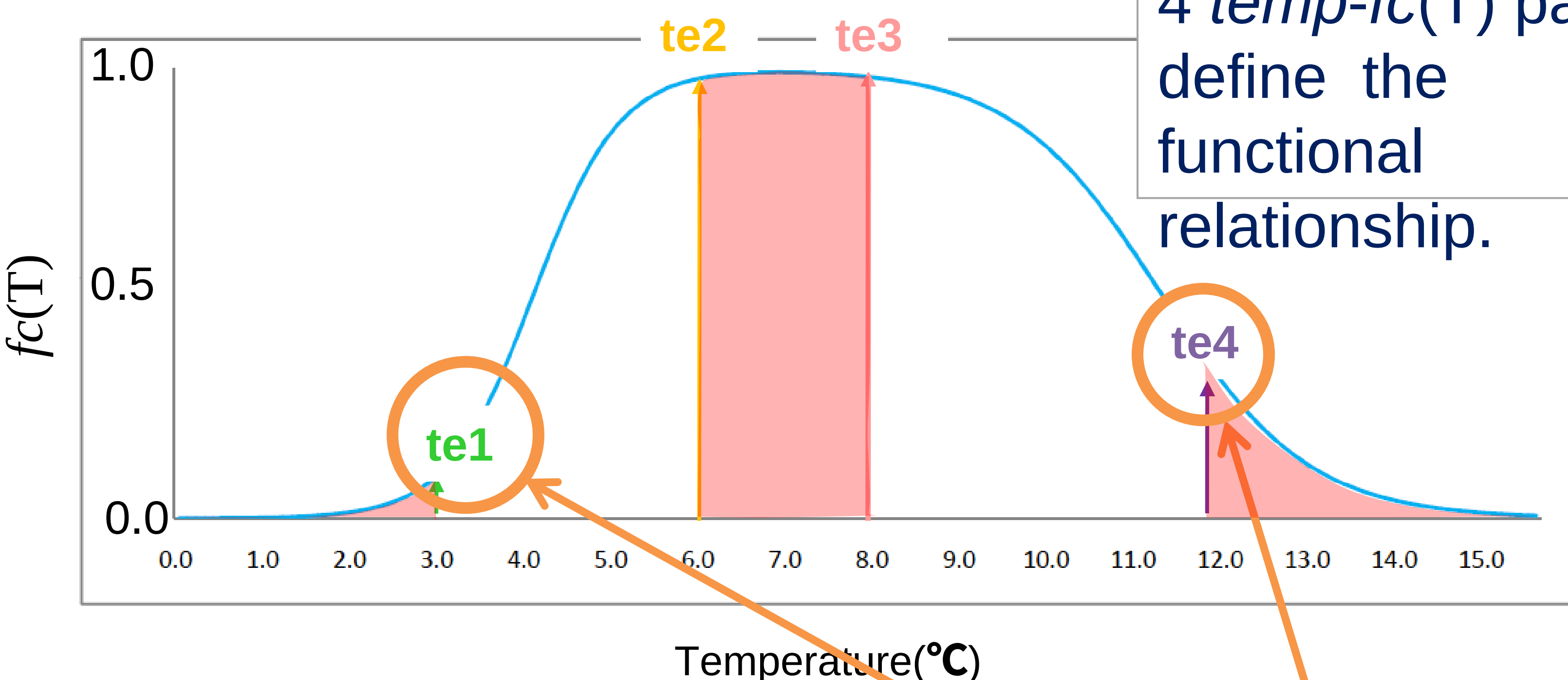
prey density (wwg·m^{-3})

fc(T) : Temperature dependent function

$$C = C_{MAX} \cdot \rho \cdot f_c(T)$$

(Megrey et al.,2002 ; Thornton and Lessen,1978)

4 *temp-fc*(T) pairs define the functional relationship.

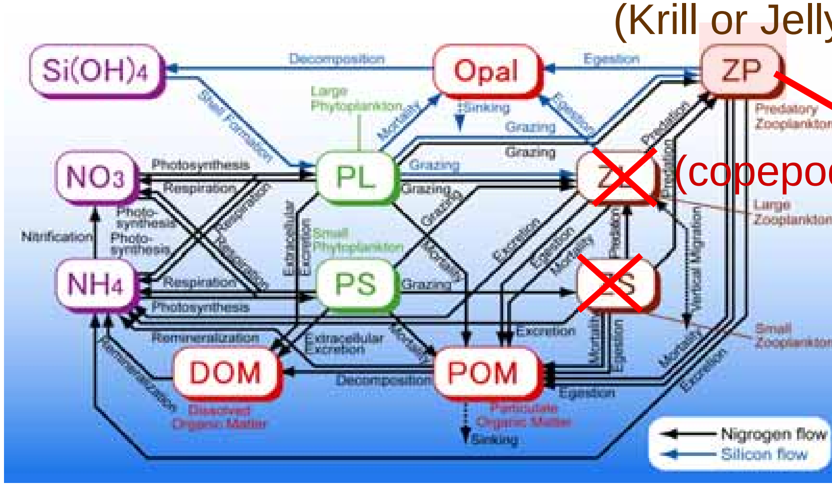


- temp. < **te1** :: unfit (too cold to grow)
- **te1** < temp. < **te2** :: less optimum
- **te2** < temp. < **te3** :: optimum
- **te3** < temp. < **te4** :: less optimum
- **te4** < temp. :: unfit (too hot to grow)

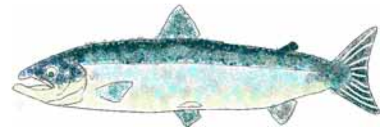
te1 & te4 value were decided according to observations (data logger research; Tanaka et al.,2005)

Input data

(Krill or Jelly fish)



(copepod)



Referring to Kaeriyama *et al*.(2004), we decided to use only ZP as prey zooplankton.

NEMURO developed by PICES Model Task Team

(North pacific Ecosystem Model Used for Regional Oceanography)

- The input data set (SST,Salinity and prey zooplankton density, verocity) was obtained from the result of NEMURO which is coupling **3-D** physical model (Aita *et al*.,2007).

- NEMURO is represented in Nitrogen unit (mol N・L^{-1}).

So, we converted NEMURO's value (ZP) into wet weight (wwg).

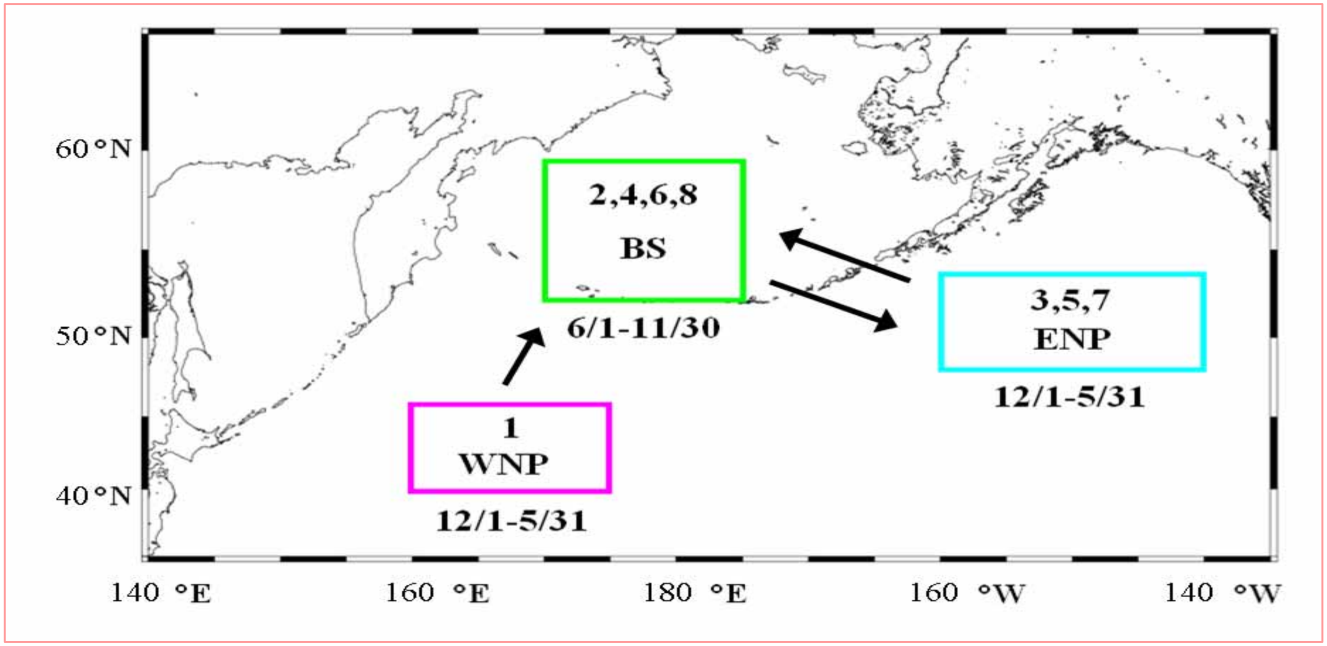
But the converted value is very small compared with observational. Therefore, we adjust the NEMURO's value (ZP) (wwg・m^{-3}) using observational data as follows;

$$\frac{\text{observational zooplankton value}}{\frac{1}{30}\sum_{1971\text{yr.}}^{2000\text{.yr}} \text{Sep.ZP value (Aita et } \mathit{al}\text{.2006)}} = 1.937$$

Prey value = 1.937・ZP (wwg・m^{-3})

Observation data: vertical distribution (mg・m^{-3}) in the Bering Sea in the daytime on Sep. 8-10th, 2003 (TINRO Center,Vladivostok,Russia ,NPAFC Doc.**769**)

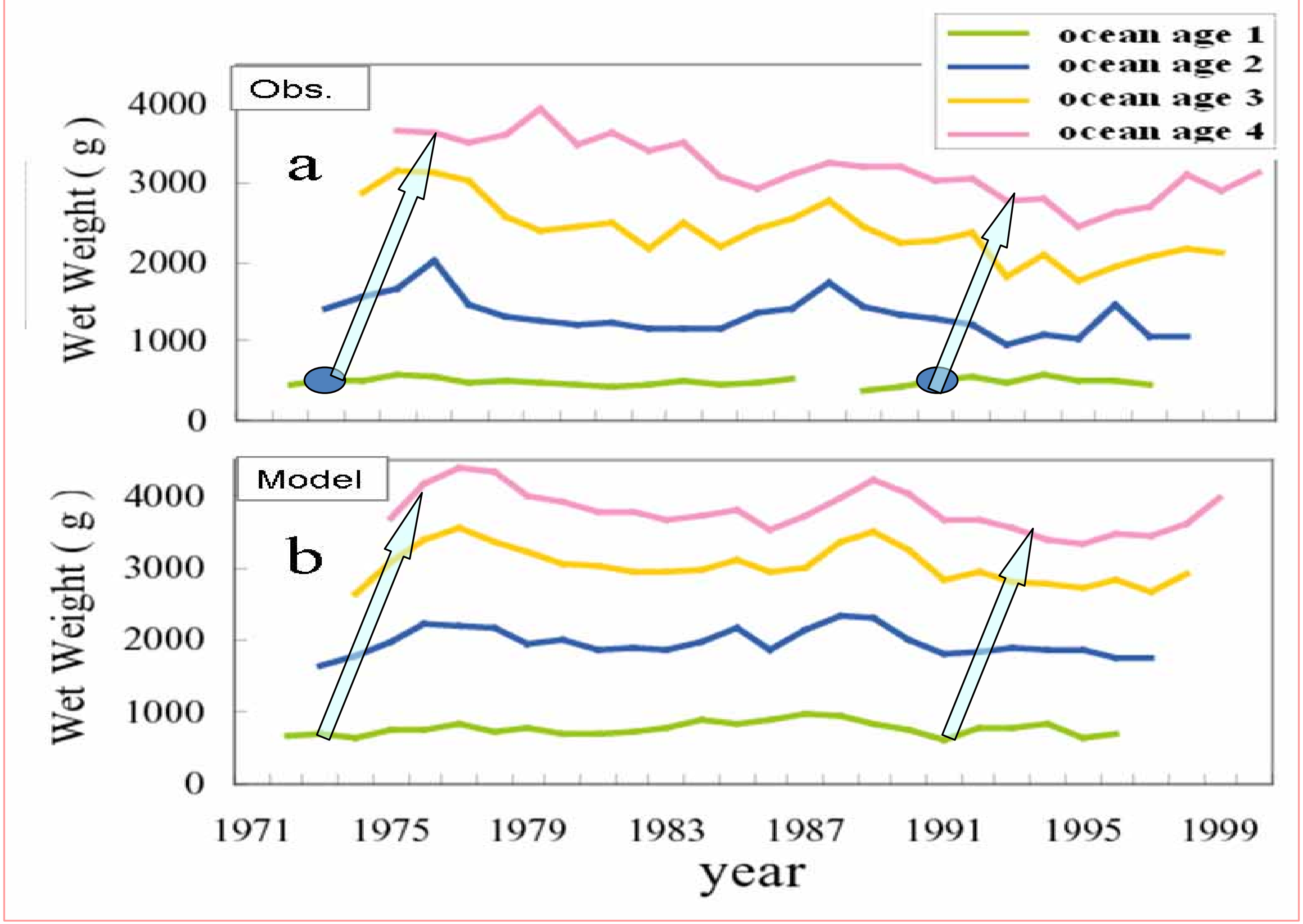
Migration route and model setting



Schematic view of the three oceanic spatial domains and the numbers of life stages simulated in the model. The three oceanographically domains correspond to the western north Pacific (WNP), Bering Sea (BS), and eastern north Pacific (ENP).

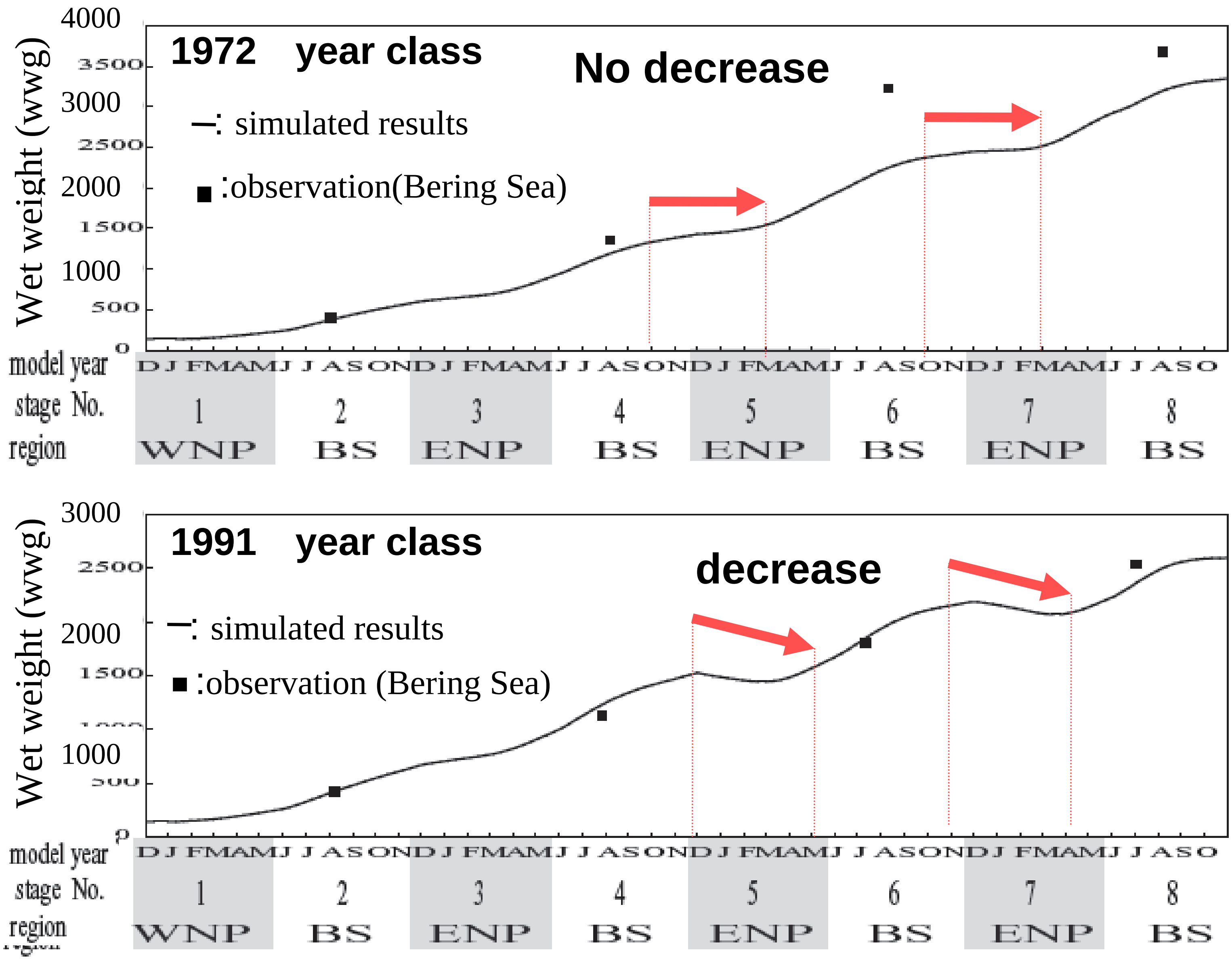
Model assumptions

1. No top down control from salmon to ecosystem.
2. No carrying capacity and no interspecific interaction.
3. Salmon instantaneously migrate between each domain.

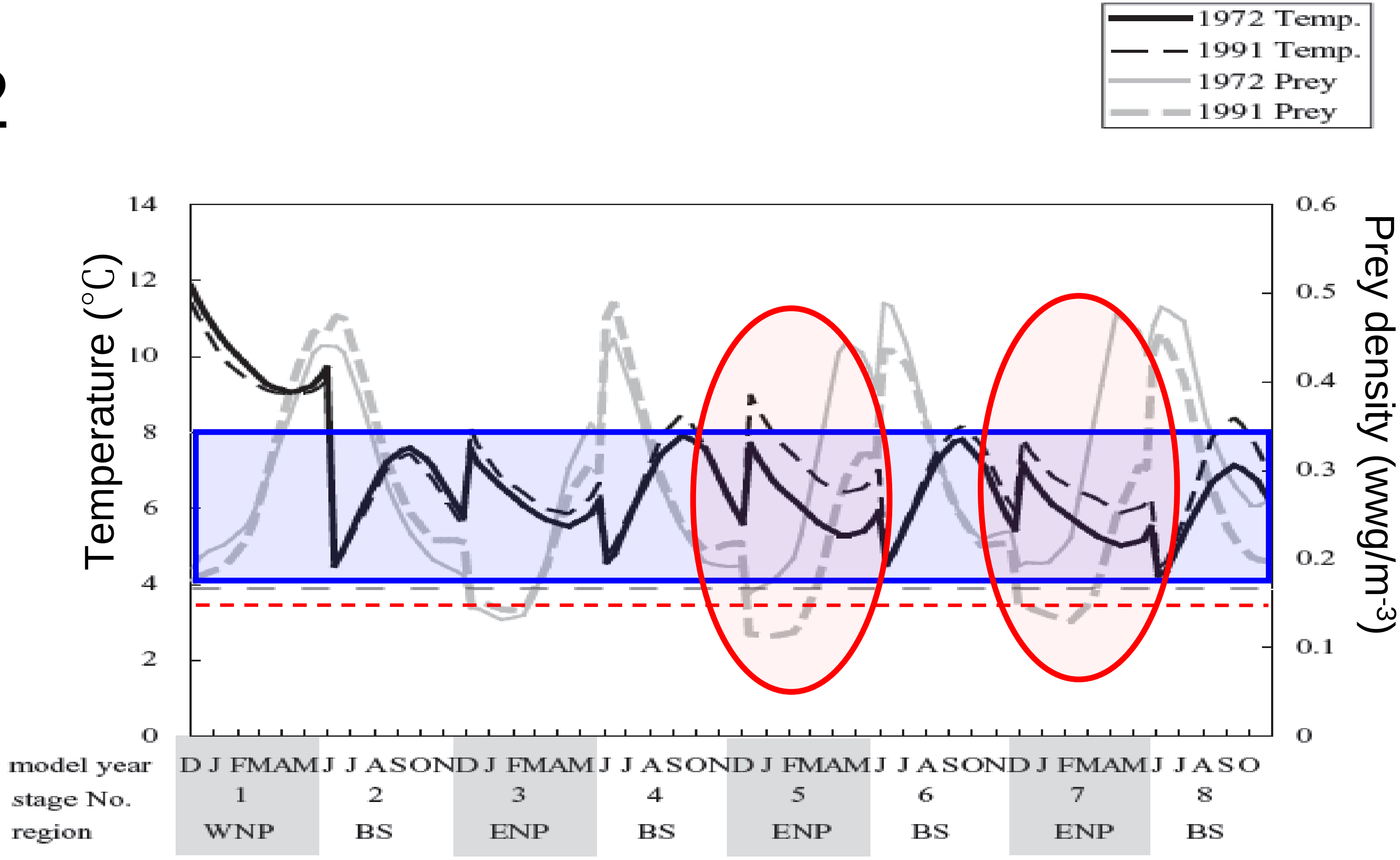


Interannual change in body size in the Bering Sea in summer from 1971 to 1999 (a) and simulated one (b).

Model can reproduce the reduction of body size, though the carrying capacity is not introduced into the model.



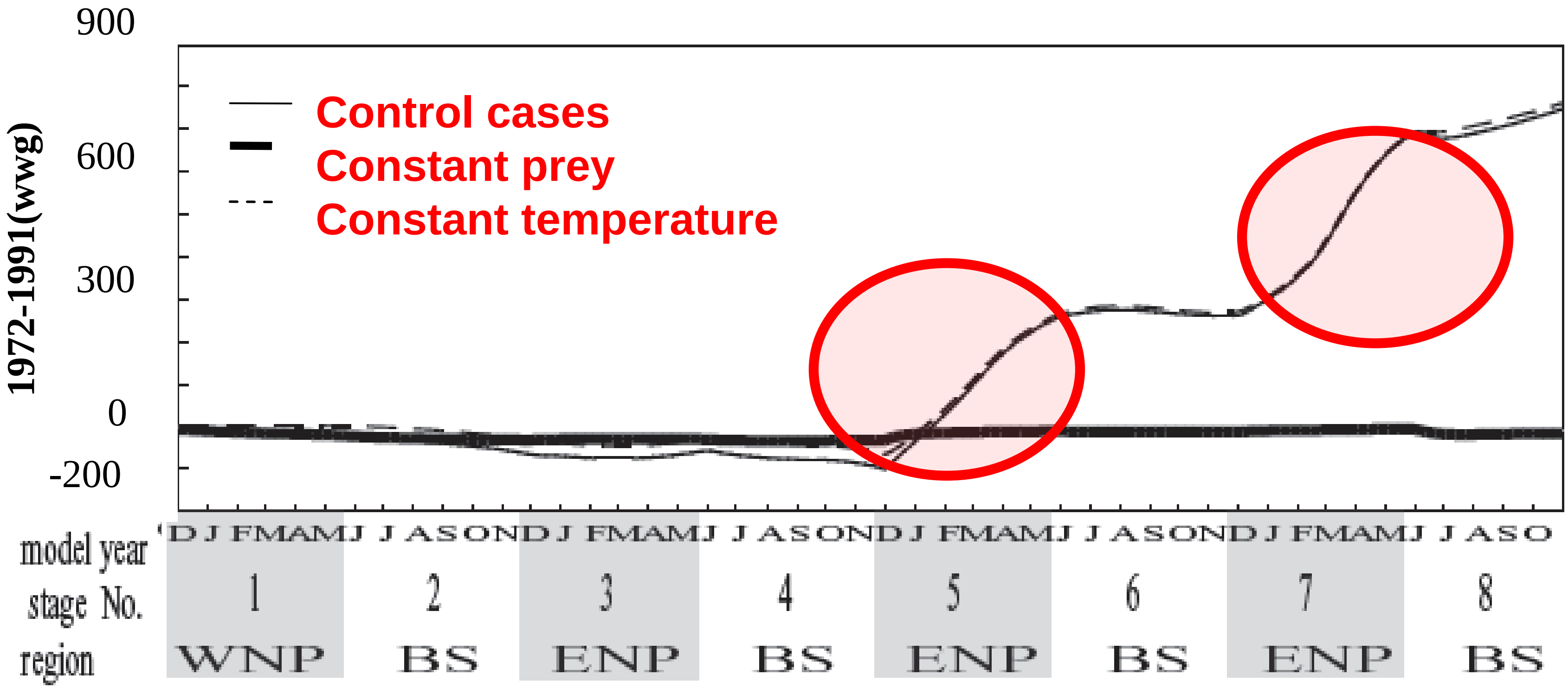
Simulated wet weight and observed one for 1972 year class (solid circles), and for 1991 year class (solid triangles).



Water temperature and prey densities that 1972 and 1991year class experienced.

The difference of prey density and temperature between 1972 and 1991 occurred from winter to spring in ENP (Gulf of Alaska).

The prey density in BS is enough for the growth of salmon.



The difference of wet weight between 1972 and 1991 year class, for control cases (thin line), for constant prey with time dependent temperature case (bold line), and for constant temperature with time dependent prey case (dashed line).

The difference of growth occurs from winter to spring in ENP.

The model can not reproduce the difference of growth by only temperature.

Summary

1. When ------ Winter and Spring
2. Where ------ The Gulf of Alaska
3. What ------ Prey density

Mechanism of size reduction

Temperature Low (High)

↓

Mixed layer Develop (Not develop)

↓

Entrainment of nutrient High (Low)

↓

Primary production High (Low)

↓

Prey density High (Low)

↓

Growth Increase (Decrease)

Indirect relationship

Suggestion from the model

- The size reduction is caused by the bottom up control.
- The prey density in summer in the Bering Sea is enough for growth of chum salmon.

Future study

- We need to consider
  the density effect,
  the competition with other species,
  and the realistic migration in the growth model.

Thank you.

If You have any question on the simulation model, please contact T. Azumaya: azumaya@affrc.go.jp