The impact of density - dependent processes on growth of Japanese sardine (*Sardinops melanostictus*)

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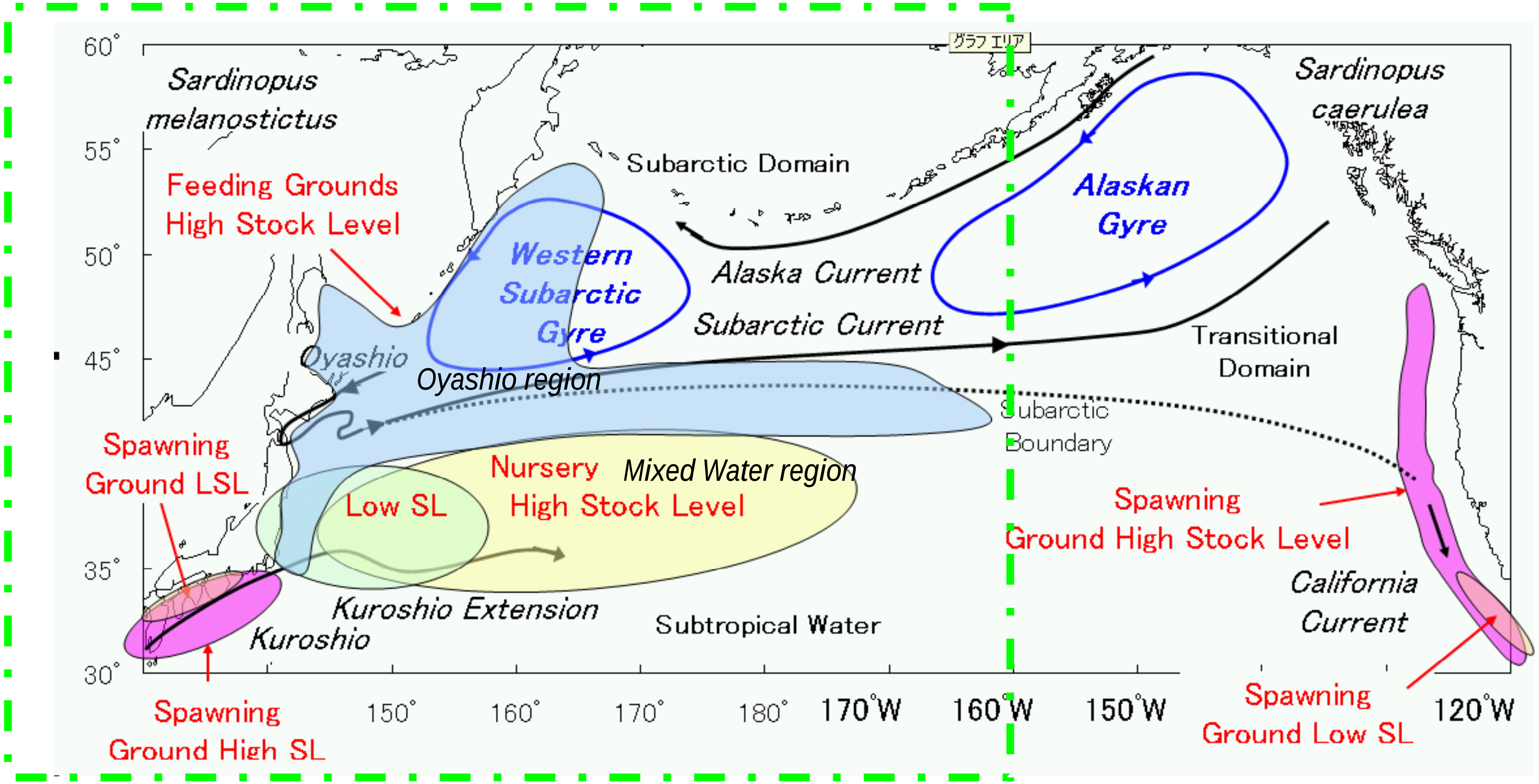
5. Graduate School of Environmental Science, Hokkaido University

POMAL Population Outbreak of Marine Life

Study for the prediction and control of the population outbreak of the marine life in relation to environmental change

CREST 戦略的創造研究推進事業
Core Research for Evolutional Science and Technology

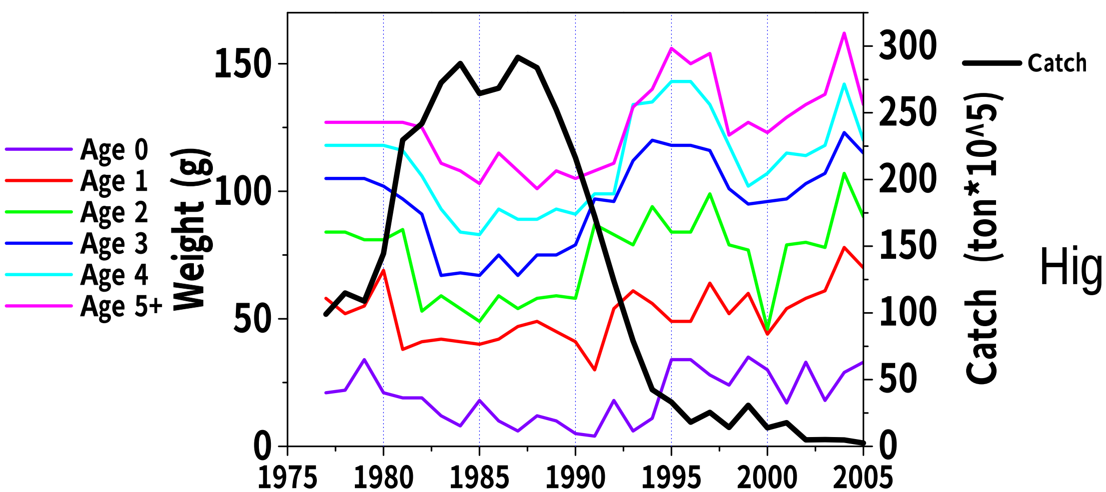
Japanese sardine habitats



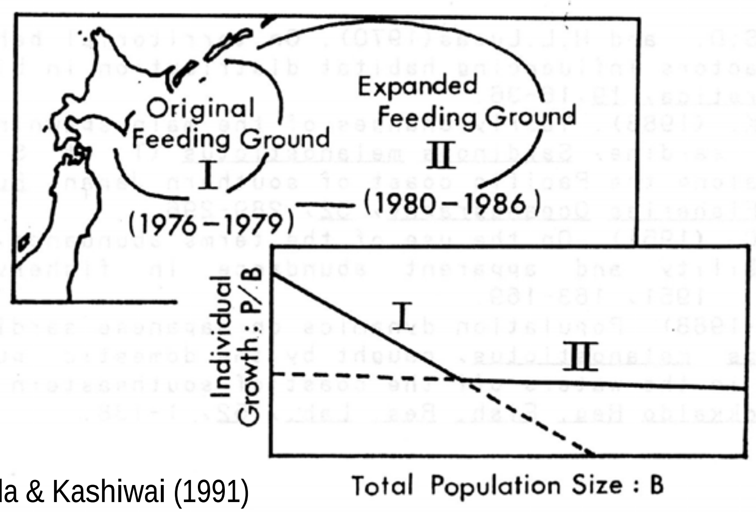
Courtesy of Dr. A. Yatsu

Back Ground

Weights & Catches of the Japanese sardine



High Stocks => Decreasing weighs (small size)



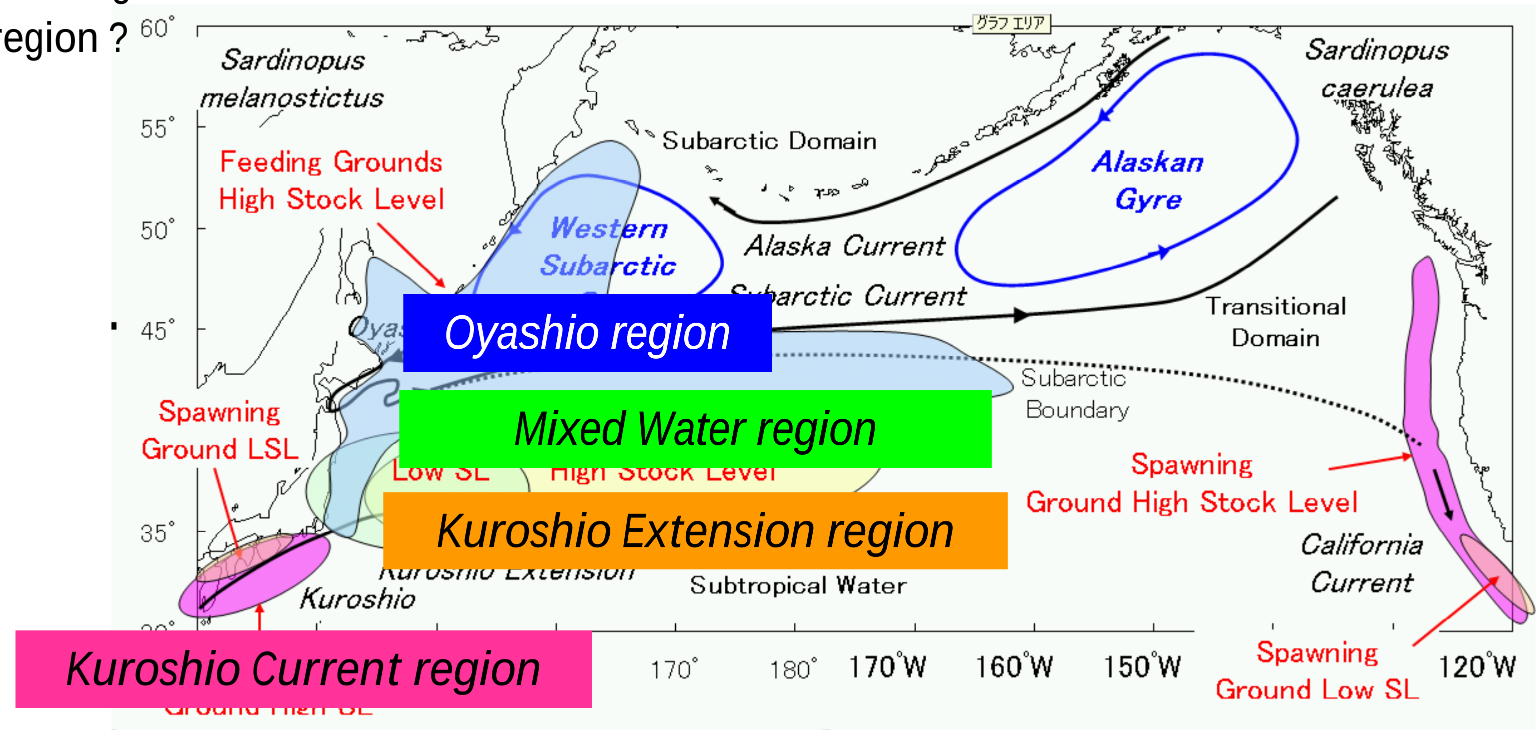
Wada & Kashiwai (1991)

High Stocks => Expanding feeding ground

These seem to be the effects of density-dependence.

Questions

- When would the deceleration of growth start in their life history?
  - Larval stage (Winter-early Spring) ?
  - Juvenile stage (late Spring -Winter) ?
- Where would the deceleration of growth occur?
  - Kuroshio Current region ?
  - Kuroshio Extension region ?
  - Mixed Water region ?
  - Oyashio region ?



Objective

- To investigate the impact of density-dependent processes on growth and distribution of Japanese sardine,
- we carried out a multi-trophic level ecosystem model including Japanese sardine under scenarios of high and low standing stocks.

Ecosystem Model

Climate Model

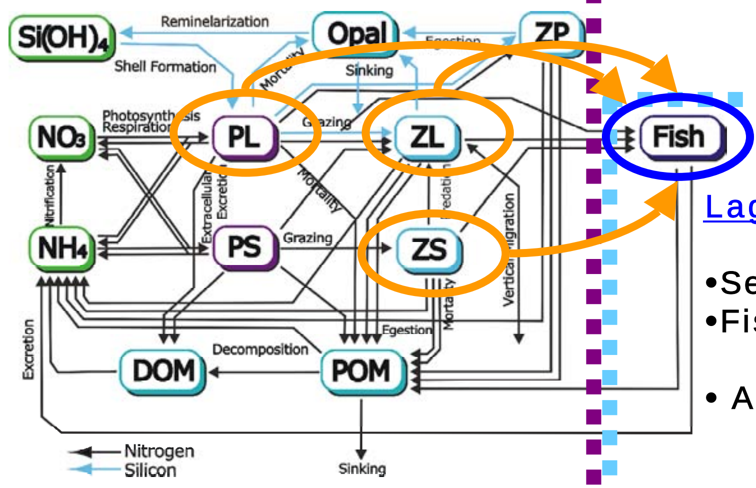
MIROC 3.2 (The CCSR/NIES/FRCGC Coupled Ocean-Atmosphere GCM)
Horizontal Resolution (Ocean Part): 1/4X1/6

Forcing at the year 1900

Simulated

Velocity Field
Temperature
Salinity
Vertical Diffusivity,
Solar Radiation
etc..

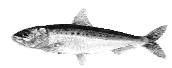
3D- Lower Trophic Ecosystem Model (NEMURO)



Forcing

Climetological physical fields

Sardine Migration Model
(Okunishi et al ,E.M. accepted)



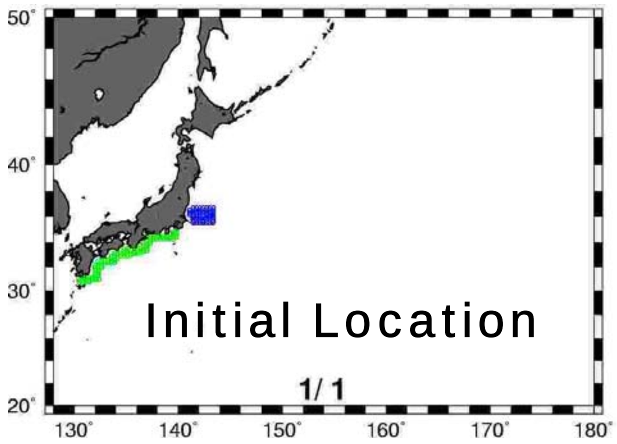
2D - Individual Based Model (IBM)

Lagrangean Model
for simulating migration
- **Sea surface current** from climate model
- **Fish swim** by searching for local optimal habitats during feeding migration.
- Adult fish is strongly oriented in homeward direction during spawning migration.

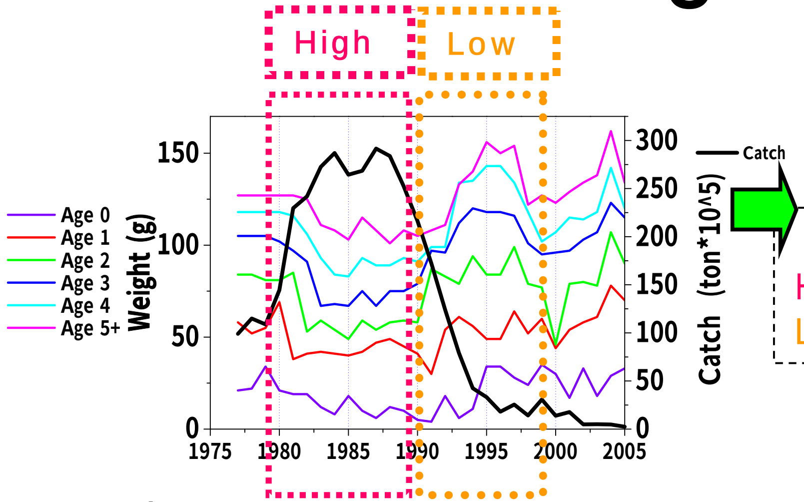
Bioenergetics Model
for simulating growth
- **SST** from Climate model
- **Forage density** from NEMURO

<Population & Mortality>
1. Super-individuals were used to allow the IBM to represent the sardine population.
2. The internal number in a super-individual is reduced due to mortality.
3. Mortality rate
   Early larvae: 0.075 / day (Kuroda, 1991)
   Late larvae : 0.01 / day (Kuroda, 1991)
   Juvenile– Adult: 0.001/day (Kawai, 1987)

Experimental Setting



Age 0 ● Spawning regions (Larvae)
Age 1 ● Wintering places (Juvenile)
Age 2+ ● Spawning regions (Adult)



Scenarios

High stocks：1978-1989
Low stocks：1990-1998

Initial Condition

Particle number (Model)

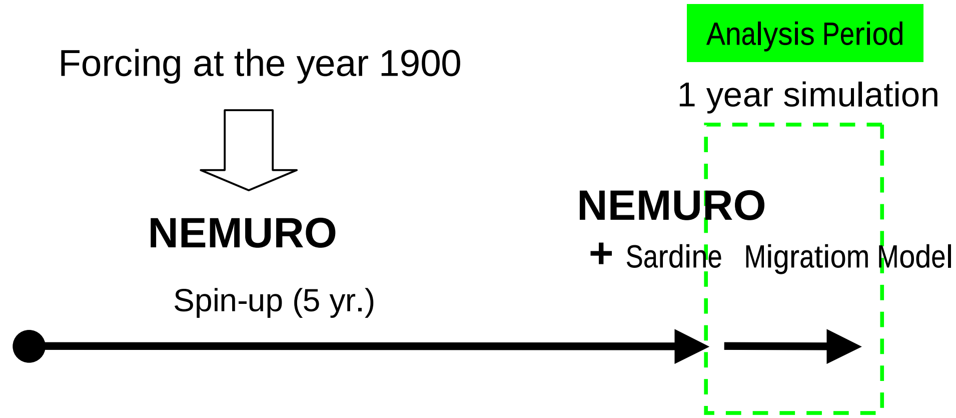
	Age 0	Age 1	Age 2+
High Stocks and Low Stocks	9,000	5,200	9,000

Stock abundance in particle[10^6 individual / particle]

	Age 0	Age 1	Age 2+
High Stocks (1978-1989)	93.3	34.6	21.9
Low Stocks (1900-1999)	5.9	1.9	3.2

Initial weight (g)

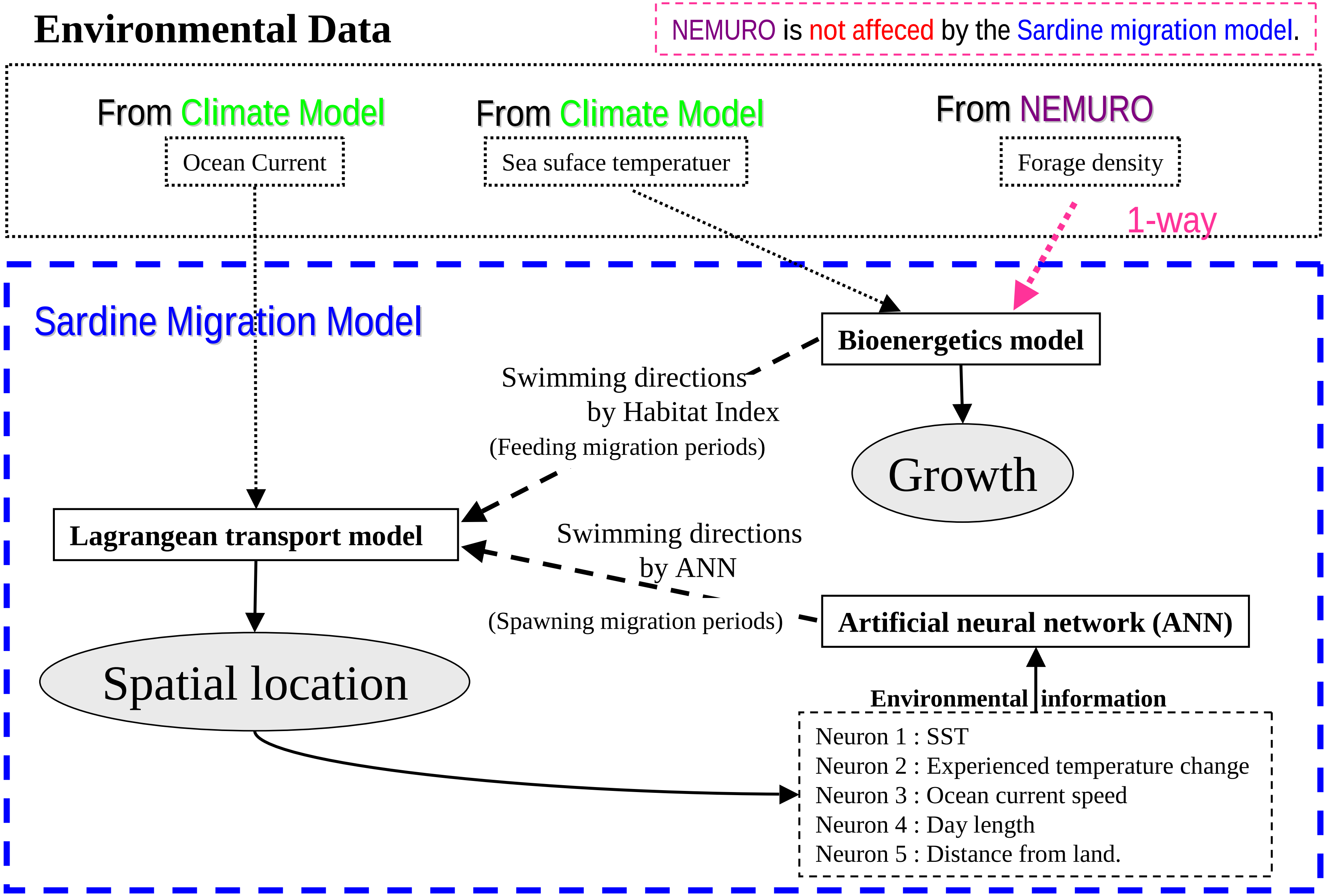
	Age 0	Age 1	Age 2+
High Stocks and Low Stocks	1.5×10^{-3}	18	49



3 Case Simulations

Simulation 1 (S1): 1-way model, Low stocks
Simulation 2 (S2): 2-way model, Low stocks
Simulation 3 (S3): 2-way model, High stocks

One-way model



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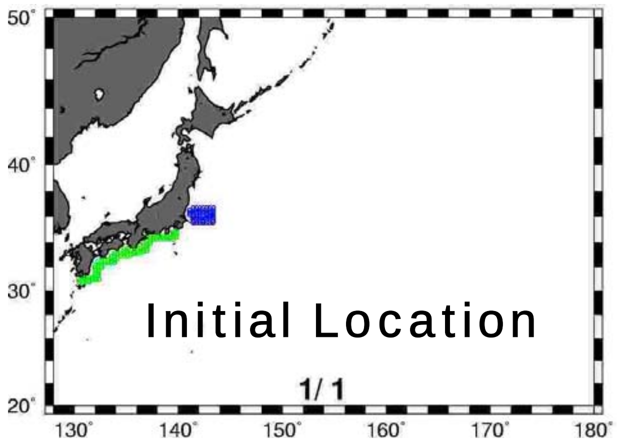

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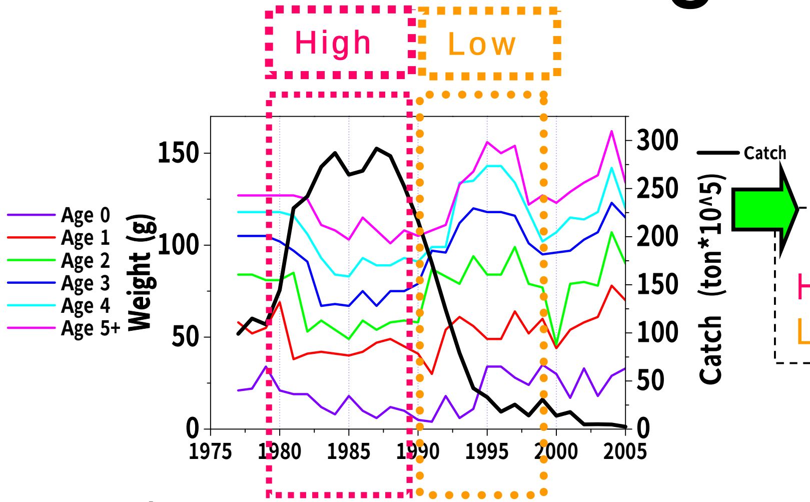

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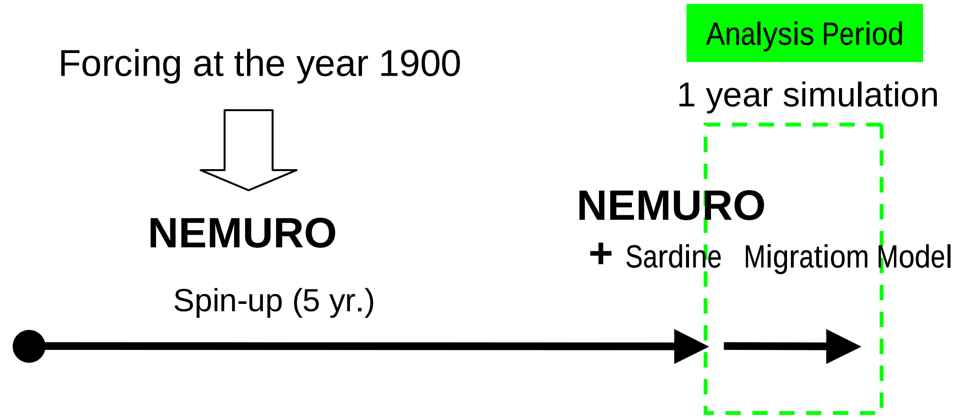

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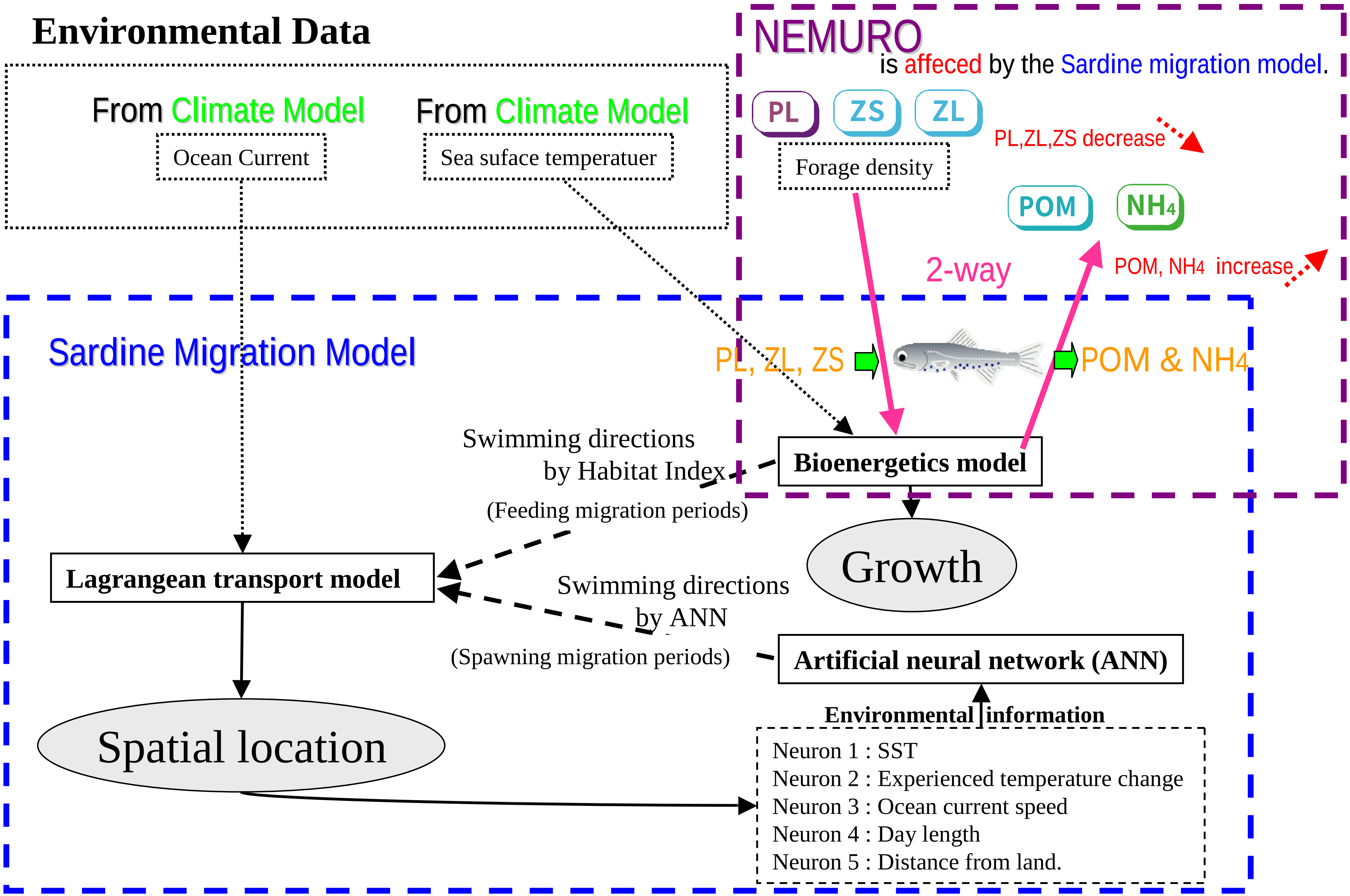
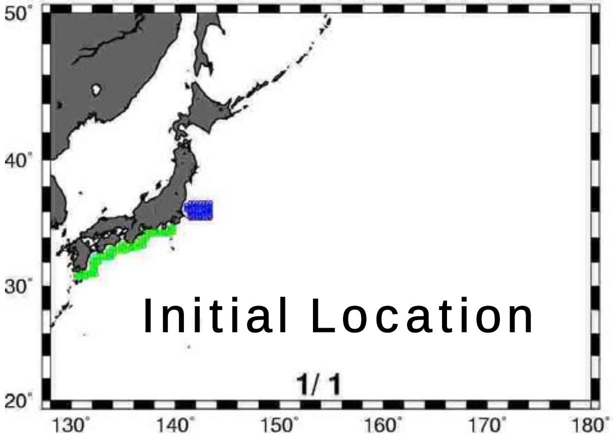
Simulation 3 (S3): 2-way model, High stocks

Two-way model



Experimental Setting



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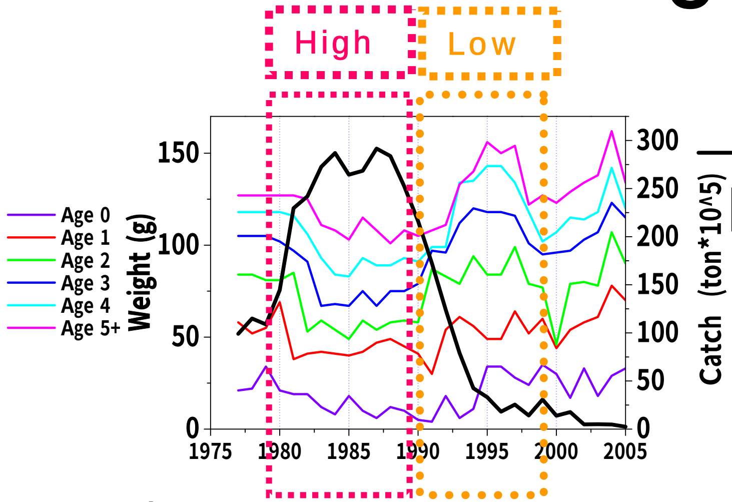

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High stocks : 1978-1989
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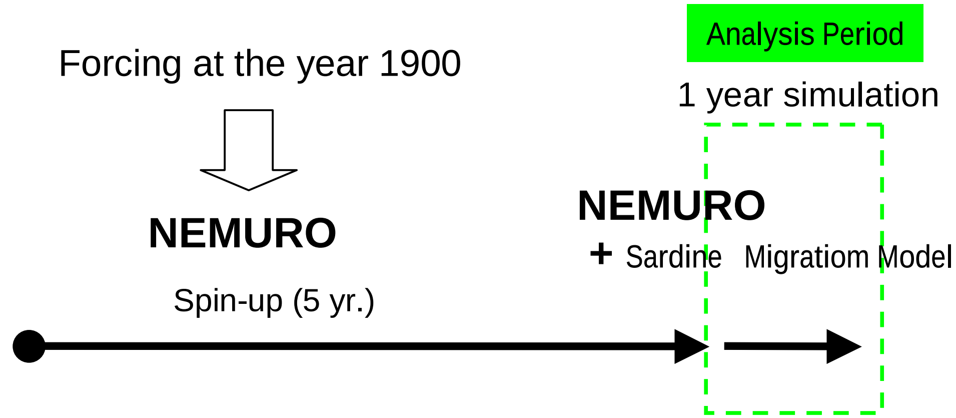

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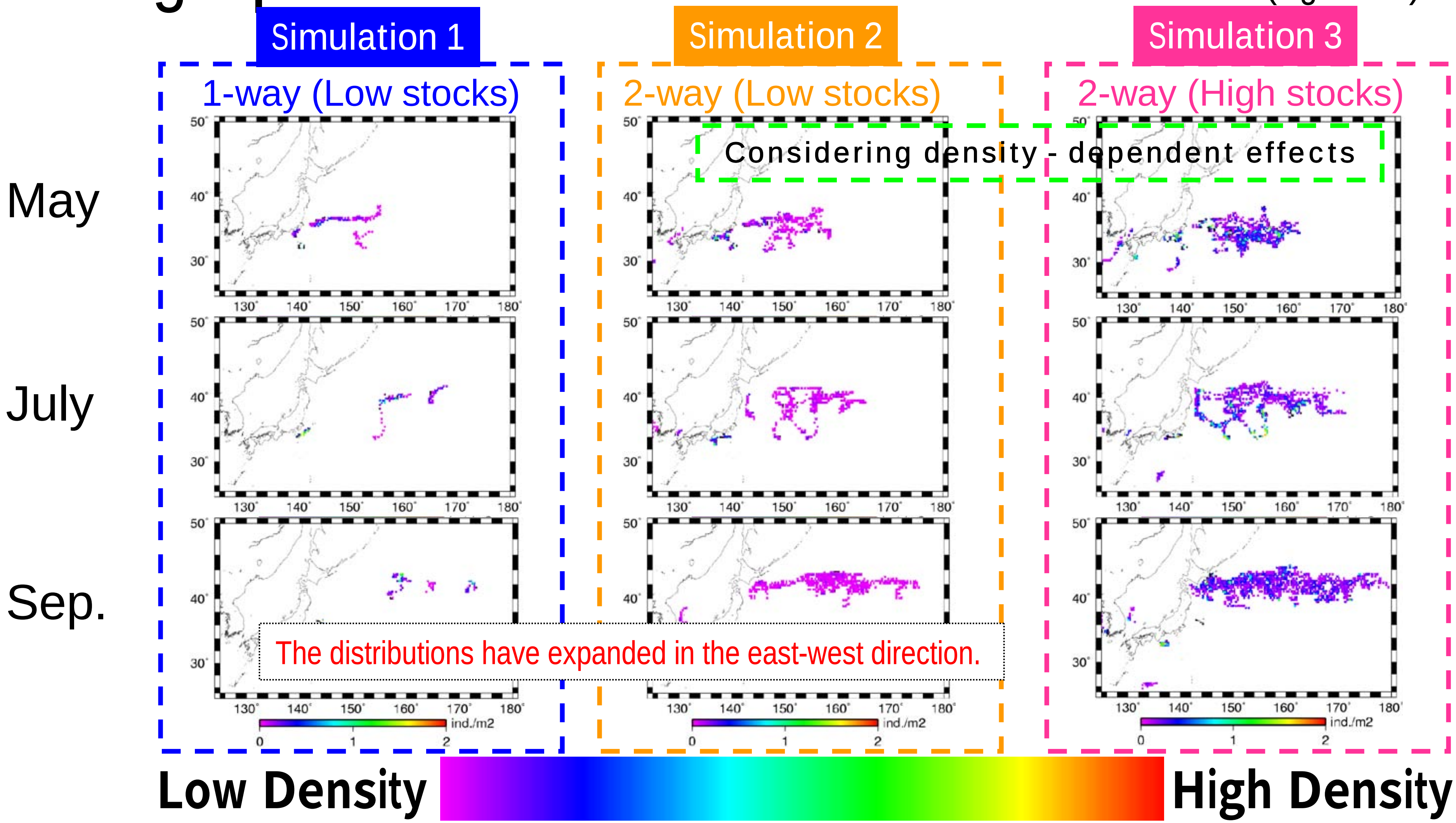
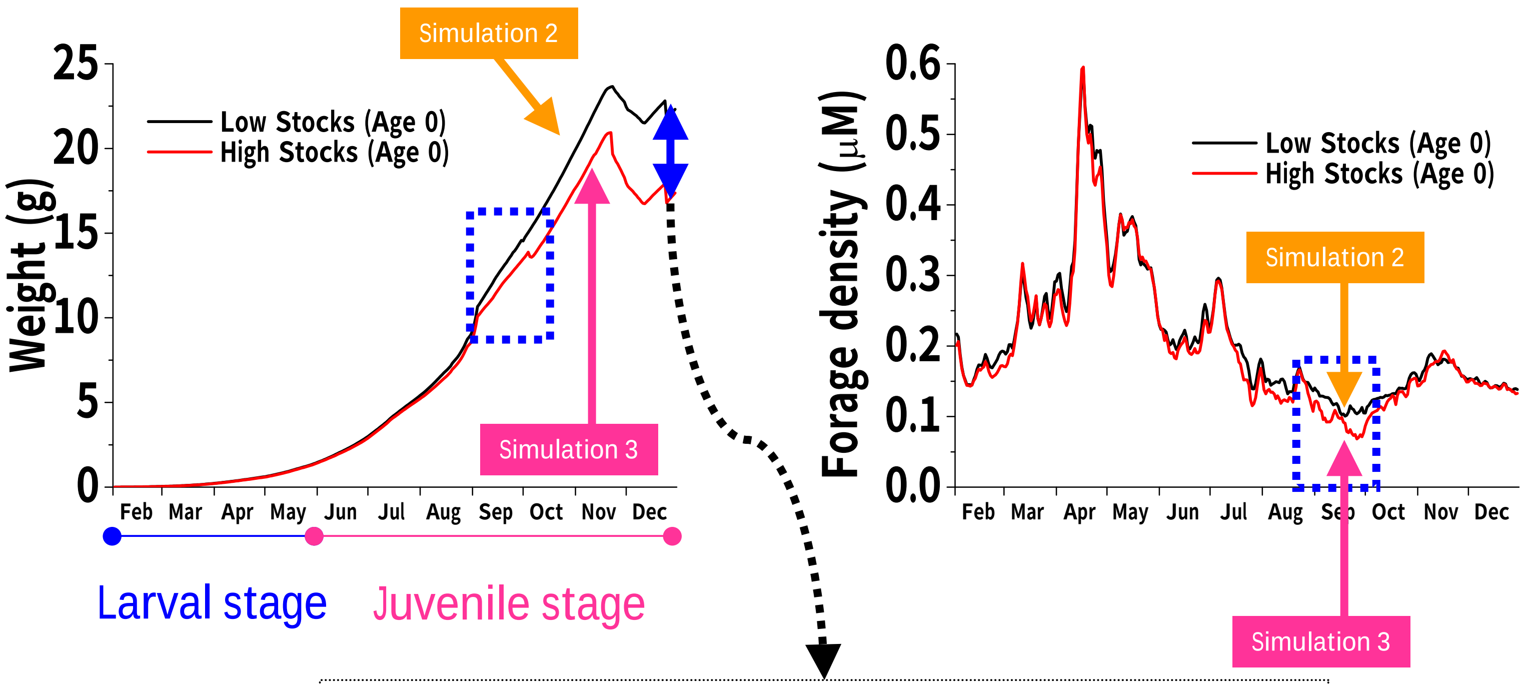
Geographical Distributions of Adult fish (Age = 2+)



- High Stocks ⇒ Low Forage density ⇒Expanding feeding ground

•Under the scenario of high standing stocks, the occupied regions by adult sardine cover widespread areas.
•The impact of density-dependent on distributions is strong.
•Model results appear to provide support for the hypothesis of density-dependent habitat selection.

Average weight

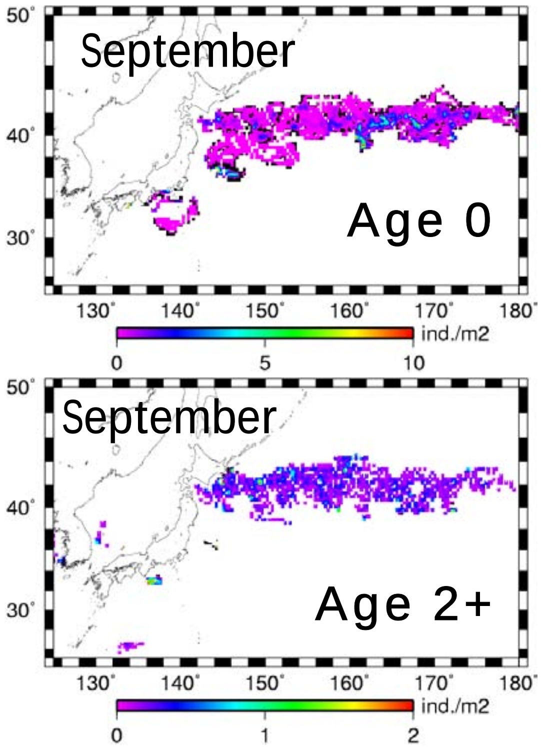


Difference in weight between S2 and S3 after 1 year
Model : 4.9g
Observation : 4.0 g

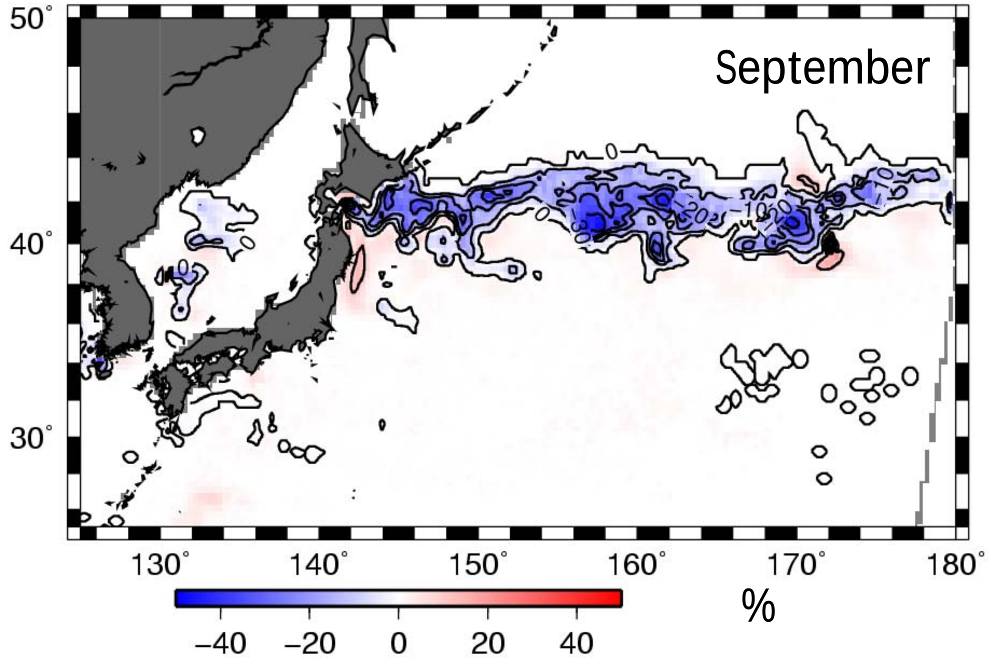
In early autumn, Age 0 fish has slowly growth rate under the scenario of high standing stocks because forage density becomes significantly low.

In early autumn

Geographical Distributions



Anomaly of Forage density (PL + ZS + ZL)



- Forage density is lower by 10 to 20 % in the Mixed water and Oyashio regions in the S3 than that in S2 due to high feeding pressure of adult sardine.
- The deceleration of growth at Age 0 fish becomes marked in the Mixed Water and Oyashio regions in early autumn.

Summary

- The model reproduced the expanding distributions by the effect of density-dependent.

- When would the deceleration of growth start in their life history?
- Where would the deceleration of growth occur?
- Model results suggest that the deceleration of growth of sardine starts at the juvenile stage in the Mixed Water and Oyashio regions .

- The effect of density-dependence among trophic levels and fish seems to be one of the most important factors which determine the geographical distribution of adult sardine and growth of young sardine.