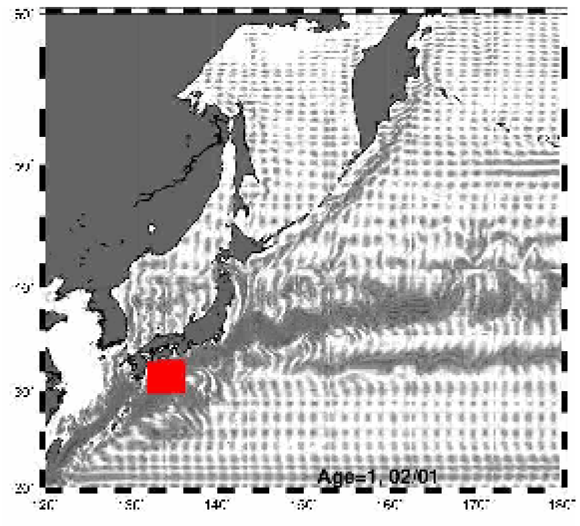
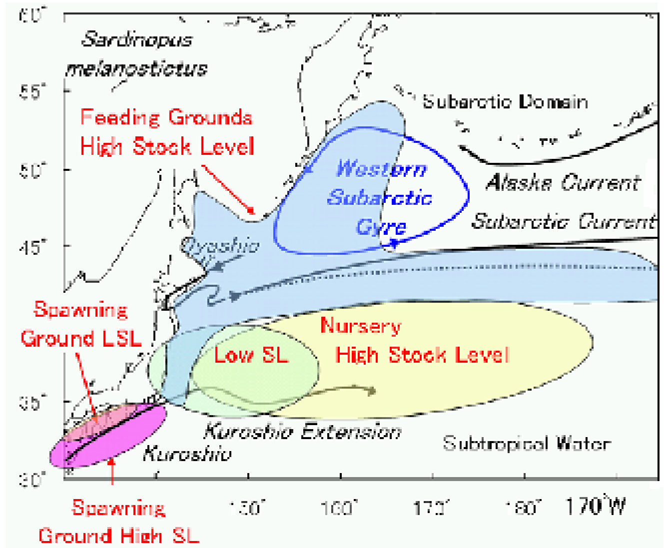
A migration model of Japanese sardine using artificial neural network



Model Results (2 Years)



Courtesy of Dr. A. Yatsu

Takeshi Okunishi[1], Yasuhiro Yamanaka[2,3,4], Shin-ichi Ito[1]

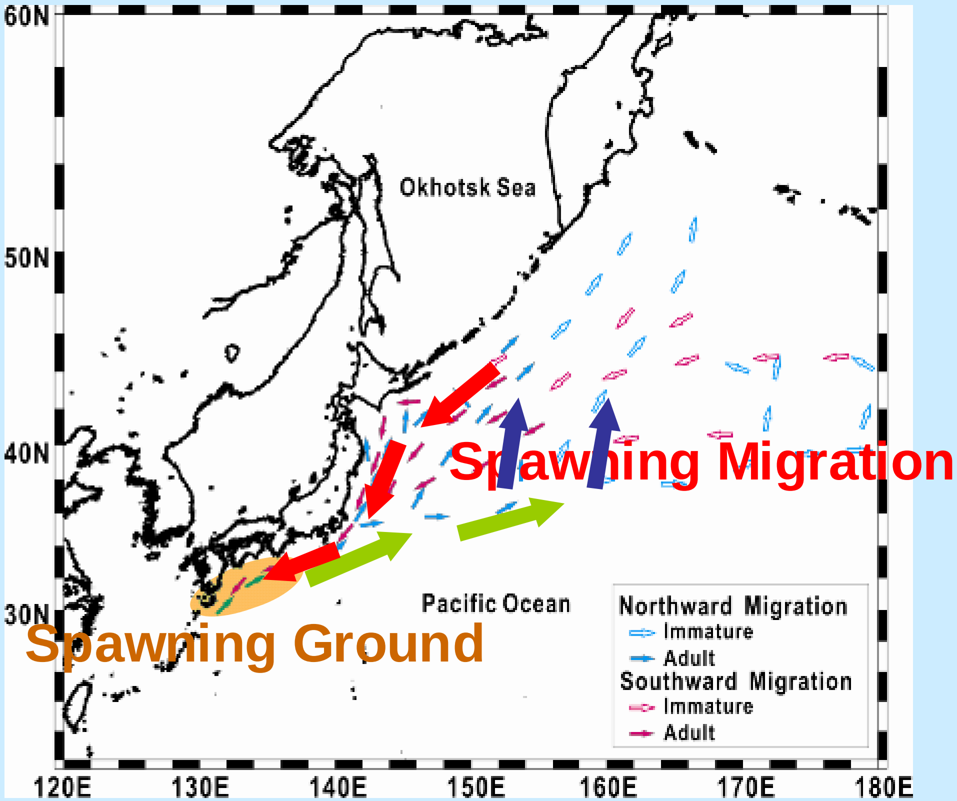
- **1 Tohoku National Fisheries Research Institute, Fisheries Research Agency**
- **2 Graduate School of Environmental Science, Hokkaido University**
- **3 Core Research for Evolutional Science and Technology, Japan Science and Technology Agency**
- **4 Frontier Research Center for Global Change, Japan Agency for Marine-Earth Science and Technology**

Purposes of this study

- The stock has exhibited dramatic changes.
- The stock fluctuation is related to interdecadal North Pacific ocean/climate variability (Yasuda et al., 1999).
- To produce a forecast of climate impacts on the production and distribution of Japanese sardine, we developed a horizontal 2D-model coupled fish bioenergetics.
- A key is how to reproduce the spawning migration of Japanese sardine.

Spawning Migration

- **Adult fish return to spawning grounds along the Pacific coast of Japan during autumn and winter.**



Presumed northward migration (Feeding migration) and southward migration (Spawning migration) according to Kuroda (1991).

A migration model of Japanese sardine

- **Model (Individual Based Model)**
  - Bioenergetics Model
  - Lagrangean Model

Transport & Movement

$$x^{n+1} = x^n + \left(U_1 + [U_2 \, or \, U_3]\right) \cdot \Delta t + R$$

U_1: Passive transport (ocean current)

U_2: Feeding migration
(Search for local optimal habitats)

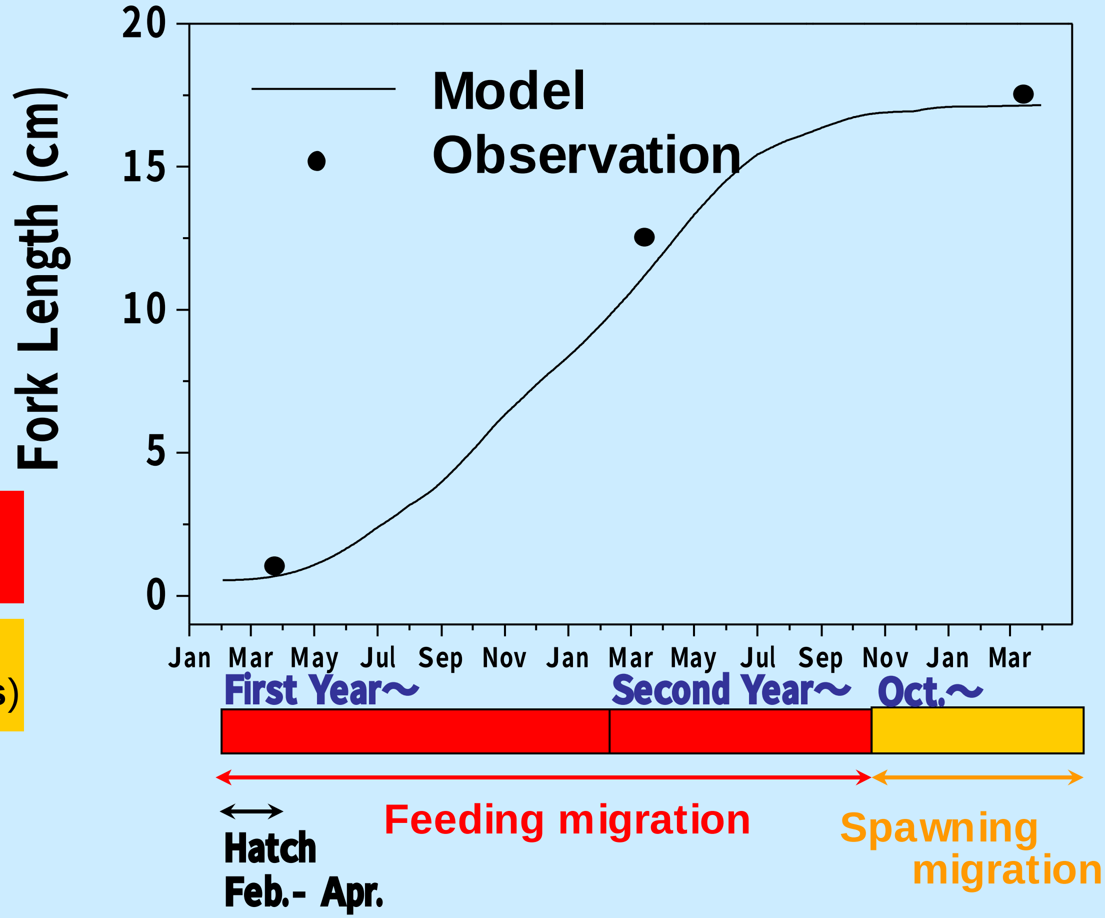
U_3: Spawning migration
(using an **Artificial neural networks**)

Swimming speed = 3 Body Length s^{-1}

R : Diffusion $R = r \cdot \sqrt{2 \cdot \Delta t \cdot D}$

r : normal random number $(-1 \sim 1)$

D : diffusion coefficient



- **Total Egg Number=29,192**
- **Mortality rate = 0.**

- **Data**
  - Ocean Current : Annually averaged currents by Sakamoto et al.,(2005)
  - SST : Monthly mean SST on World Ocean Atlas 2005 (WOA05)
  - Chl-a : monthly climatology Chl-a concentration on the SeaWiFS
  - Zooplankton Biomass = 0.3 * Phytoplankton Biomass

Bioenergetics Model for Sardine

The bioenergetics sub-model is based on the model of the North Pacific Ecosystem Model for Understanding Regional Oceanography For Including Saury and Herring; NEMURO.FISH (Megrey & Kishi, 2002)

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

change of weight

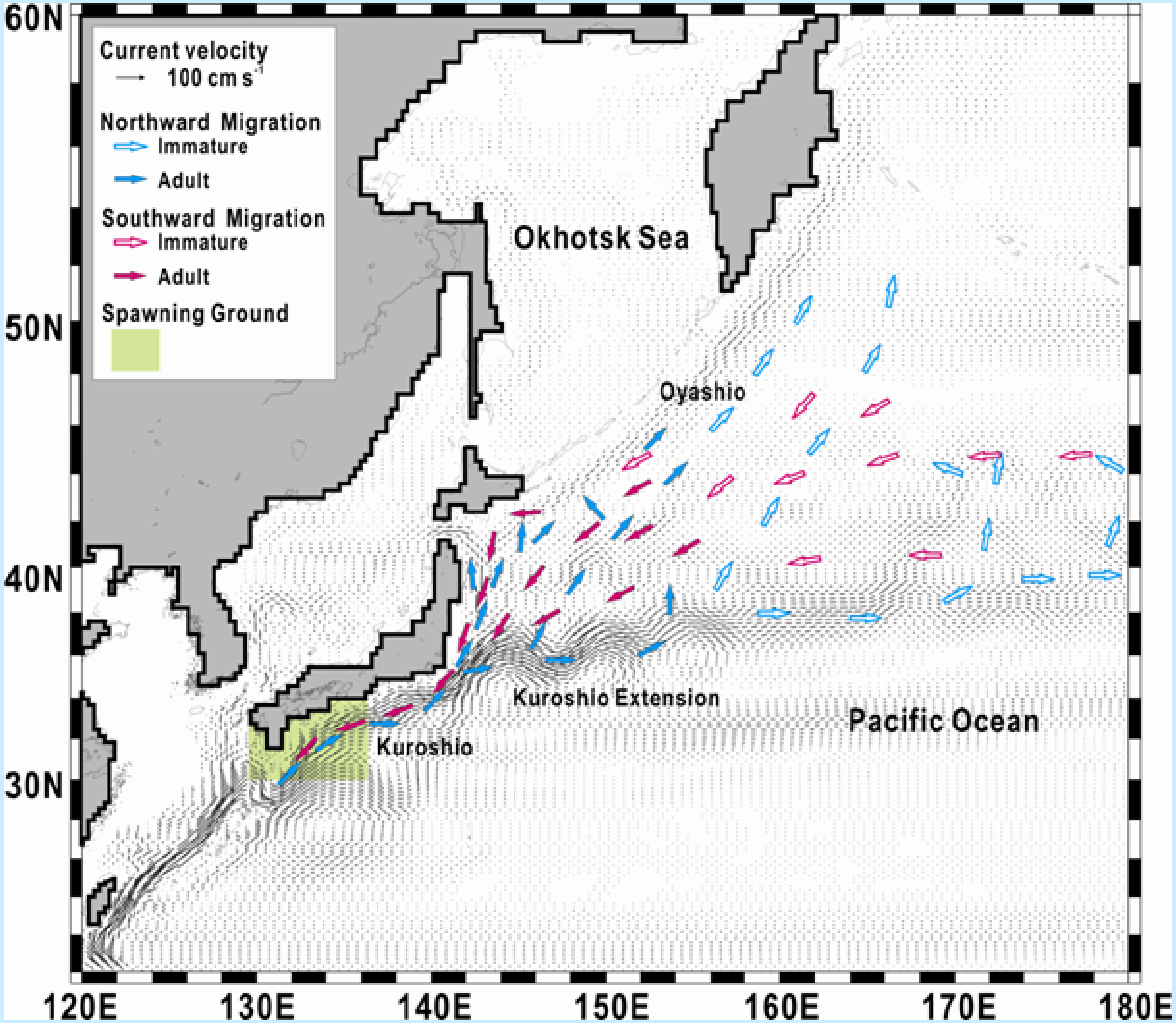
C: consumption

R: respiration (loses through metabolism)

S: specific dynamic action (digesting food)

F: egestion

E: excretion



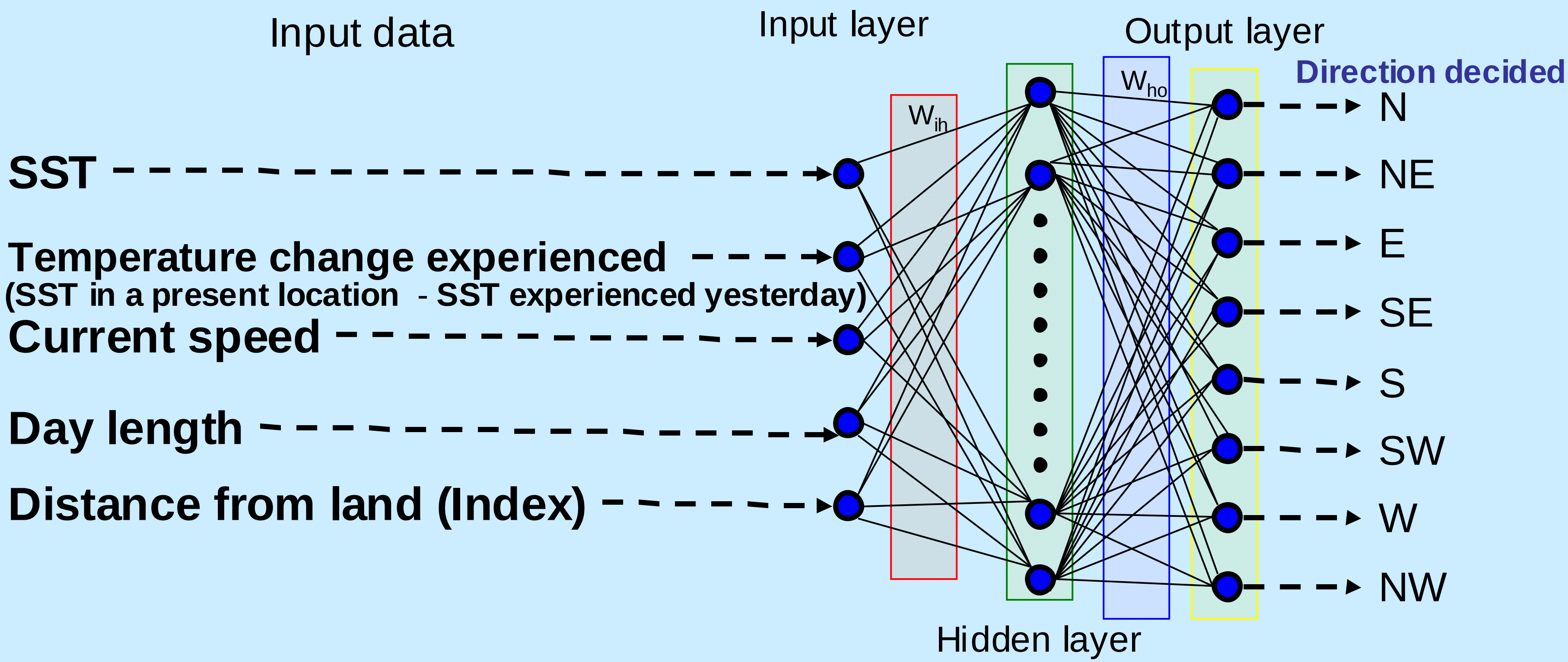
Domain in the model

Hypothesis for spawning migration

- Japanese sardine can recognize
  geographical orientation
  (using solar orientation or magnetic fields),
  changes in temperature,
  current speed,
  day length,
  the difference between coastal region and ocean region.

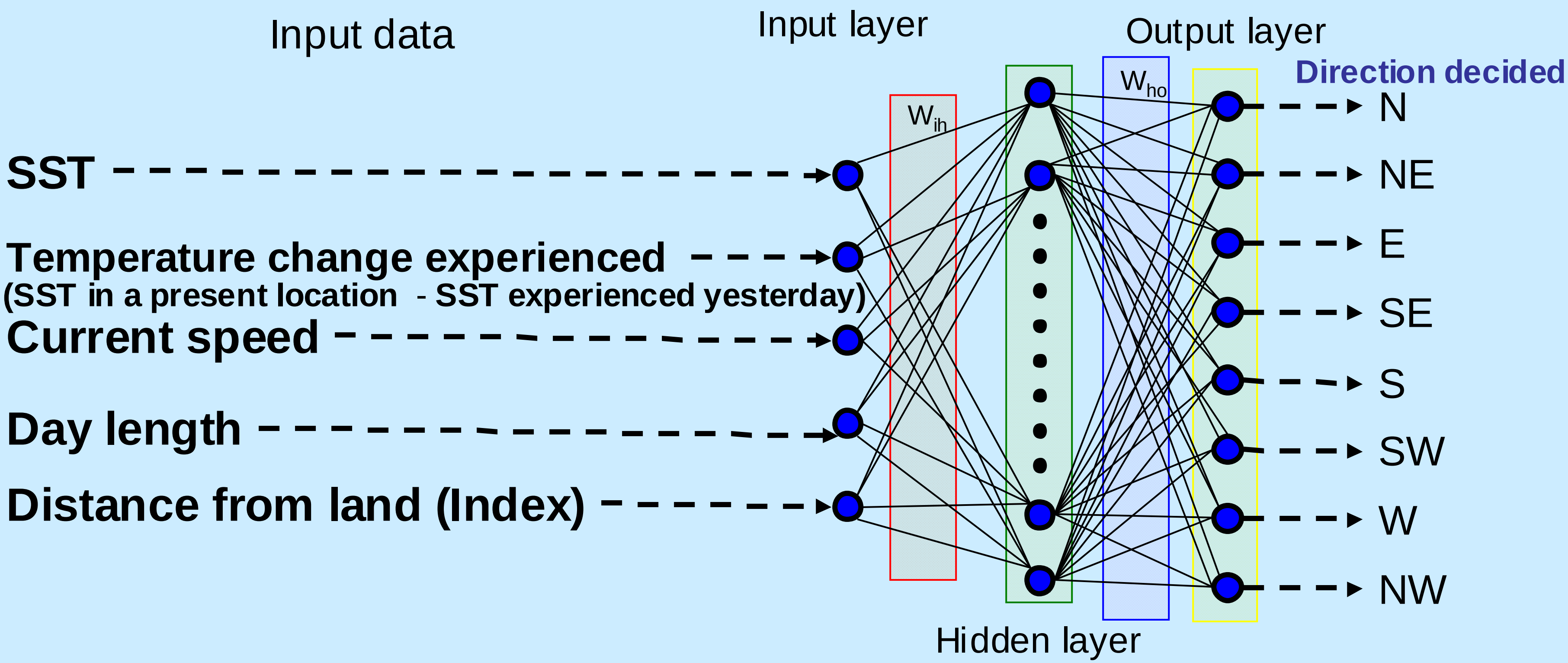
- They use these information for orientation cues.

Spawning Migration using ANN



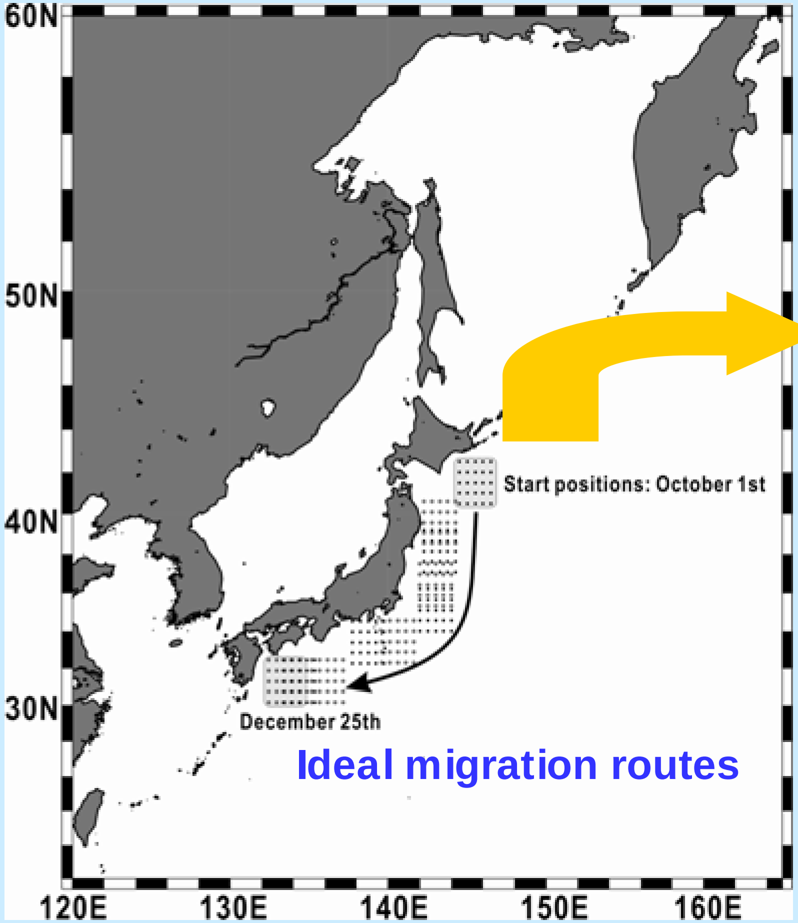
An orientation during spawning migration was modeled using ANN.

The fish move according to the direction decided by weights in ANN.



1. **Case 1;** **the weights are trained with standard back propagation method with training data.**
2. **Case 2;** **genetic algorithm (GA) is used to adjust the weights.**
3. **Case3;** **the weights of ANN is decided by a combination method of both cases 1 and 2.**

Case 1: trained with standard back propagation method



Leaning data

- **The temporal-spatial input and output data were extracted from the trajectories as leaning data.**

SST

Temperature change experienced

Current speed

Day length

Distance from land

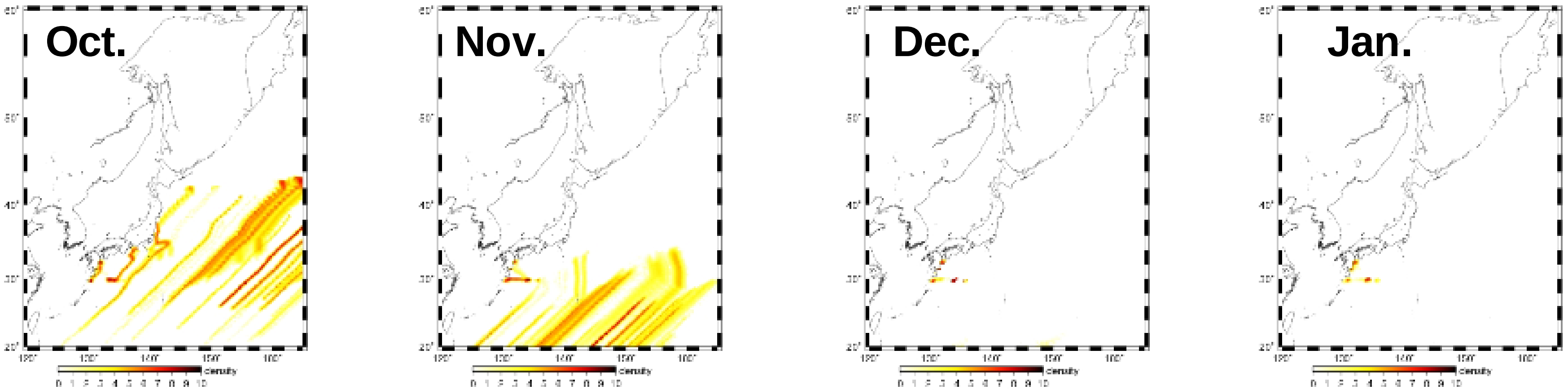
Direction

Training Method：Back Propagation method (+ Gradient Descent method)

→ **Decide the weights of ANN**

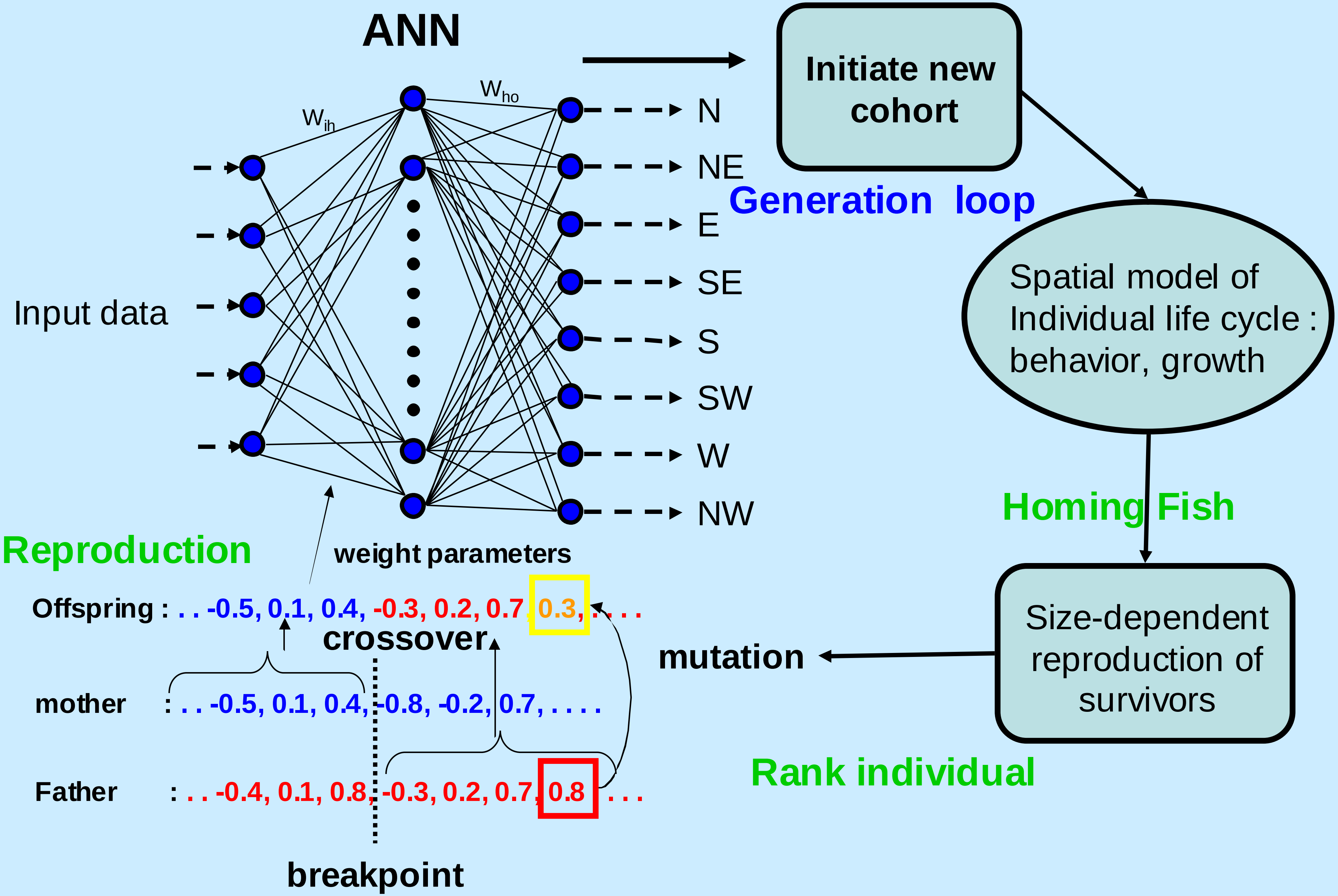
Results in Case 1

Predicted monthly mean of relative sardine density during spawning migration



- **Most fish don’t return to the spawning ground.**
- **The weights don’t possess structures permitting proper handling with the unexperienced input information.**
- **Because the weights are derived by learning with only the few training data.**

The Genetic Algorithm - Concept



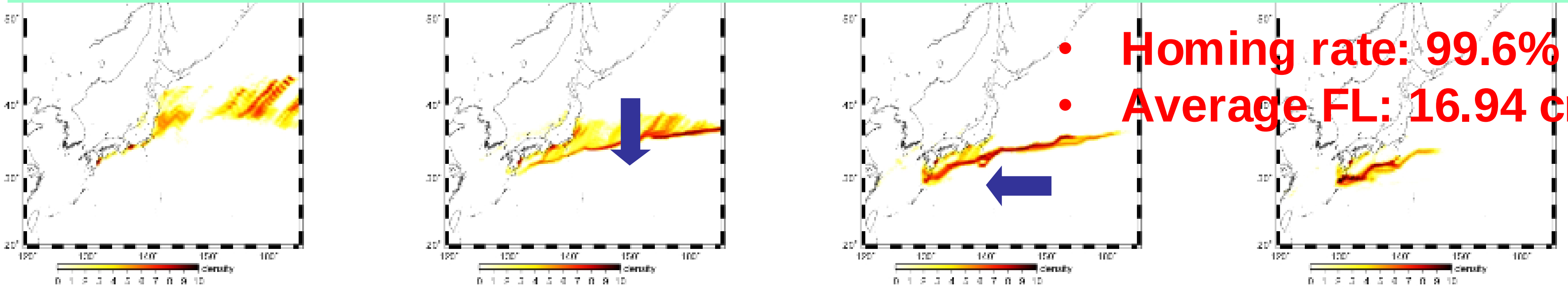
The experiments using ANN + GA

- Case 2: the GA is used to adjust the weights
  - Initial weights are randomly (-1 ～ 1) .
  - The simulation was carried out for 300 generations .

- Case 3: the weights are decided by a combination method both of Cases 1 (BP: training) and 2 (GA)
  - The weights are initiated randomly however based on the results in Case 1.
  - The weights are set at up to 30 % above or below Case 1's values by using normal random number.
  - The simulation was carried out for 300 generations.

Case 2: GA

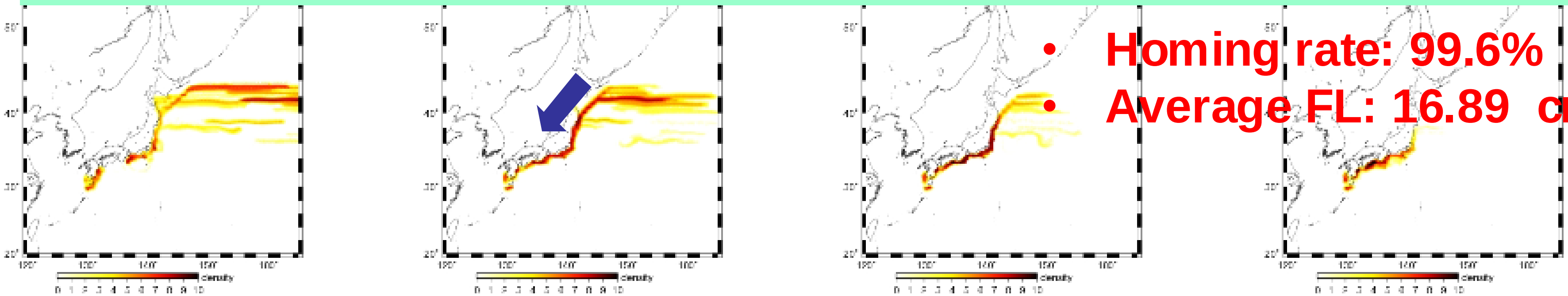
Most fish cross the Kuroshio Extension, and migrate to the spawning ground.



- **Homing rate: 99.6%**
- **Average FL: 16.94 cm**

Case 3: GA+BP

In Case 3, the model can reproduce most realistic spawning migration.



- **Homing rate: 99.6%**
- **Average FL: 16.89 cm**

Predicted monthly of mean relative sardine density during spawning migration

Summary

- To simulate reliable spawning migration, ANN system is useful.
- We are strongly in favor of integrating both standard back propagation and the GA to find optimum the weights of ANN.
- Japanese sardine may be able to return to their spawning grounds using the environmental information, such as the changes in temperature, current speed and day length for orientation cues.