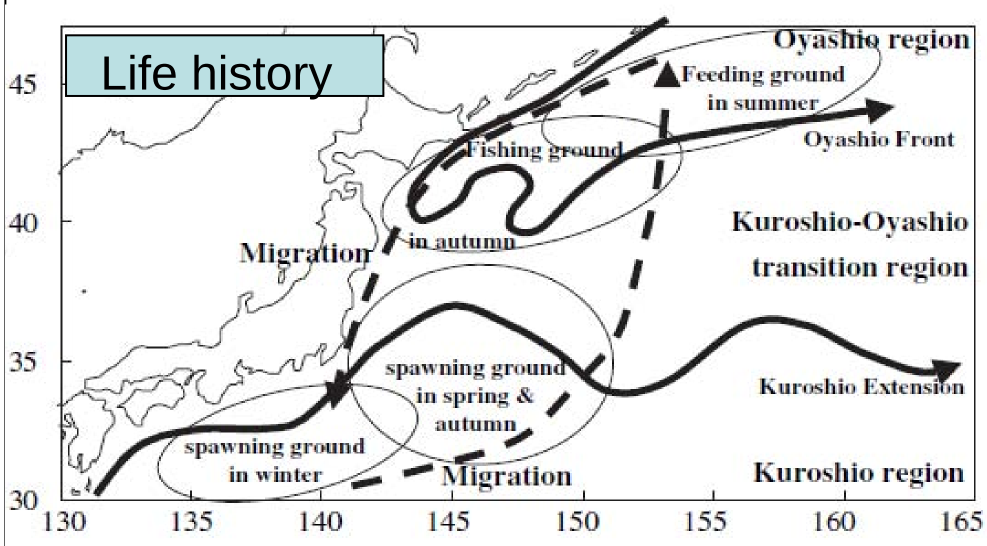
Development of a two-dimensional fish model to simulate biomass of Pacific saury using Eulerian method

Fumitake Shido, Yasuhiro Yamanaka, Shin-ichi Ito,
Taketo Hashioka, Daiki Mukai, and Michio J. Kishi

Oct 17th ’2006 PICES 15th in Yokohama, JAPAN

Introduction

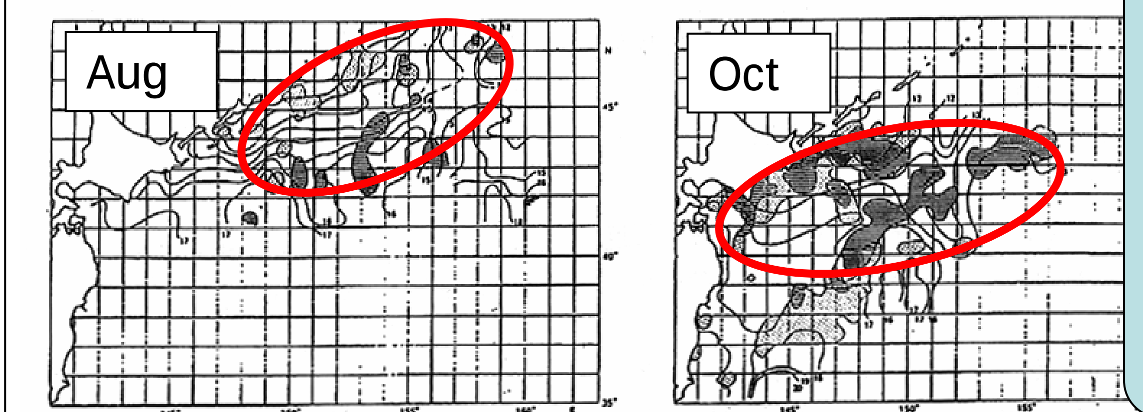
- **Pacific saury** is a famous commercial fish in Japan.



(Sugisaki and Kurita, 2004, Ito et al., 2004)

Young saury migrates northward, and stays around here with its growth until summer.

Larval and juvenile hatched in winter are advected by Kuroshio and its extension



Observed distribution of Pacific saury catches [Kosaka 2000]

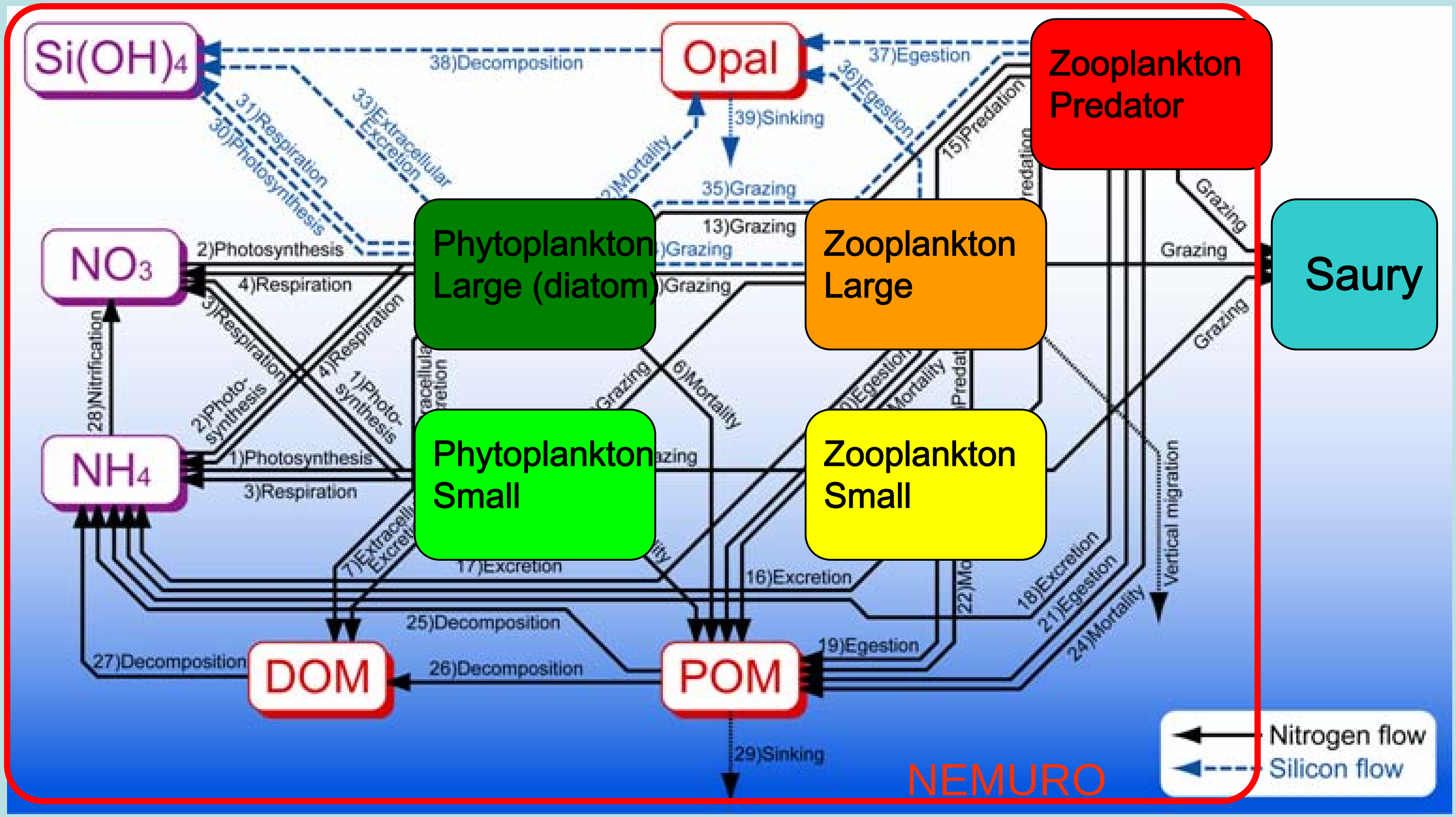
[Photo] Pacific saury (*Cololabis saira*)

Japanese name: **samma**

In this study,

- We developed 2-D model to simulate geological distribution and growth using Eularian method.
- We adopted fish biomass concentration by Eulerian method, because we have intent to deal with an interaction of zooplankton biomass with fish biomass as a two-way coupling in the predator-prey system in near future.

NEMURO.FISH of PICES



- We developed a 2-D model based on NEMURO.FISH (Ito et al., 2004)
- For our 2-D simulation, we used zooplankton distributions calculated by 3D NEMURO (Hashioka and Yamanaka, in press)

Equations for Eulerian Model

2-D extended Bioenergetics model:

$$\frac{\partial B}{\partial t} = -\nabla \cdot \mathbf{v} B + W \kappa \nabla^2 N + G \cdot B,$$

Population dynamics model:

$$\frac{\partial N}{\partial t} = -\nabla \cdot \mathbf{v} N + \kappa \nabla^2 N,$$

with assumption without mortality

B: Biomass(=*N*·*W*) [g/km^2]

W: Weight [g]

N: Number density [/km^2]

v: fish advection [km/day]

κ: diffusion coefficient

G: fish growth rate [/day]

Model domain: 20-50°N and 120-170°E

Horizontal resolution: 1/4° x 1/6°

We used the following data sets:

(1)temperature and zooplankton(0-20m)

(Hashioka and Yamanaka , *in press*)

(2) zooplankton(0-200m)(WOA01)

(3) ocean currents (Sakamoto *et al.*, 2005)

Swimming direction is as follows

(1) Feb01-Mar31: no swimming,

(2) Apr01-Aug31: toward high growth rate region,

(3) Sep01-Jun31: toward the hatched position, along high growth rate region.

The local growth rate for Pacific saury

$$G = \frac{1}{W}\frac{dW}{dt} = [\; C - (E + F + S \quad + R + P)]\,\frac{CAL_z}{CAL_f}$$

- G: Growth rate
- W: Wet weight(g)
- C: Consumption (increase weight)
- E: Excretory weste
- F: Feces
- S: SDA
- R: Respiration
- P: Egg Production
- E, F, S, R, P: (decrease weight)

(PICES MODEL/REX TASK TEAM, 2002, Ito et al., 2004)

Migration velocity of saury (*v*)

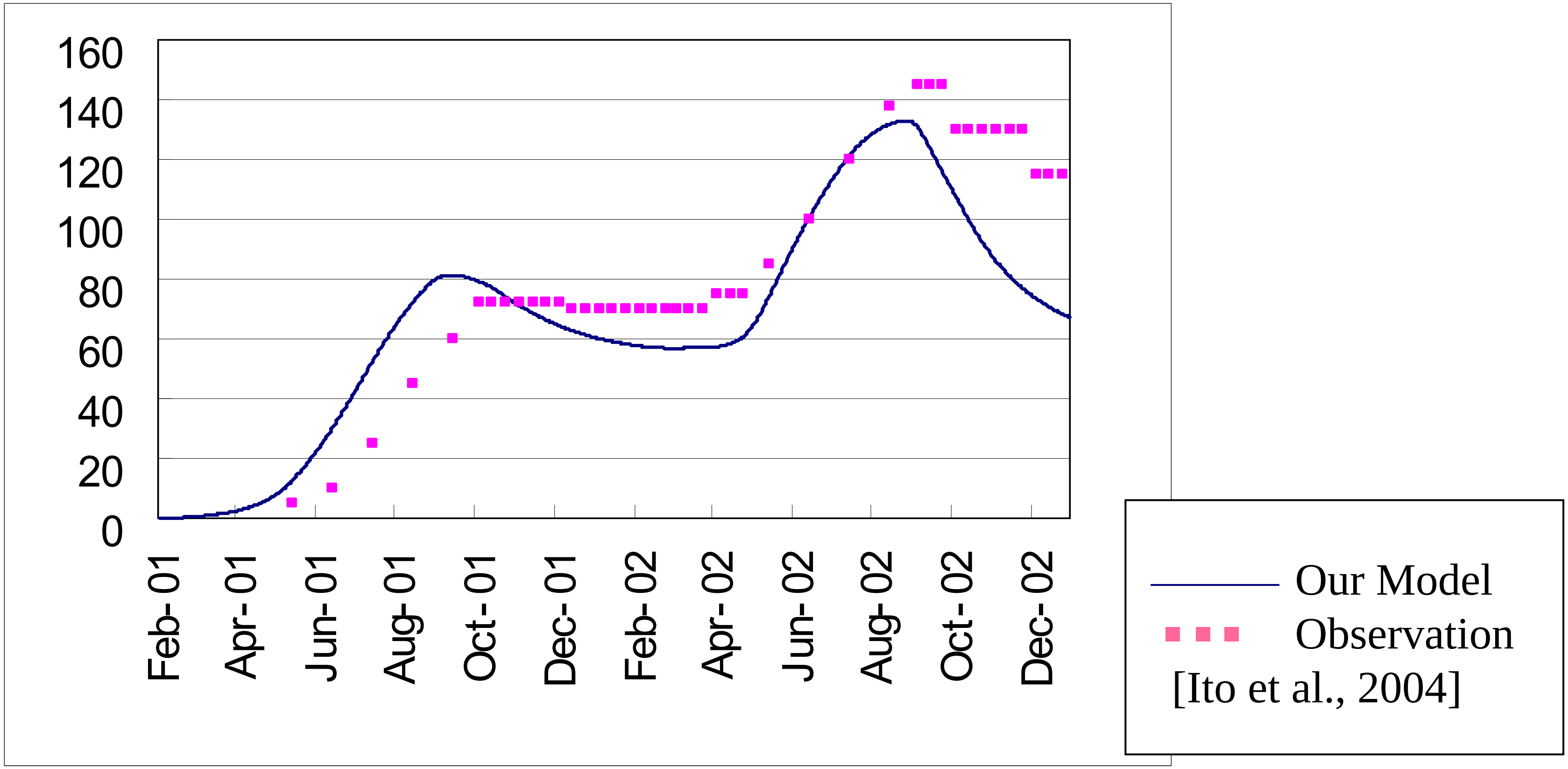
$$v \;=\; v_{swim} \;+\; v_{adv}$$

[migration]= [Swimming] + [Advection by current]

Swimming speed is defined as a function of wet weight of saury. (Ito et al., 2004)

$$|V_{swim}| = 12.3 \times W^{0.33}$$

The results by Eulerian model(1)

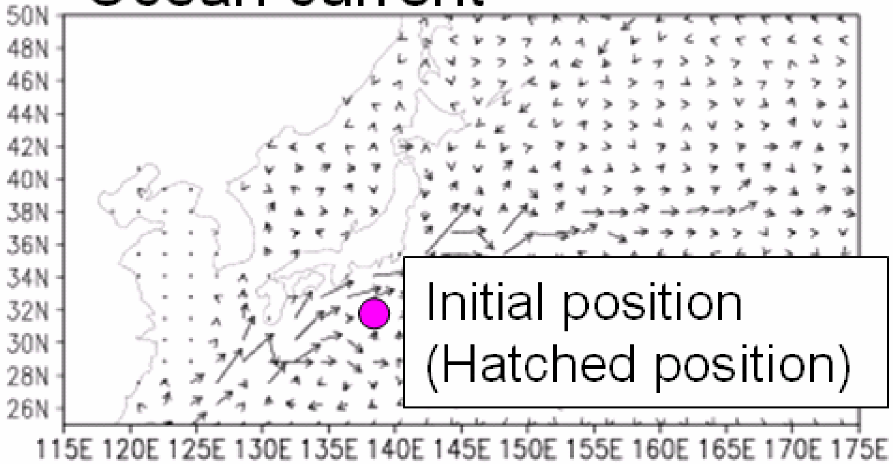


Eulerian model successfully simulated

the observed wet weight of saury during two years.

The results by Eulerian model(2)

Ocean current



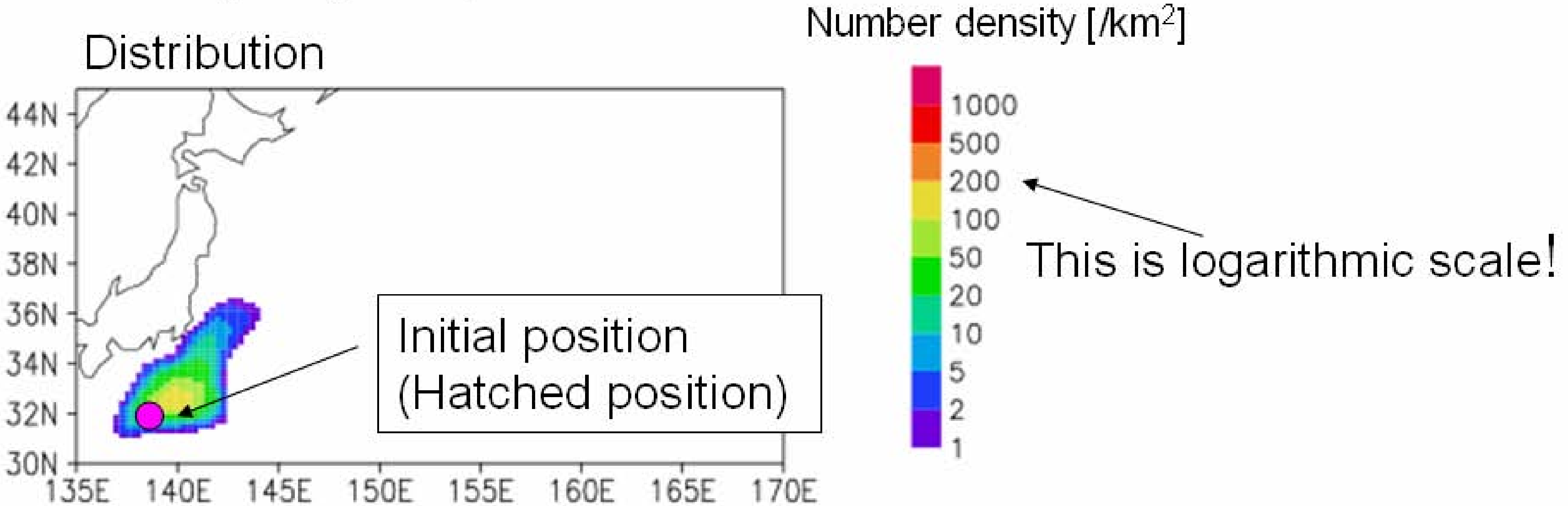
Number density [/km^2]

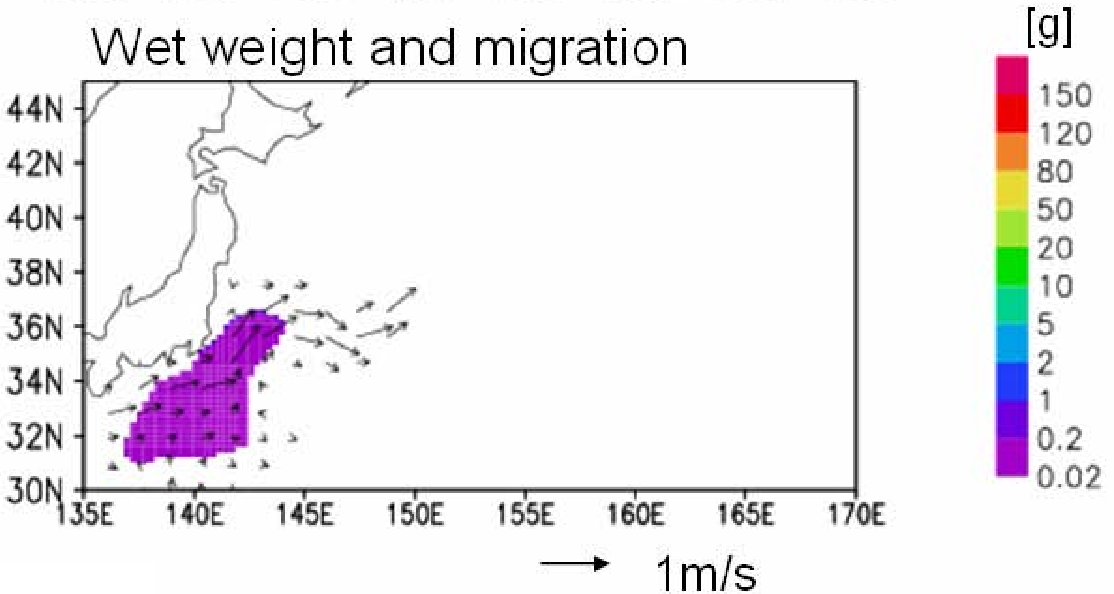
We assumed
saury hatched in February 1st at the point of 32°N and 138°E.

→ 1m/s

The results by Eulerian model(2)

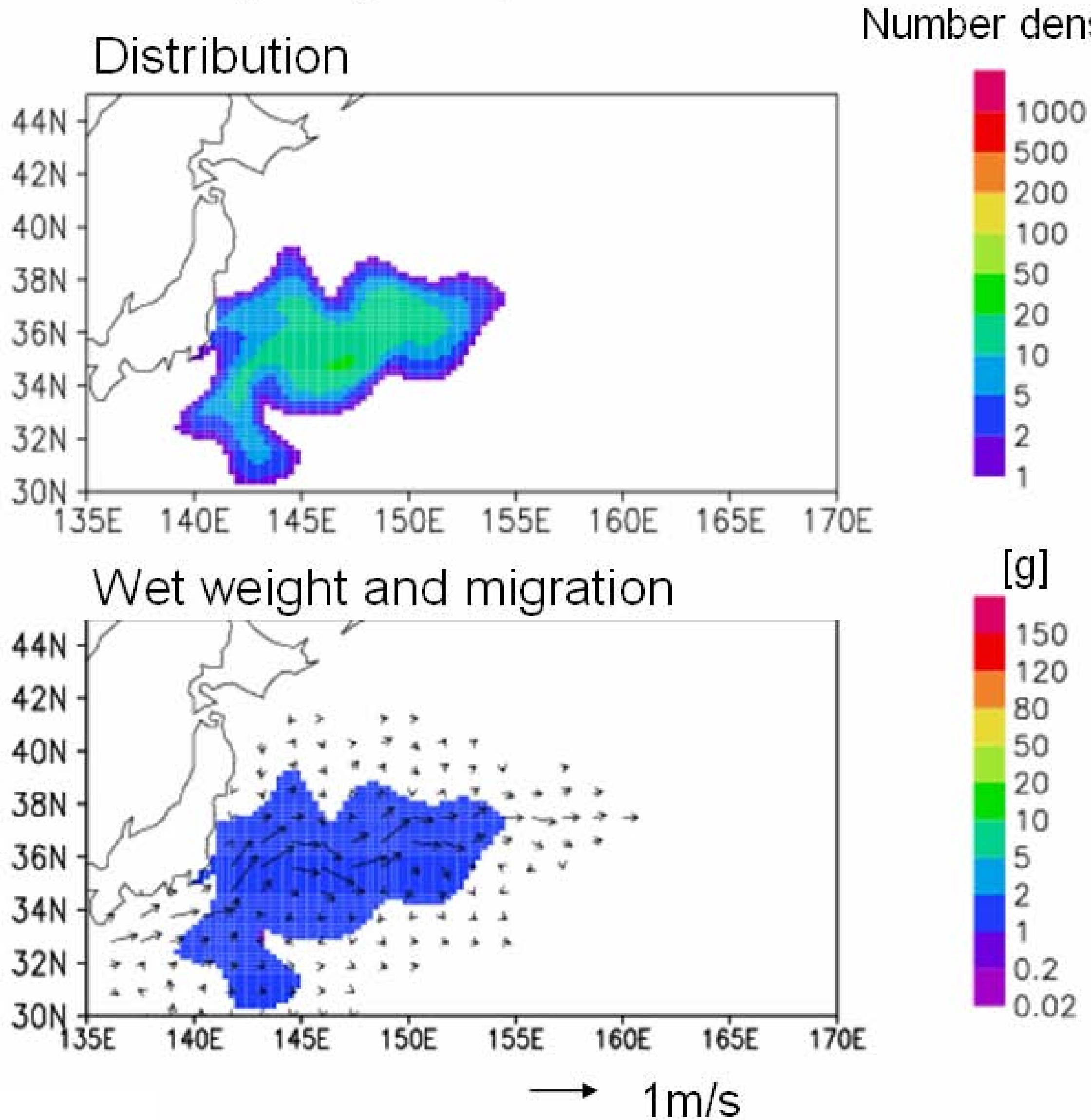
Feb15(1st year)





The results by Eulerian model(2)

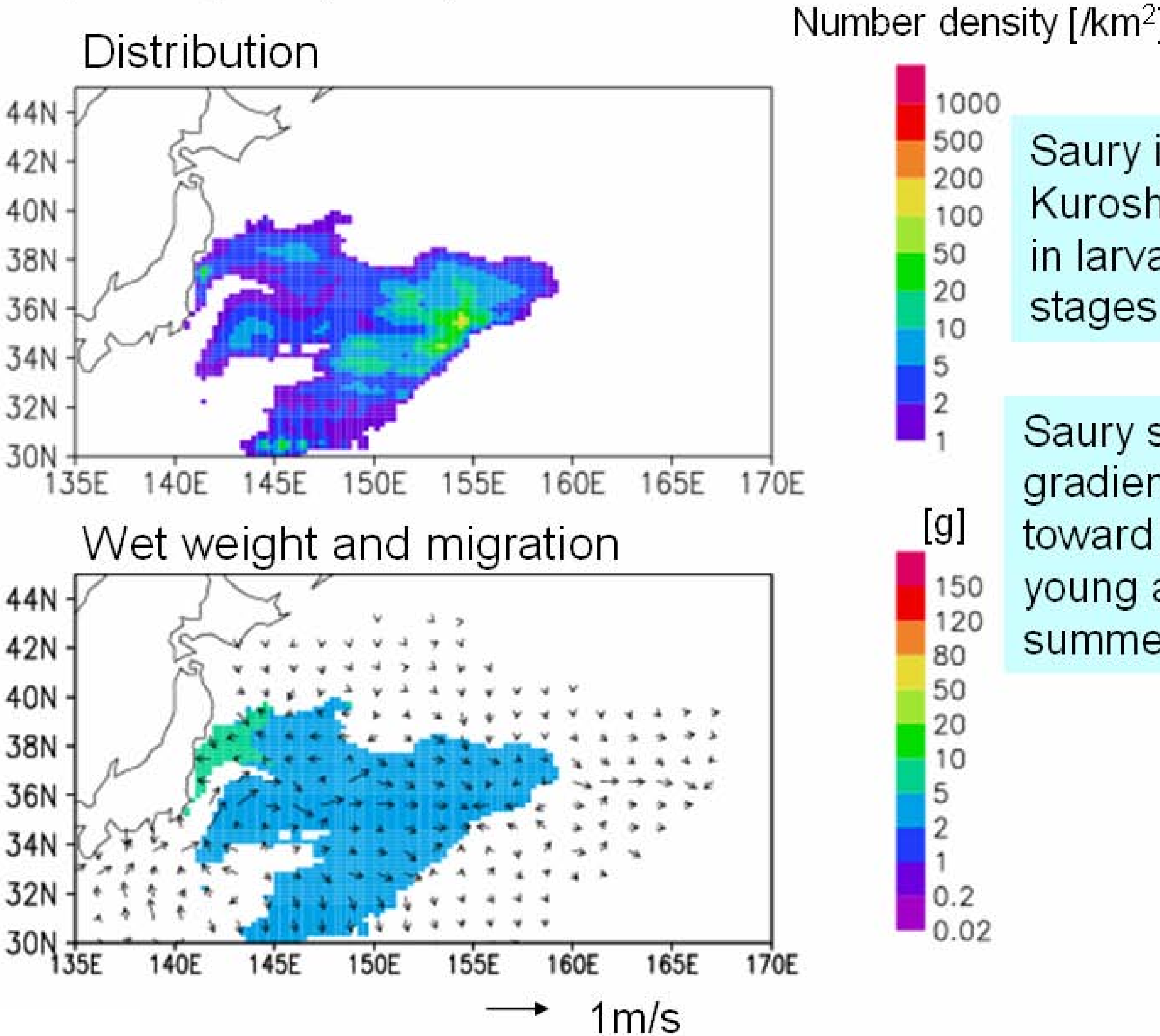
Mar15(1st year)



Saury is advected by Kuroshio and its extension in larvae and juvenile stages.

The results by Eulerian model(2)

Apr15(1st year)



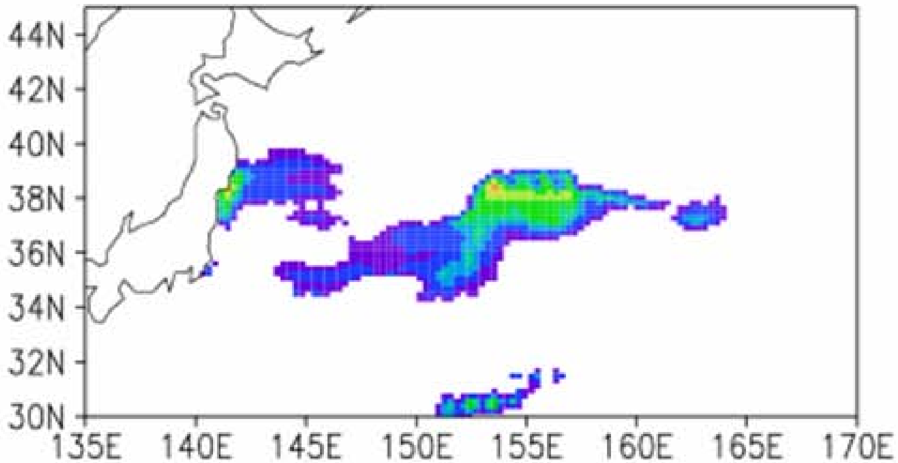
Saury is advected by Kuroshio and its extension in larvae and juvenile stages.

Saury swims along up-gradient of net growth rate toward good habitat for young adult stage until summer.

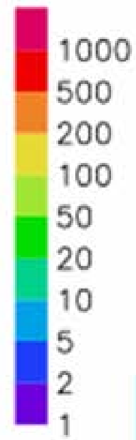
The results by Eulerian model(2)

May15(1st year)

Distribution

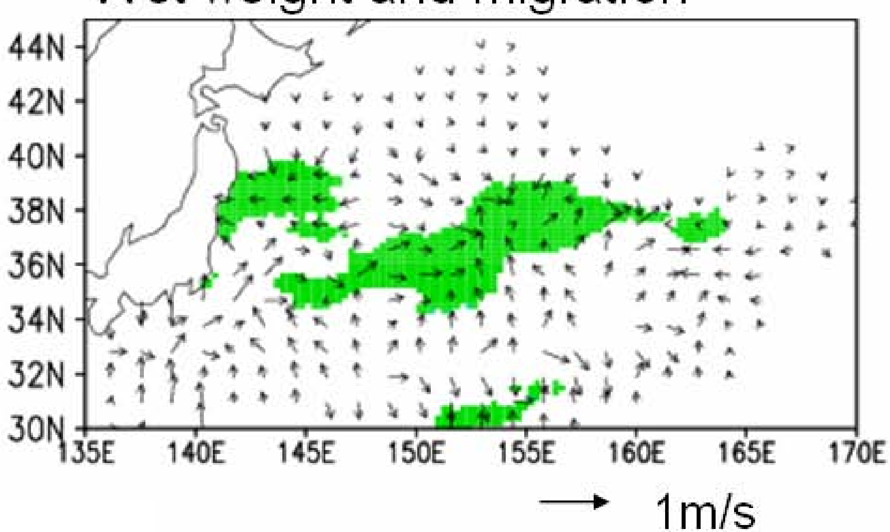


Number density [/km^2]

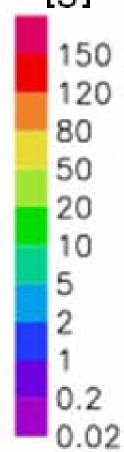


Saury is advected by Kuroshio and its extension in larvae and juvenile stages.

Wet weight and migration



[g]

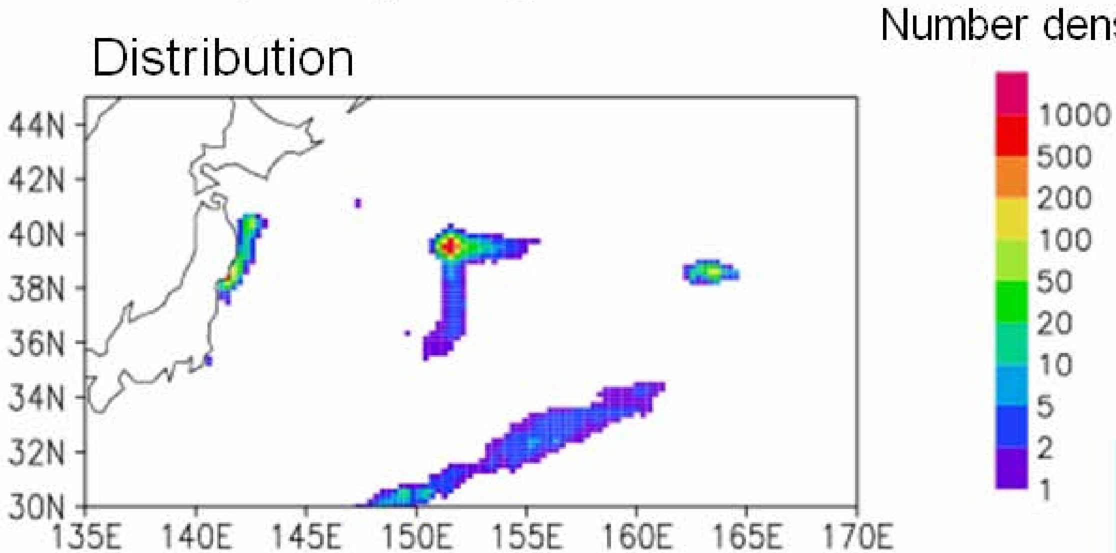


Saury swims along up-gradient of net growth rate toward good habitat for young adult stage until summer.

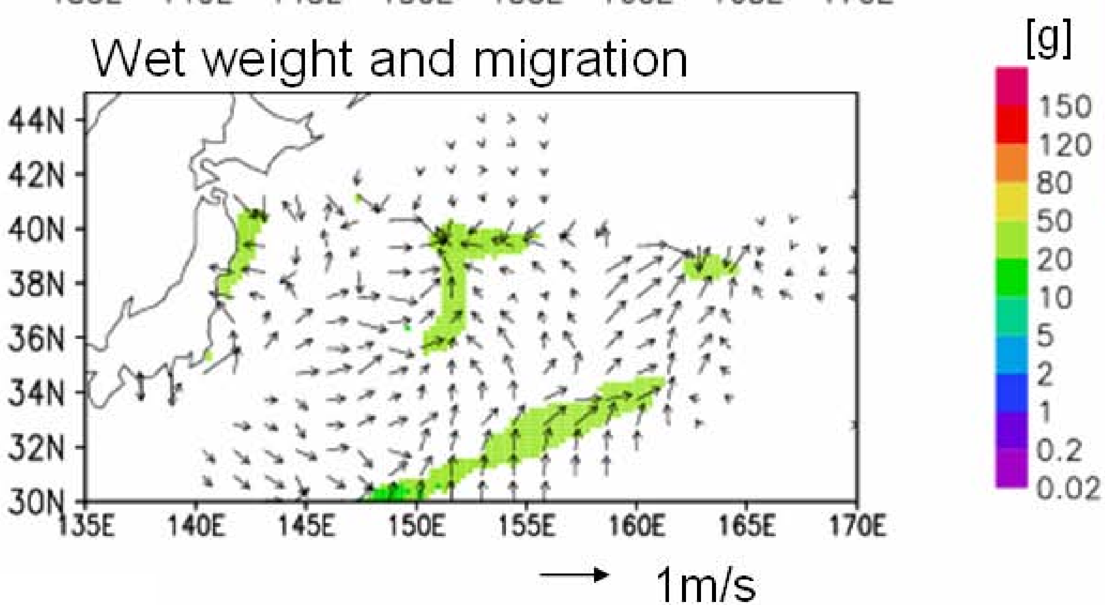
The results by Eulerian model(2)

Jun15(1st year)

Distribution



Wet weight and migration



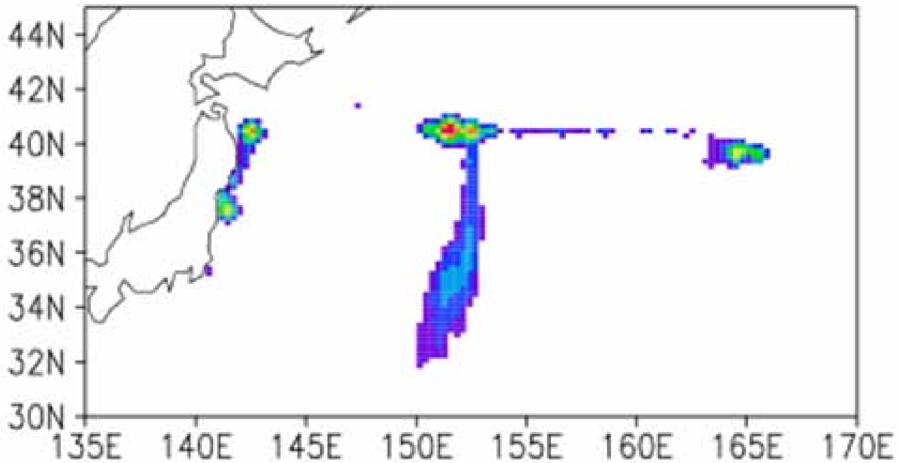
Saury is advected by Kuroshio and its extension in larvae and juvenile stages.

Saury swims along up-gradient of net growth rate toward good habitat for young adult stage until summer.

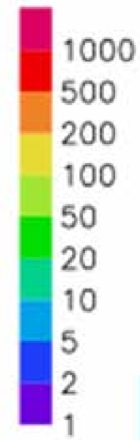
The results by Eulerian model(2)

Jul15(1st year)

Distribution

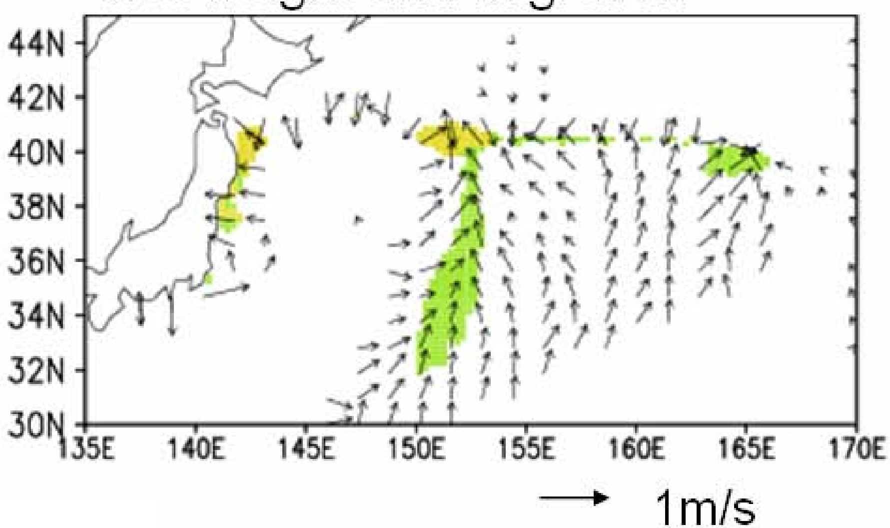


Number density [/km^2]

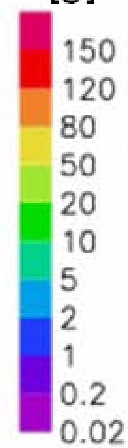


Saury is advected by Kuroshio and its extension in larvae and juvenile stages.

Wet weight and migration



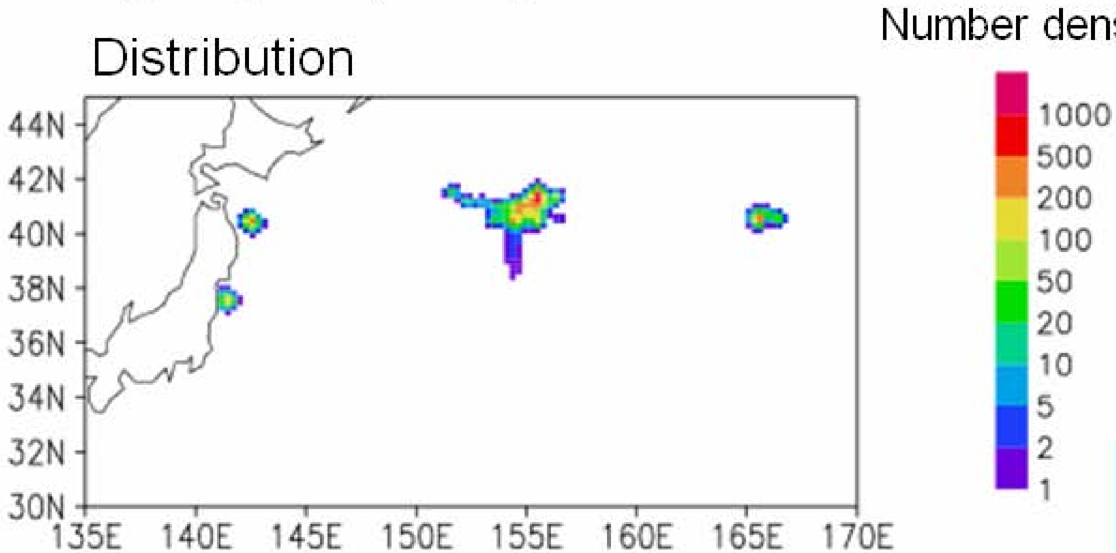
[g]



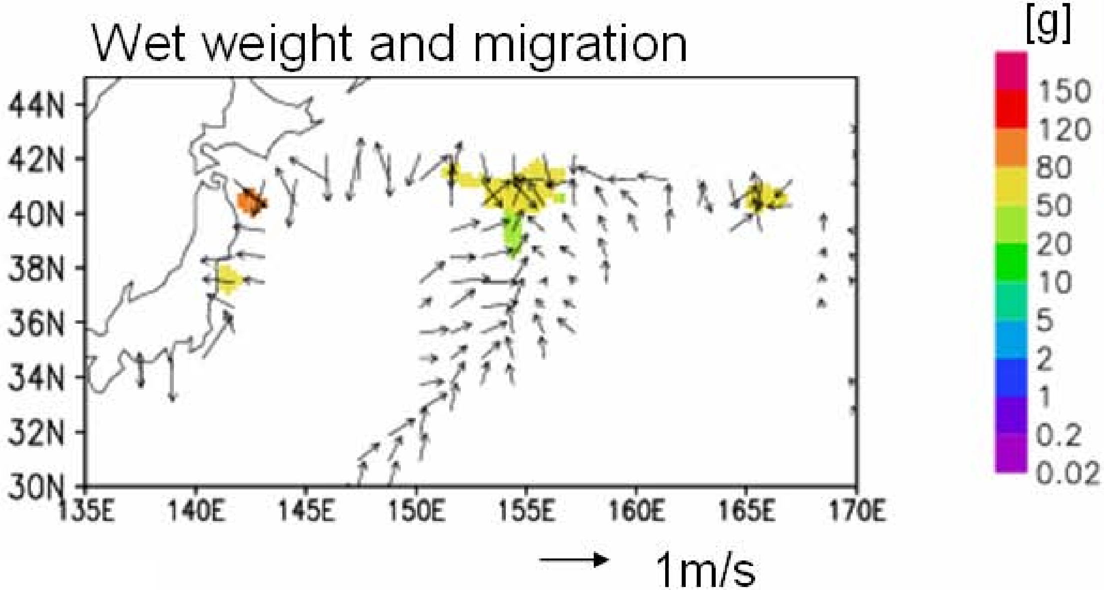
Saury swims along up-gradient of net growth rate toward good habitat for young adult stage until summer.

The results by Eulerian model(2)

Aug15(1st year)



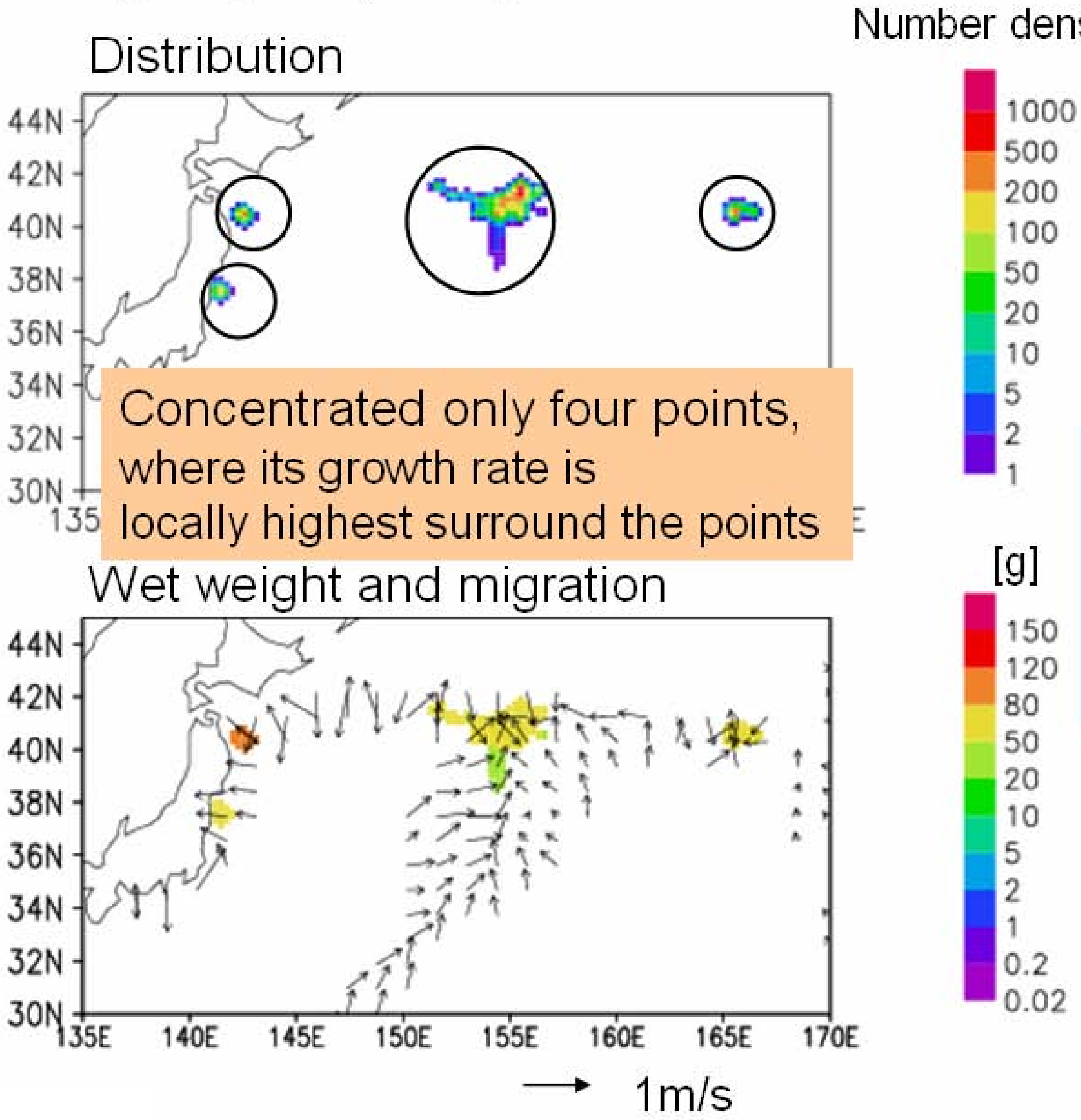
Saury is advected by Kuroshio and its extension in larvae and juvenile stages.



Saury swims along up-gradient of net growth rate toward good habitat for young adult stage until summer.

The results by Eulerian model(2)

Aug15(1st year)



Concentrated only four points, where its growth rate is locally highest surround the points

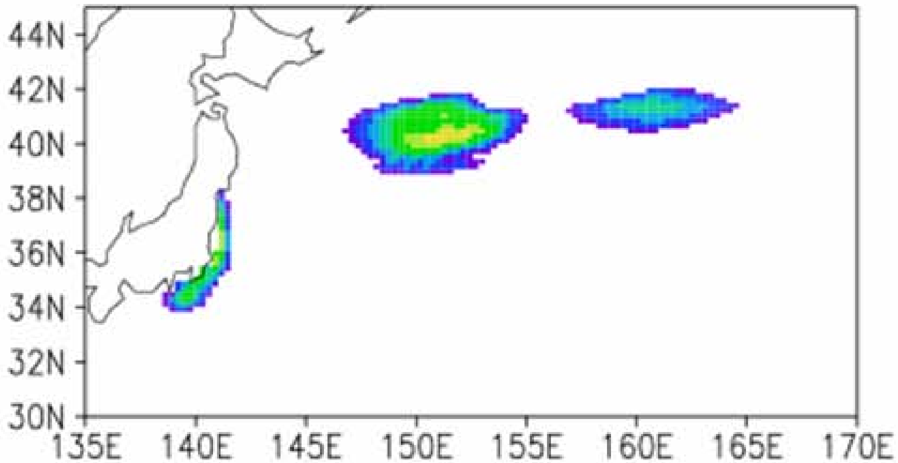
Saury is advected by Kuroshio and its extension in larvae and juvenile stages.

Saury swims along up-gradient of net growth rate toward good habitat for young adult stage until summer.

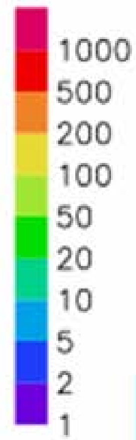
The results by Eulerian model(2)

Sep15(1st year)

Distribution

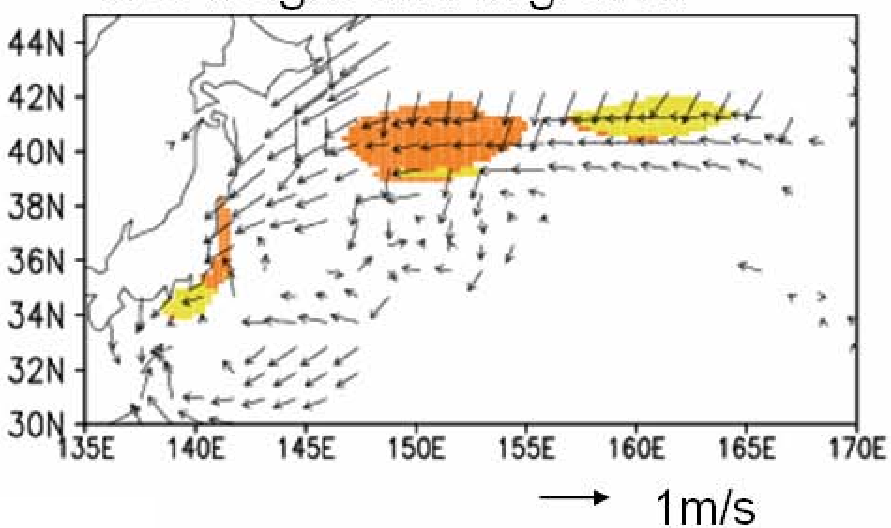


Number density [/km^2]

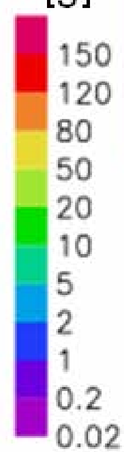


Saury is advected by Kuroshio and its extension in larvae and juvenile stages.

Wet weight and migration



[g]

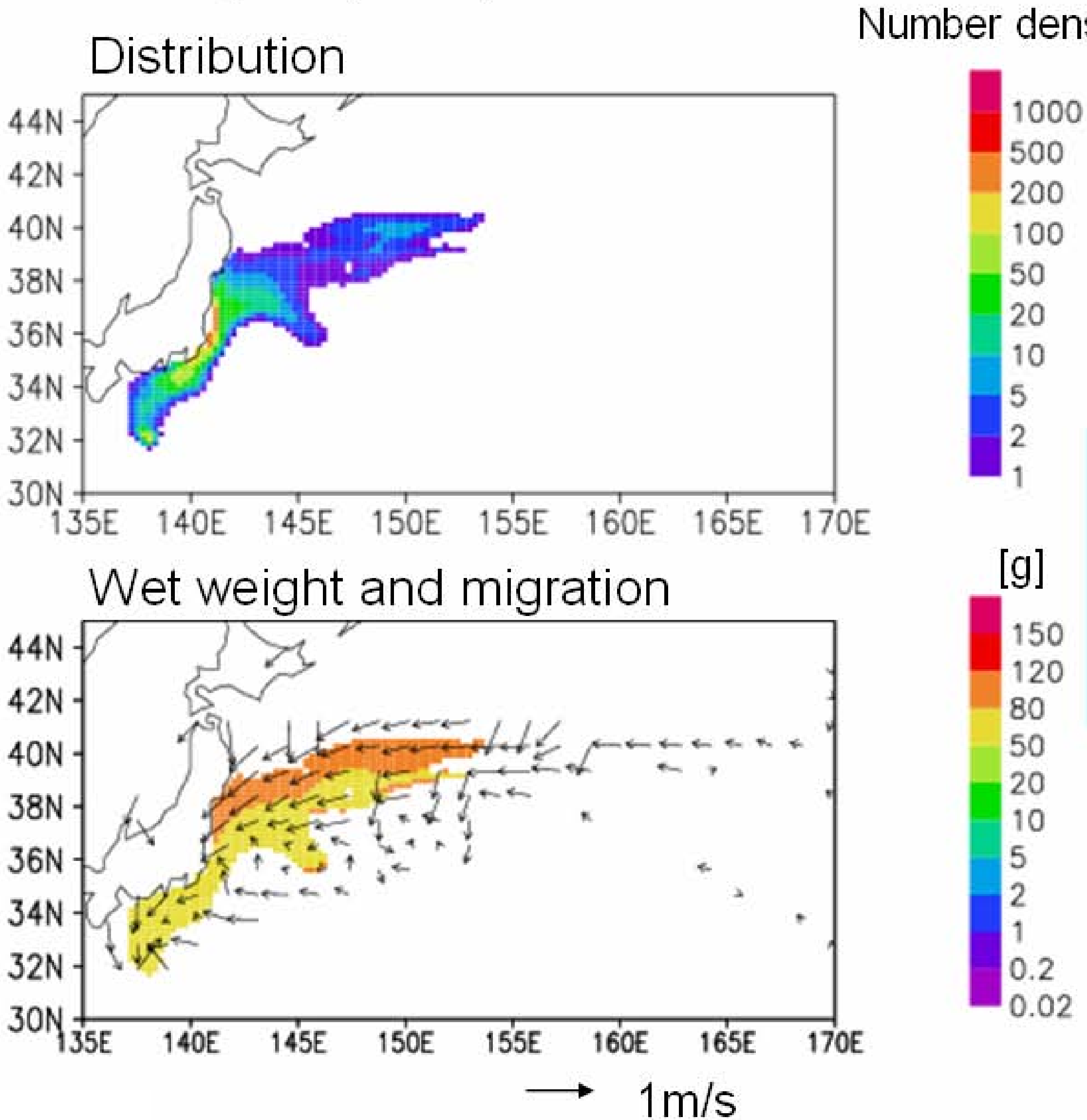


Saury swims along up-gradient of net growth rate toward good habitat for young adult stage until summer.

Saury swims back toward its hatched area in adult stage from autumn to winter.

The results by Eulerian model(2)

Oct15(1st year)



Saury is advected by Kuroshio and its extension in larvae and juvenile stages.

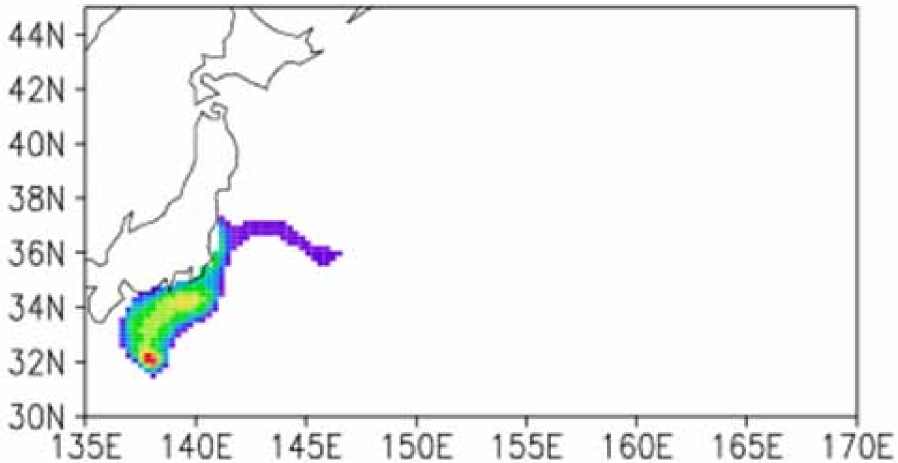
Saury swims along up-gradient of net growth rate toward good habitat for young adult stage until summer.

Saury swims back toward its hatched area in adult stage from autumn to winter.

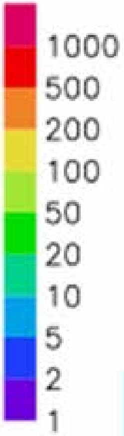
The results by Eulerian model(2)

Nov15(1st year)

Distribution

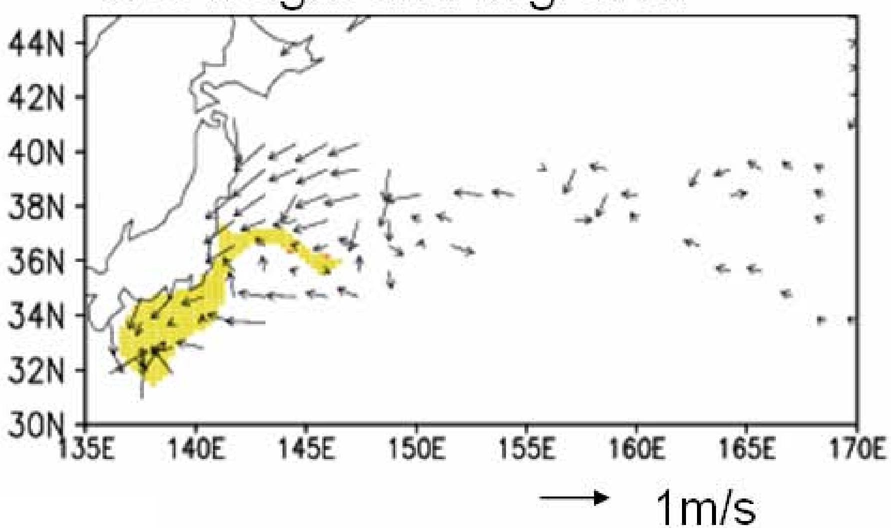


Number density [/km^2]

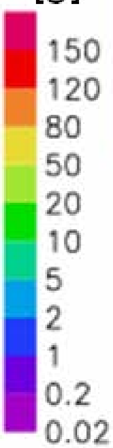


Saury is advected by Kuroshio and its extension in larvae and juvenile stages.

Wet weight and migration



[g]



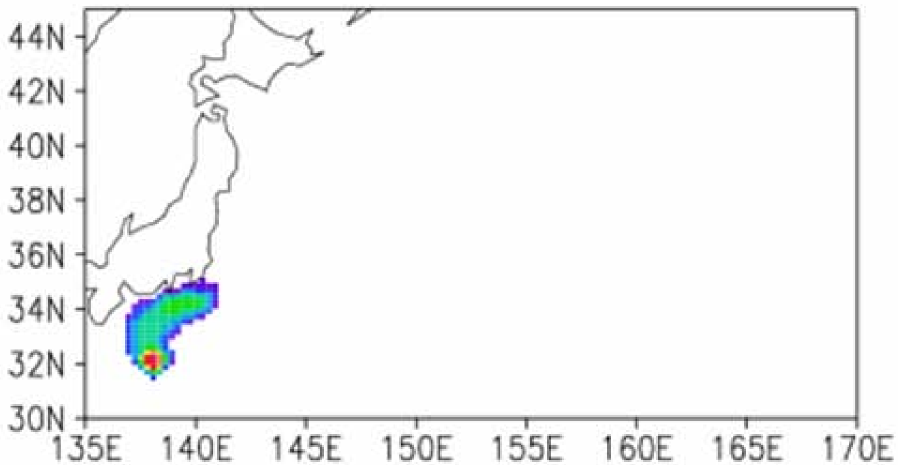
Saury swims along up-gradient of net growth rate toward good habitat for young adult stage until summer.

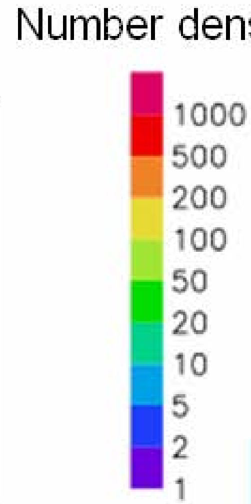
Saury swims back toward its hatched area in adult stage from autumn to winter.

The results by Eulerian model(2)

Dec15 (1^{st} year)

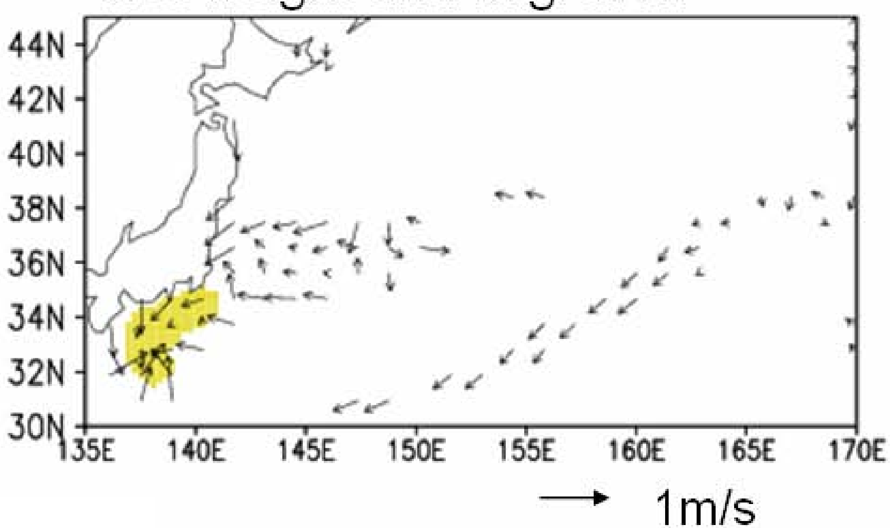
Distribution

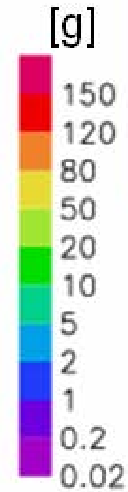




Saury is advected by Kuroshio and its extension in larvae and juvenile stages.

Wet weight and migration



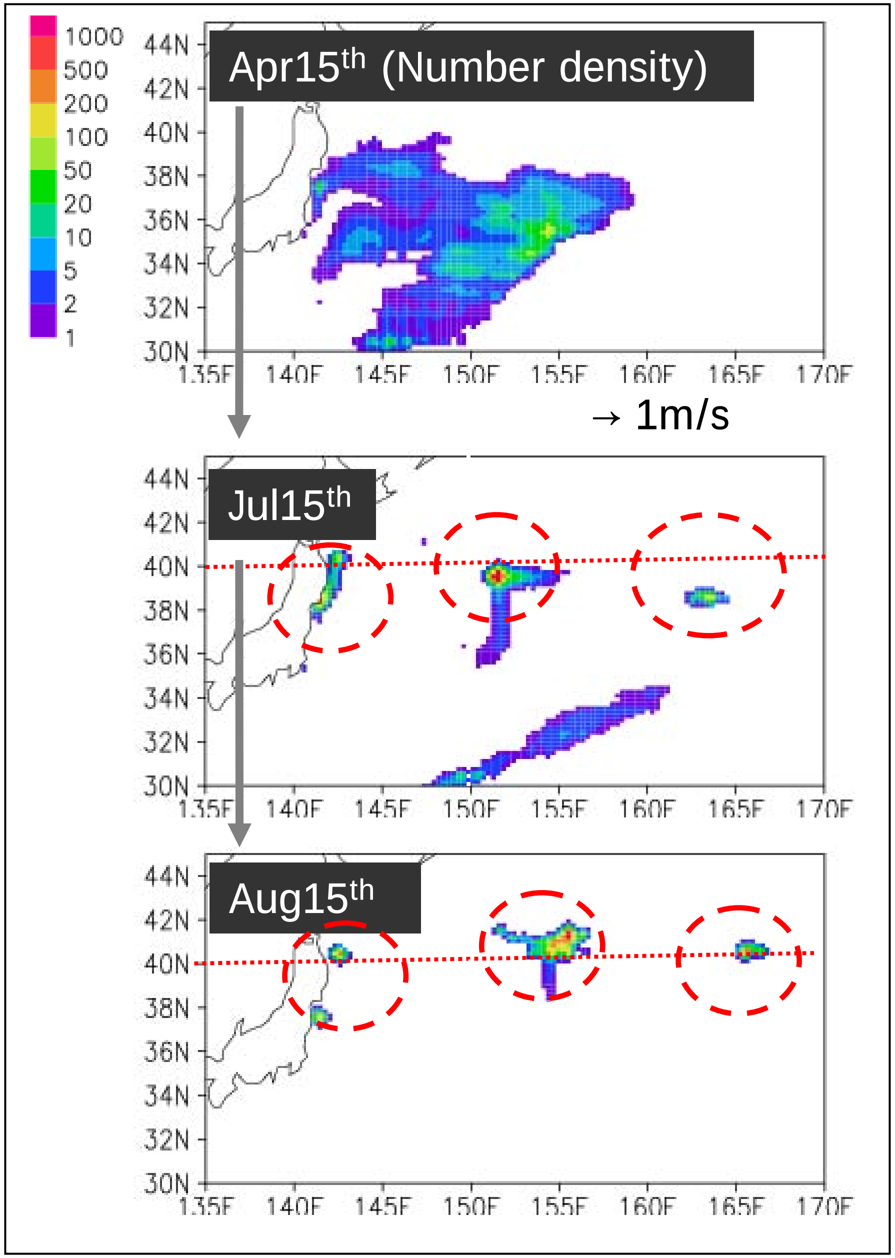


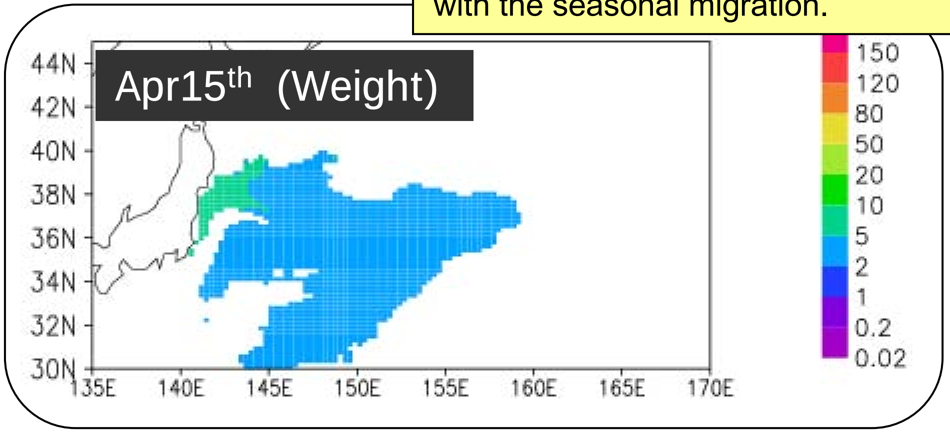
Saury swims along up-gradient of net growth rate toward good habitat for young adult stage until summer.

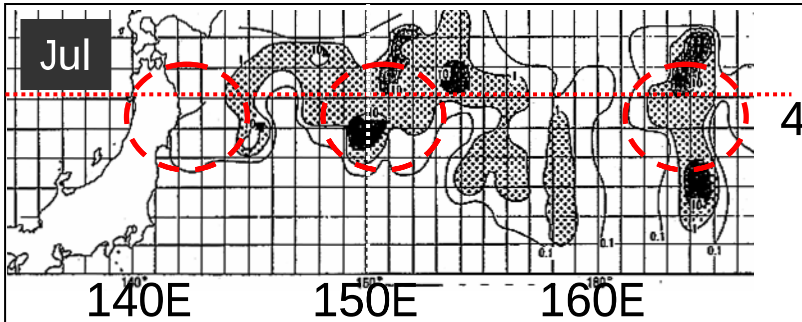
Saury swims back toward its hatched area in adult stage from autumn to winter.

The results by Eulerian model(3)

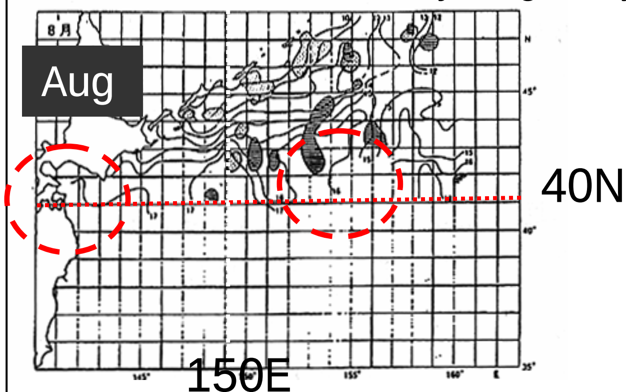
Eulerian model successfully simulated
the observed geological distributions
with the seasonal migration.







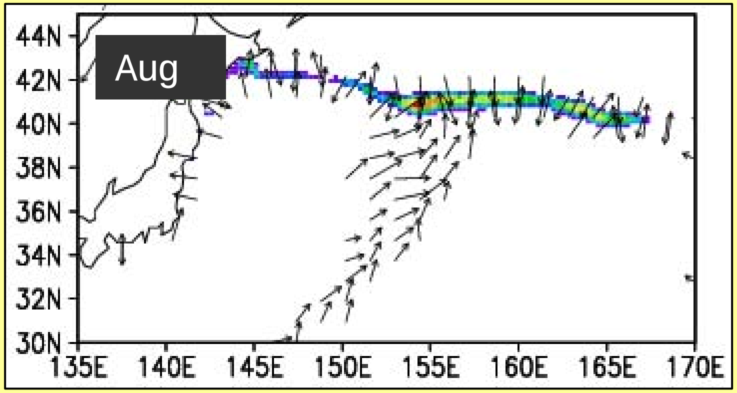
Observed Distribution of young saury (Kosaka 2000)



Observed Distribution (catches) (Kosaka 2000)

Case study

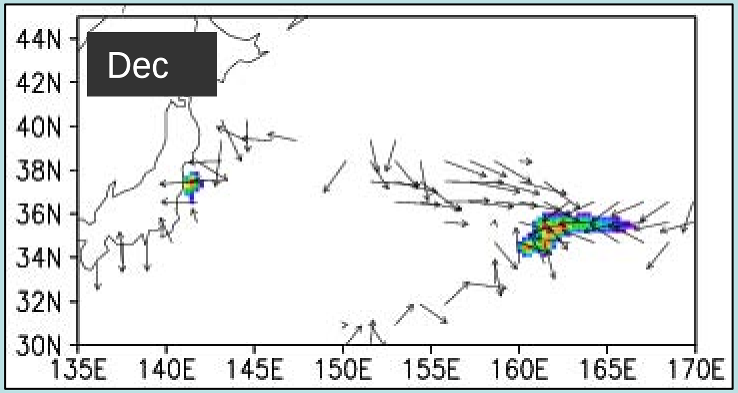
Migration toward optimal **temperature** instead of high growth rate until summer



Most of saury is located along the isothermal line, dose not have patch-like distribution like the control case.

This result suggest that horizontal fluctuation of zooplankton density is important to make patch-like saury distribution.

Migration toward optimal growth rate **for its larvae** instead of hatched point in autumn



Most of saury migrates eastward, 160E or more east

As the observed distribution of saury expands the entire North Pacific, this assumption might not be unrealistic.

Conclusions and future plan

- Eulerian model successfully simulated the observed geological distributions with the seasonal migration.
- We are going to deal with an interaction of zooplankton biomass with fish biomass as a two-way coupling in the predator-prey system in near future.
- We need to adopt population dynamics model with realistic mortality rate for more realistic simulation.