Euler-type and Individual Based modeling approaches for fish migration: an example of Pacific saury

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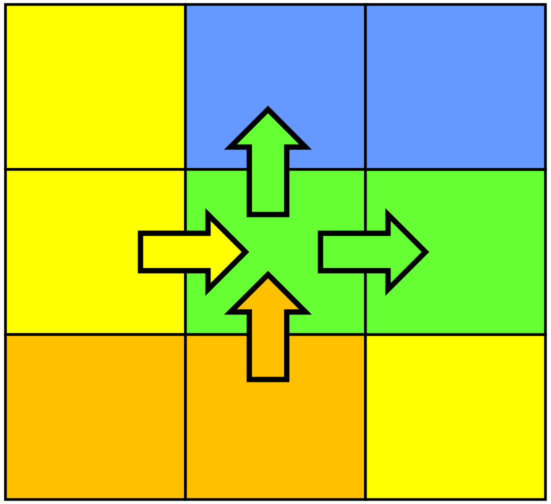
Today's Contents

Euler type model of Pacific saury
Individual based model of Pacific saury
Discussion

Three types of models applied to Pacific saury

1. Euler type model

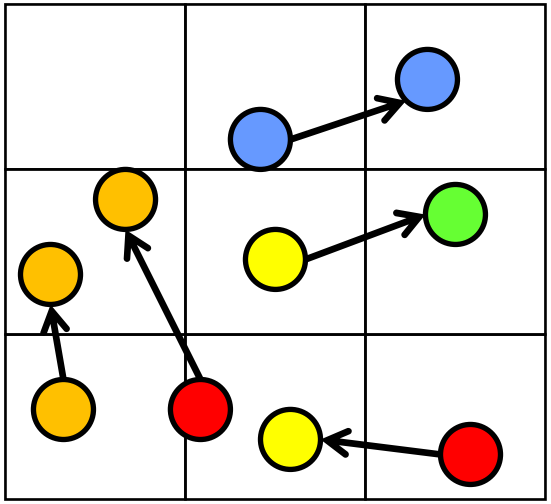
budget of biomass is calculated on the geometrically fixed grid.



- intermediate computational cost
- impossible to trace individual tracks

2. super-IBM

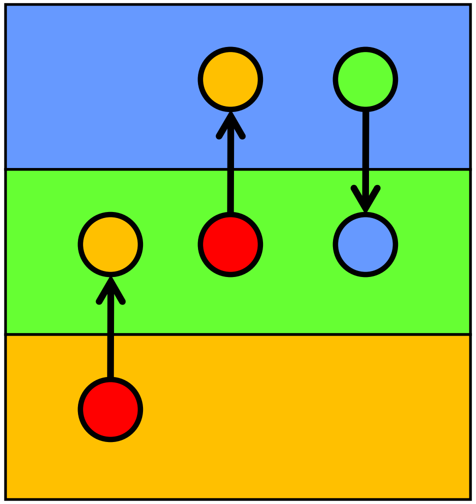
calculate movement and increase/decrease of population.



- possible to trace individual tracks
- high computational cost to represent all biomass

3. simple model

calculate movement and increase/decrease of population



- low computational cost
- life history is closed for this version
- impossible to argue the influence of meso-scale phenomena

Euler type model (Pacific saury)

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

- $\frac{\partial B}{\partial t}$: change of biomass
- $-\nabla \cdot \mathbf{v} B$: movement
- $W \kappa \nabla^2 N$: disfusion
- $G \cdot B$: growth

B: biomass (g/km^2)

v: velocity (km/day)

W: av. wet weight(g)

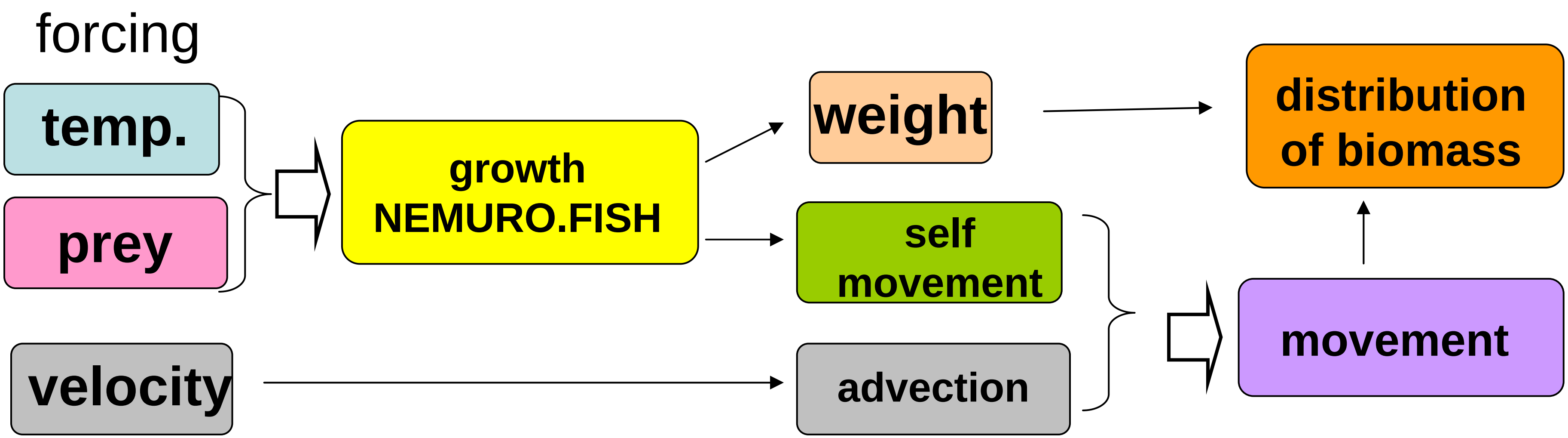
N: number (1/km^2)

G: growth rate (day^{-1})

v = self movement + advection

self movement = 2 x BL (cm) / sec

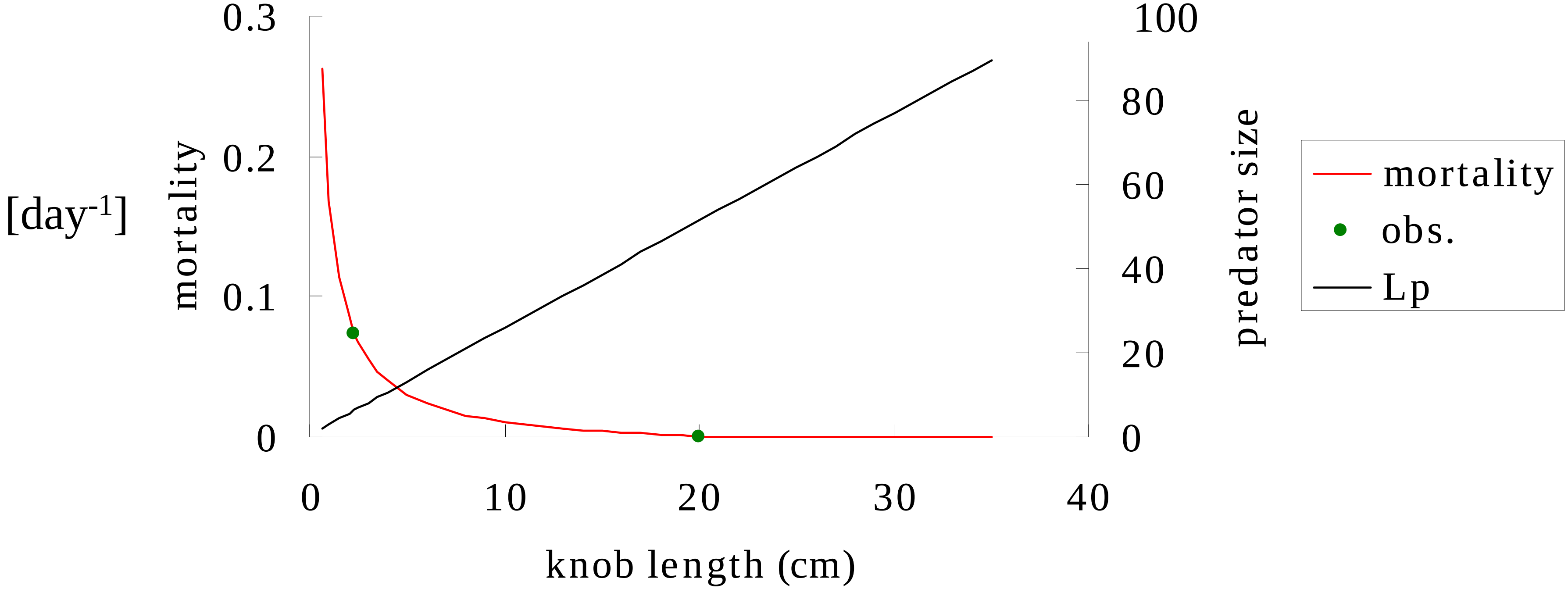
time step: 1 hour, *k* = 1.0x10^2 (m^2/s)



mortality

Miller *et al.*, 1988

$$m = \frac{100 - \left(\left(Lp / Ll + 3.37 \right) / 44.76 \right)^{-2.28}}{100}$$



Observations

Watanabe et al. (2003): 0.0741/day for 2.3 cm

Ueno et al. (2006): 0.22/yr(=0.000688/day) for 20 cm

Growth-mortality hypothesis (Anderson, 1998)

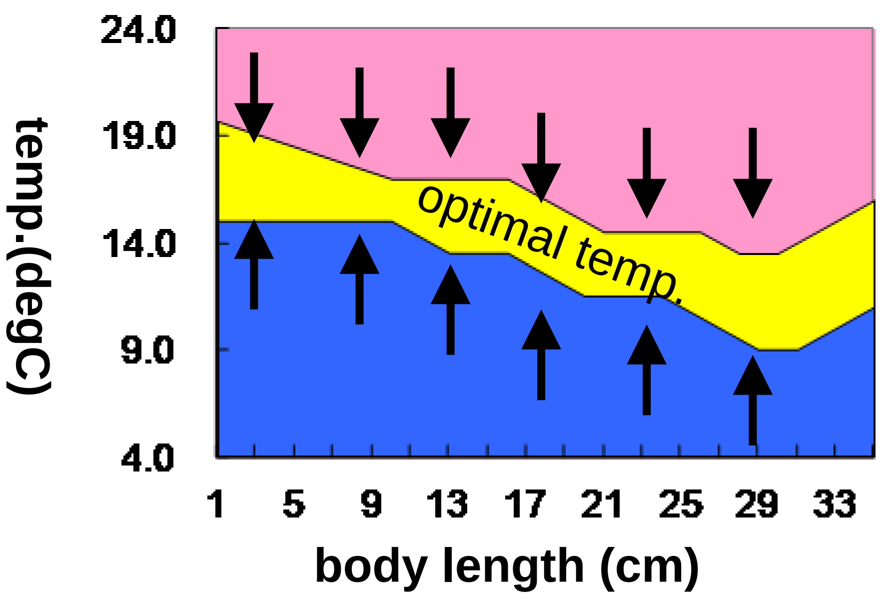
migration of Pacific saury

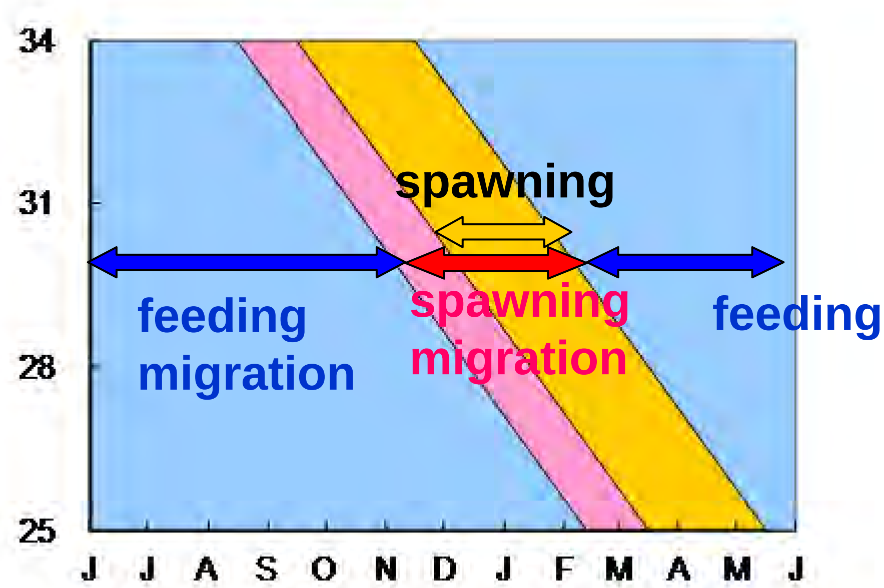
(1) feeding migration

- fitness (max. growth)
- fish outside of the optimal temp. zone directs into the optimal temp. zone

(2) spawning migration

•spawning period depends on BL
•spawning migration starts 1 month advanced to the spawning period
•spawning period continues 2 month
•fitness (min. duration spawned egg reaches 1.5 cm).





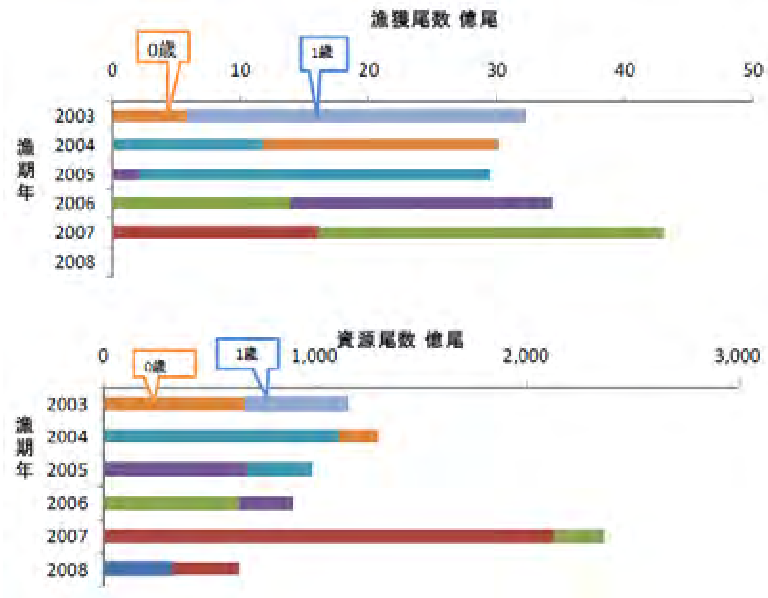
major question to apply the model

backgrounds

a. fluctuation in age classes
   large (1-year) or small (0-year)

b. no information on spawning intensity of 1-year and 0-year fishes

=> need for stock assessment



Ueno et al.,2009

objective

a. invistigate mechanism determine fluctuation of age classes

b. speculate spawning intensity of each year classes

realistic simulation is needed.

boundary conditions

velocity: Ambe08 (satellite altimetry with surface drifter)
provided by Daisuke Ambe in FRA, 1/3 deg. resolution

temp.: MODIS/Terra (1/12 deg. resolution)

Chl-a: SeaWiFS (1/12 deg. resolution)
convert to zooplankton

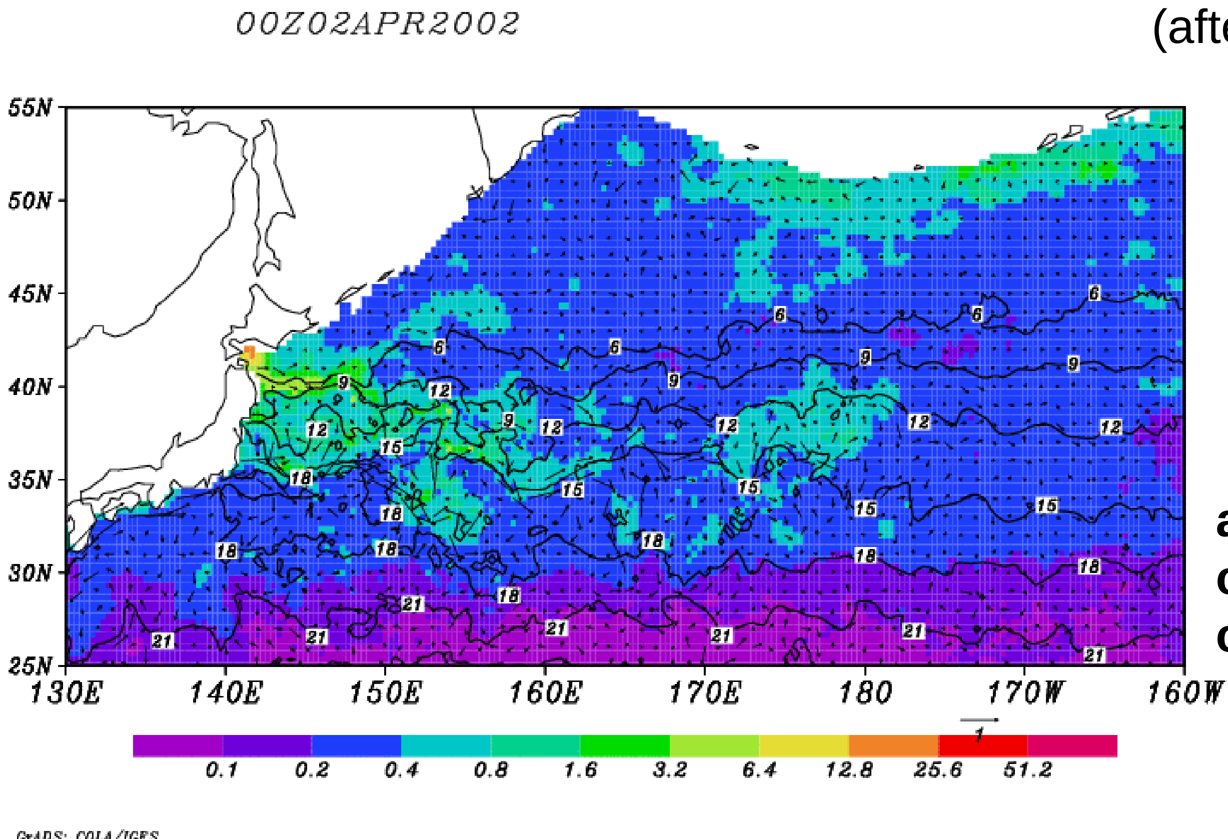
1.0 [mg chl.a/ m^3] is converted to

ZS 0.38 [g/m^3]

ZL 0.75 [g/m^3]

ZP 0.15 [g/m^3]

(after Ikeda et al. 2008)



arrow: **velocity** (m/s)

contour: **temp.** (degC)

color: **Chl-a** (mg/m^3)

initial condition

synoptic field survey for Pacific saury during 2002-2006

12 blocks (6 in zonal and 2 in temp.: 9-15 degC & 15-18 degC) were set and density of saury was calculated in each blocks.

each BL classes between 17-33 cm was calculated individually (resolution is 1 cm).

model integration was started from June 15th.

year	vel	temp	Chl-a	trawl	juvenile net
2002	O	O	O	O	--
2003	O	O	O	O	--
2004	O	O	O	O	--
2005	O	O	O	O	O
2006	O	O	O	O	O
2007	--	O	O	O	O

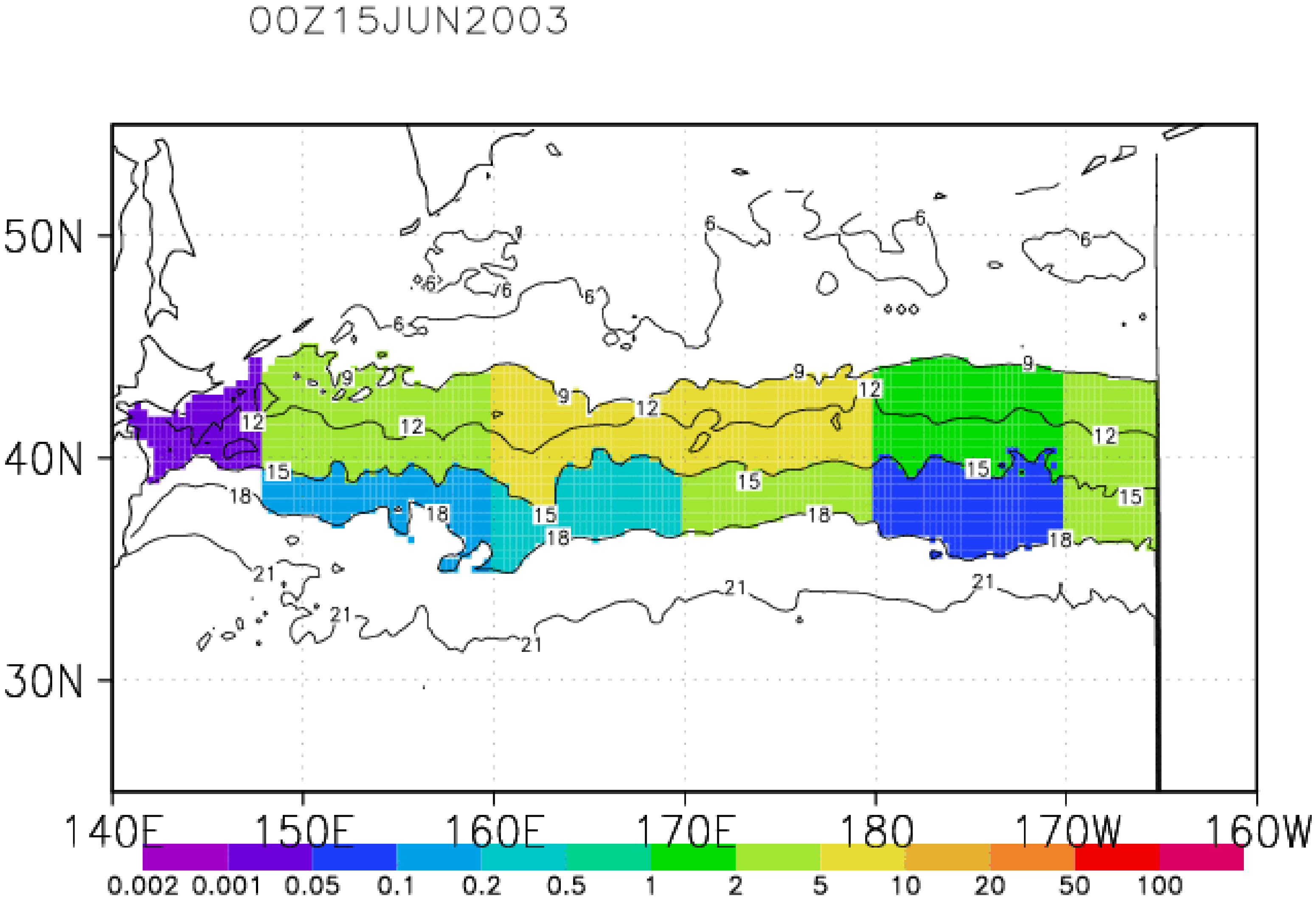
density of fish = catch / S / F

S: towed area

F: catch efficiency

(Stock assessment report, 2008)

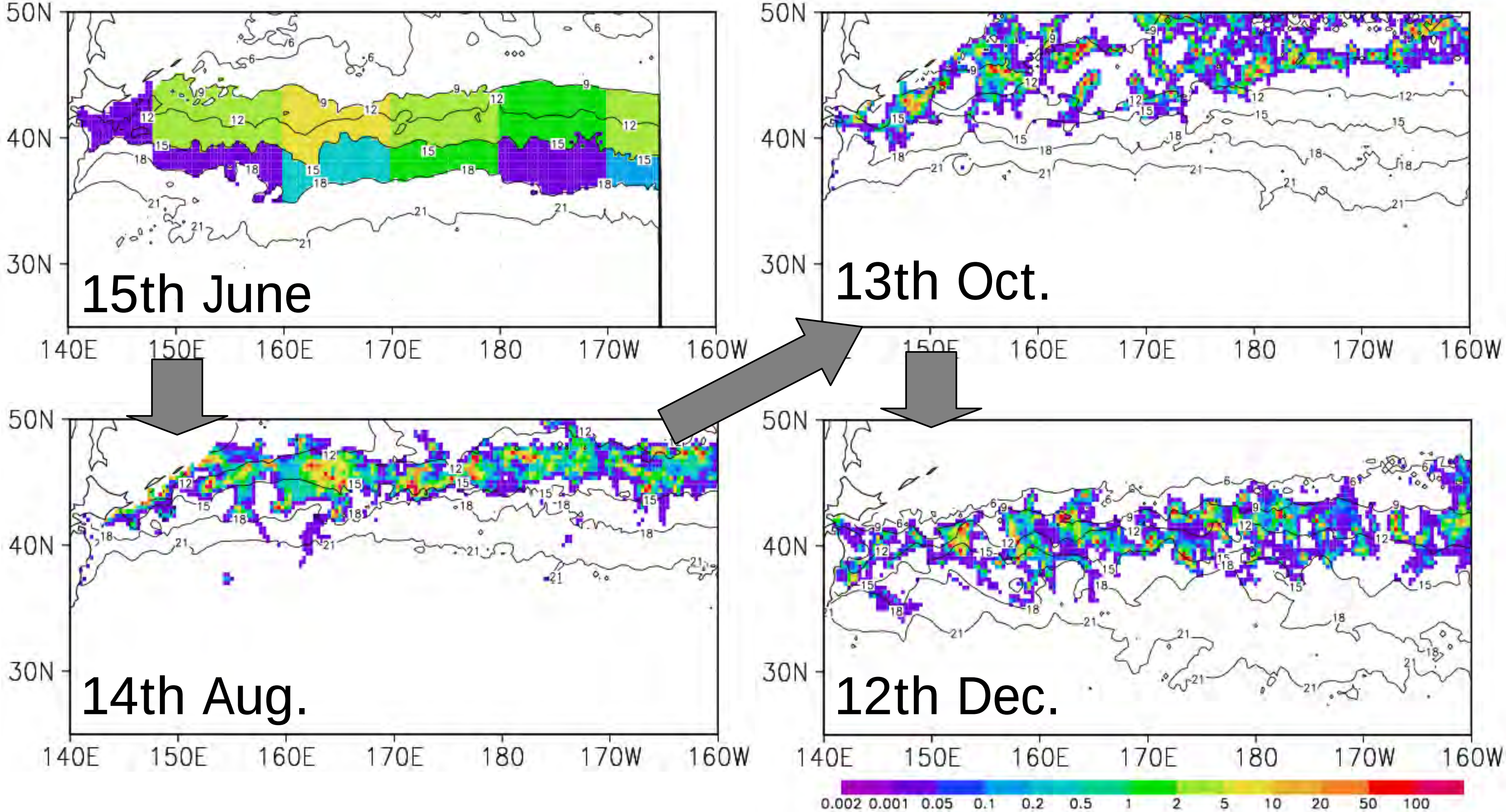
example of integration (2003)



example of integration (2003)

major features of migration are reproduced.

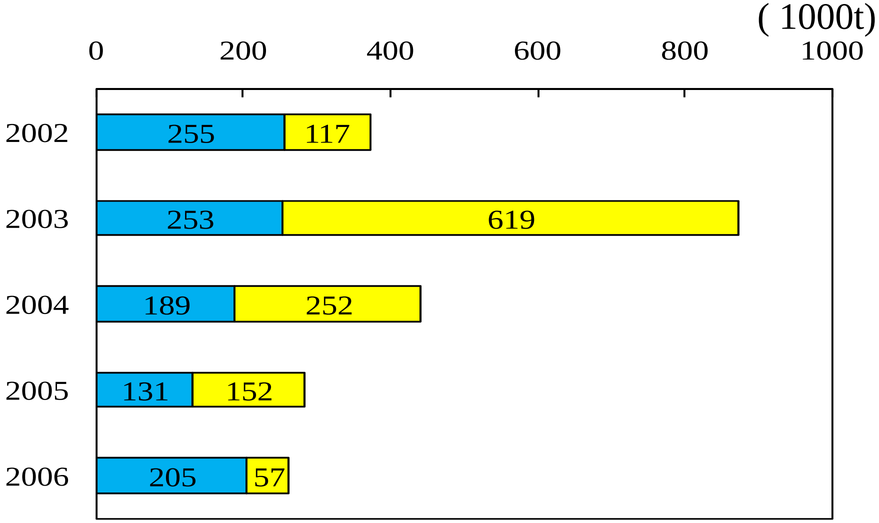
failure: westward migration in spawning season



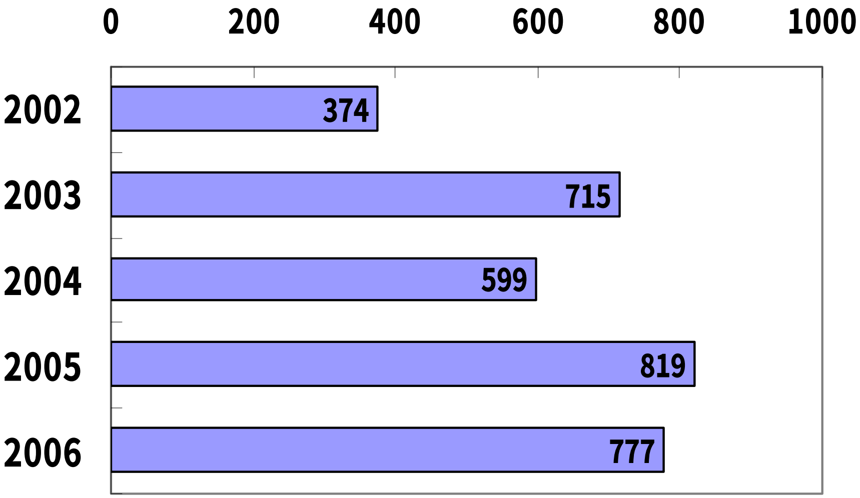
1-years saury distribution (larger than 28 cm in initial) on day 0, 61, 121, 181 from the start of integration in 2003.

migrated biomass to Japan coastal area

model



migration index



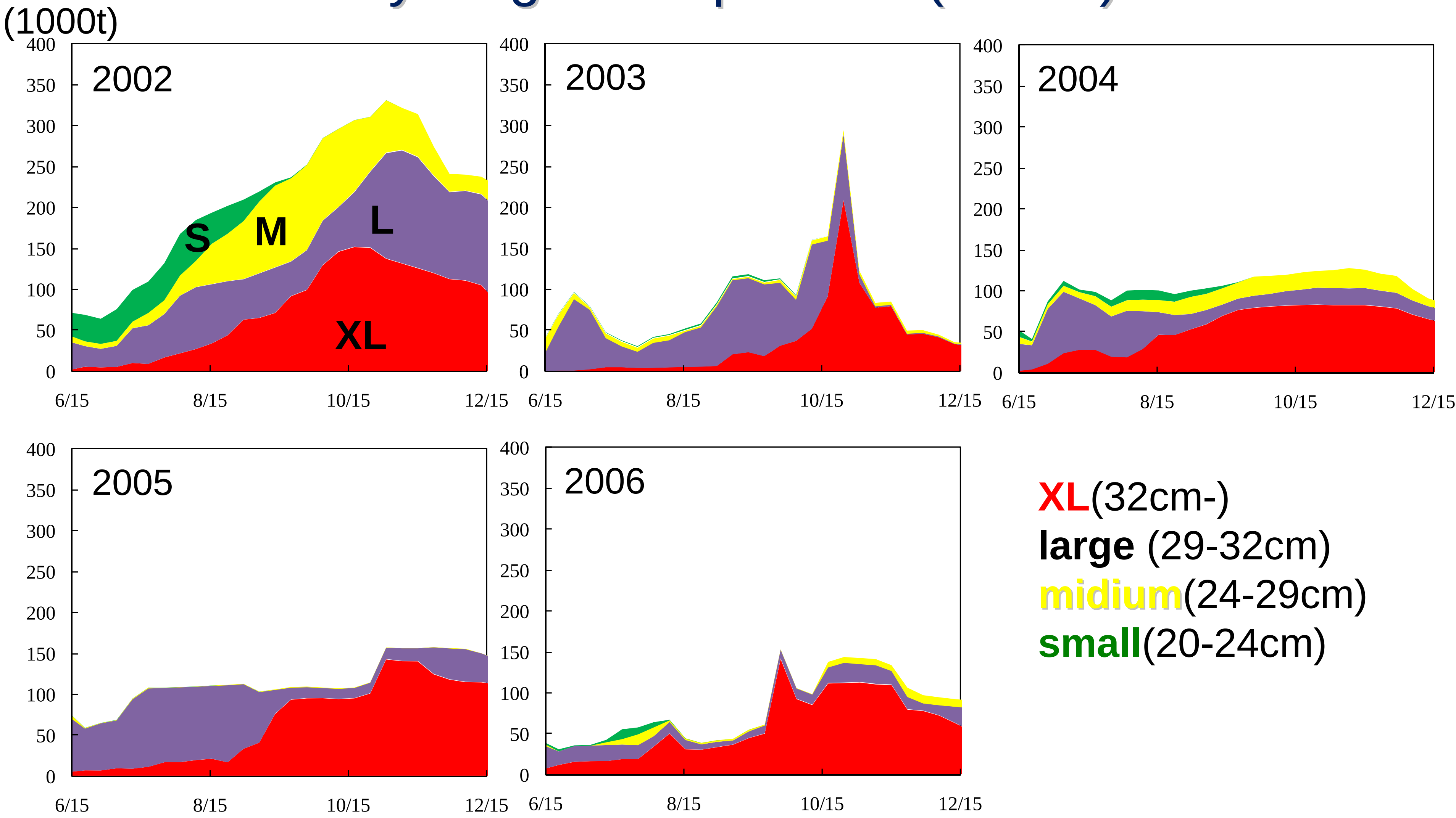
blue: biomass in the west of 150E on 31th July.

Yellow: biomass across 150E during 1st Aug. - 31th Oct.

migration index (TNFRI, 2011)
sum of CPUE (30' grid) in the fishing grounds

It is impossible to compare directly these values.
Tendency from 2002 to 2004 seems better.
Model may underestimate in 2005 & 2006.
Westward movement in the spawning migration may be needed to get reasonable results.

body length composition (model)

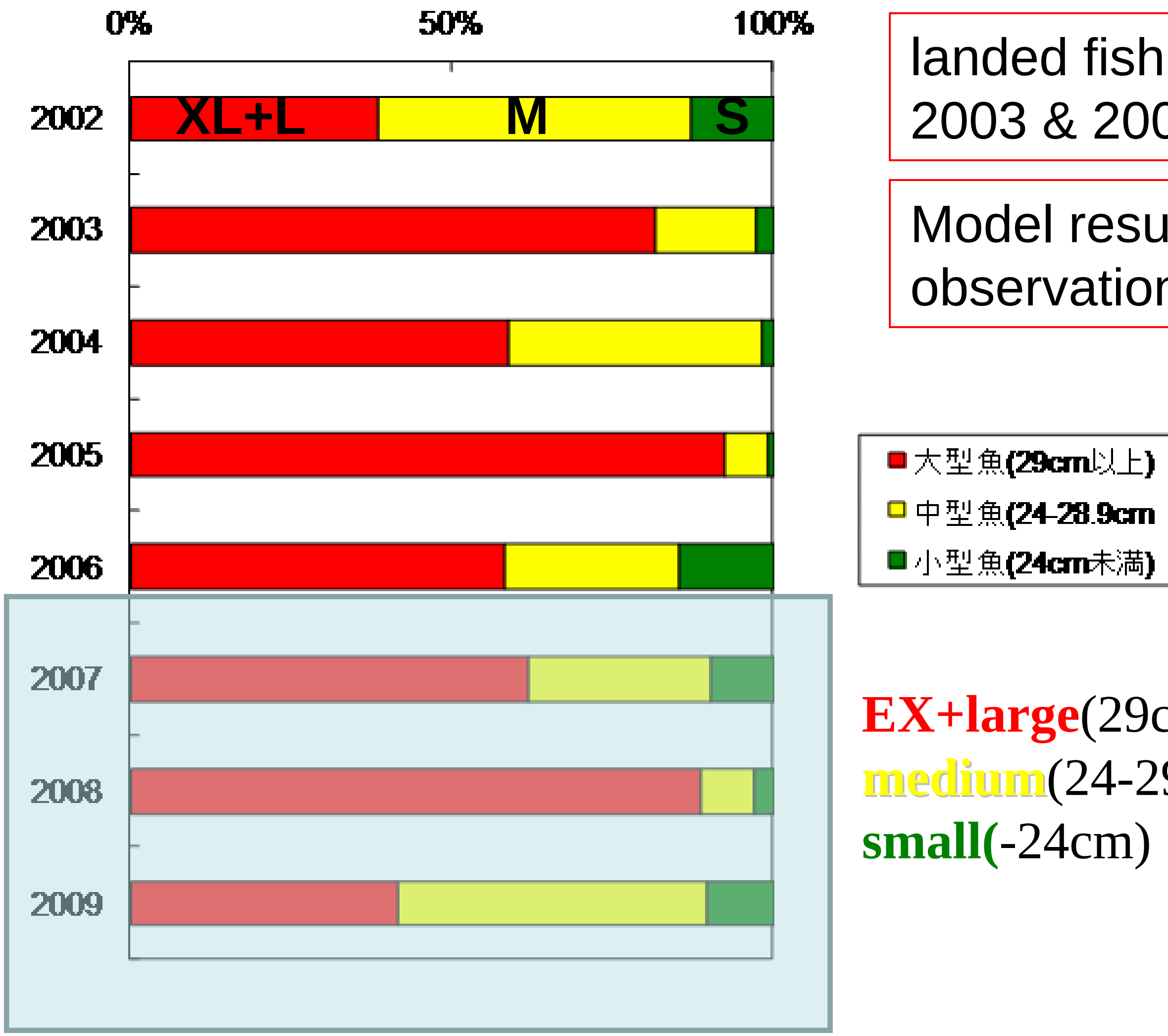


XL(32cm-)
large (29-32cm)
midium(24-29cm)
small(20-24cm)

saury biomass west of 148°E during fishing season.

XL & L are dominant in 2003 & 2005.

Observation in catch

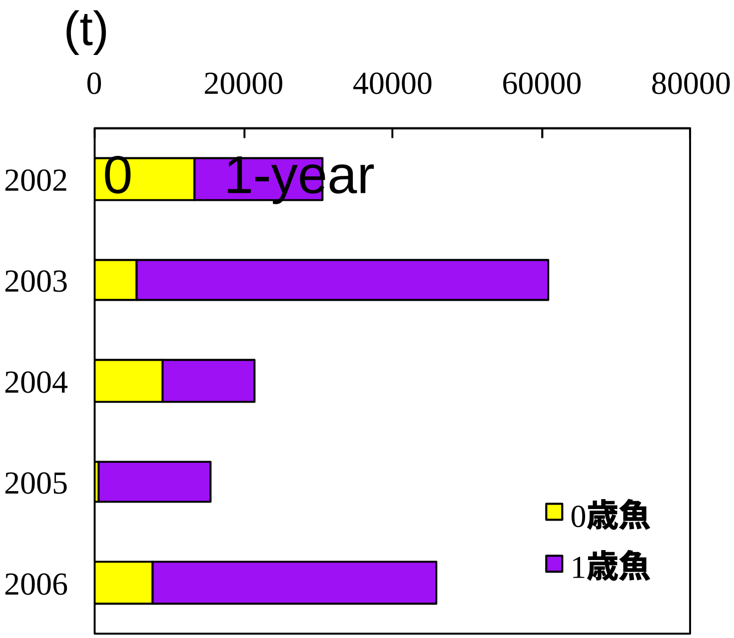


landed fish: XL & L are dominant in 2003 & 2005.

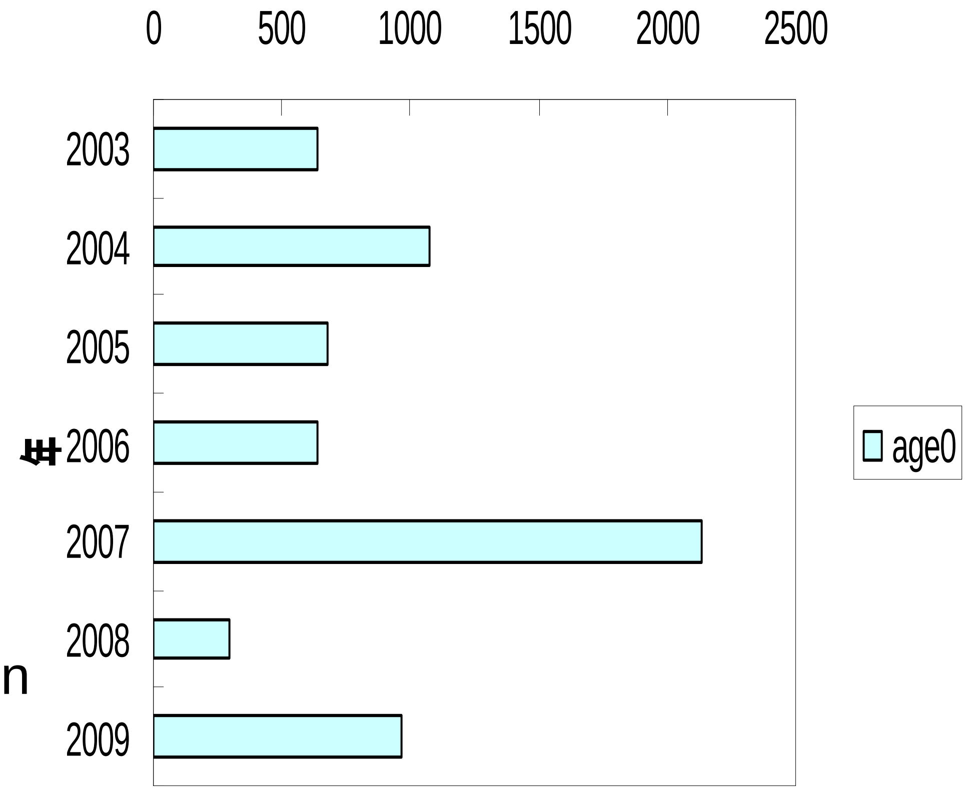
Model result is consistent with the observation.

EX+large(29cm-)
medium(24-29cm)
small(-24cm)

Egg production



Egg production by 0 & 1-year fish in the model west of the dateline during Sep. to May.



Recruitment index in the next year (observation).

56-68% in 2002&2004.
90% & 83% in 2003 & 2006.
averaged contribution of 1-year fish is 77%.

Egg production (model) and next year recruitment seem consistent.

Conclusion for Euler type model

Realistic simulation by an Euler type model

reasonable migration except for westward spawning migration.

Migration to Japan coastal area

underestimation in 2005 & 2006.

westward movement may be needed.

Size composition

reasonable compared with observation.

Egg production

model reproduced egg production consistent with observational next year recruitment.

model estimated 1-year fish contributes 77% (56〜83%) of egg production.

Problems:

1.artificial mixture of body size of fishes.

2.model's failure in westward migration in spawning season.

S-IBM (Super individual based model) of Pacific saury

Period:

2002/2/1 – 2004/1/31 (2 years)

Initial condition:

put eggs in the area of 18.5-20.0 degC based on Iwahashi et al. (2006).

migration:

same as one of the Euler model

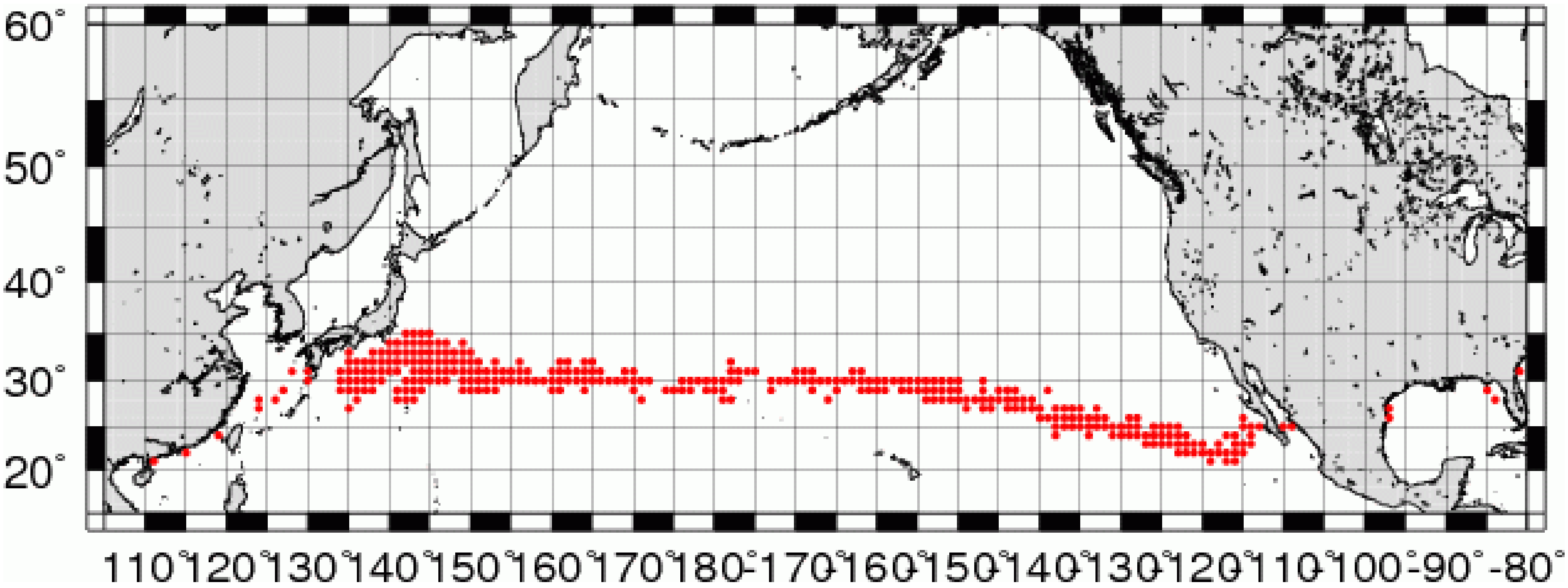
in test case, eastward migration during spawning season converted westward

Evaluation:

end points of spawning migration after 2-years.

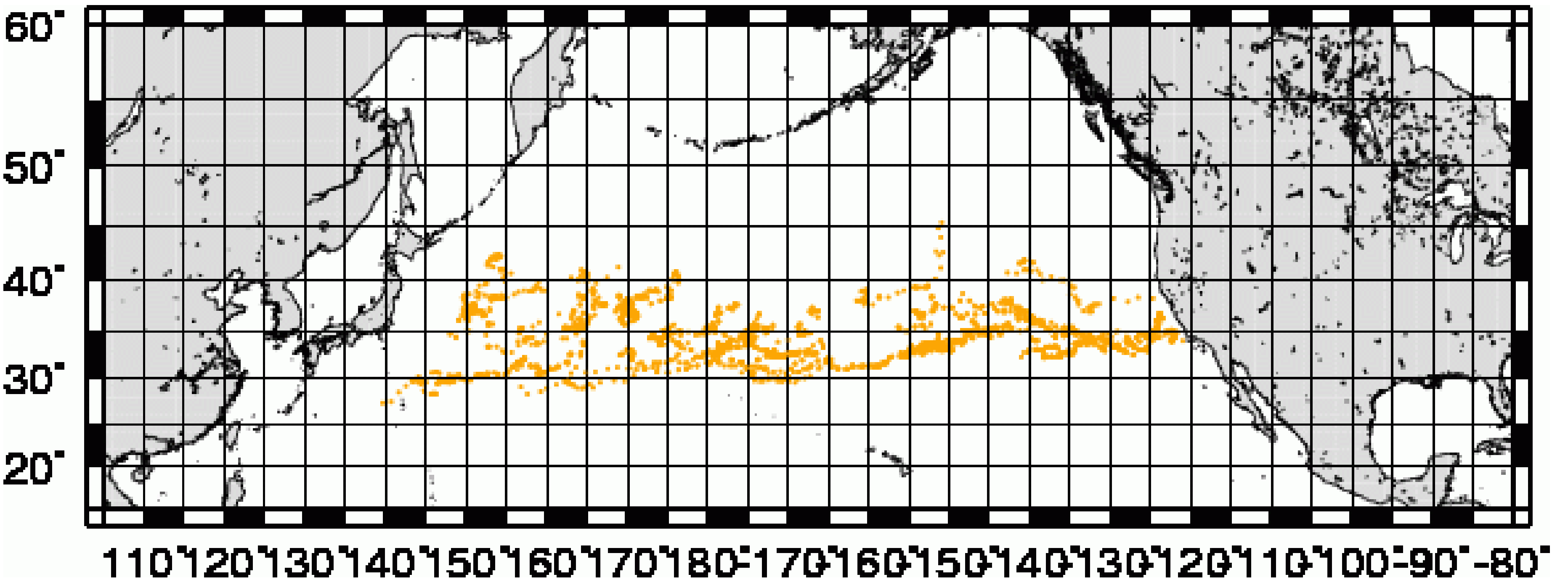
success if fish is within 15-19.7 degC and bigger than 25 cm

Initial condition



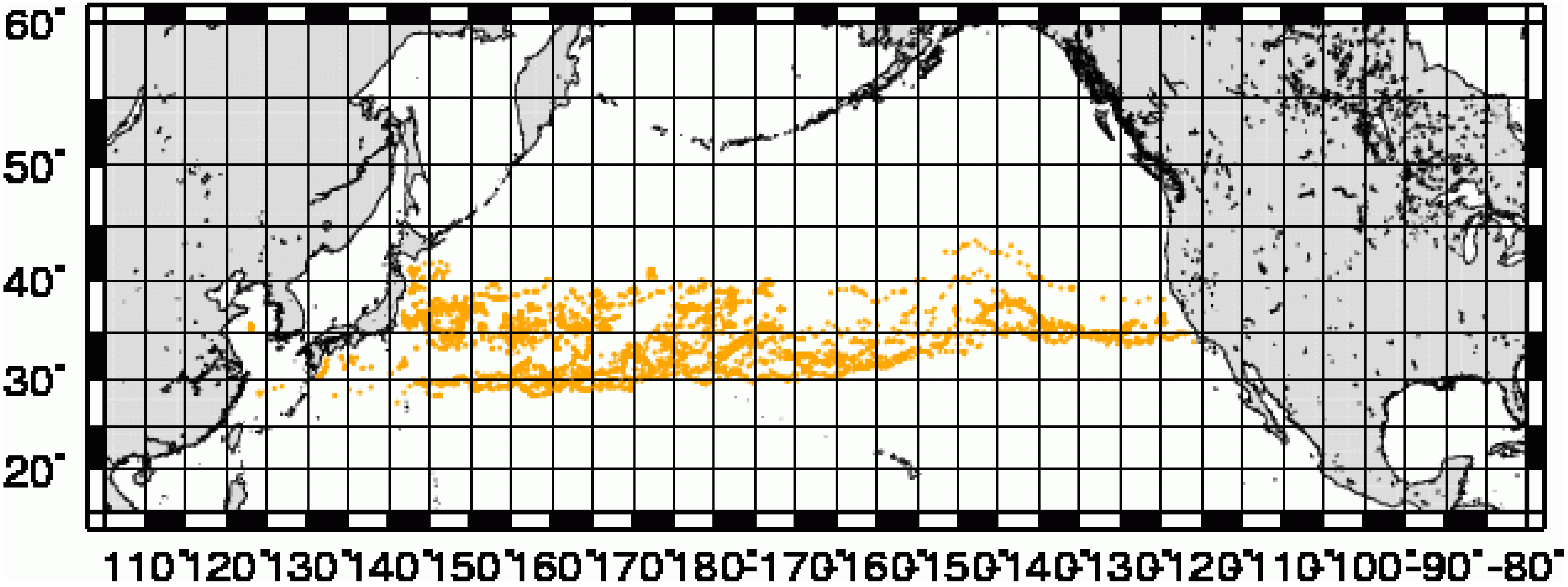
18.5 – 20 degC, 1degx1deg resolution.

spawning grounds in 2nd year



No spawning ground is formed around Japan.
Distribution is biased to the eastward.

spawning grounds in 2nd year
(artificial westward migration case)



Spawning ground is also formed around Japan.

Conclusion

Euler type model

1.It works.
2.However, there is artificial mixture of size classes.
3.Therefore, we must divide the size classes and this need computational cost.

S-IBM

1.Effective to trace the movement.
2.Need huge computational cost to cover all biomass.

Migration algorism

1.Feeding migration seems easier to imitate.
2.Spawning migration seems difficult to imitate.