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 (Atlantic saury)

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

change of biomass

\( v = \text{self movement} + \text{advection} \)

self movement = \(2 \times BL\, (cm) / \text{sec} \)

time step: 1 hour,  \( k = 1.0 \times 10^2 \, (m^2/s) \)

forcing

\( B, W, N, G \)

self movement

advection

distribution of biomass

movement
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)
(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

**objective**

a. investigate 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)

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

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)
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.

density of fish = catch / S / F
S: towed area
F: catch efficiency
(Stock assessment report, 2008)
example of integration (2003)
00Z15JUN2003
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.
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.
saury biomass west of 148°E during fishing season.

XL & L are dominant in 2003 & 2005.

Model result is consistent with the observation.

EX+large (29cm-)
medium (24-29cm)
small (-24cm)
Egg production by 0 & 1-year fish in the model west of the dateline during Sep. to May.

- 90% & 83% in 2003 & 2006.
- Averaged contribution of 1-year fish is 77%.

Recruitment index in the next year (observation).

Egg production (model) and next year recruitment seems 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
  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.
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.