# Uncertainty of fish growth projection caused by uncertainty of physical forcing.

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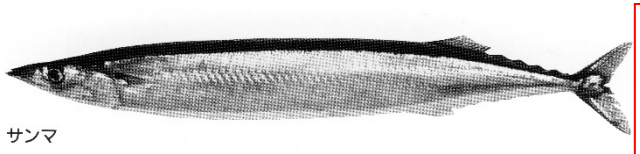
## Today's contents

1. Life history of saury and NEMURO.FISH
2. Single projection of Pacific saury
3. Ensemble projection of Pacific saury
4. Projection with 2D-migration

# Catch of Pacific Saury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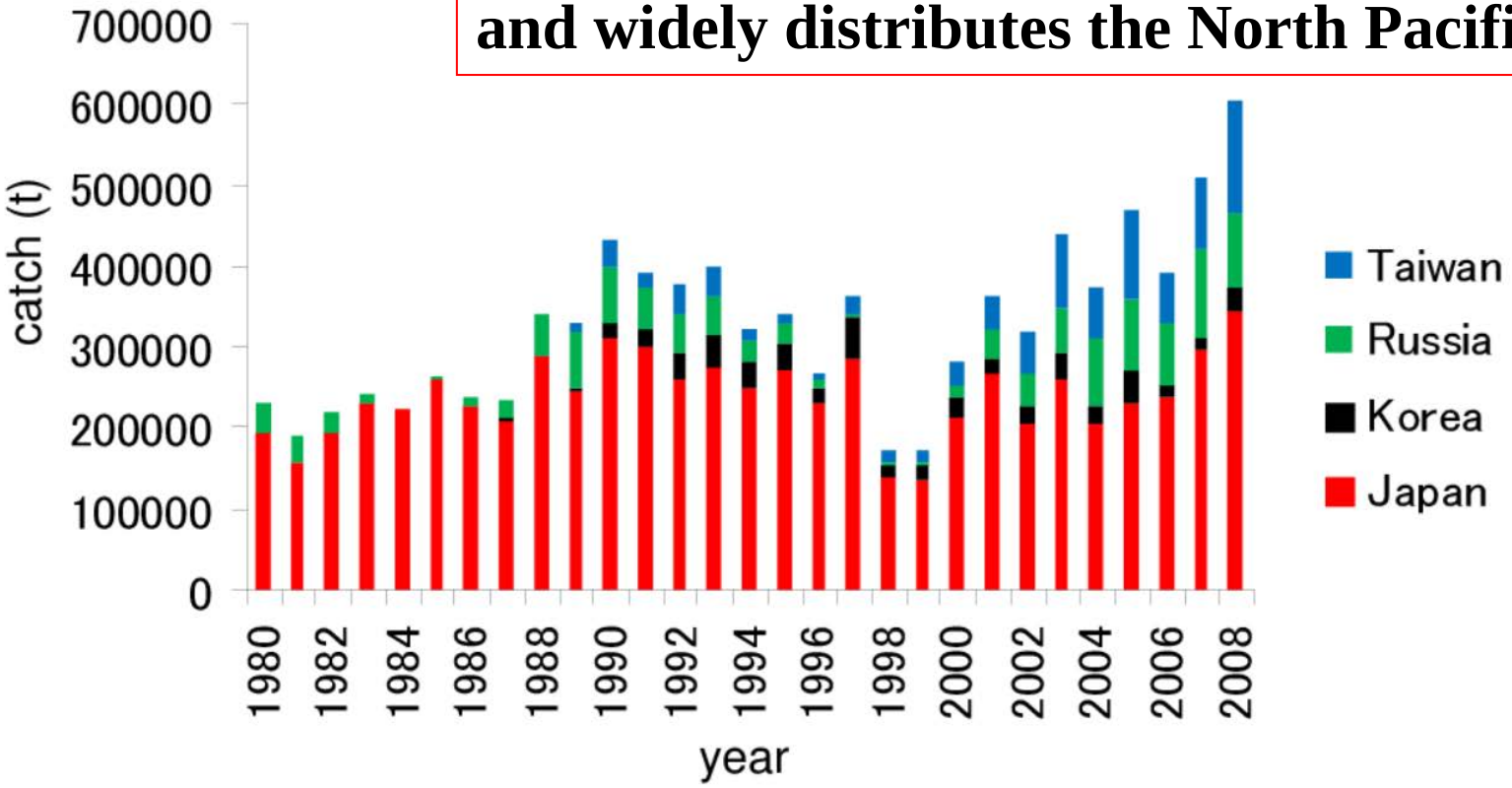
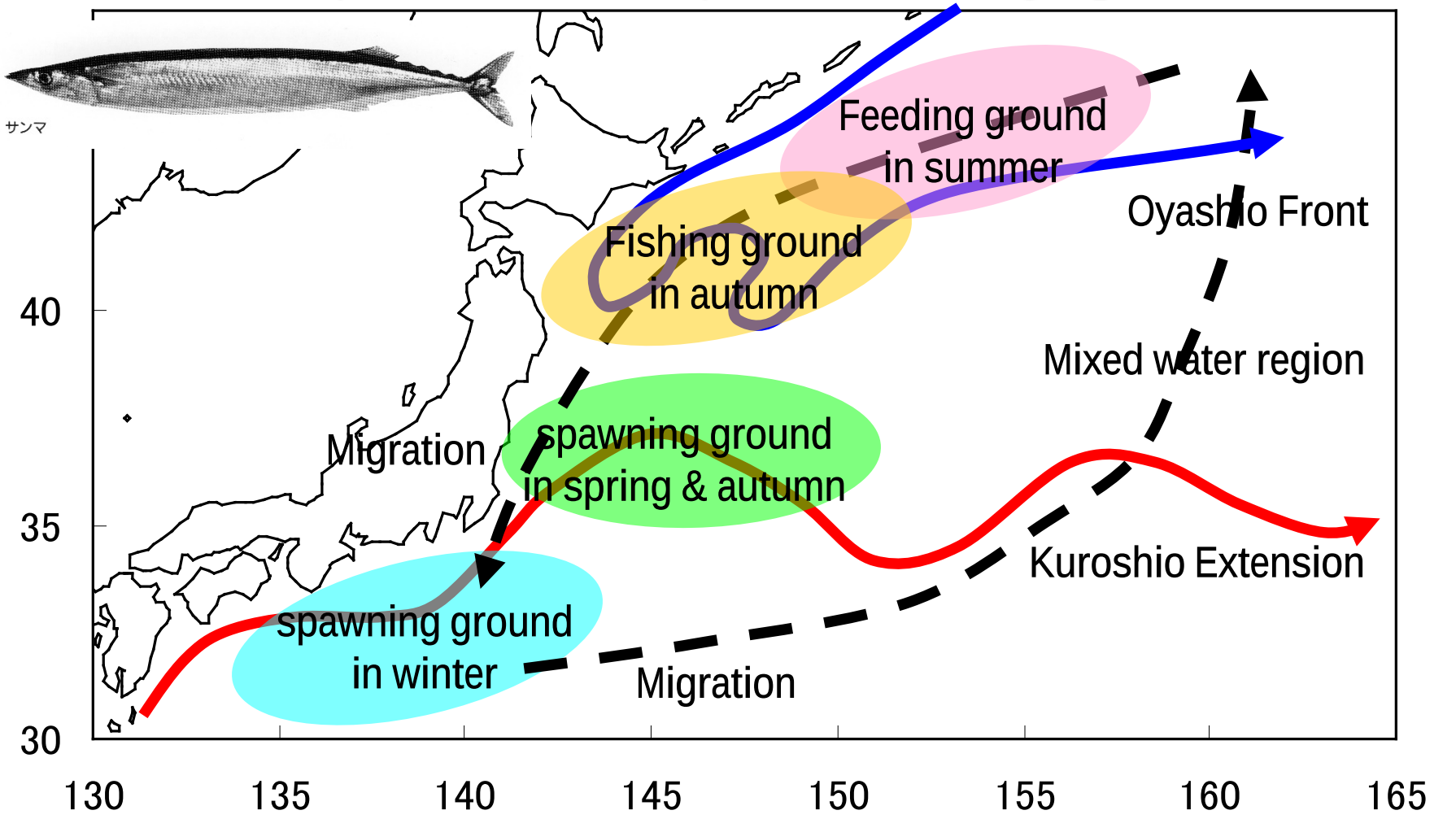
**Pacific saury is one of the dominant small pelagic fish in the northwestern Pacific and widely distributes the North Pacific.**




Ito et al. (2013, ICES-JMS)

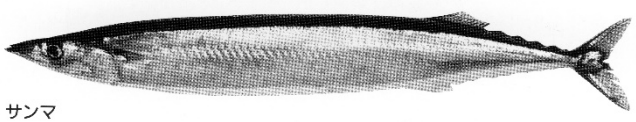
# Life History of Pacific Saury with Oceanographic Features

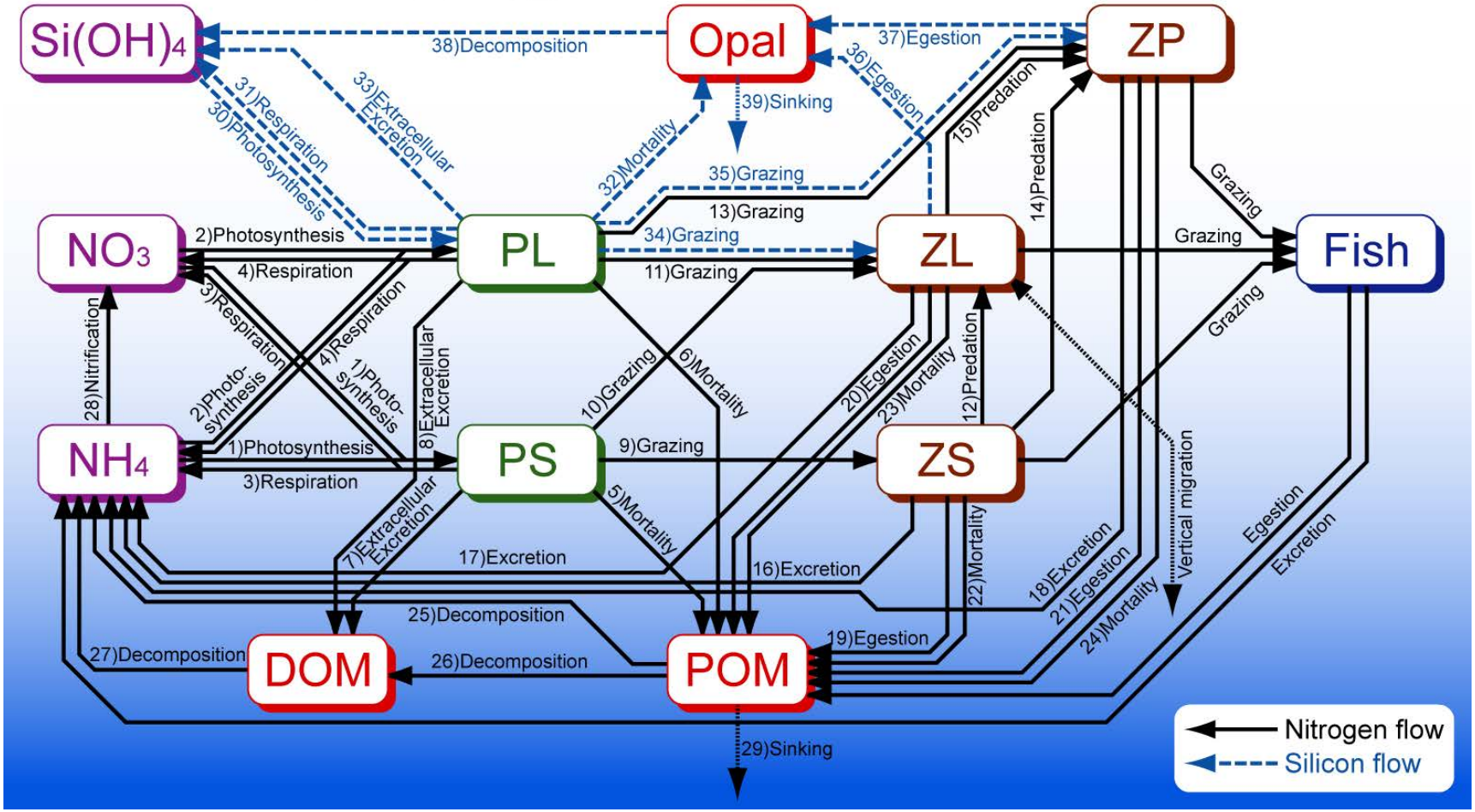



Ito et al. (2004a, Fish. Oceanogr.)

# NEMURO.FISH

## NEMURO for Including Saury and Herring




Megrey et al. (2007a, Ecol. Model.), Ito et al. (2004b Fish. Oceanogr.) etc.

# 3-box version

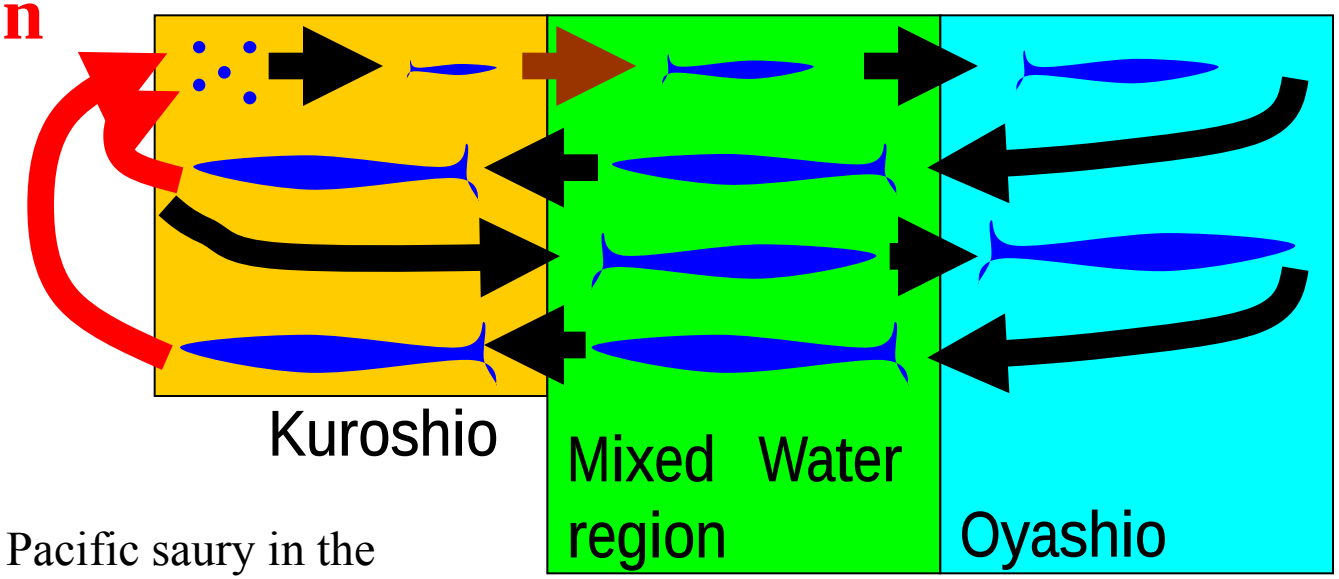
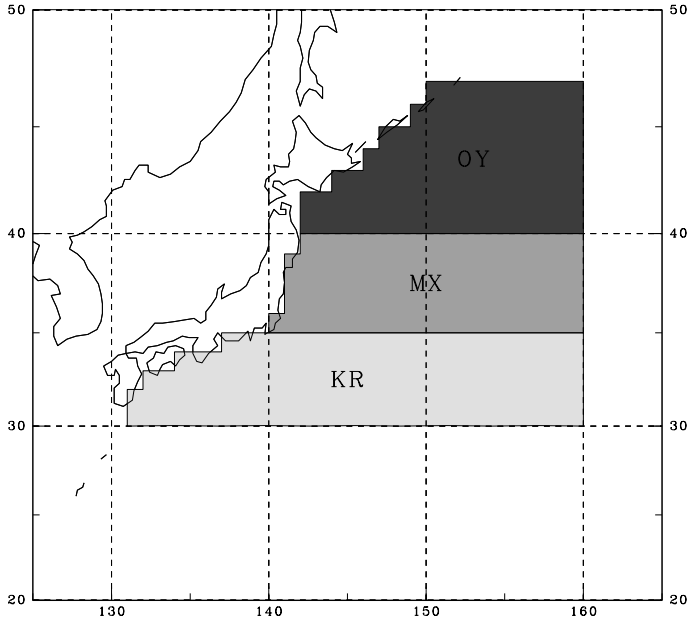



Table 2. Life stages of Pacific saury in the saruy bioenergetics model

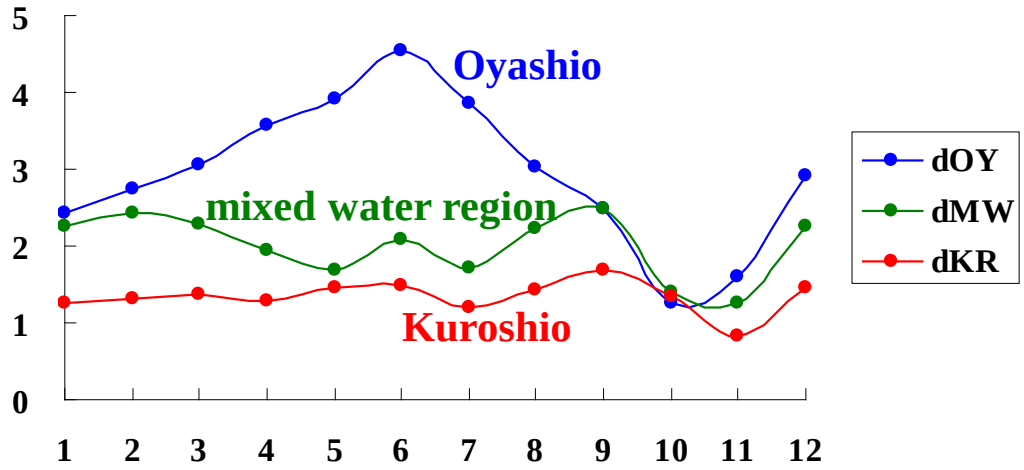
| Stage | region |
|---|---|
| larvae | Kuroshio |
| juvenile & young | mixed region |
| small | Oyashio |
| adult | mixed region |
| adult matured | Kuroshio |
| adult | mixed region |
| adult | Oyashio |
| adult | mixed region |
| adult matured | Kuroshio |

1. **NEMURO.FISH successfully, reproduced reasonable growth of Pacific saury (Ito et al. 2004, Fish. Oceanogr.).**
2. **NEMURO.FISH reasonably reproduced growth difference between cohorts spawned in different seasons (Mukai et al. 2007, Ecol. Model.).**
3. **NEMURO.FISH reasonably reproduced inter-annual variation of Pacific saury growth except for influences by Japanese sardine (Ito et al. 2007, Ecol. Model).**

# Pacific saury: Global warming experiment




**Temp. anomaly in 2050**
**(from MIROC model, A2 scenario)**

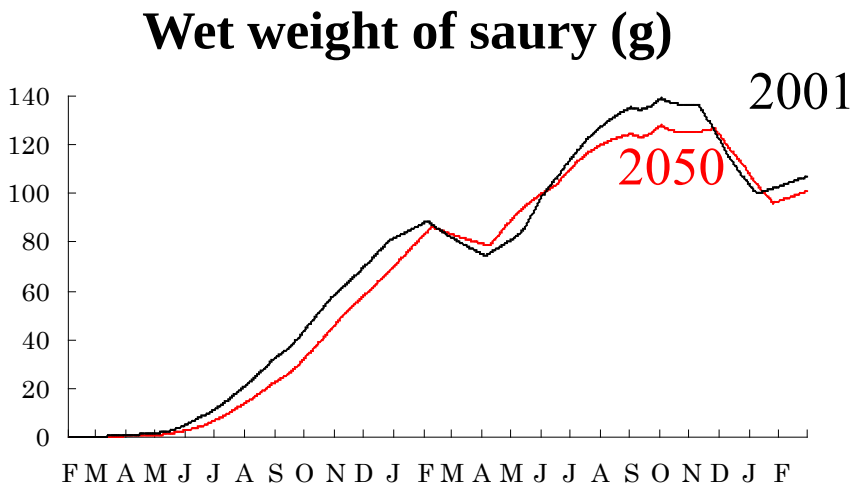



Ito et al. (2010, Oxford Press)

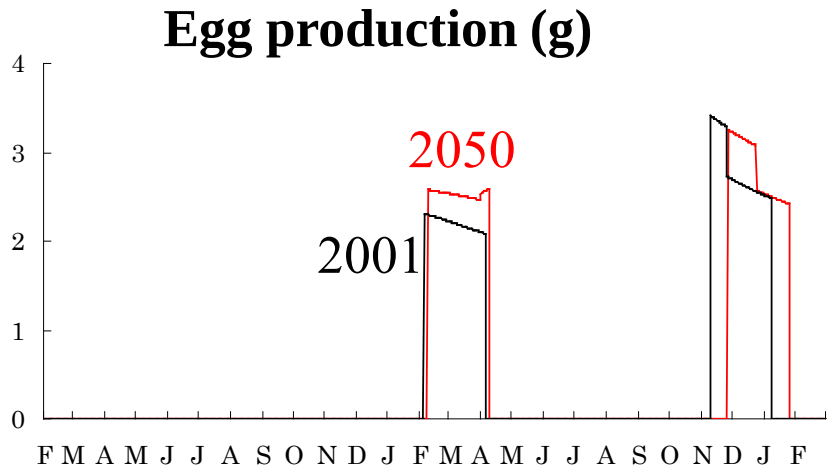
**numerical experiment**

1. **Averaged SST anomaly in three ocean domains.**
2. **Estimate future SST field by adding SST anomaly with current SST.**
3. **Integrate NEMURO.FISH with future SST.**

# *Pacific saury: Global warming experiment*



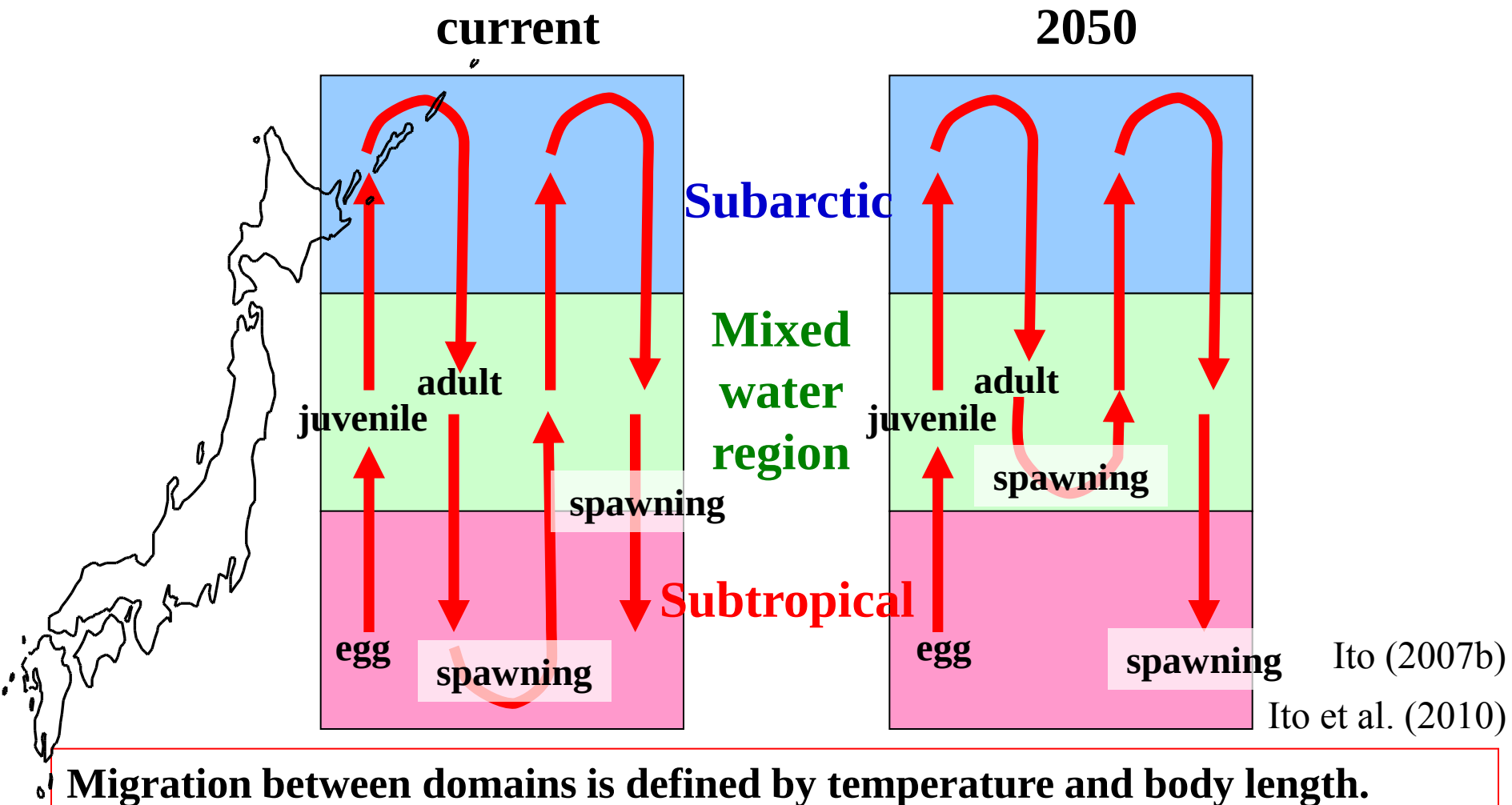

**Under global warming, the wet weight of adult saury was reduced about 10 g because of the decrease of prey zooplankton.**




**However, the egg production was enhanced by global warming.**

Ito (2007b), Ito et al. (2010)

# *Pacific saury (Global warming): simple model application*

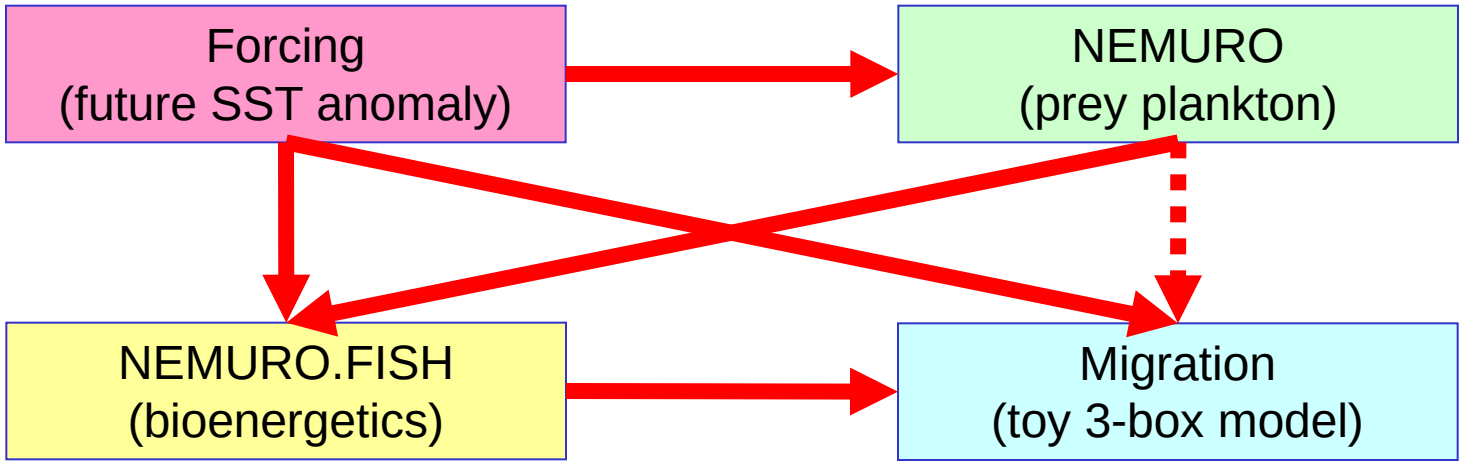



Ito (2007b)

Ito et al. (2010)

**Migration between domains is defined by temperature and body length. Under global warming situation, fish size is reduced and temperature is enough high in the mixed water region.**
**These factors prevent southward migration of saury in 1st winter and delay 2nd year migration. As a result, saury egg production is enhanced.**

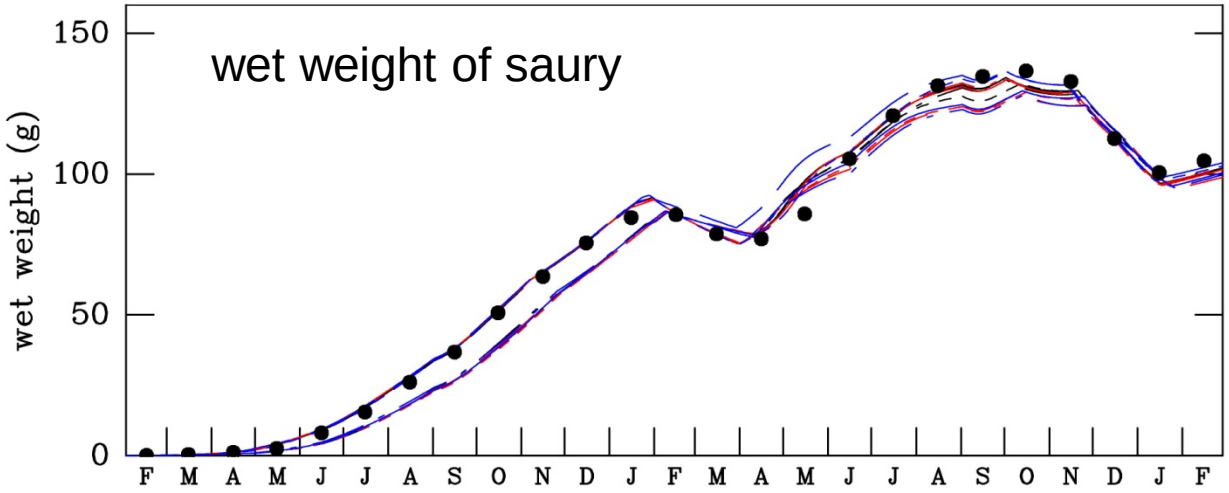
# Is the projection reliable?




- All components of model have uncertainty.
- IPCC-ARs showed ensemble predictions of future climate.
- However, Ito et al. (2010) used only one SST prediction.

As a first step, we conducted ensemble projection of saury growth using these multi-SST predictions.
Overland and Wang (2007) concluded only 12 models of IPCC-AR4 models successfully reproduced PDO (Pacific Decadal Oscillation).

# Ensemble experiment with 12 IPCC-SSTs (A1B senario)




- Control run (1950-1999)

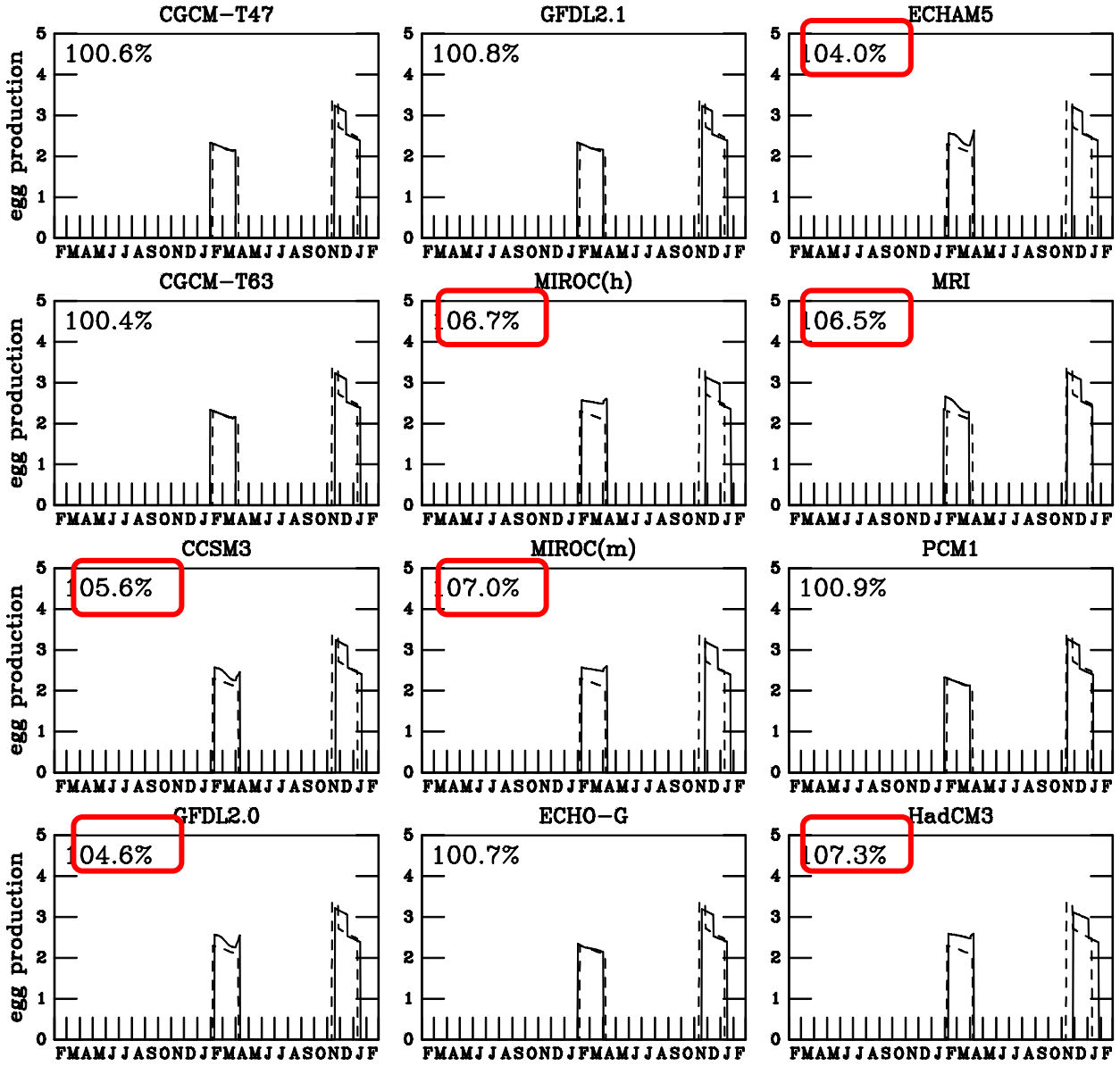
Ito et al. (2013, ICES-JMS)

ukhadcm3
pcm1
mri
mpi
miub
mirocM
mirocH
gfdl21
gfdl20
ccsm3
cccmat63
cccmat47

Results can be divided to 3 categories

1) reduction of weight in the 1st and 2nd years
   ccsm3, gfdl20, mirocH, mirocM, mpi, ukhadcm3
2) reduction of weight in the 2nd year
   cccmat47, cccmat63, gfdl21, miub
3) no decrease (or increase) of weight
   pcm1, mri

# Ensemble experiment with 12 IPCC-SSTs (A1B scenario)




egg production

Broken: Control run (1950-1999)
Solid: 2050-60

Egg production was enhanced in several cases but not in other cases.

Ito et al. (2013, ICES-JMS)

# Dependency on emission scenarios

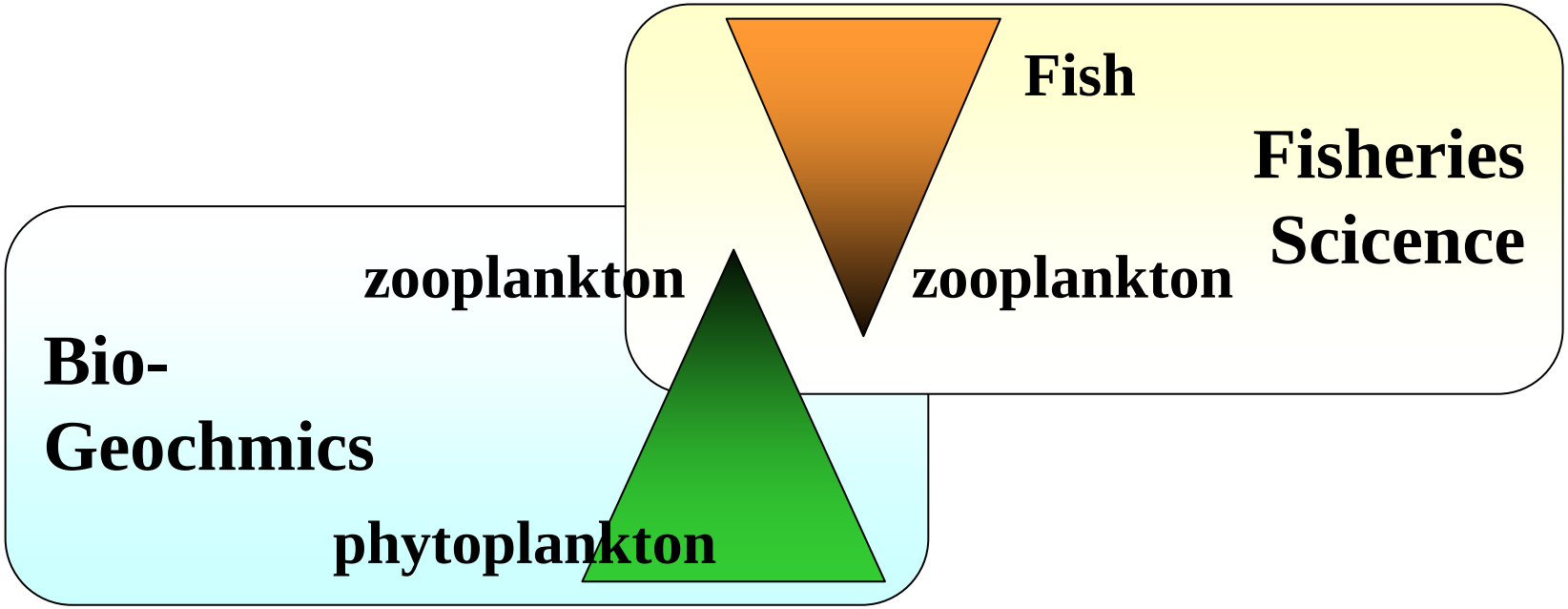
24 (73%) of 33 runs showed decrease of saury weight.
The result seems robust.
However only 11 (33%) showed decrease in egg production.

| | A2 | A1B | B1 |
|---|---|---|---|
| ukhadcm3 | 1st&2nd year decrease | 1st&2nd year decrease | 1st&2nd year decrease |
| mirocH | | 1st&2nd year decrease | 1st&2nd year decrease |
| mirocM | 1st&2nd year decrease | 1st&2nd year decrease | 2nd year decrease |
| cccm3 | 2nd year decrease | 1st&2nd year decrease | 2nd year decrease |
| mpi | 2nd year decrease | 1st&2nd year decrease | no decrease |
| gfdl20 | no decrease | 1st&2nd year decrease | |
| miub | 1st&2nd year decrease | 2nd year decrease | 2nd year decrease |
| cccmat63 | | 2nd year decrease | no decrease |
| ccmat47 | 2nd year decrease | 2nd year decrease | no decrease |
| gfdl21 | no decrease | 2nd year decrease | 2nd year decrease |
| mri | 2nd year decrease | no decrease | 2nd year decrease |
| pcm1 | no decrease | no decrease | no decrease |

Ito et al. (2013, ICES-JMS)

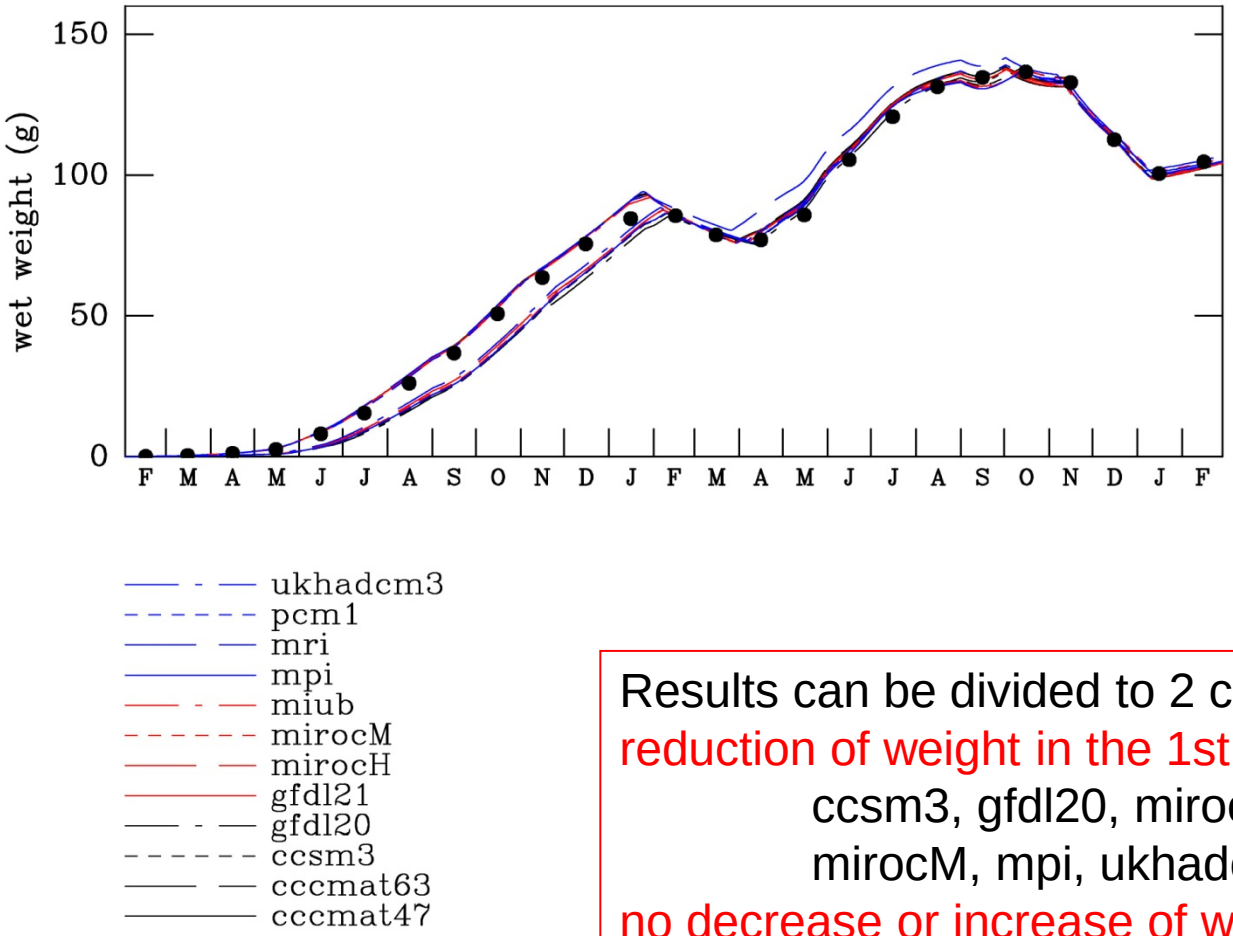
# Ensemble experiment with IPCC-SSTs

- The ensemble experiments showed the range of potential outcomes caused by different SST forcing.
- However, the biological model also has uncertainty.
  Especially, accuracy of zooplankton responses has large uncertainty.
  This is because bottom-up focusing scientists start from phytoplankton and top-down focusing scientists start from fish. Therefore, zooplankton resolution or accuracy often becomes an weakness.
- However, the most benefit of model study is that it is possible to separate the direct effects of SST and its effect through prey production.
  We conducted an ensemble experiment in which only SST is changed but the prey density is kept as the same as the control run (1950-1999).



# Ensemble experiment (direct effect of SST)
# A1B

only change the SST but keep the prey density as same as the control run.




- Control run (1950-1999)

No projection showed decrease in 2nd year, and hence enhancement of egg production.

SST directly affects the juvenile growth.

Results can be divided to 2 categories

reduction of weight in the 1st year

ccsm3, gfdl20, mirocH, mirocM, mpi, ukhadcm3

no decrease or increase of weight

cccmat47, cccmat63, gfdl21, miub, pcm1, mri

Ito et al. (2013, ICES-JMS)

# Conclusion of Ito et al. (2013, ICES-JMS)

**Model results suggested the possibilities of**
- **size reduction (73%), and**
- **number increase (33%)**

**of Pacific saury under global warming conditions. However, model and other forcing contain uncertainty.**

**A merit of model investigation is that it enables to separate causes. Model results suggested**
- **SST increase (especially in MW) directly reduces juvenile growth, and**
- **prey decrease influences on the growth of adult and migration pattern, hence egg production.**

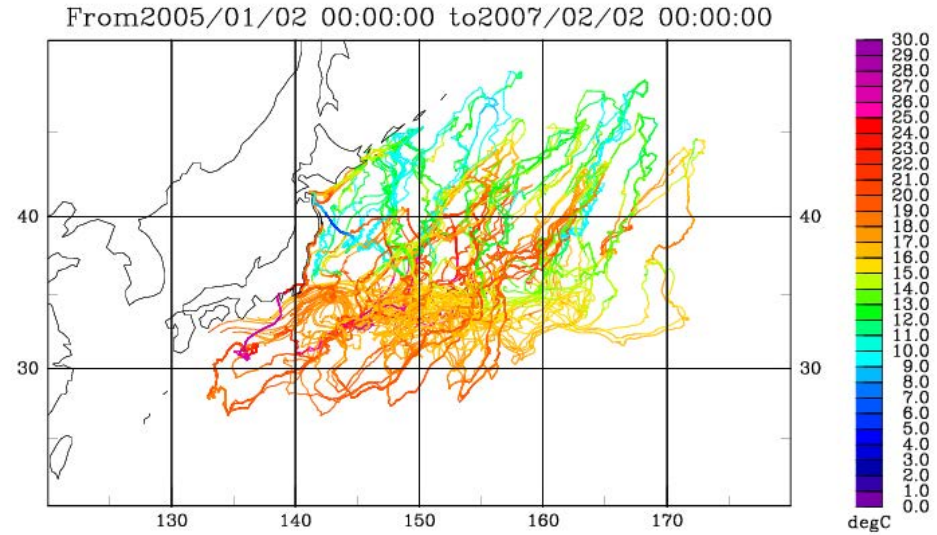
**To reduce the uncertainty, it is important to**
- **fill the parameter gaps in biological model**
- **conduct projections with more realistic conditions (including 2D-migration, sequential future climate forcing, etc.)**

# Example: CHOPE-eNEMURO (Global warming exp.)

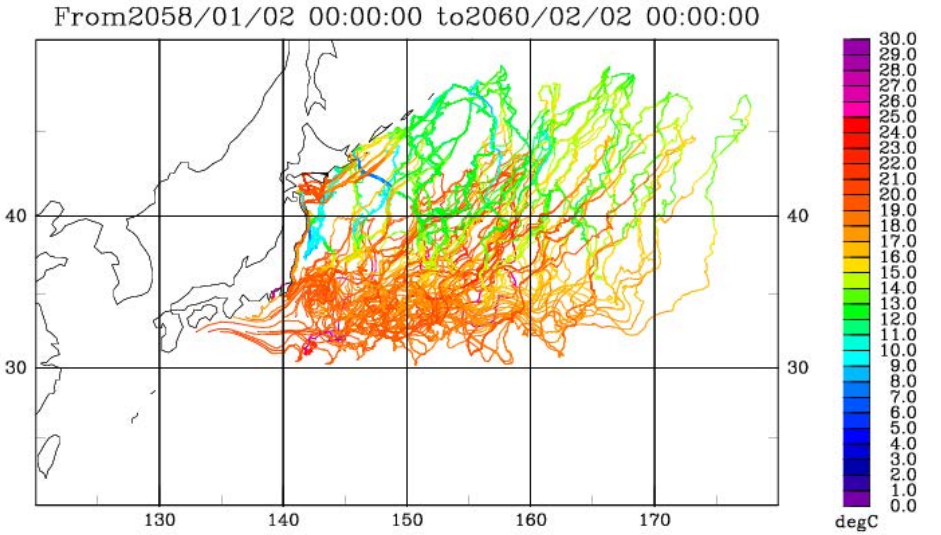
Pacific saury

Ito et al. (in prep.)

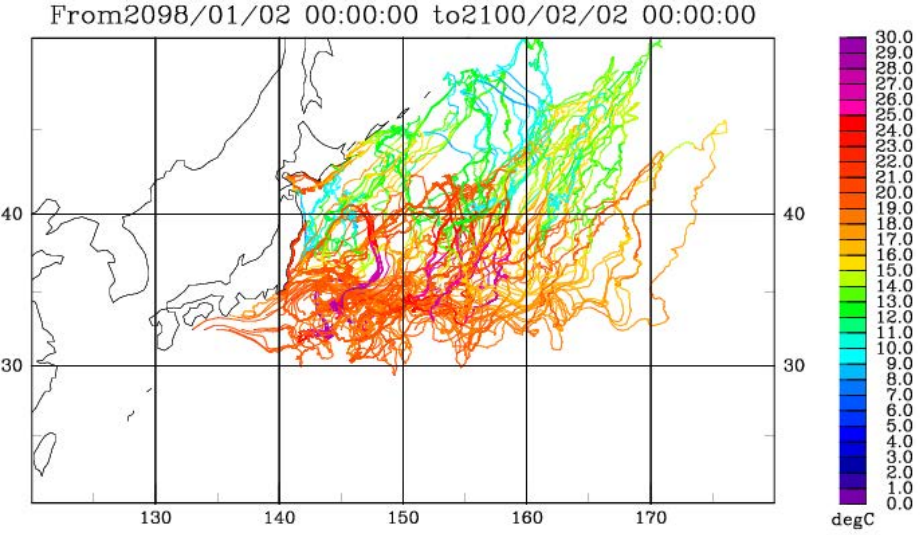
2000-2010




2050-2060




2090-2100




Higher temp.
→limitation of southward migration
→strong eastward transport of Kuroshio Extention
→offshore migration

# Example: CHOPE-eNEMURO (Global warming exp.)

Pacific saury

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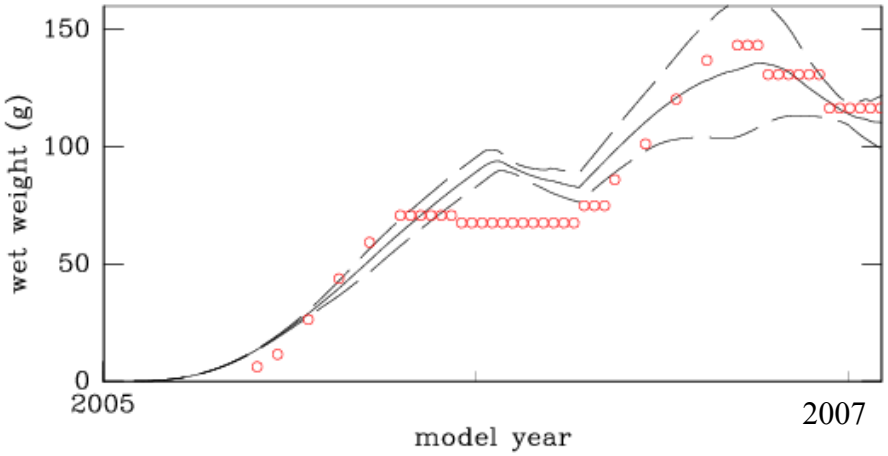
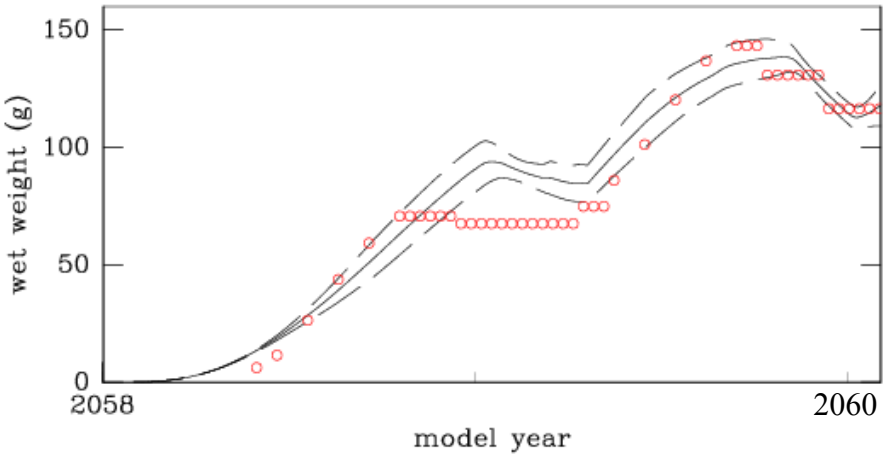
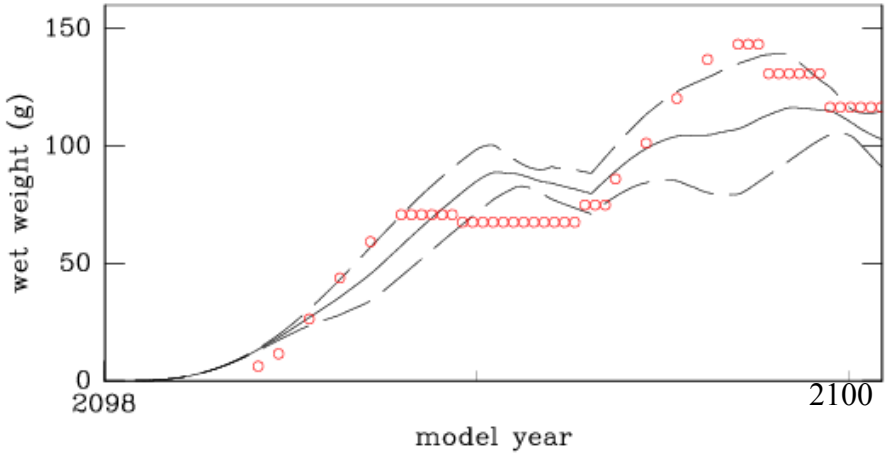
2000-2010




2050-2060




2090-2100




Higher temp.
→limitation of southward migration
→strong eastward transport of Kuroshio Extention
→offshore migration
→reduction of variation (middle size)

Decrease in prey plankton
→reduction of size (smaller size)

# Concluding remarks

**All models and forcing contain errors.**
**Especially, concerning about global warming issues, there is large uncertainty in emission scenarios.**

**There is no models can provide precise projections.**
**A merit of model application is that it can help our consideration and elucidation.**

**Additionally, it may be possible to reduce the uncertainty by**

- **filling the parameter gaps in biological models**
- **conducting projections with more realistic conditions (including 2D-migration, sequential future climate forcing, etc.)**

**These reduction of uncertainty also improve our understanding of marine ecosystems.**
**Even if we cannot make precise projections, challenges to make projections tell us decisions we must take at that stage.**