Future projection of Pacific saury to climate change and its improvements by experimental and observational approaches.

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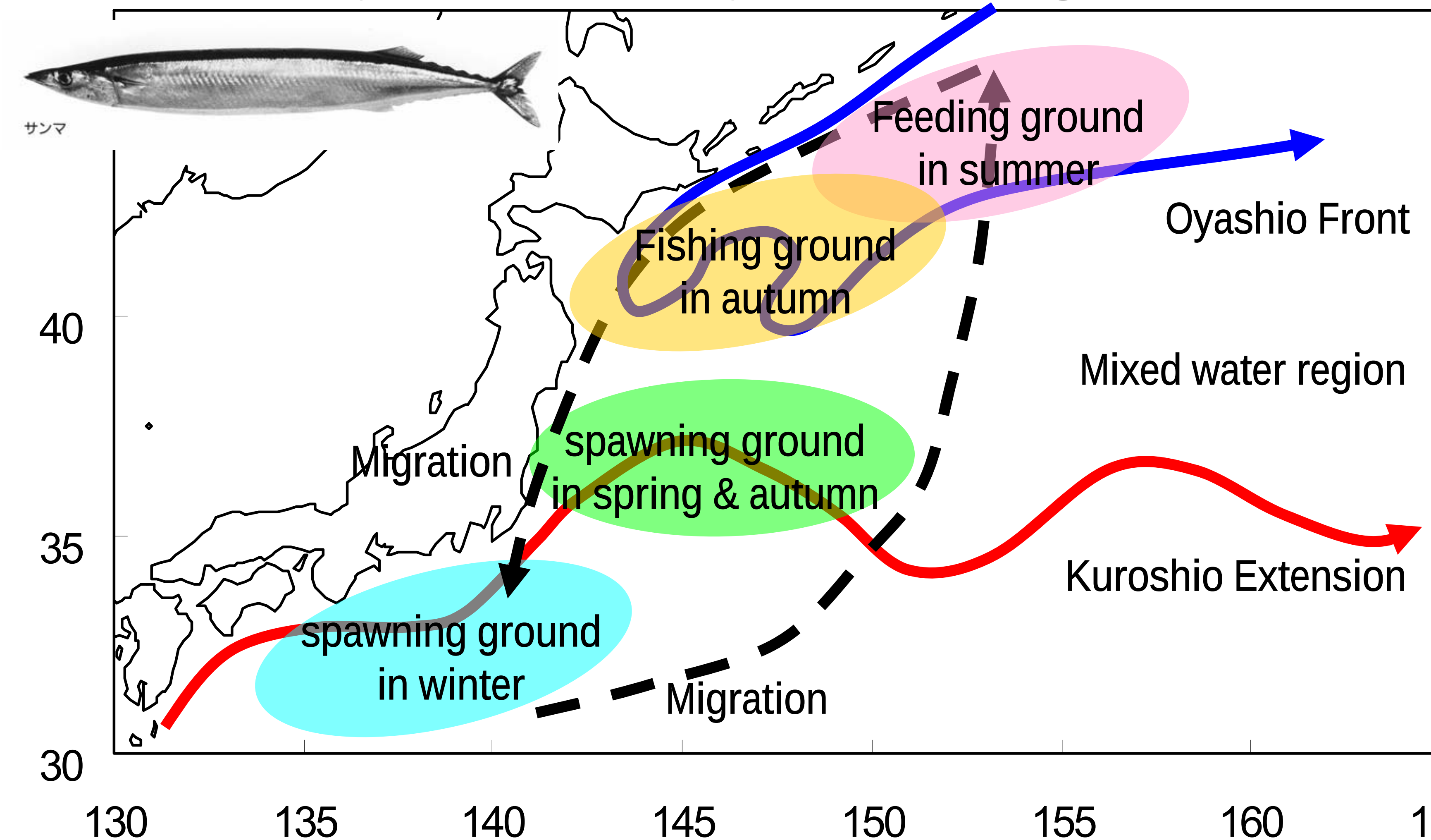
Today's contents

1. Life history of saury and NEMURO.FISH
2. future prediction of Pacific saury
3. problems of NEMURO.FISH
4. improvements by experimental approaches

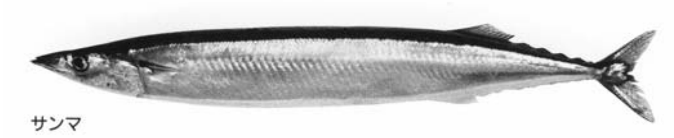
Life History of Pacific Saury with Oceanographic Features

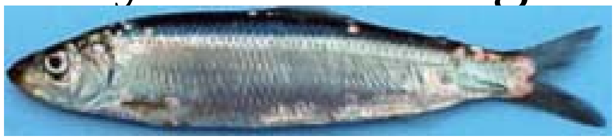


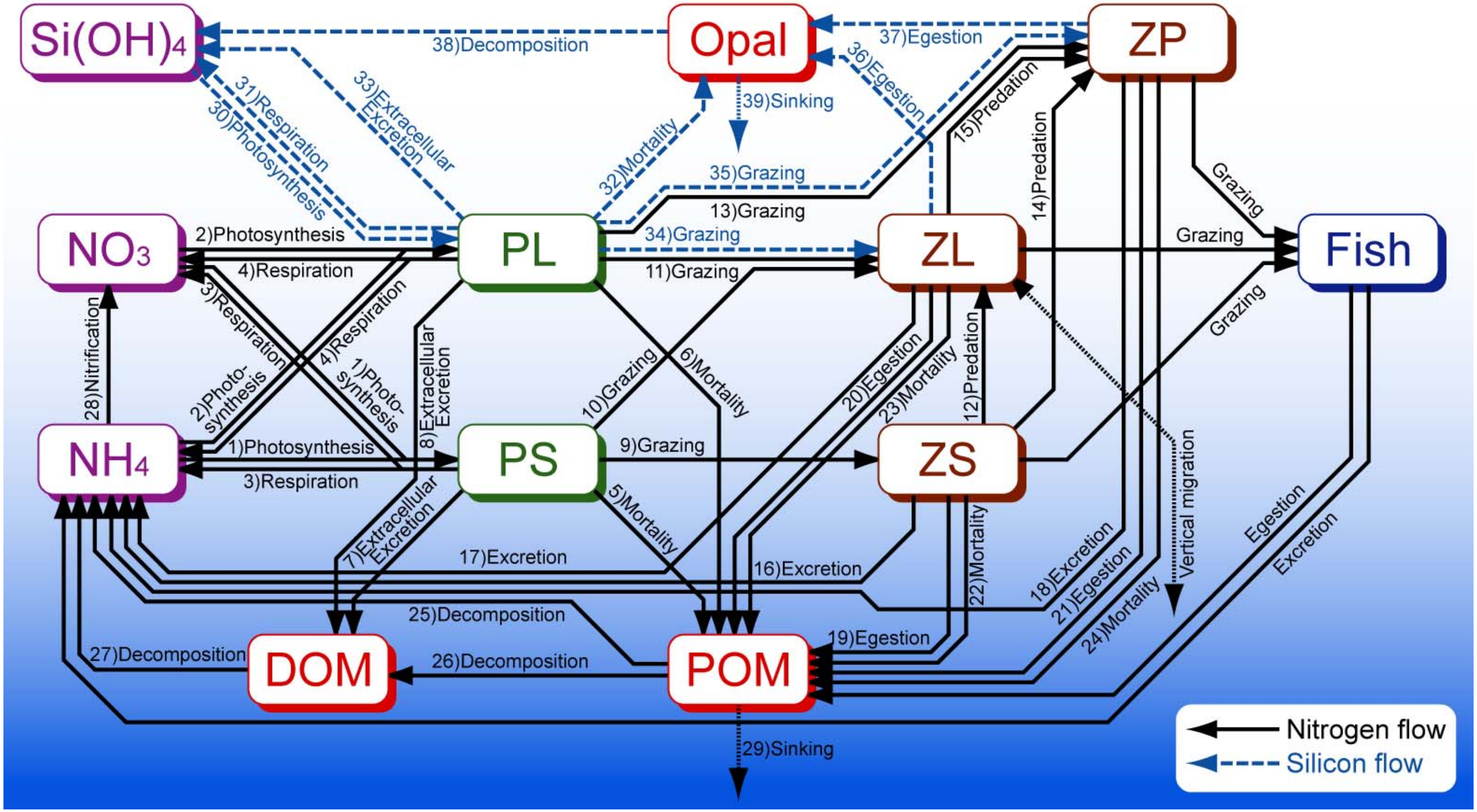
Ito et al. (2004a)

NEMURO.FISH

NEMURO for Including Saury and Herring







Megrey et al. (2007a), Ito et al. (2004b) etc.

Bioenergetics Model for herring and saury

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

change of weight

P: egg production

C: consumption

E: excretion

R: respiration (loses through metabolism)

F: egestion

S: specific dynamic action (digesting food)

3-box version

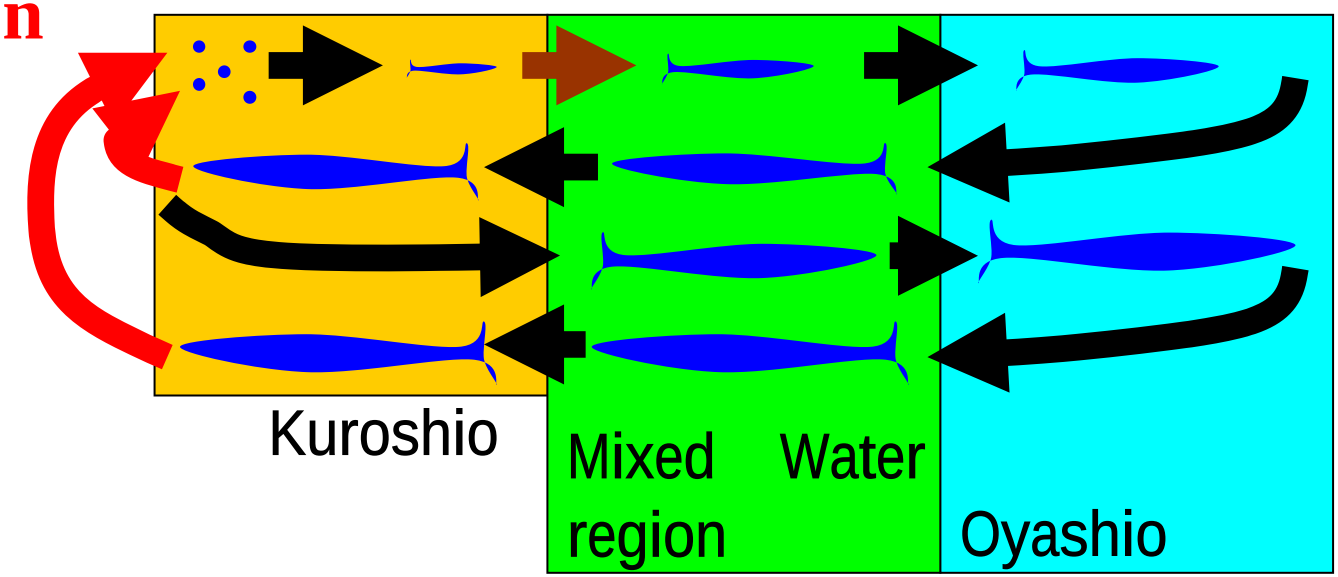
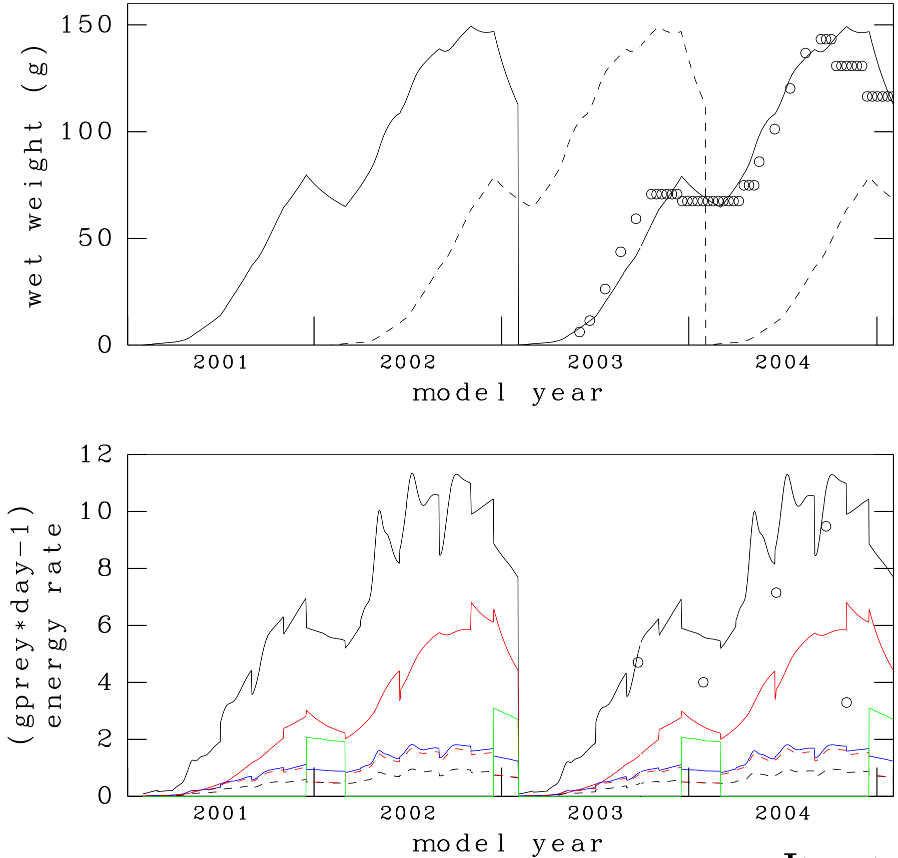


Table 2. Life stages of Pacific saury in the saruy bioenergetics model

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

9 life stages

Ito et al. (2004b)
Ito et al . (2007)
Mukai et al. (2007)



Simulated wet weight & observed growth (Kurita et al.)

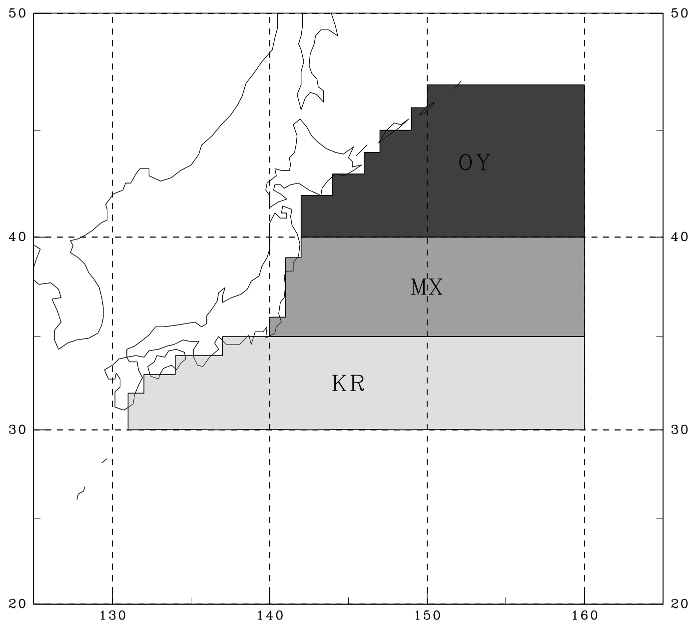
Terms of the bioenergetics equation

black solid: consumption
red solid: respiration
blue solid: egestion
black dotted: excretion
red dotted: specific dynamic action
green: egg production
open circle: observed consumption by Kurita (2002)

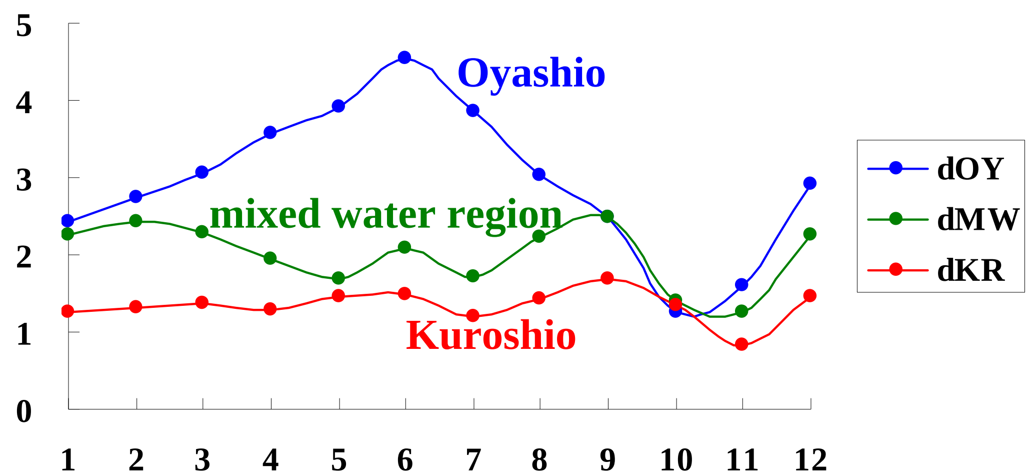
Ito et al. (2004b)

1. NEMURO.FISH reproduced realistic growth of Pacific saury.
2. An independent data, consumption, showed consistency of NEMURO.FISH with observations except for autumn.

Pacific saury: Global warming experiment



Temp. anomaly in 2050
(from CCSR/NIES/FRCGC model, A2)



Ito (2007b)

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.**

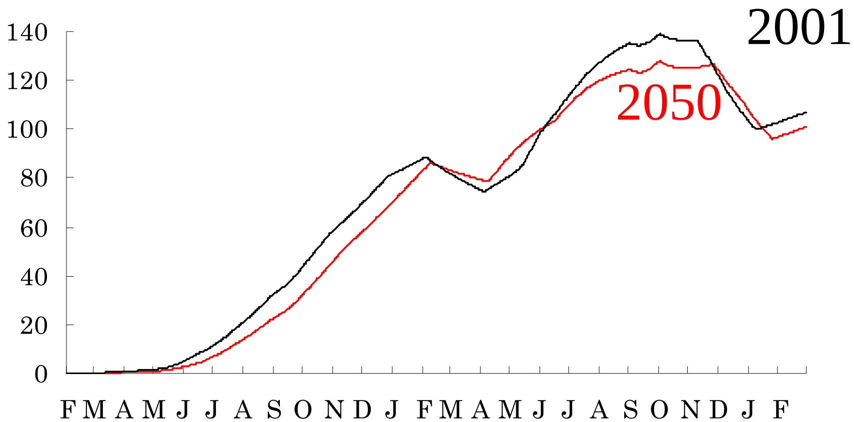
higher temperature: increase energy loss by metabolism

: enhance feeding activity

stronger stratification: decrease prey density

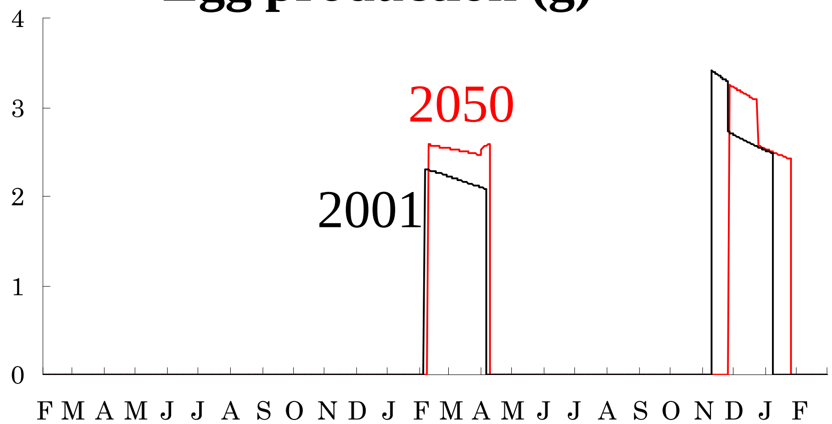
Pacific saury: Global warming experiment

Wet weight of saury (g)



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

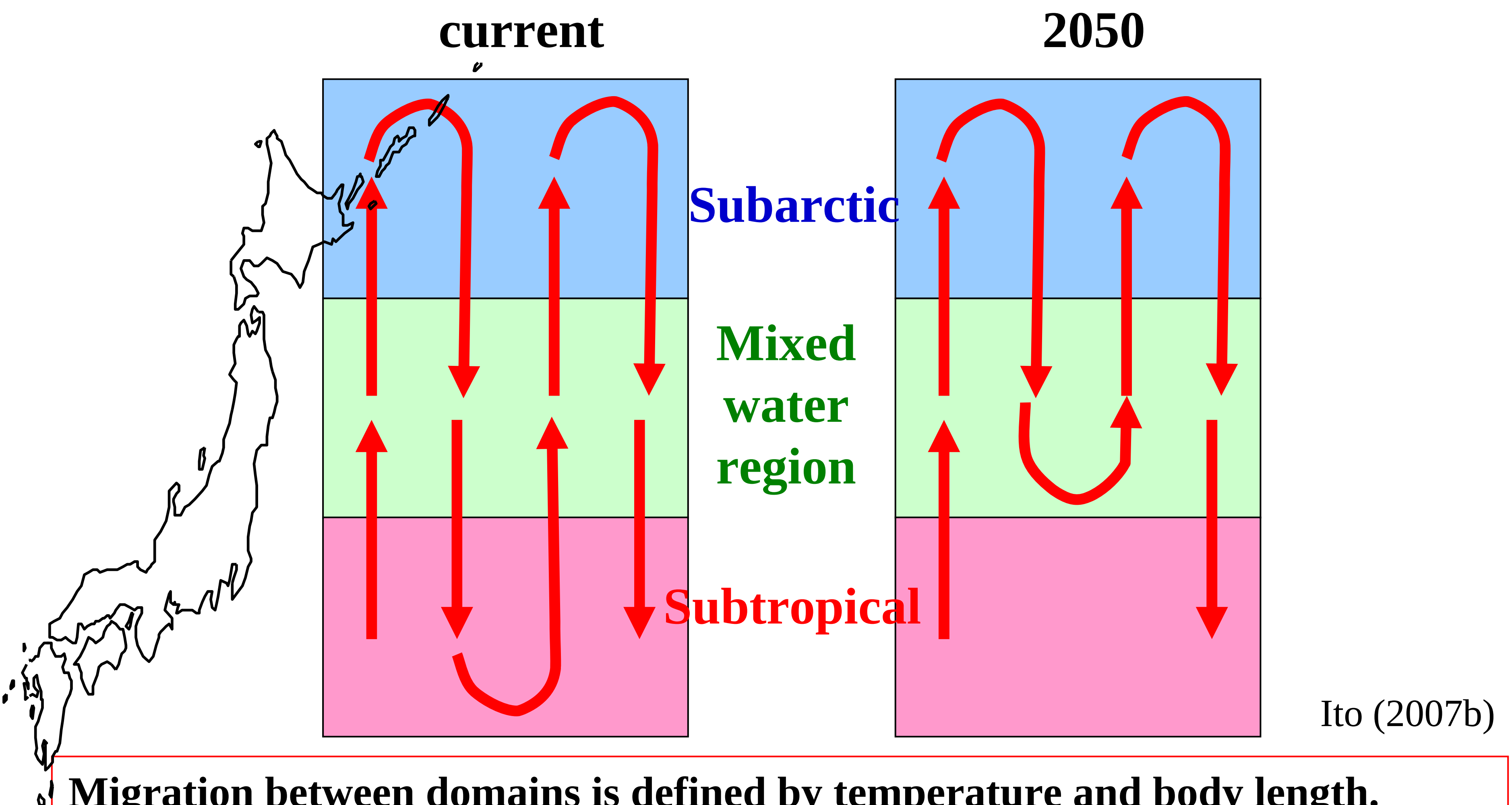
Egg production (g)



However, the egg production was enhanced by global warming.

Ito (2007b)

Pacific saury (Global warming): simple model application



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.

Problems in NEMURO.FISH (saury verion)

Ito et al. (2004):
Determine model parameters from observational results (VENFISH).
Model was improved by :
Mukai et al. (2007), Ito et al. (2007), Megrey et al. (2007)

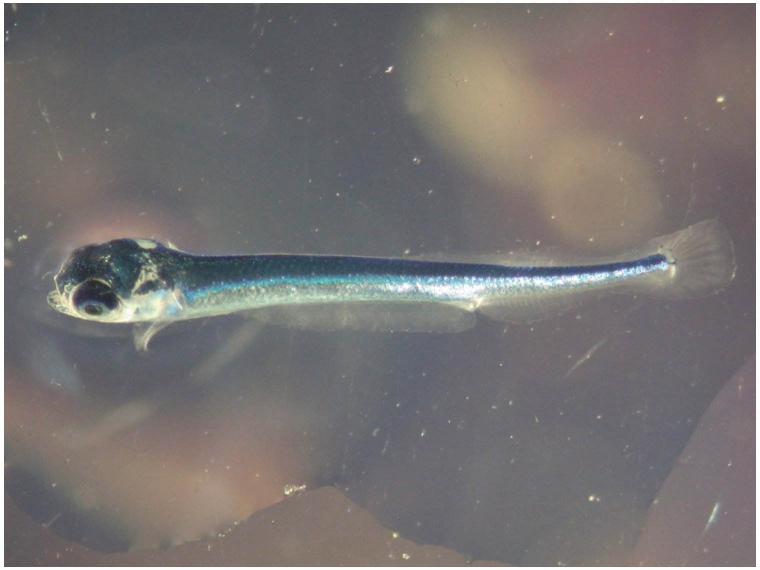
Several parameters are still unknown and borrowed from other species. We need direct measurements of those parameters.

Although raring experiments are very limited, such as Hotta (1958), Oozeki and Watanabe (2000) etc., we tried raring experiments.

Raring experiment

Use 12KL tank to rare the Pacific saury.
Caught eggs in the field and brought them to the tank.
April 29, 2005: 85 thousands larvae were hatched (about 7 mm BL)

Prey	**0 - 0 day**	**rotifer**
	1 -12 day	**rotifer, Artemia**
	13-14 day	**Artemia, copepoda**
	15-43 day	**Artemia, copepoda, feedstuff**
	44-44 day	**copepoda, feedstuff**
	45-52 day	**feedstuff**
	53-349 day	**feedstuff, mince (56-61 day & after 141 day)**



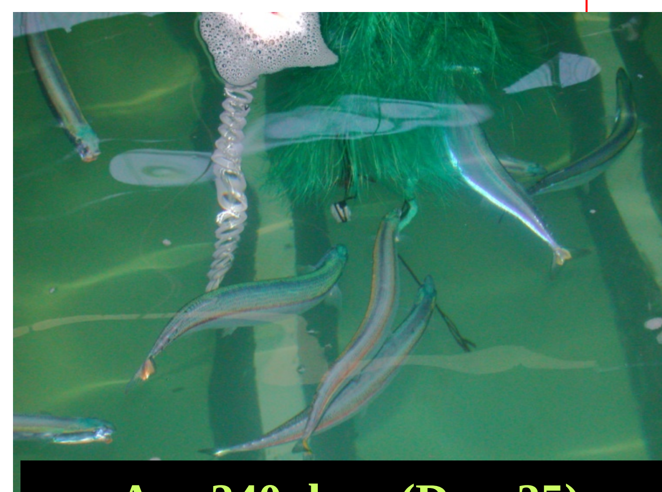
Experiments

First year

All saury died since they bumped to the wall.

Second year (covered the wall by vinyl sheet)

1. Control (repletion) experiment
   Raring saury with repletion condition in the 20 degC water tank.
   estimate consumption rate & assimilation efficiency
2. Fasting experiment
   estimate respiration
   estimate other dissipation terms
3. Ammonia estimate experiment
   estimate excretion directly
4. Swimming speed estimation
   using video recorder
   estimate temp. depencency



Age 240 days (Dec. 25)
25 cm KL
Start spawning

Fasting experiments & Experiments with different prey amount

Initial fish wet weight is 37.96g.
Feed different amount of prey and fish feed on all prey.

	prey	prey（cope）	rate	fish WW change
A	0.00g	0.0g	0.0%	-1.89g
B	7.80g	14.8g	3.9%	-1.33g
C	32.75g	62.0g	6.3%	+1.30g
D	42.77g	80.9g	21.3%	+4.81g

Terms in bioenergetics model

$$F = a_F \cdot C$$

$$E = a_E \cdot (C - F)$$

$$SDA = S \cdot (C - F)$$

$$\begin{aligned} F + E + SDA &= a_F \cdot C + a_E \cdot (C - F) + S \cdot (C - F) \\ &= \{a_F + a_E(1 - a_F) + S(1 - a_F)\} \cdot C \end{aligned}$$

Fasting experiment

case C=0

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

known as 0

In the case C=0, R=0.0192gprey/gfish/day.
If we assumed R is constant with prey density, we are able to estimate S+F+E as a residual between C and R.

Experiments with different prey amount

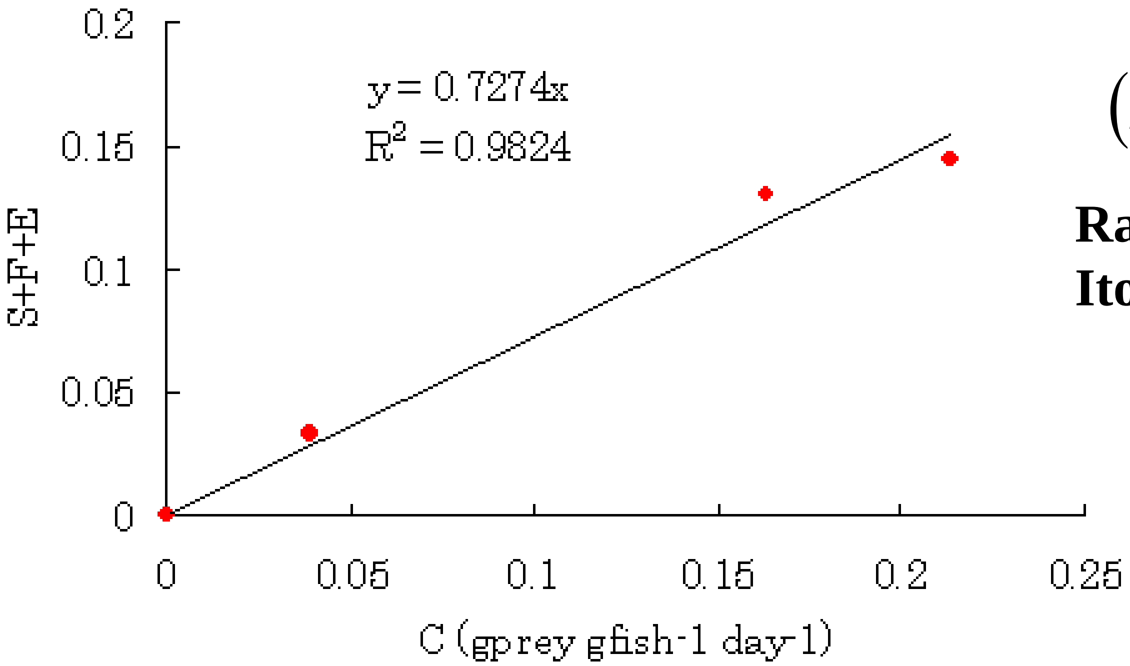
On the assumption R is constant with prey density, we estimated S+F+E.

	dw/w/dt 1/day	C（cope）gprey/gfish/day	R+S+F+E	S+F+E
A	-0.00498	0.0000	0.0192	0.0000
B	-0.00350	0.0389	0.0524	0.0332
C	0.00343	0.1632	0.1500	0.1308
D	0.01267	0.2131	0.1641	0.1449

$$SDA + F + E = a_F \cdot C + a_E \cdot (C - F) + S \cdot (C - F)$$
$$= \{a_F + a_E (1 - a_F) + S(1 - a_F)\} \cdot C$$

S+F+E must become a linear function of C.

Experiments with different prey amount



$$\left(S + a_F + a_E - S \cdot a_F - a_E \cdot a_F\right)$$

Rare-reduce 0.73

Ito et al. (2004): 0.370 , 0.391

much larger than Ito et al. (2004)

estimate ammonia increase in the tank

	Ito et al. (2004)		Raring experiment		
	juvenile	adult	juvenile	adult	
S	0.150	0.175	0.150	0.175	(assumption)
aF	0.160	0.160	0.350	0.309	(residual)
aE	0.100	0.100	0.430	0.430	(min. est.)
total	0.370	0.391	0.727	0.727	(estimation)

Table 3. Summary of the parameter values used in the saury bioenergetics model.

Symbol	Parameter description	Value
a_C	Intercept for C_{MAX} at (*te1*+*te3*)/2	0.8→0.8164
b_C	coefficient for C_{MAX} versus weight	-0.340→-0.2121
te1	Temperature for *xk1* (in ºC)	5
te2	Temperature for *xk2* (in ºC)	20*, 16#
te3	Temperature for *xk3* (in ºC)	26*, 20#
te4	Temperature for *xk4* (in ºC)	30
xk1	Proportion of C_{MAX} at *te1*	0.10
xk2	Proportion of C_{MAX} at *te2*	0.98
xk3	Proportion of C_{MAX} at *te3*	0.98
xk4	Proportion of C_{MAX} at *te4*	0.5

red: revised by raring experiment

Table 3. Summary of the parameter values used in the saury bioenergetics model.

Symbol	Parameter description	Value
Metabolism, R		
a_R	Intercept for *R*	0.0033→0.0054
b_R	Coefficient for *R* versus weight	-0.227→-0.271
c_R	Coefficient for *R* versus temperature	0.020 →keep
d_R	Coefficient for *R* versus swimming speed	0.026 →keep
S	Coefficient for Specific Dynamic Action	0.150a, 0.175b→keep
Swimming Speed, U		
a_A	Intercept *U* (< 12 ºC) (in cm/s)	2.0 →depends on size
a_A	Intercept *U* (≥ 12 ºC) (in cm/s)	12.3 →depends on size
b_A	Coefficient *U* versus weight	0.33 →depends on size
c_A	Coefficient *U* versus temperature (< 12 ºC)	0.149 →depends on size
c_A	Coefficient *U* versus temperature (≥ 12ºC)	0.0 →depends on size

a - values for stage 1 saury

b - values for stage 2 and higher saury

green: value referred to herring

Table 3. Summary of the parameter values used in the saury bioenergetics model.

Symbol	Parameter description	Value
Egestion and Excretion, F and E		
a_F	Proportion of consumed food to egested	0.16→0.350, 0.309
a_E	Proportion of consumed food to excreted	0.10→0.430
a_P	Proportion of consumed food to egg production	0.35

Conclusion and Future Perspectives

Model results suggested the possibilities of

- **size reduction, and**
- **number increase**

of Pacific saury under global warming conditions.

We filled the unknown parameters by raring experiments. But the results showed

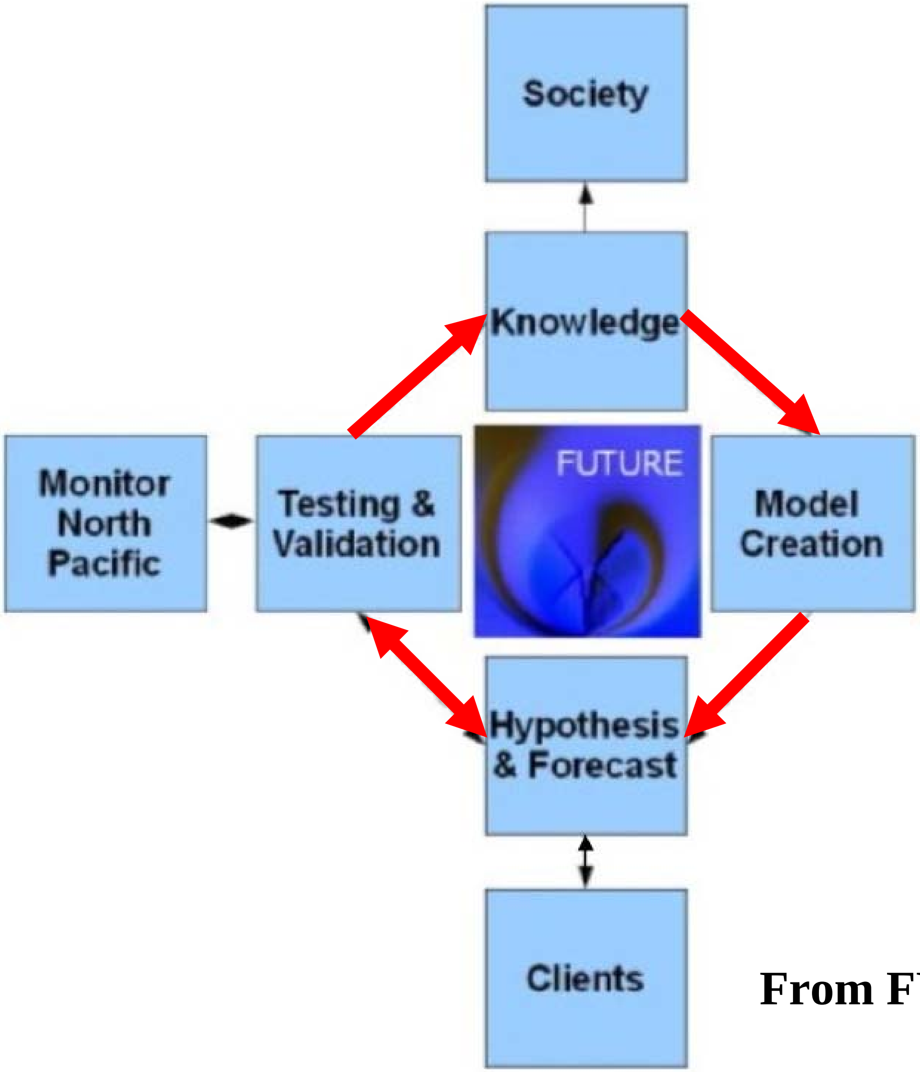
- **higher dissipation terms, and**
- **much lower assimilation rate than observation**

of Pacific saury.

Now we are trying to

- **fill the gap between experiments and observation using copepods as prey instead of feed-staff**
- **conduct experiments with different temperatures**
- **measure the parameters from field observations.**

FUTURE



Cycle between model, forecast, validation, and knowledge are essential to improve our knowledge and prediction.

From FUTURE Implementation Plan Draft