Experimental approaches to improve the accuracy of NEMURO.FISH saury growth model.

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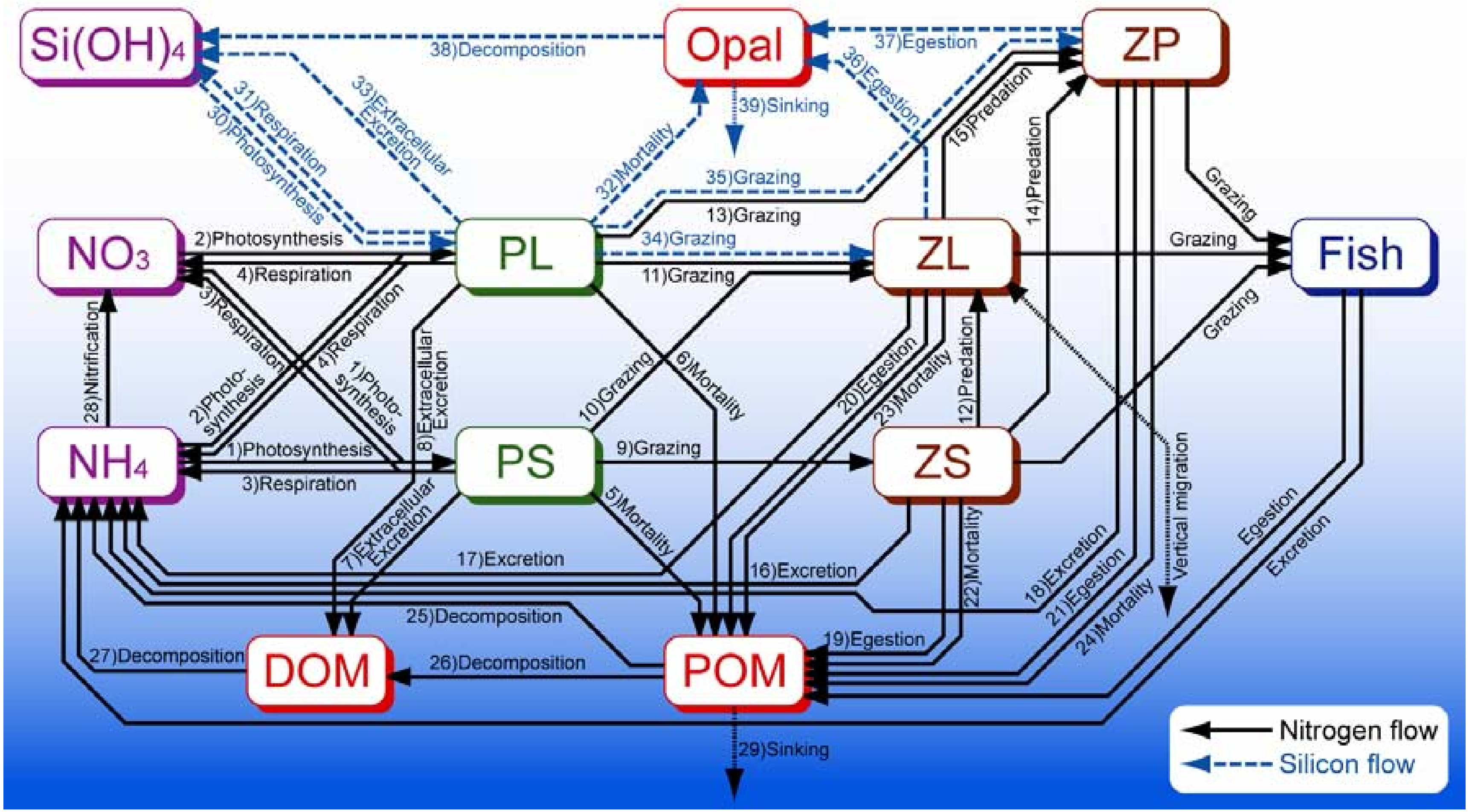
Today's contents

1. problems of NEMURO.FISH
2. raring experiments
3. model parameter estimation
4. future perspectives

NEMURO.FISH
NEMURO For Including Saury and Herring



Megrey et al. 2007

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

C: consumption

R: respiration (loses through metabolism)

S: specific dynamic action (digesting food)

F: egestion

E: excretion

P: egg production

Problems in NEMURO.FISH (saury ver.)

Several parameters were borrowed from herring since there were no information about the parameters of saury.

Ito et al. (2004): tuned the unknown parameters by fitting the growth to the observation and confirmed the model consumption rate showed realistic value (compare with other independent observation data).

Model was improved by :

Mukai et al. (2007), Ito et al. (2007), Megrey et al. (2007)

Several parameters are still unknown and we need more direct measurements of those parameters.

Raring experiments are very limited.

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)**


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

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.

   re-estimate consumption rate

   estimate assimilation efficiency

2. Fasting experiment

   exclude prey consumption term

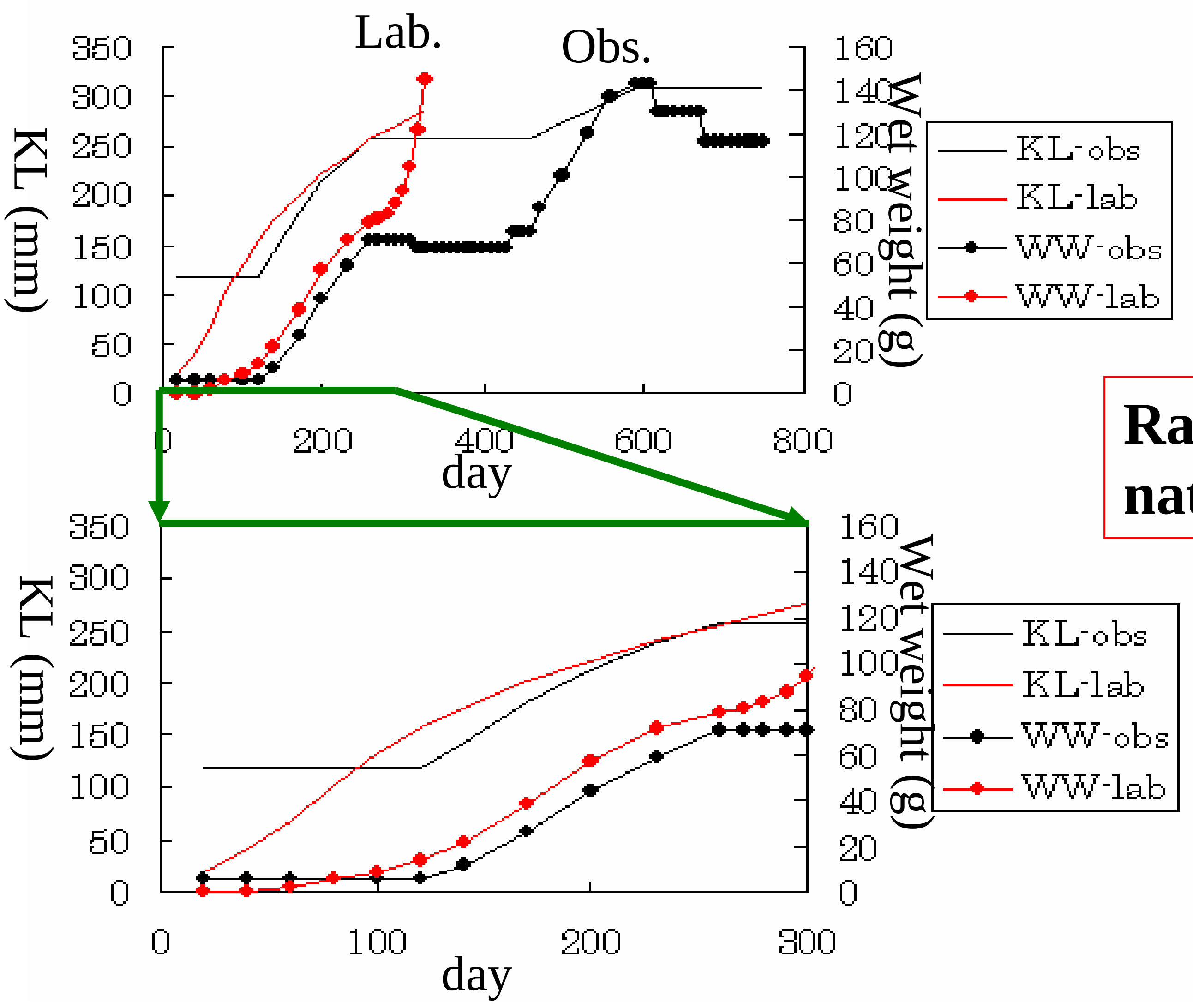
3. Ammonia estimate experiment

   estimate excretion directly

   (mainly done by Dr. Shiomoto)

   (not shown today)

Repletion experiment



Rapid growth than natural condition.

Pacific Saury Bioenergetics Model

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

$$F = a_F \cdot C \qquad : a_F = 0.16$$

$$E = a_E \cdot (C - F) \qquad : a_E = 0.10$$

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

$$R = a_R \cdot W^{b_R} \cdot f_R(T) \cdot activity \cdot 5.258$$

$$activity = e^{(d_R \cdot U)}$$

$$U = a_A \cdot W^{b_A} \cdot e^{(c_A \cdot T)}$$

$$f_R(T) = e^{(c_R \cdot T)}$$

Consumption of Pacific Saury

$$C = C_r \cdot f_C(T)$$

$$C_r = \sum_{j=1}^{n} C_j$$

$$C_j = \frac{C_{MAX} \cdot \dfrac{PD_{ij} \cdot v_{ij}}{K_{ij}}}{1 + \sum_{k=1}^{n} \dfrac{PD_{ik} \cdot v_{ik}}{K_{ik}}}$$

$$C_{MAX} = a_C \cdot W^{b_C}$$

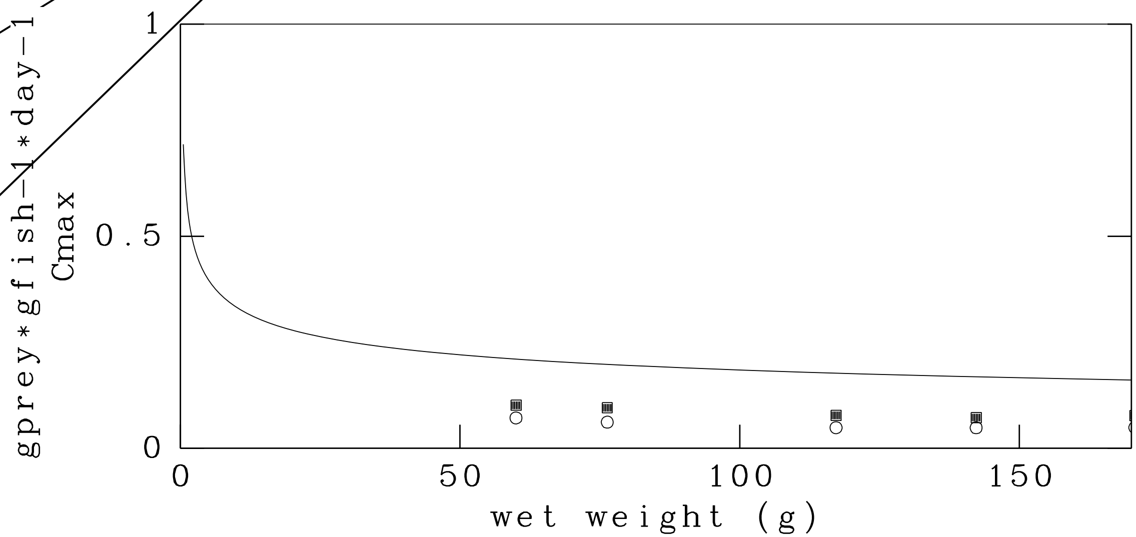
consumption

vulnerability

depends on prey density

weight

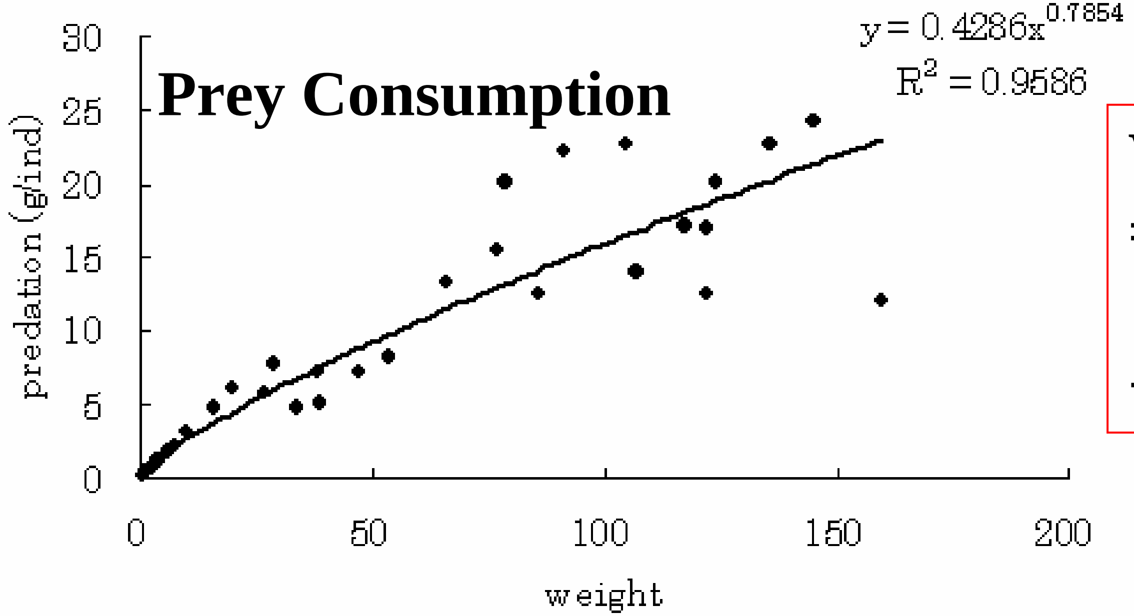
temperature



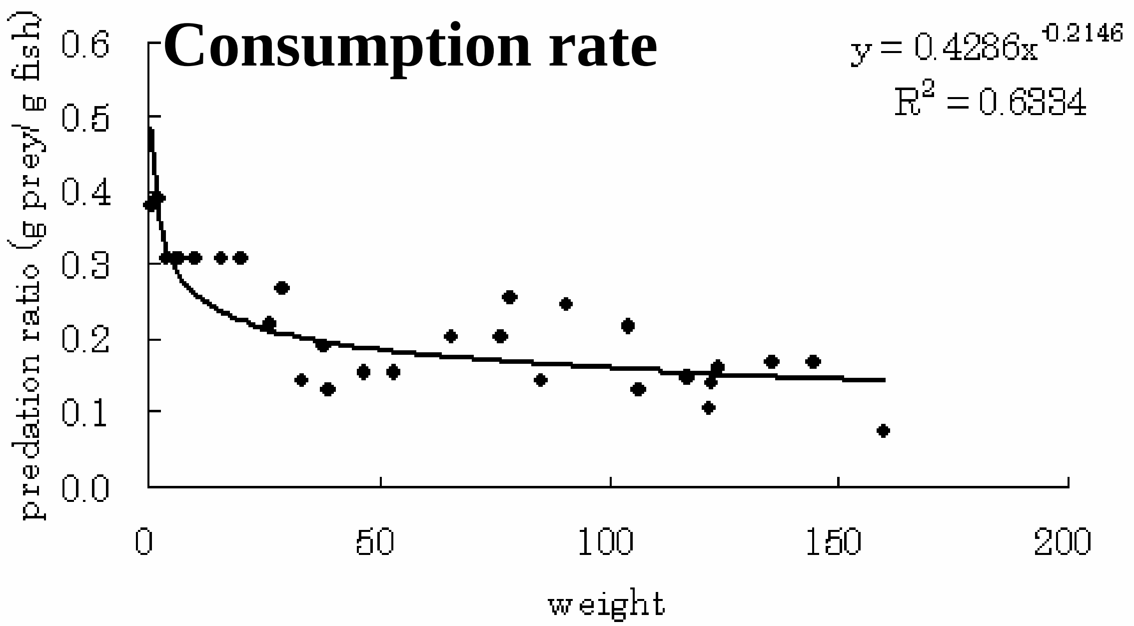
Hotta (1958) showed Cmax in laboratory was twice of field value.

Ito et al. (2004) define Cmax curve to cross the twice value of the field observation (Kurita & Sugisaki 2004). But the data was limited between 60 -140 gWW fish.

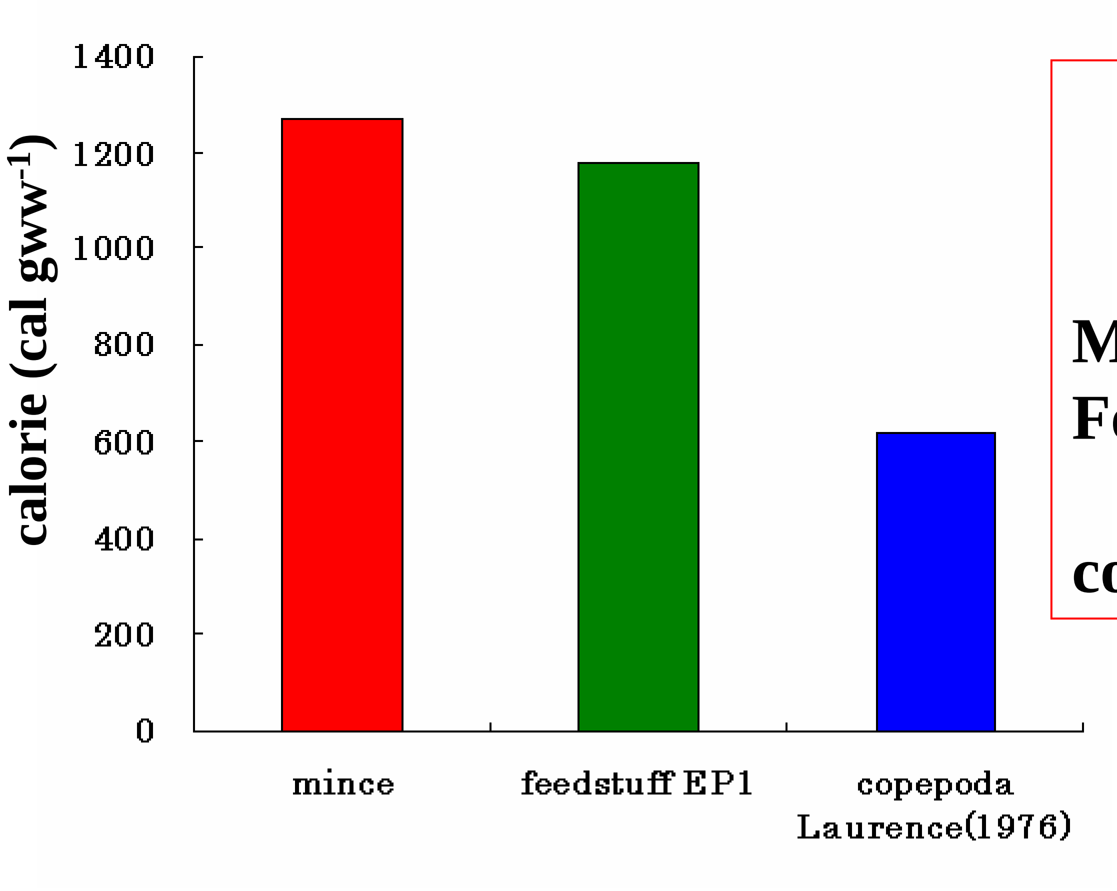
Predation (weight base): Repletion experiment



Wet weight of prey
= 3.86 * dry weight of
feedstuff
+ wet weight of mince



Calorie comparison of prey



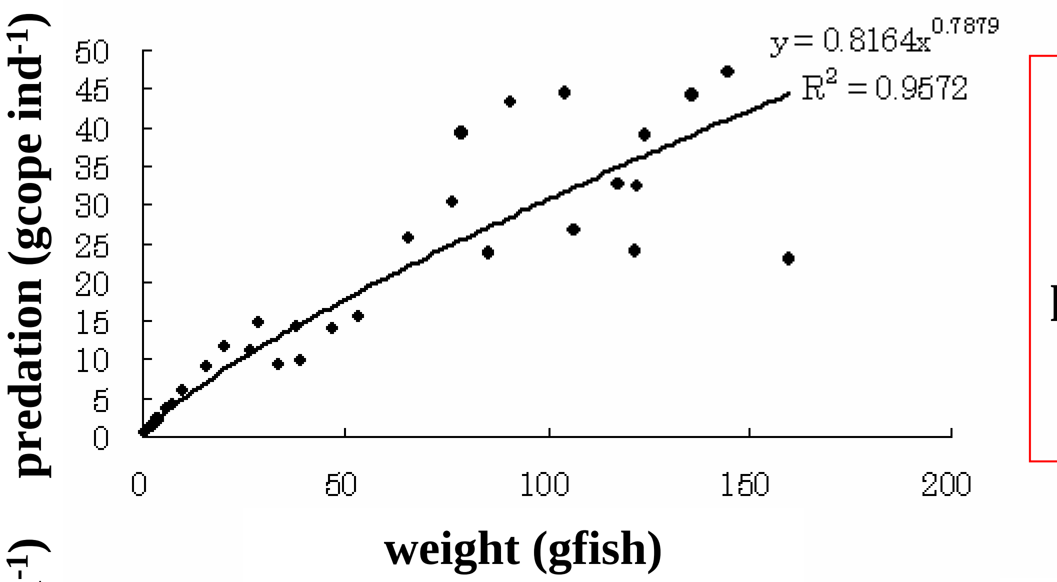
Calorie equivalent for unit wet weight

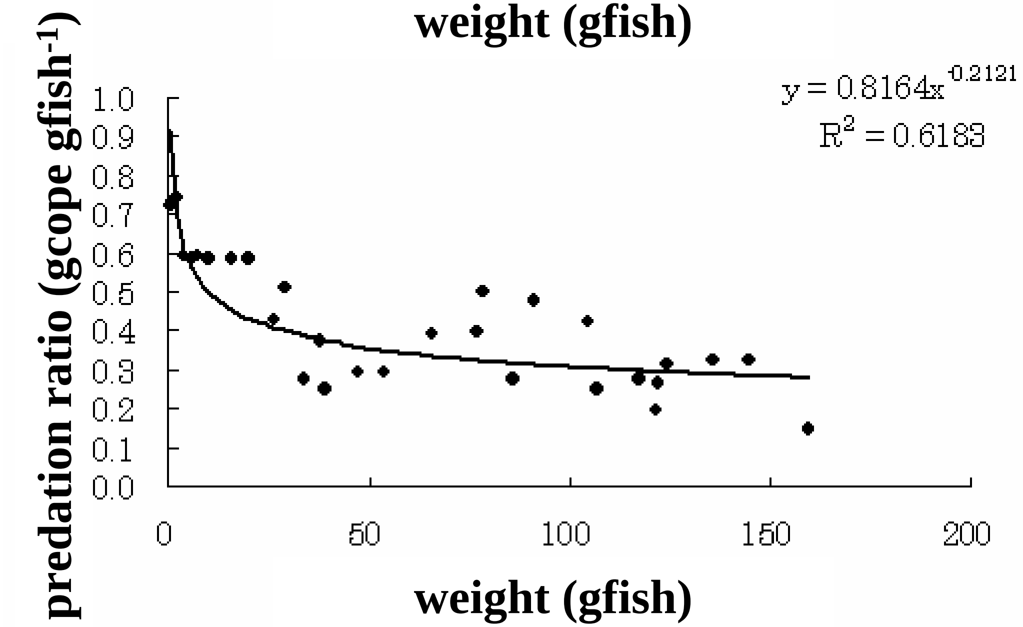
Mince: 1269 cal/g
Feedstuff: 1178 cal/g

copepoda： 617 cal/g

Feedstuff: 4547.3 (cal/g) / 3.86 = 1178 cal/g

Predation (copepoda base): Repletion experiment





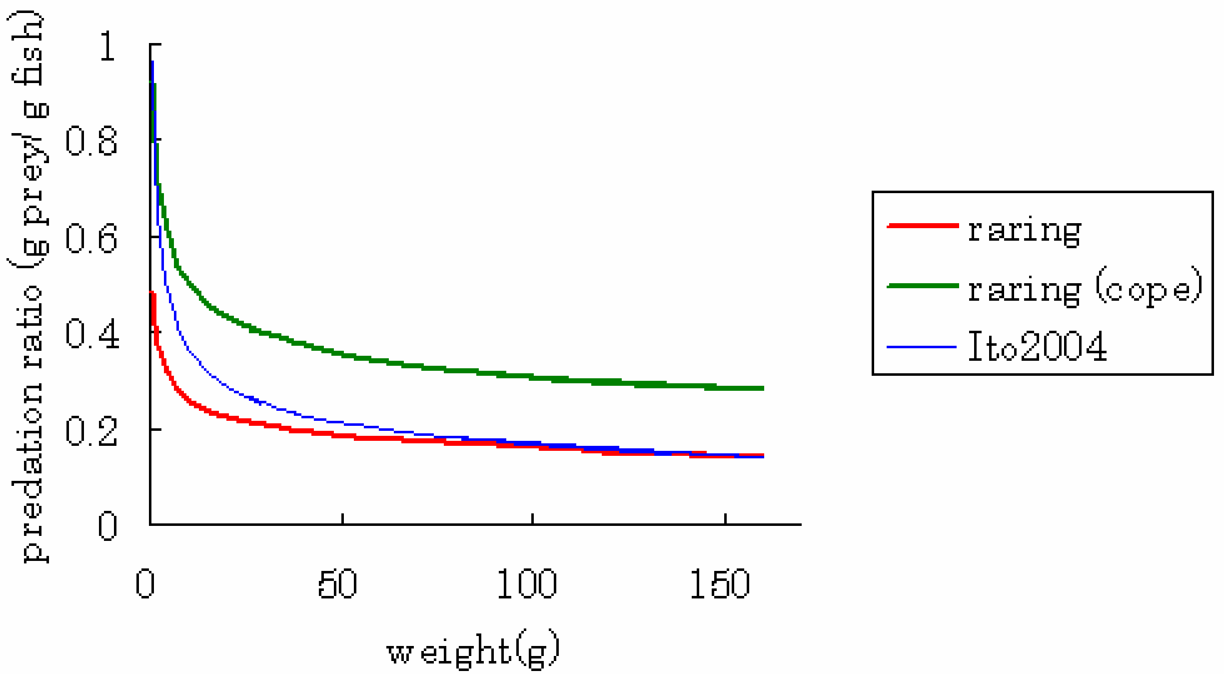
Convert the prey consumption to wet weight of copepoda

prey (g) = (mince *1269 cal/g + feedstuff*1178 cal/g) / 617 cal/g

$$C_{MAX} = a_C \cdot W^{b_C}$$

a_C=0.8164
b_C=-0.2121

Comparison between laboratory experiment and Ito et al. (2004)



- Laboratory experiment showed lower Cmax compared with Ito et al. (2004) especially in the larval stage.
- It becomes higher than the value in Ito et al. (2004) when it is converted to copepoda wet weight (especially in post larval stages).

Hotta (1958) showed Cmax in laboratory was twice of field value.

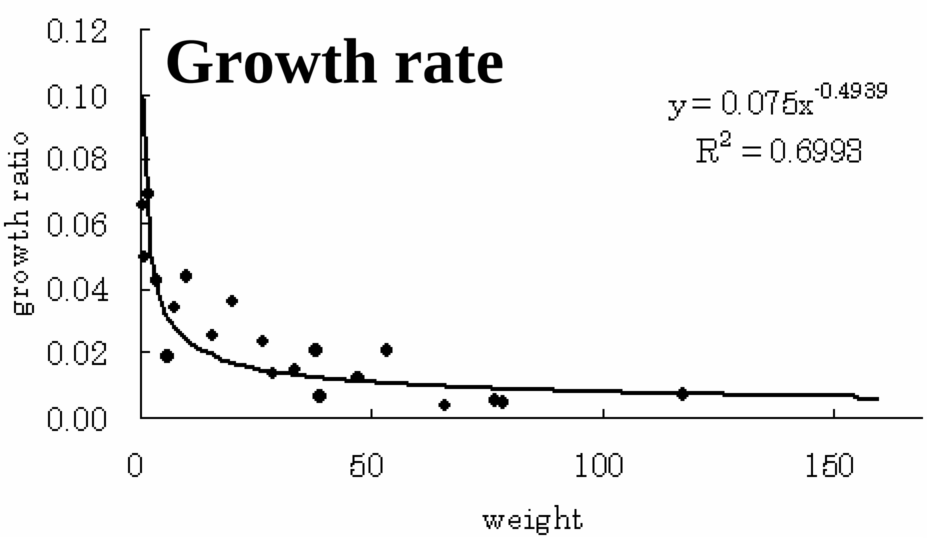
Ito et al. (2004) define Cmax curve to cross the twice value of the field observation (Kurita & Sugisaki 2004). But the data was limited between 60 -140 gWW fish.

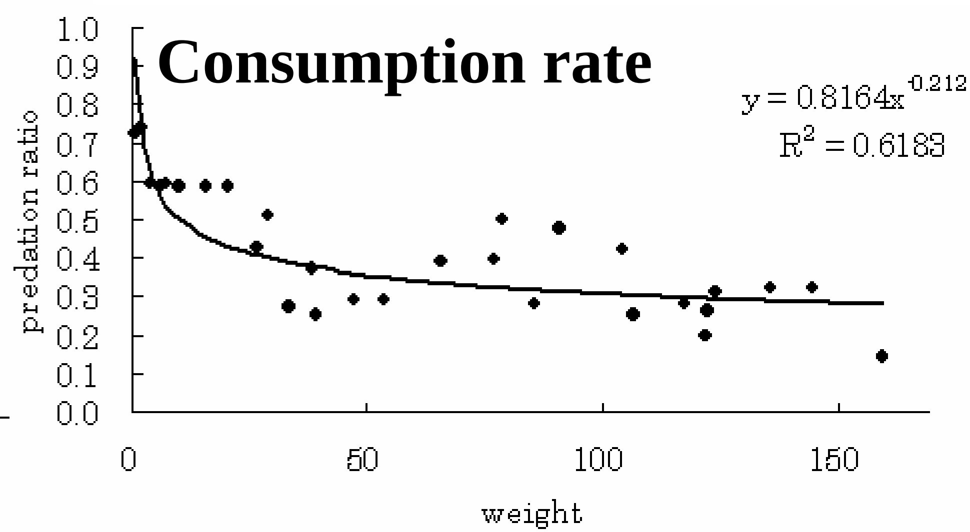
Pacific Saury Bioenergetics Model

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

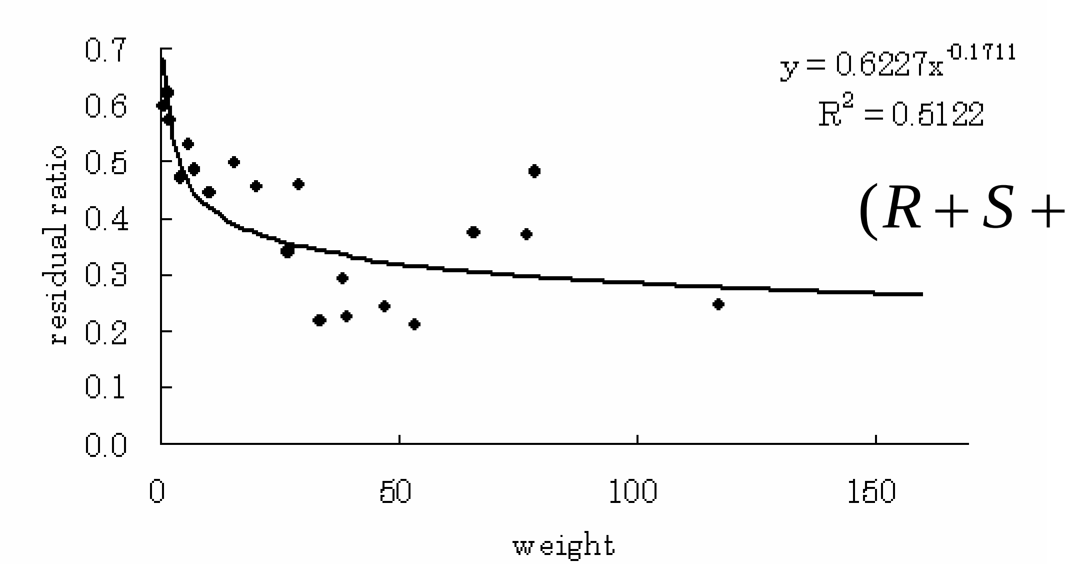
known residual Known (0)

The residual was calculated as the copepoda based value using the calorie ratio.



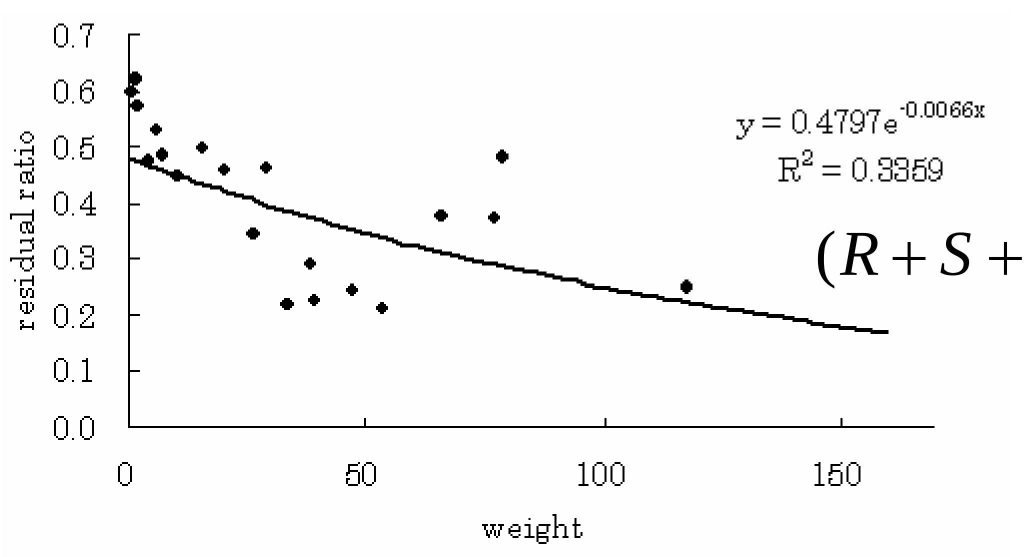


Residual



Allometry

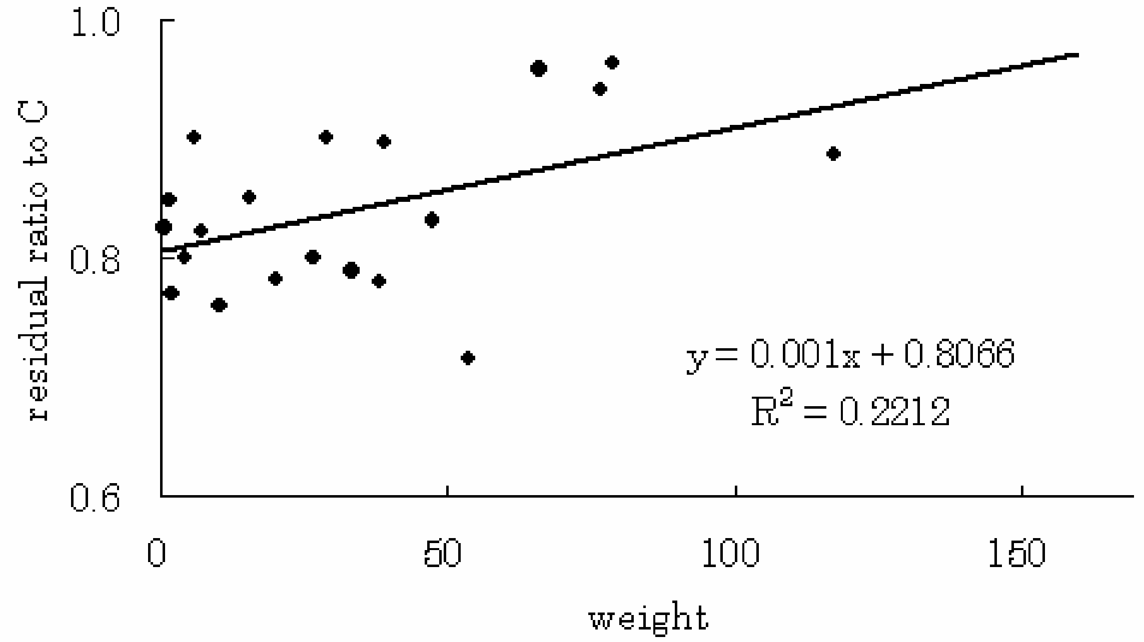
$$(R+S+F+E+P)=0.6227\cdot W^{-0.1711}$$



Exponential function

$$(R+S+F+E+P)=0.4797\cdot e^{-0.0066W}$$

anti-assimilation efficiency



$$\frac{(R+S+F+E+P)}{C} = 0.001 \cdot W + 0.8066$$

Average 84% (SD7.0%)

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

Experiments with different prey amount

case C=0

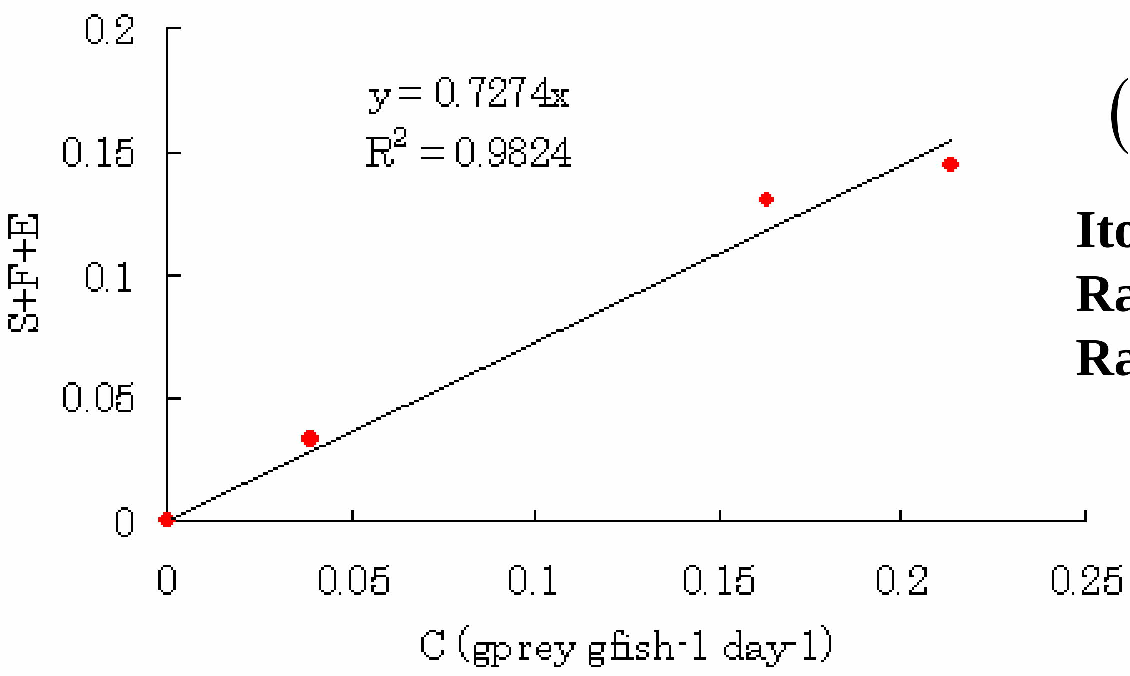
$$\frac{dW}{W \cdot dt} = \left[C - (R + S + F + E + P)\right] \cdot \frac{CAL_z}{CAL_f}$$

known as 0

In the case C=0, R=0.0192gprey/gfish/day.
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

Experiments with different prey amount



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

Ito et al. (2004): 0.370 , 0.391
Rare-full 0.84 (min 0.72)
Rare-reduce 0.73

much larger than Ito et al. (2004)

ammonia experiment not shown today

	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
a_A	Intercept U (≥ 12 ºC) (in cm/s)	12.3
b_A	Coefficient U versus weight	0.33
c_A	Coefficient U versus temperature (< 12 ºC)	0.149
c_A	Coefficient U versus temperature (≥ 12ºC)	0.0

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

Future Perspectives

Further model improvements are necessary to reduce uncertainty.

- **experiments with other temperatures**
- **swimming speed (video analysis)**
- **egestion estimation**

Requirements for ecosystem based management model

- **proper model for target species (resolve life history)**
- **reflect direct environmental factors (temp, current)**
- **interaction between prey production, hence ocean structure**
- **species interaction (competition, predators, etc.)**
- **hence, migration (at least 2 dimension)**

Please see NEMURO mafia 15 presentations.

S1(Cisco, Preikshot), S2(Fujii), S3(Kishi, Talyor, Okunishi, Shido, Ito), S5(Megrey), S9(Hermann, Colbert), BIO(Ito), CCCC(Wei), W3(Megrey), W6(Hashioka)