Overview of application of the NEMURO-bioenergetic coupled model on north-western Pacific fishes

Benchmark and toward FUTURE works

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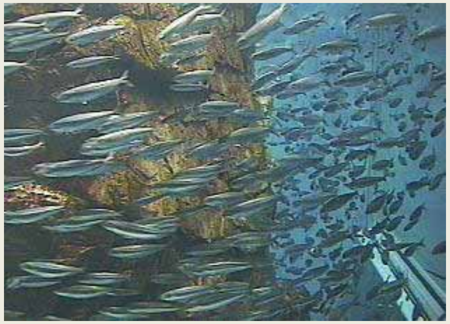
Benchmark for single fish

Benchmark for multi-species fish by NEMURO.SAN



$$d(Biomass)/dt = d(Weight*Number)/dt$$
$$= N(dW/dt) + W(dN/dt)$$

Bio-energetic model

Population dynamics/ Lagrangean model

Bioenegetics Model

$$\frac{dW}{W \cdot dt} = [C - (R + SDA + F + E + P)]$$

W:wet weight(g), t:time(day),
C:consumption (gprey/gfish/day),
R:respiration or losses through metabolism (gprey/gfish/day),
SDA: specific dynamic action or losses due to energy costs of digesting food (gprey/gfish/day),
F:egestion or losses due to feces (gprey/gfish/dday),
E:excretion or losses of nitrogenous excretory wastes (gprey/gfish/dday),
P:egg production or losses due to reproduction (gprey/gfish/d)

★Foods of saury are ＺＳ，ＺＬ，ＺＰ **with selective function**

(VENFISH, 2002 PICES MODEL/REX TASK TEAM, 伊藤ら2002)

consumption

NEMURO

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

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

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

$$C_{MAX} = a_c \cdot W^{b_c}$$

$$f_c(T) = gcta \cdot gctb$$

where

$$tt5 = \frac{1}{(te2 - te1)}$$

$$t5 = tt5 \cdot a\log\left[0.98 \cdot \frac{(1.0 - xk1)}{(0.02 \cdot xk1)}\right]$$

$$t4 = e^{[t5 \cdot (T - te1)]}$$

$$tt7 = \frac{1}{(te4 - te3)}$$

$$t7 = tt7 \cdot a\log\left[0.98 \cdot \frac{(1.0 - xk4)}{(0.02 \cdot xk4)}\right]$$

$$t6 = e^{[t7 \cdot (te4 - T)]}$$

PD_{ij} :density of prey type j (g wet weight/m^3),

v_{ij} :vulnerability of prey type *j* to predator *i*

K_{ij} :half saturation constant (g wet weight/m^3),

c consumption rate (g/g/d),

C_{MAX} :maximum consumption rate (g/g/d),

$f_c(T)$:temperature dependence function for consump

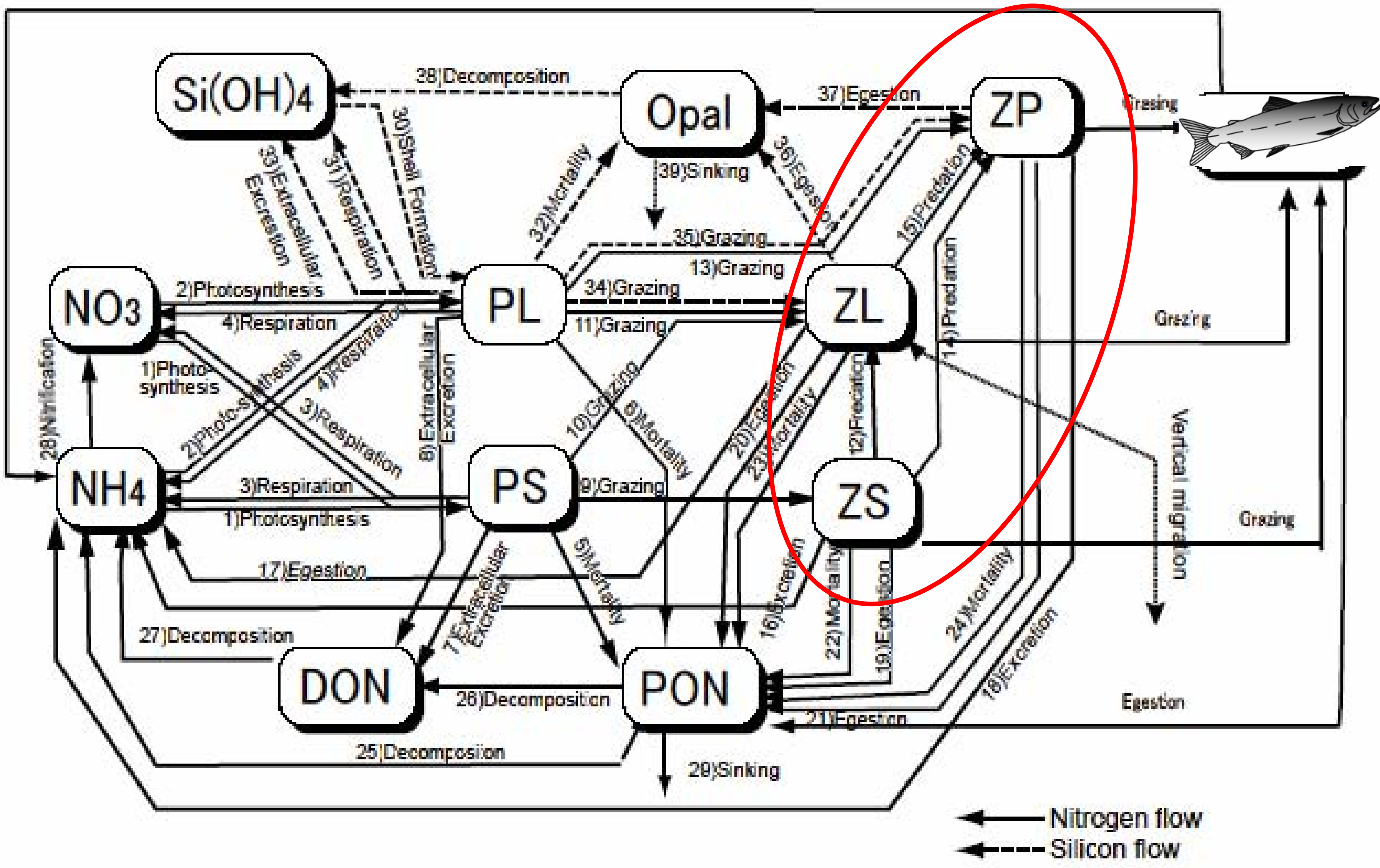
i predator type

$$gcta = \frac{(xk1 \cdot t4)}{(1.0 + xk1 \cdot (t4 - 1.0))}$$

$$gctb = \frac{(xk4 \cdot t6)}{(1.0 + xk4 \cdot (t6 - 1.0))}$$

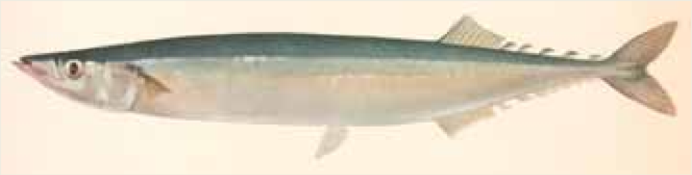
Physical model

N E M U R O . F I S H



Si(OH)4
Opal
ZP
NO3
PL
ZL
NH4
PS
ZS
DON
PON
38)Decomposition
37)Egestion
30)Shell Formation
31)Respiration
33)Extracellular Excretion
32)Mortality
39)Sinking
36)Egestion
35)Grazing
13)Grazing
34)Grazing
11)Grazing
15)Predation
14)Predation
2)Photosynthesis
4)Respiration
1)Photo-synthesis
2)Photo-synthesis
4)Respiration
3)Respiration
28)Nitrification
8)Extracellular Excretion
10)Grazing
6)Mortality
20)Egestion
23)Mortality
12)Predation
3)Respiration
1)Photosynthesis
9)Grazing
17)Egestion
7)Extracellular Excretion
5)Mortality
16)Excretion
22)Mortality
19)Egestion
24)Mortality
18)Excretion
27)Decomposition
26)Decomposition
25)Decomposition
29)Sinking
21)Egestion
Grazing
Grazing
Grazing
Egestion
Vertical migration
Nitrogen flow
Silicon flow

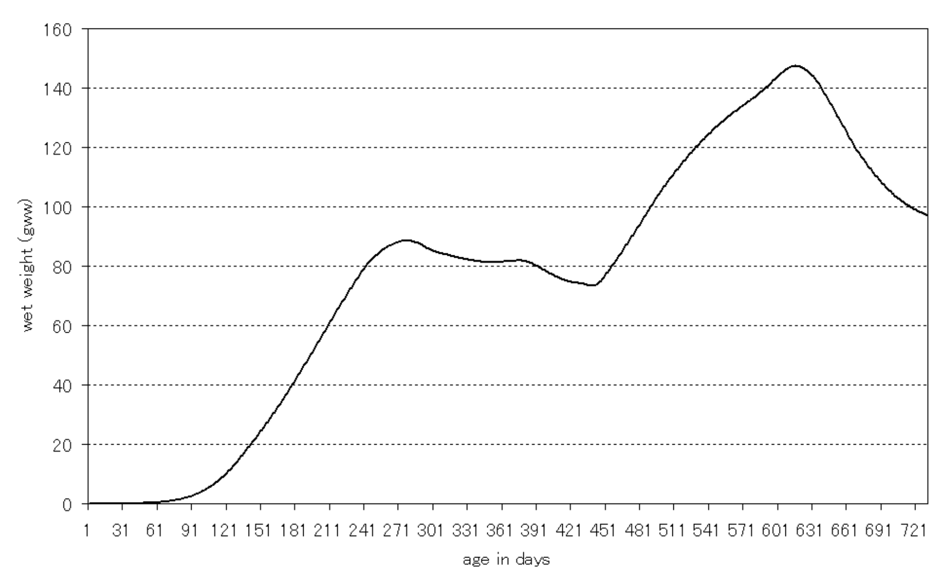
Pacific Saury (Mukai et al., 2007)



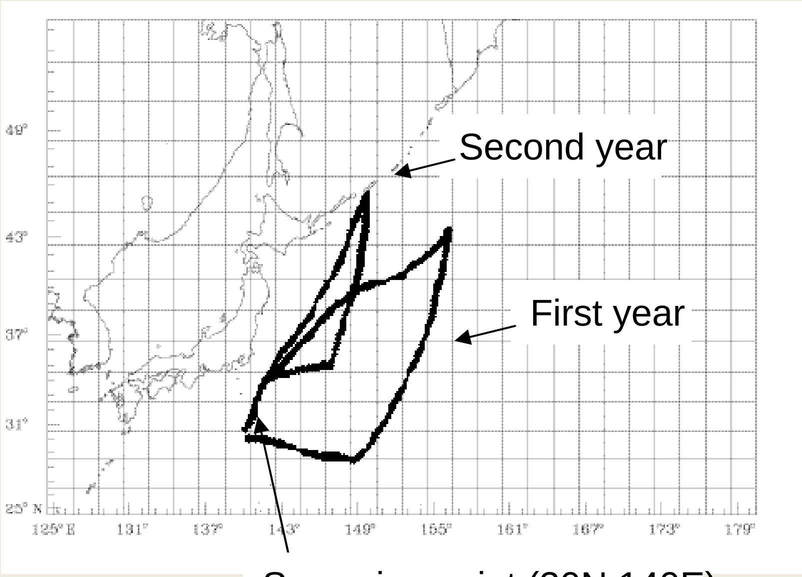
Results

Modeled 52 years (1946-1997) mean saury growth and migration routes of Pacific saury.

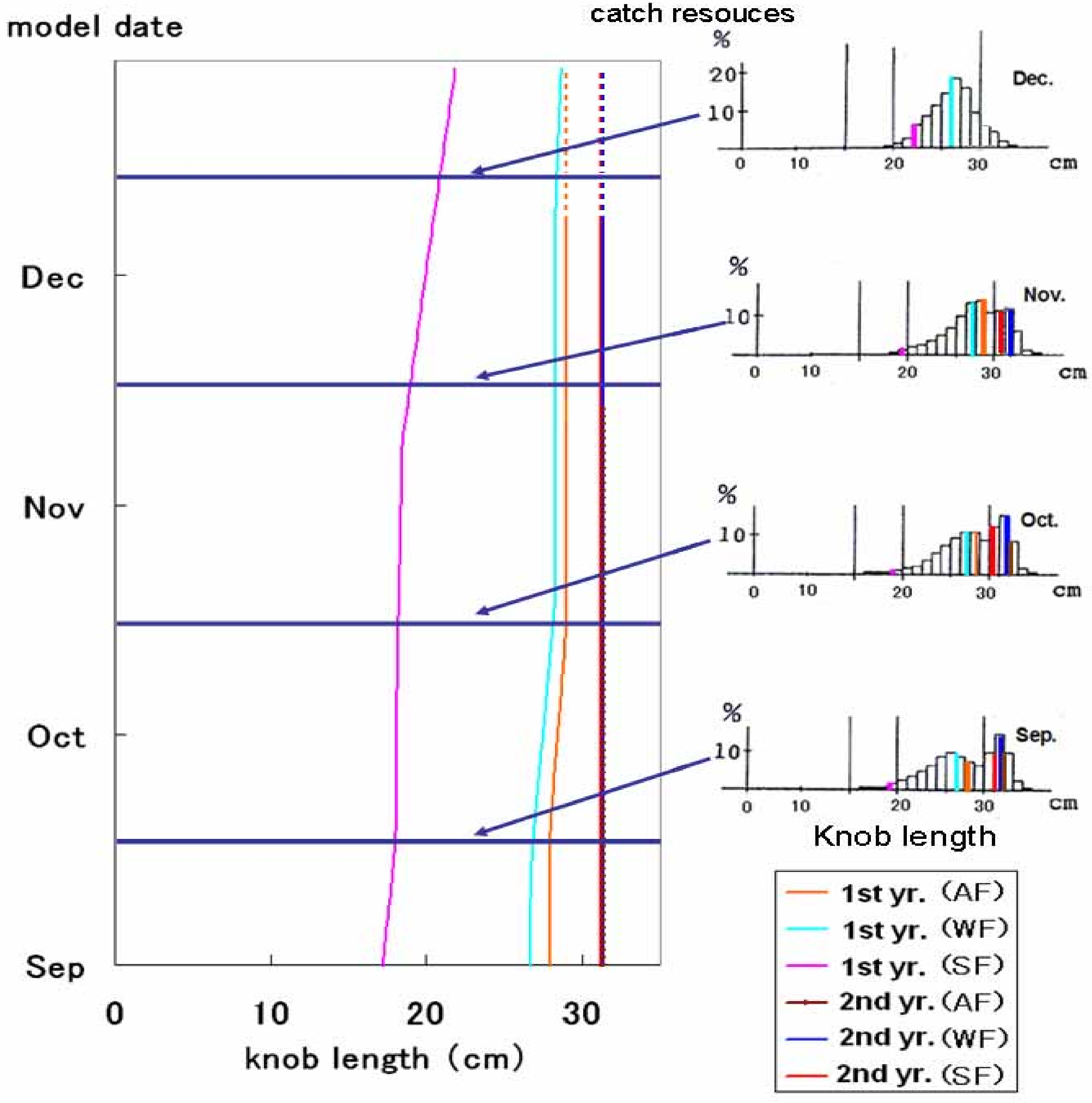
Weight (2 years cycle)



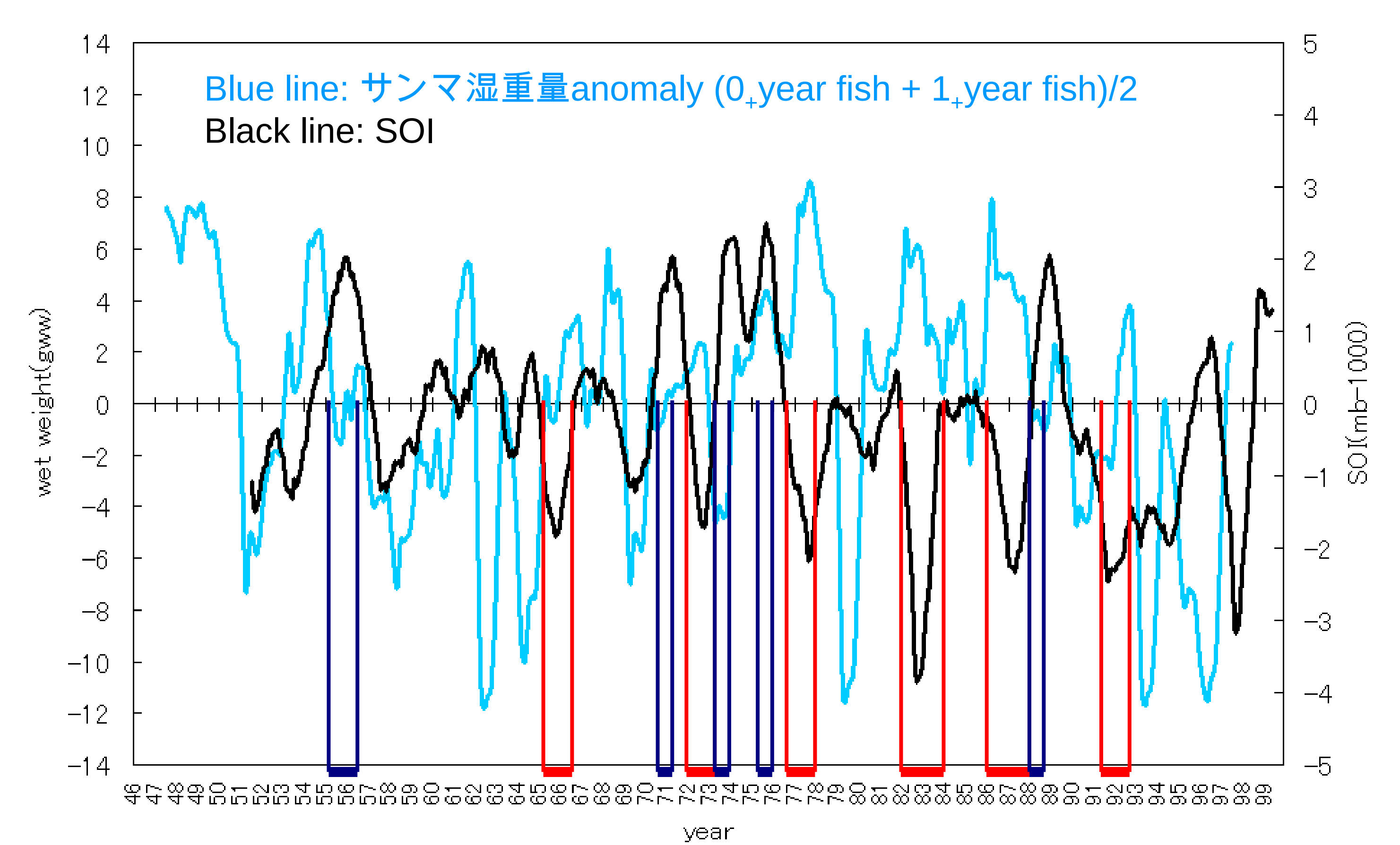
Migration routes



Two modes of caught fish size! ← spawning season

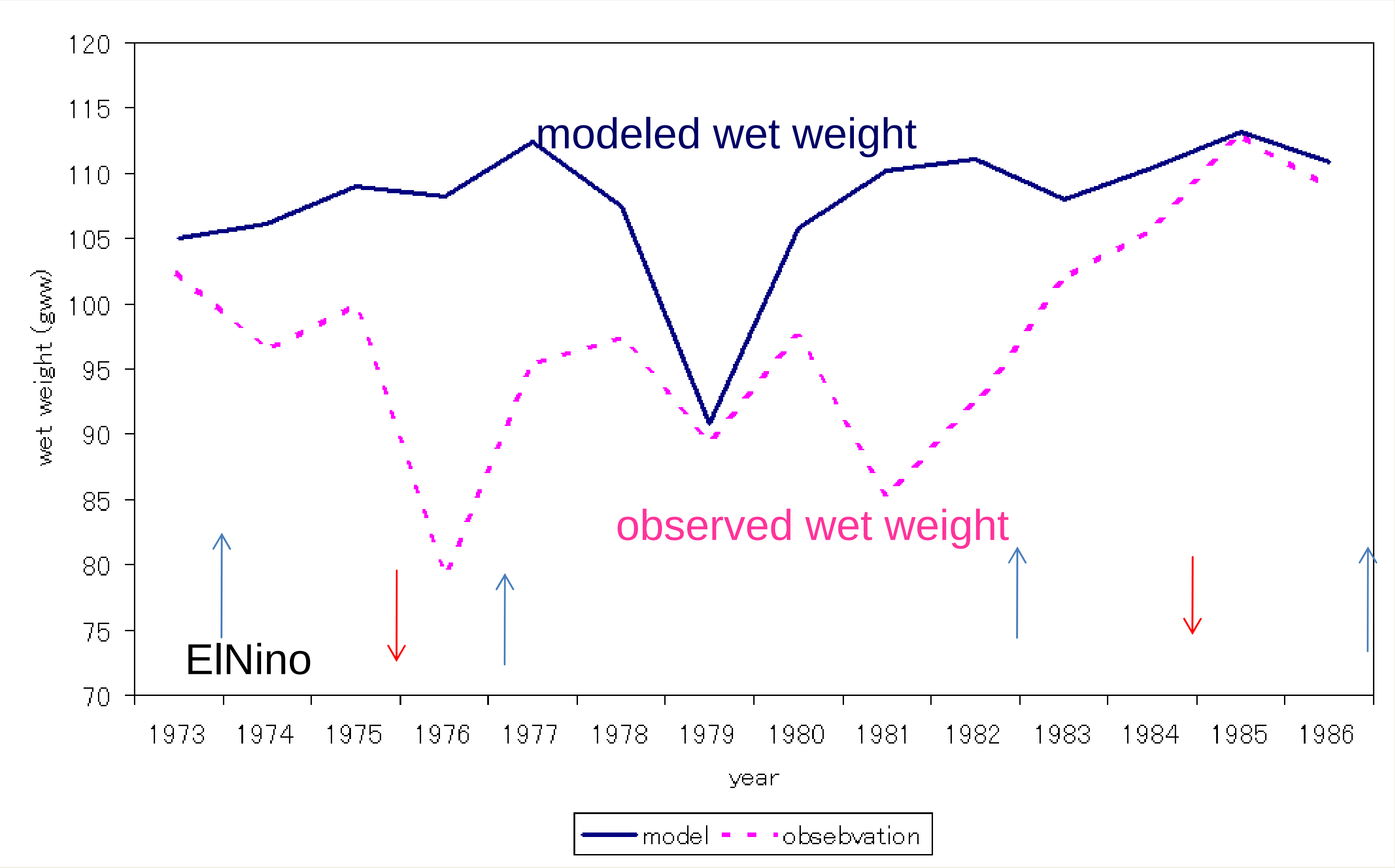


Results (interannual variability)

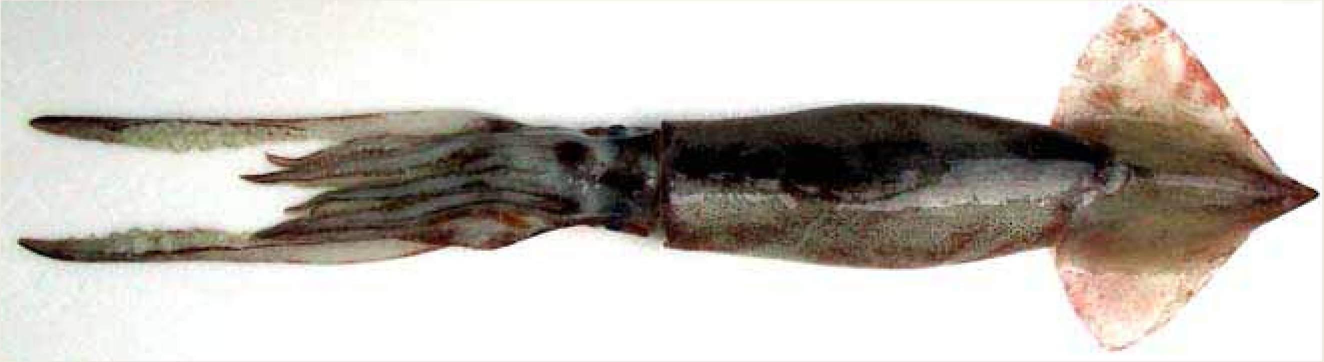


- El Niño years:
  Growth rate of saury is higher!
- La Niña years:
  Growth rate of saury is lower!

Results (interannual variability-2)

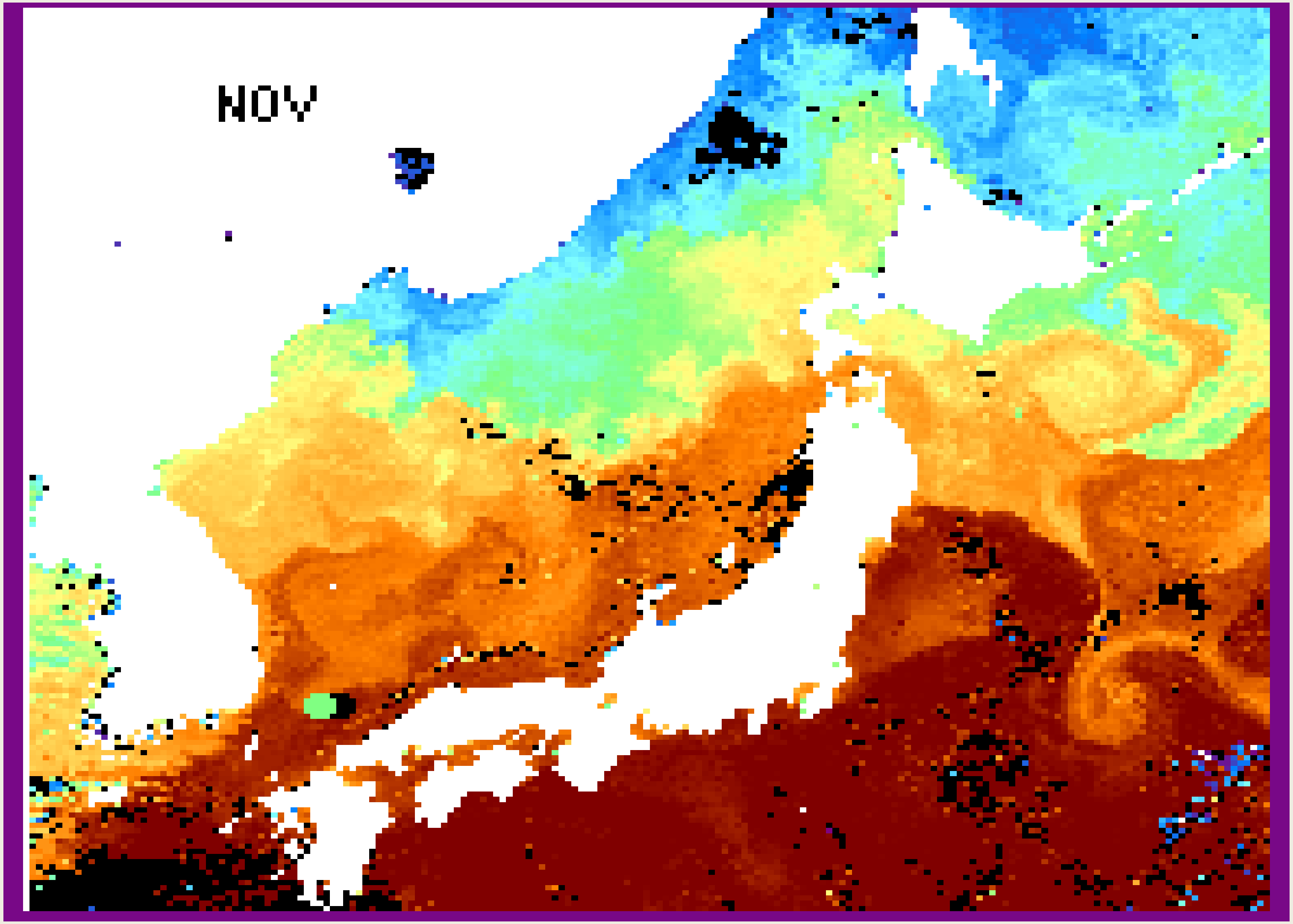


Common squid
Bio-energetic Model + NEMURO
in Japan Sea



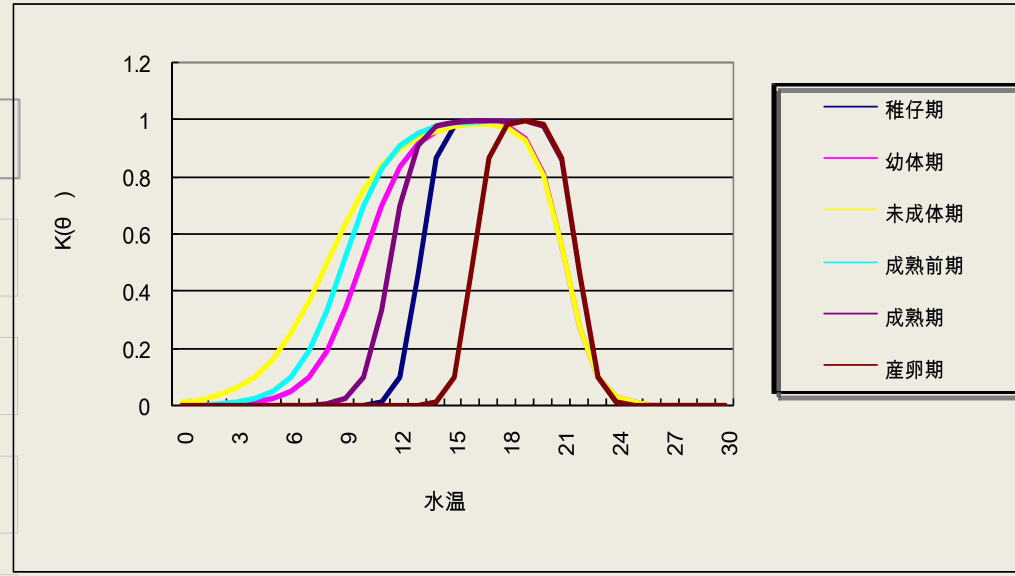
Two Migration root and SST

Tsushima group and Subarctic gro



Temperature function

stage	*period*
1.larvae	1101-1215
2.juvenile	1216-0401
3.young	0402-0502
4.Pre mature	0502-0702
5.mature	0703-0903
6.spawning	0904-1031



温度とステージ

	te1	te2	te3	te4
STAGE1	12	15	18	23
STAGE2	7	15	18	23
STAGE3	4	15	18	23
STAGE4	6	14	20	23
STAGE5	10	14	20	23
STAGE6	15	18	20	23

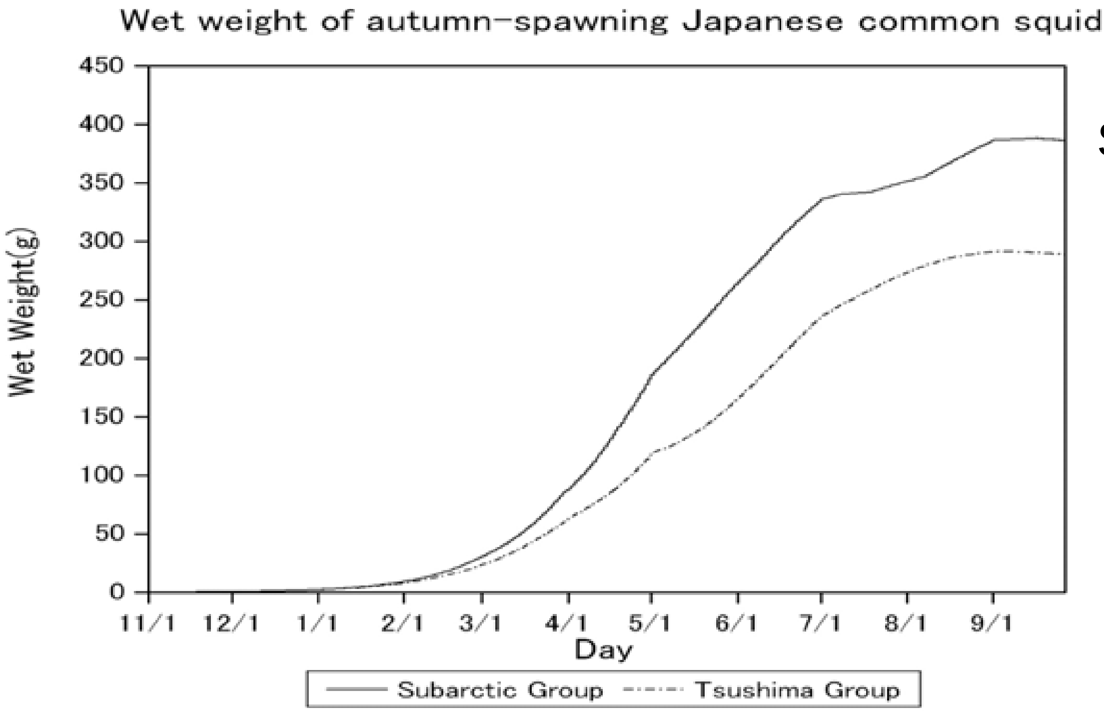
Suitable temp.

Horizontal grids: 1 °× 1

Vertical grids   5 4 levels

CCSR(U-Tokyo) COCO

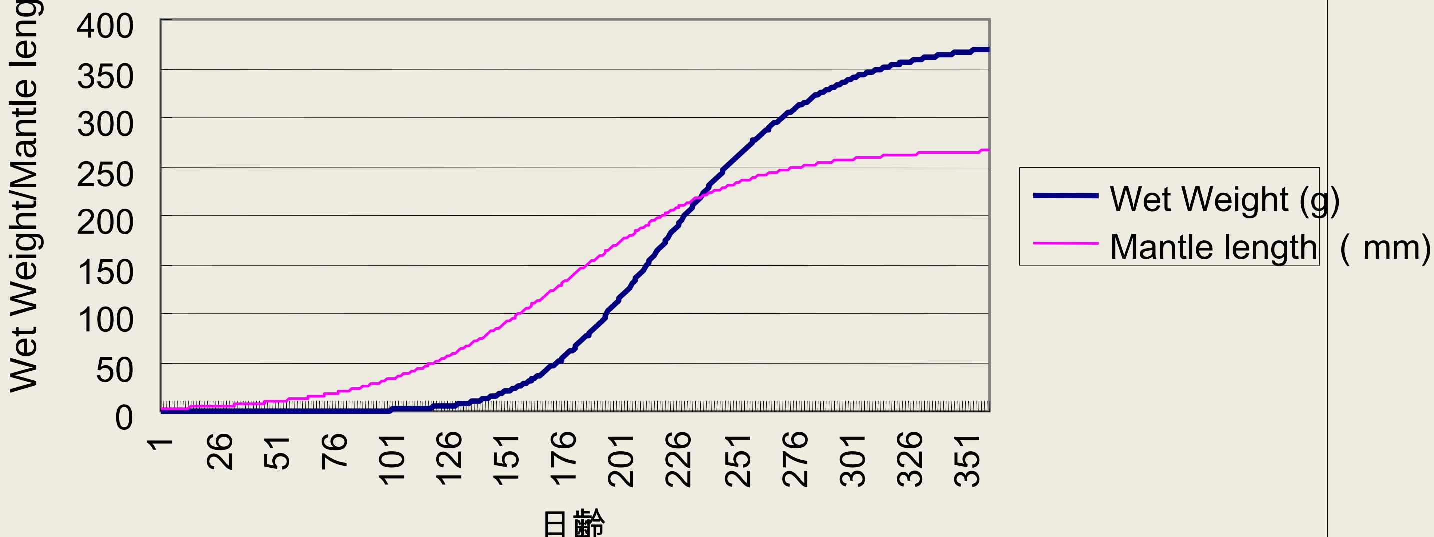
Temperature, ZS, ZP :
averaged over 0~20 m

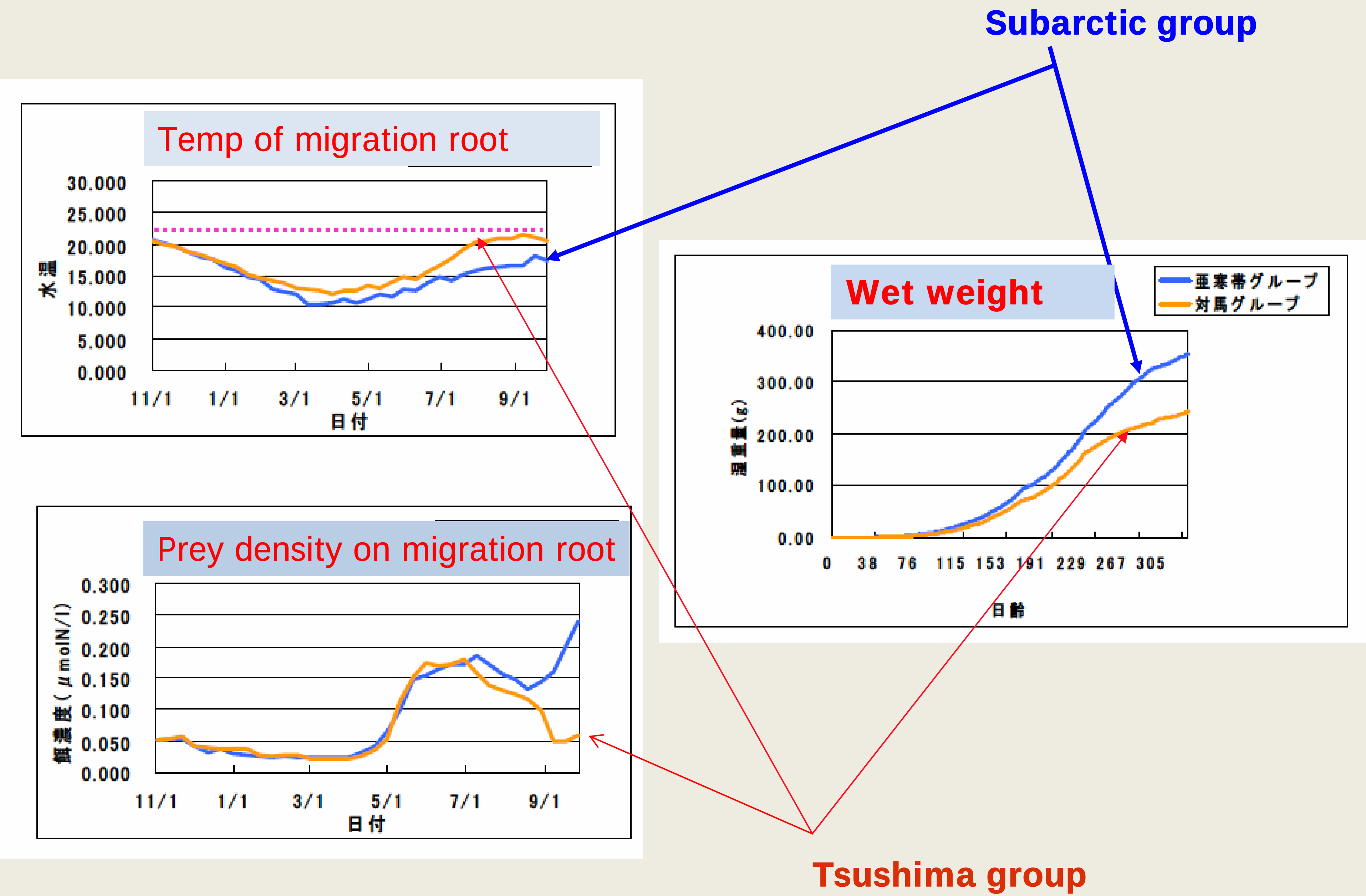


Subarctic group

Tsushima group

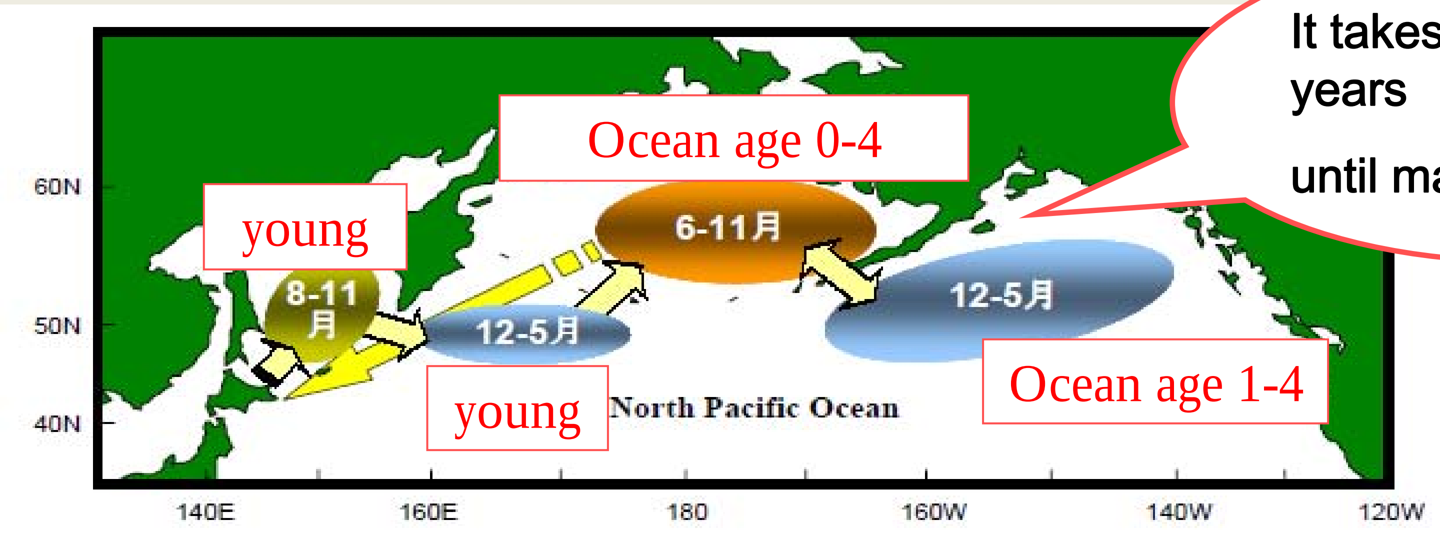
(Kidokoro et al 1999)





Subarctic group
Temp of migration root
30.000
25.000
20.000
15.000
10.000
5.000
0.000
水温
11/1
1/1
3/1
5/1
7/1
9/1
日付
Wet weight
亜寒帯グループ
対馬グループ
400.00
300.00
200.00
100.00
0.00
湿重量(g)
0
38
76
115
153
191
229
267
305
日齢
Prey density on migration root
0.300
0.250
0.200
0.150
0.100
0.050
0.000
餌濃度(μmolN/l)
11/1
1/1
3/1
5/1
7/1
9/1
日付
Tsushima group

Chum Salmon



It takes 2 - 6 years

until maturity

Many returns

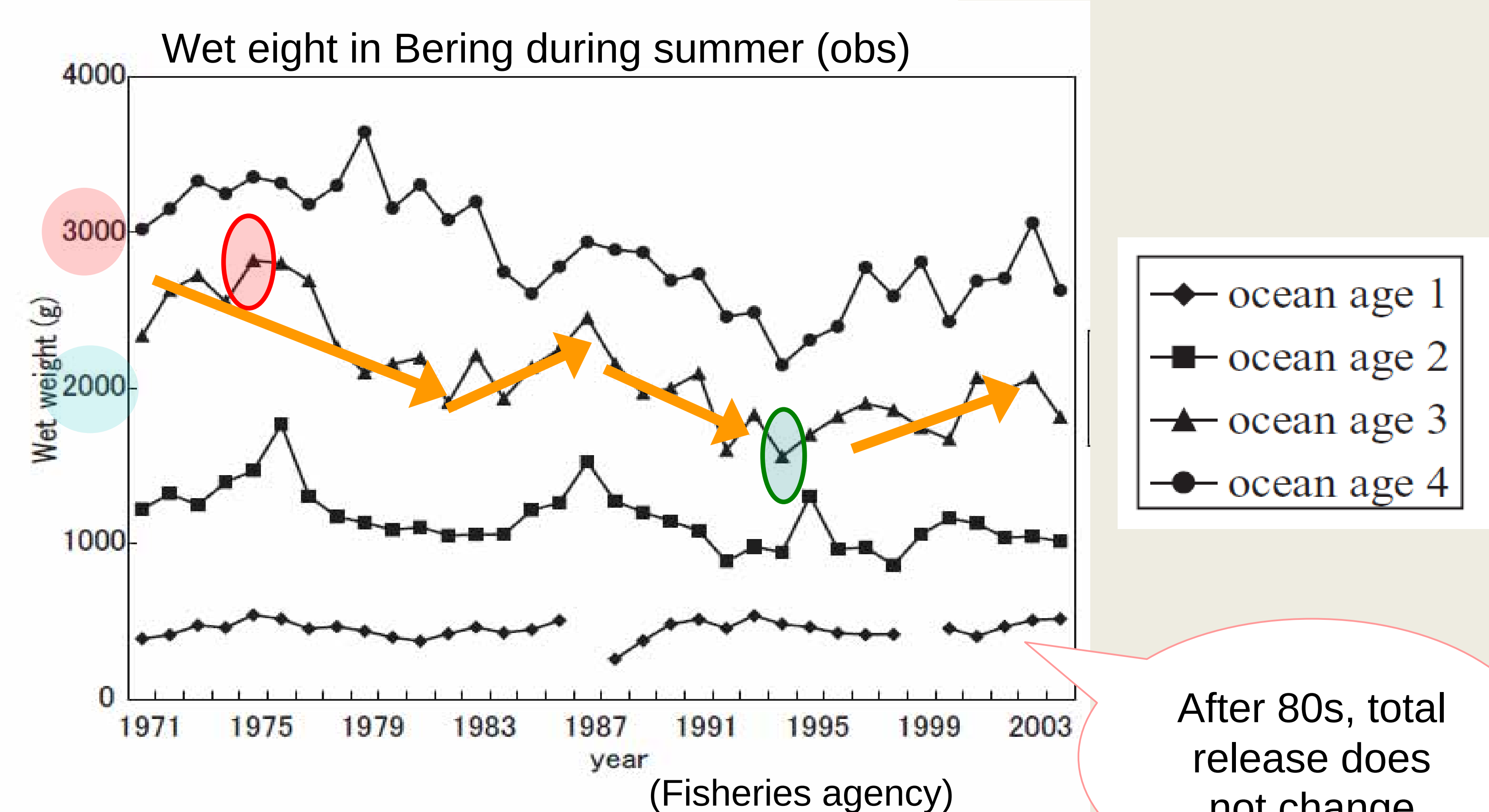
In ocean age 3

（浦和,2000　さけ・ます資源管理センターニュースNo. 5　pp3-9 ）

Japanese salmon is maintained by artificial release

- early summer : release
- July - Aug. : Okhotsk sea
- Dec. - May :Northwestern Pacific
- Migration to Bering Sea until June. Winter:
- Gulf of Alaska, Summer: Bering
- Maturity >> Sep-Dec. go back to river

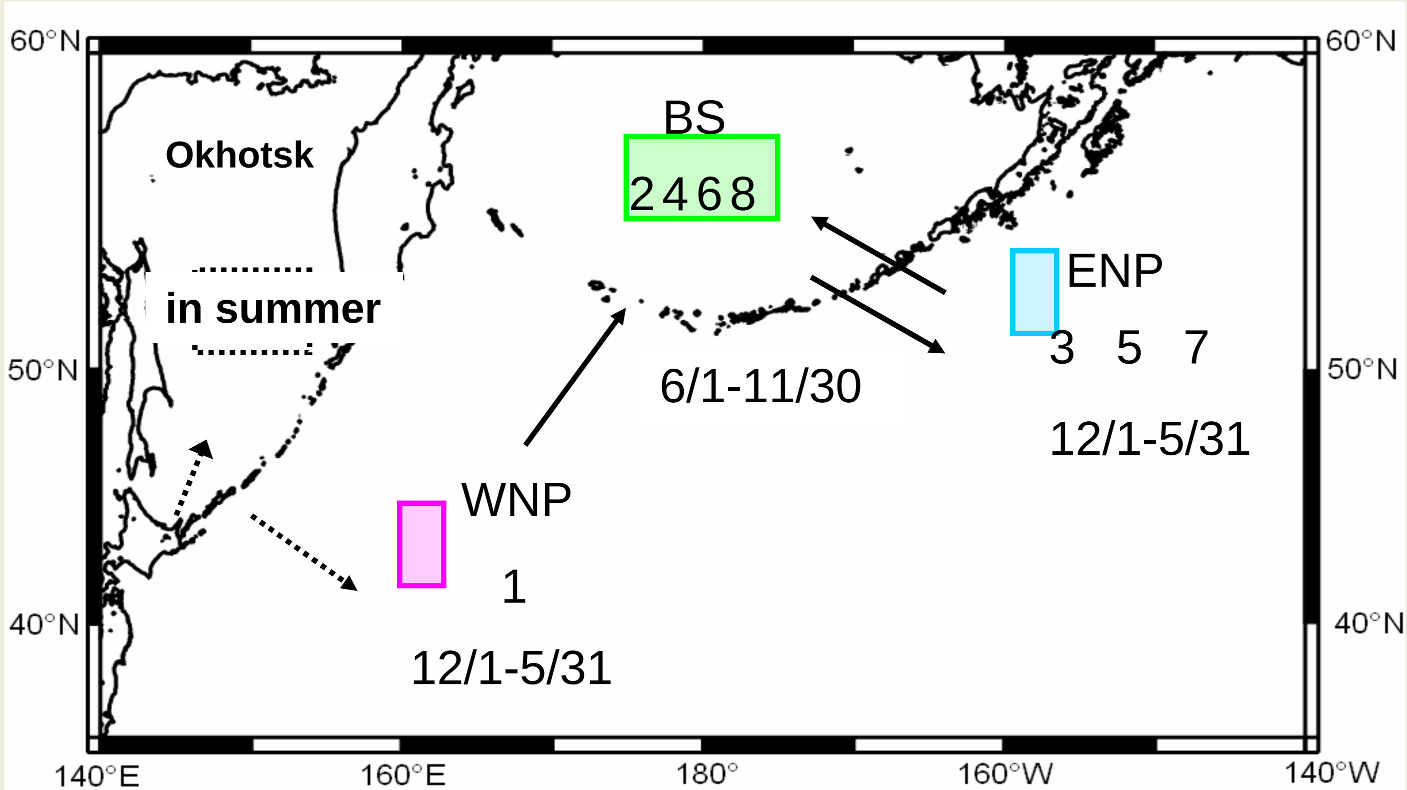
Interannual variability of wet weight



After 80s, total release does not change

(**Ishida *et al.*(1993)， Kaeriyama (1998)， Azumaya and Ishida (2000)ら**)

MODEL-1- Box model



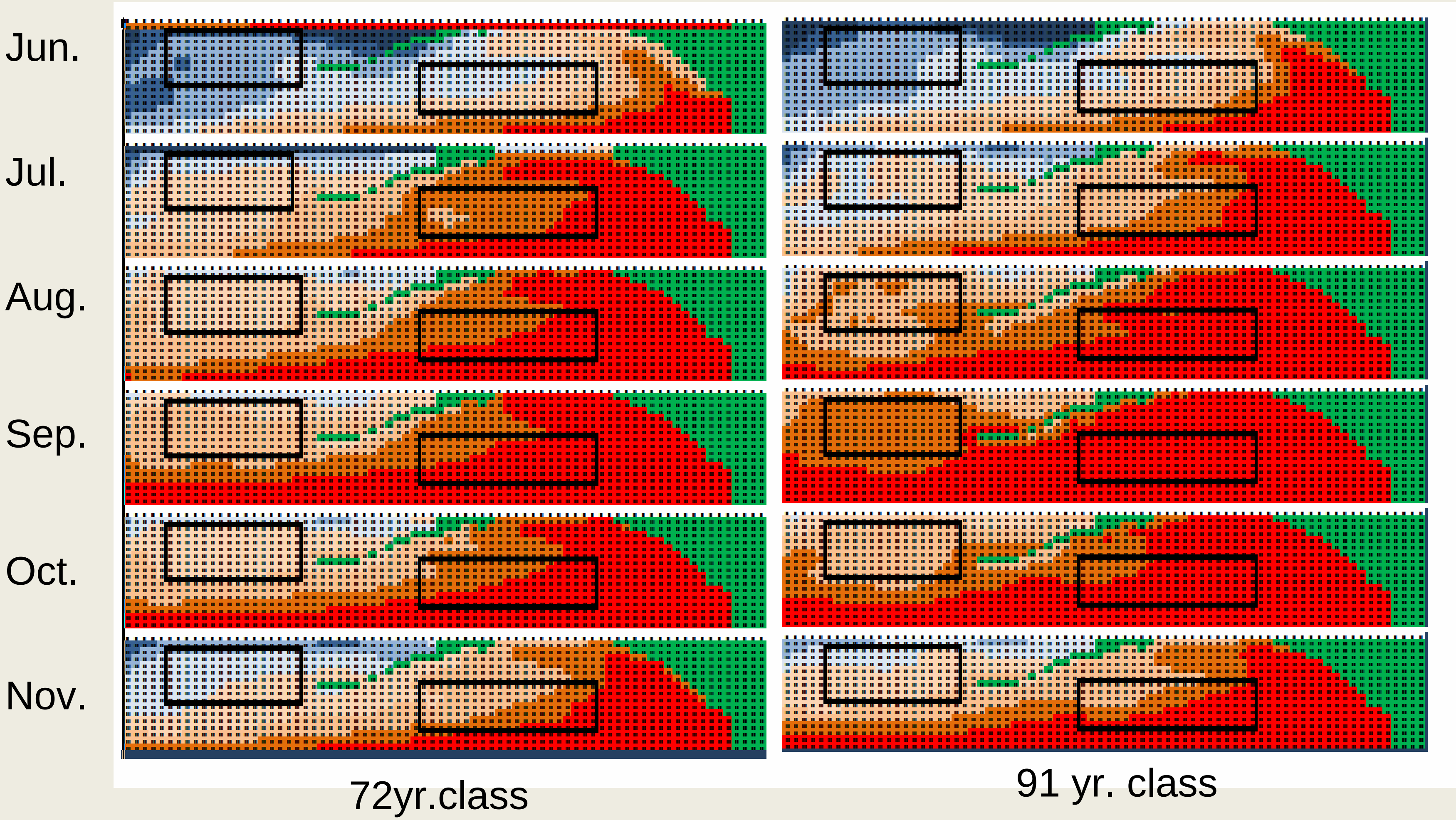
Model year DJFMAM JJASON DJFMAM JJASON DJFMAM JJASON DJFMAM JJOSON

Stage No.(Ocean Age) 1(0 -1) 2 (1) 3(1-2) 4 (2) 5 (2-3) 6 (3) 7 (3-4) 8 (4)

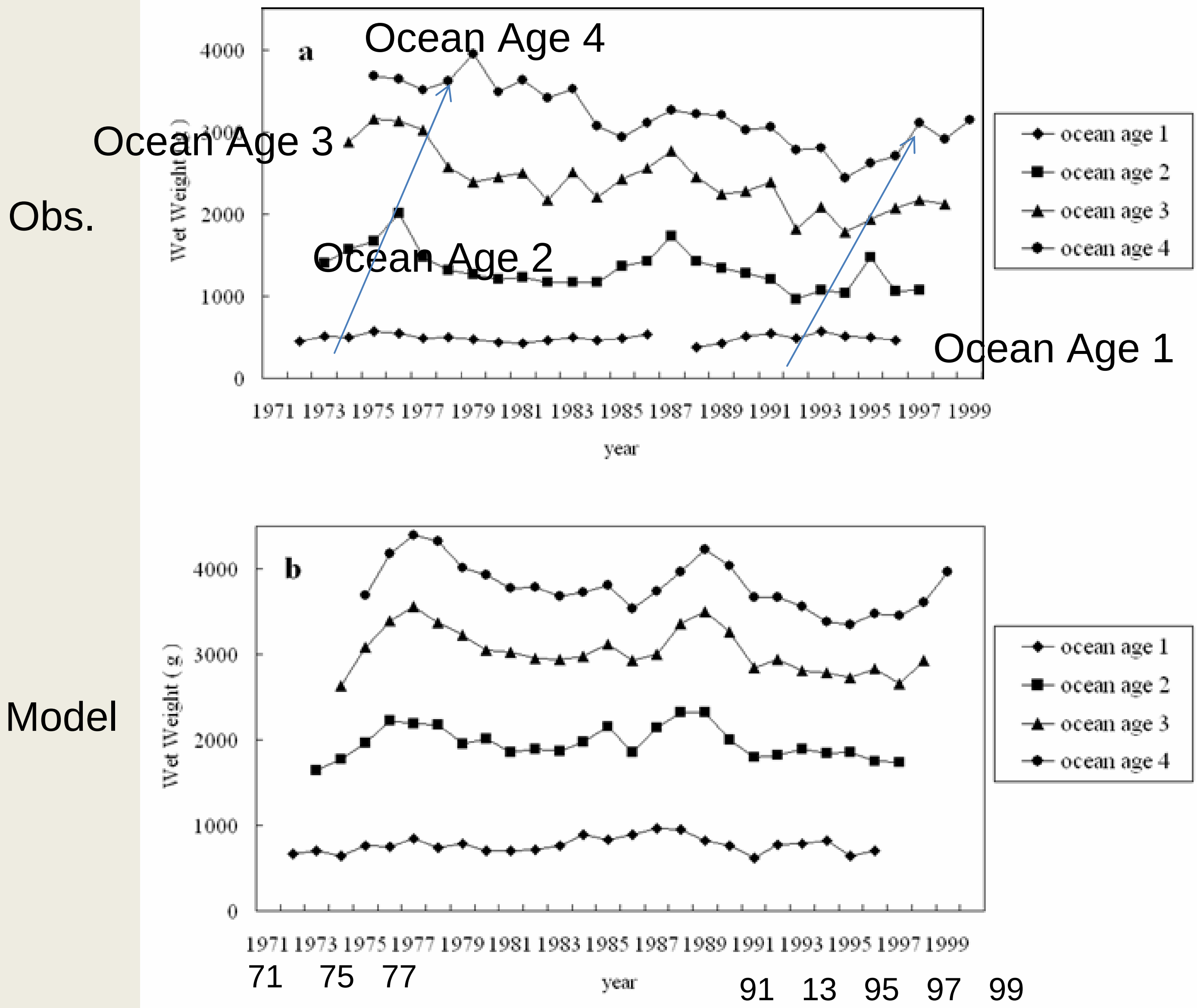
Divided into 8 stages, based on Urawa (2000).

Migration is determined by calendar date.

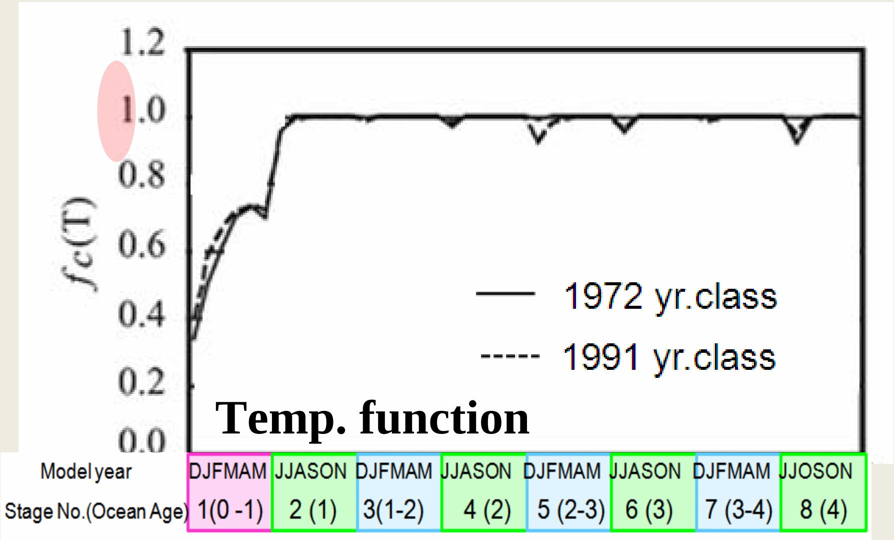
72yr.class vs. 91yr class (Temp. ; age = 4.0 ,Summer)

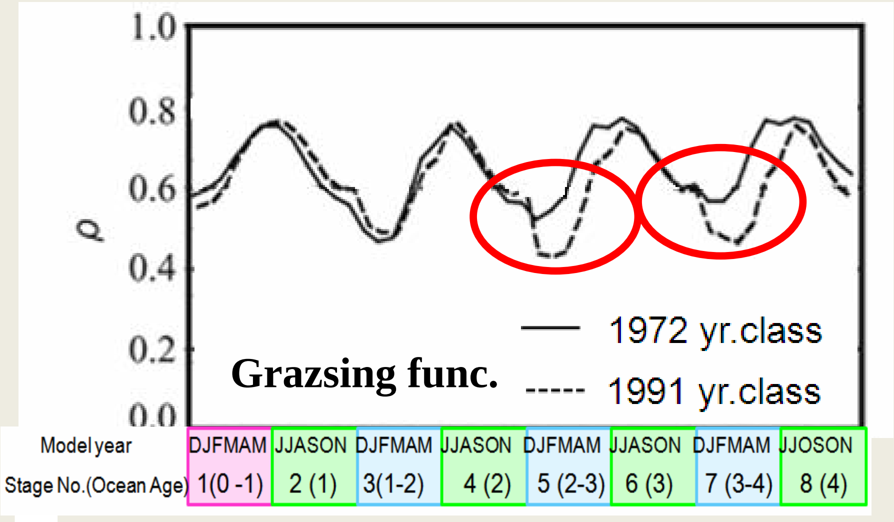


Time dependent wet weight



Temperature dependent term and food density dependent term





Temperature term shows almost 1

➢**Food density term changes at Gulf of Alaska :**
（1972 Year class ＞ 1991 year class）

After 1976 regime shift, SST of Northeastern Pacific increased, MLD decreased, and zooplankton also decreased(Aita *et al.*,2007)

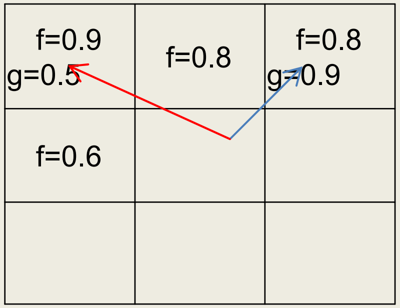
Model -2 Horizontal 2-D continuous migration

Salmon migrates

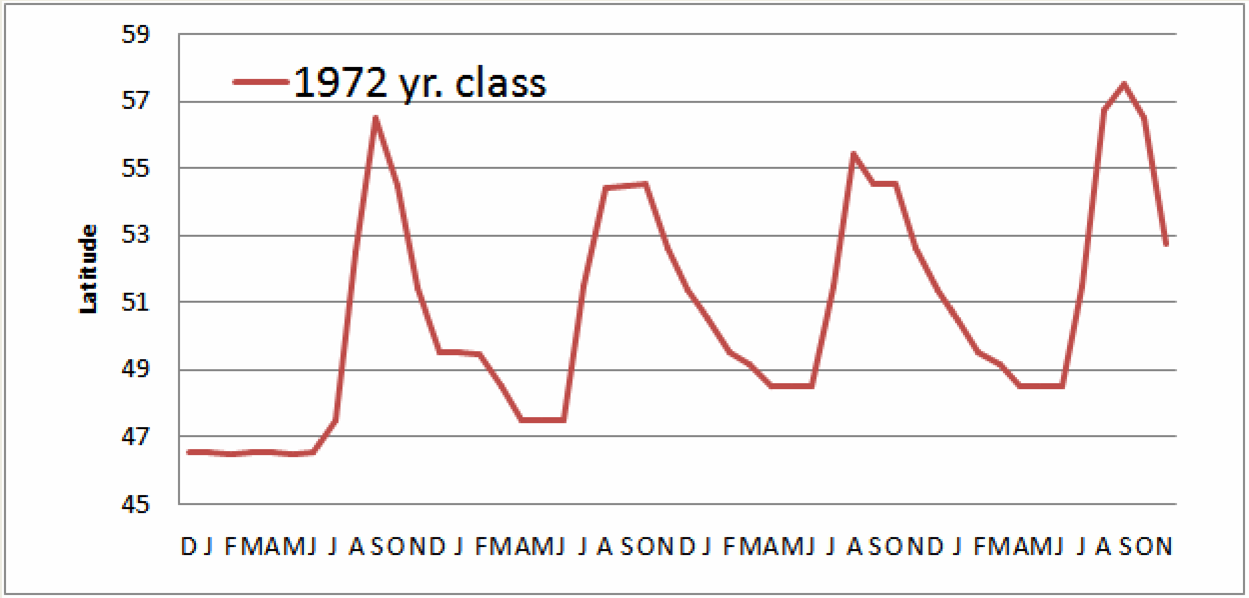
1)Toward suitable temperature (f(T))

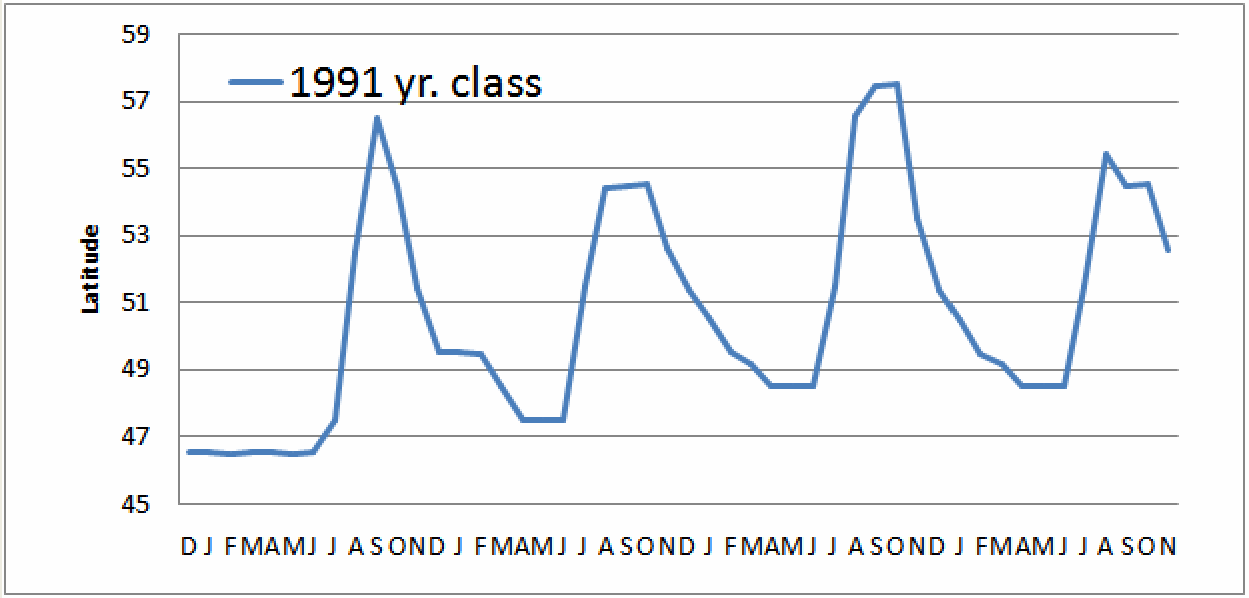
2)Toward suitable prey density (g(prey))

3)Combination above two + advection

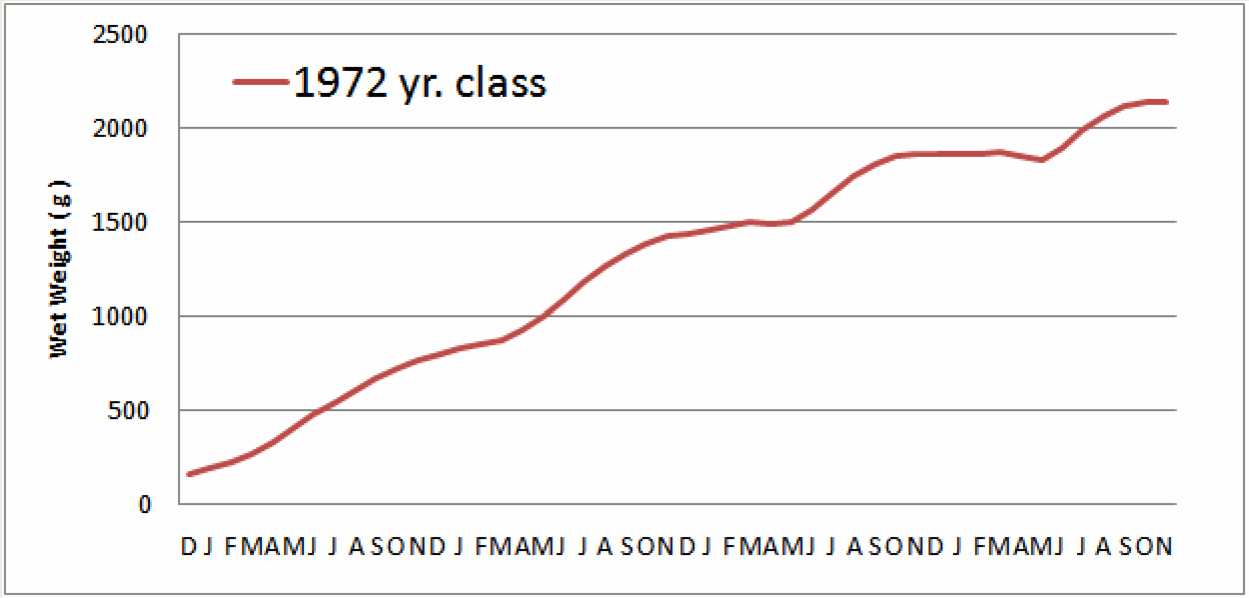


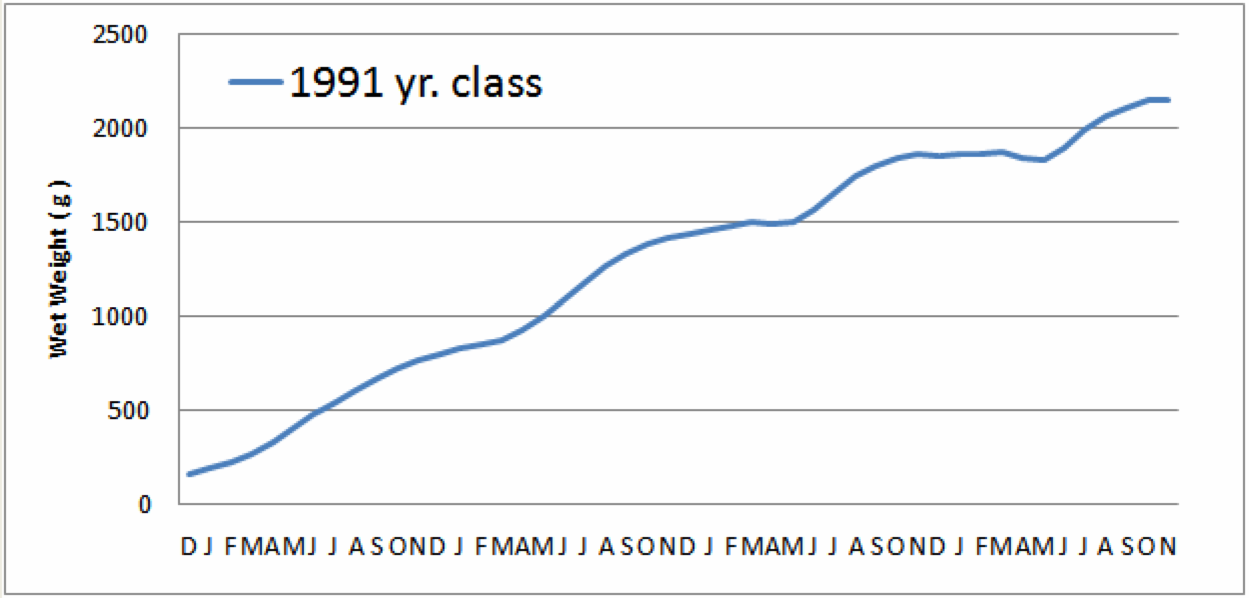
Migration Route :Combination Oriented





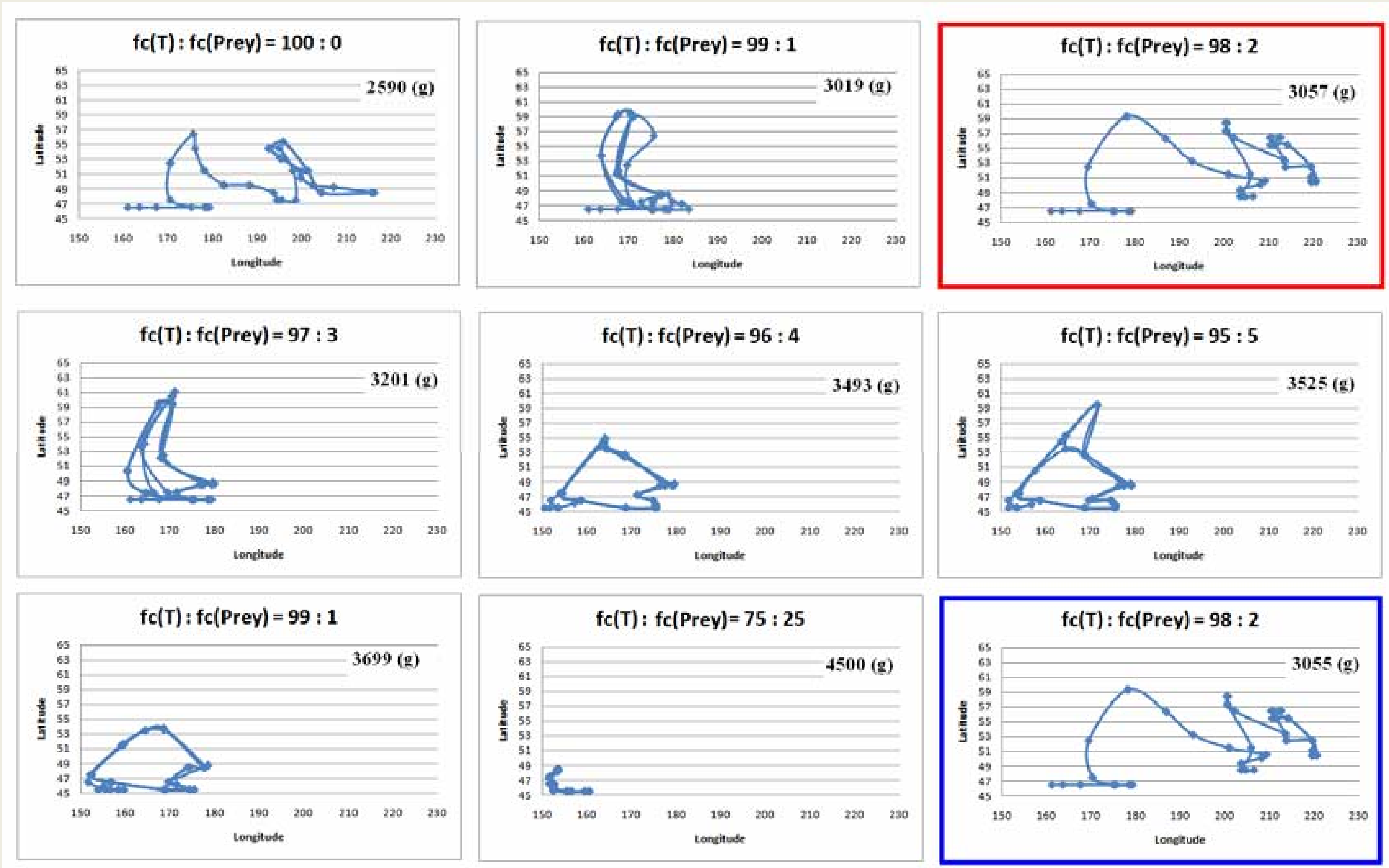
Wet weight: Combination Oriented

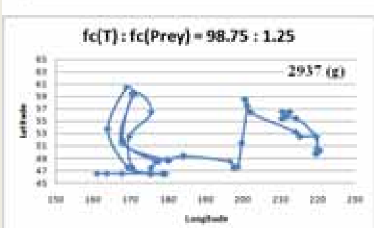




No difference

Migration route: Changing f(t)/g(prey) (1972 yr.class)





1991 yr.class

Conclusion

1) NEMURO.FISH can succeeds to simulate time dependent wet weight for saury, squid, salmon.

2) Criteria of migration is VERY important.

To migrate toward best growth may bring about no difference of growth.

3) Multi species modelling must be included for W(dN/dt)