Interannual response of fish growth to the 3-D global NEMURO output with realistic atmospheric forcing. Part II: Pacific saury growth

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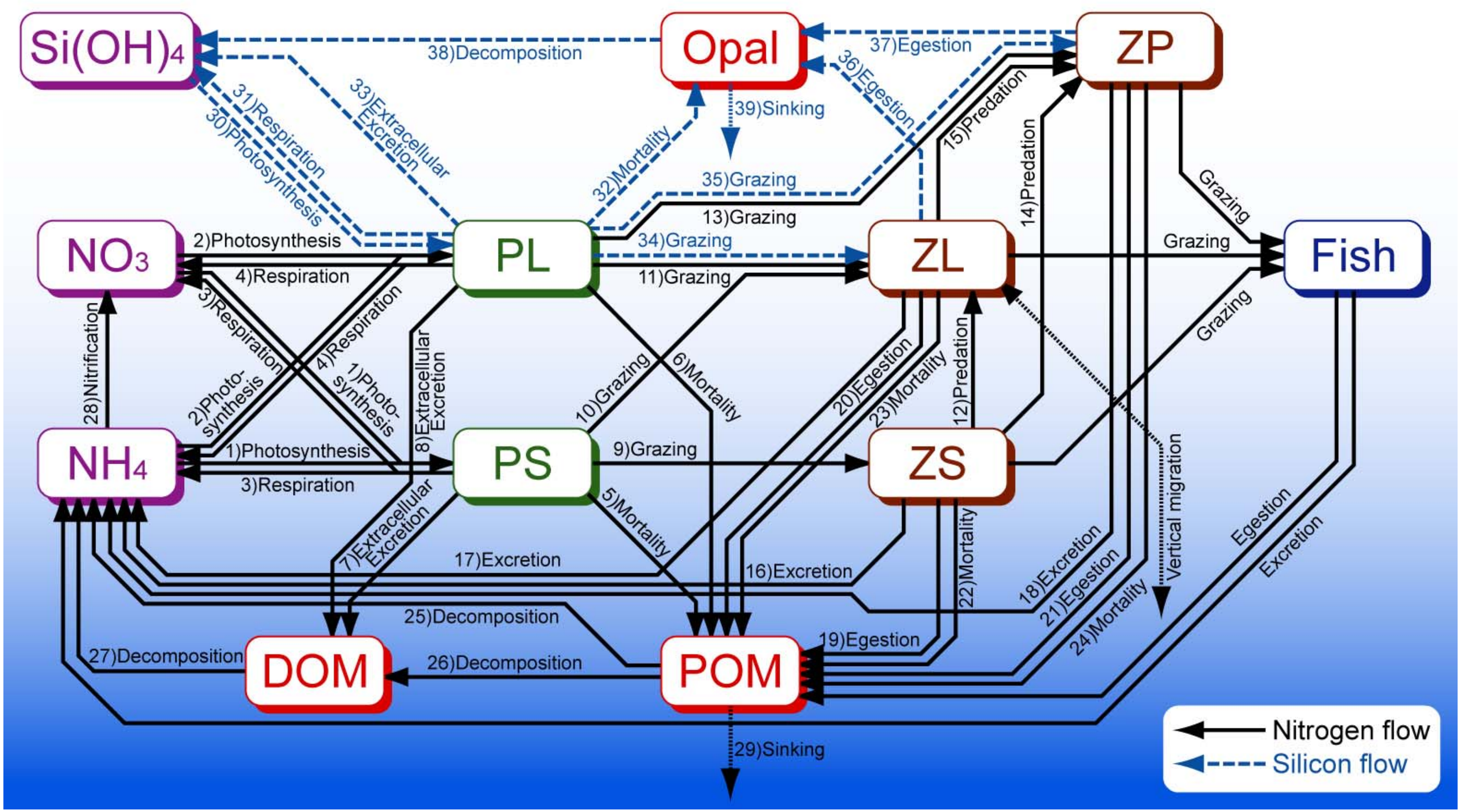
NEMURO.FISH



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

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)

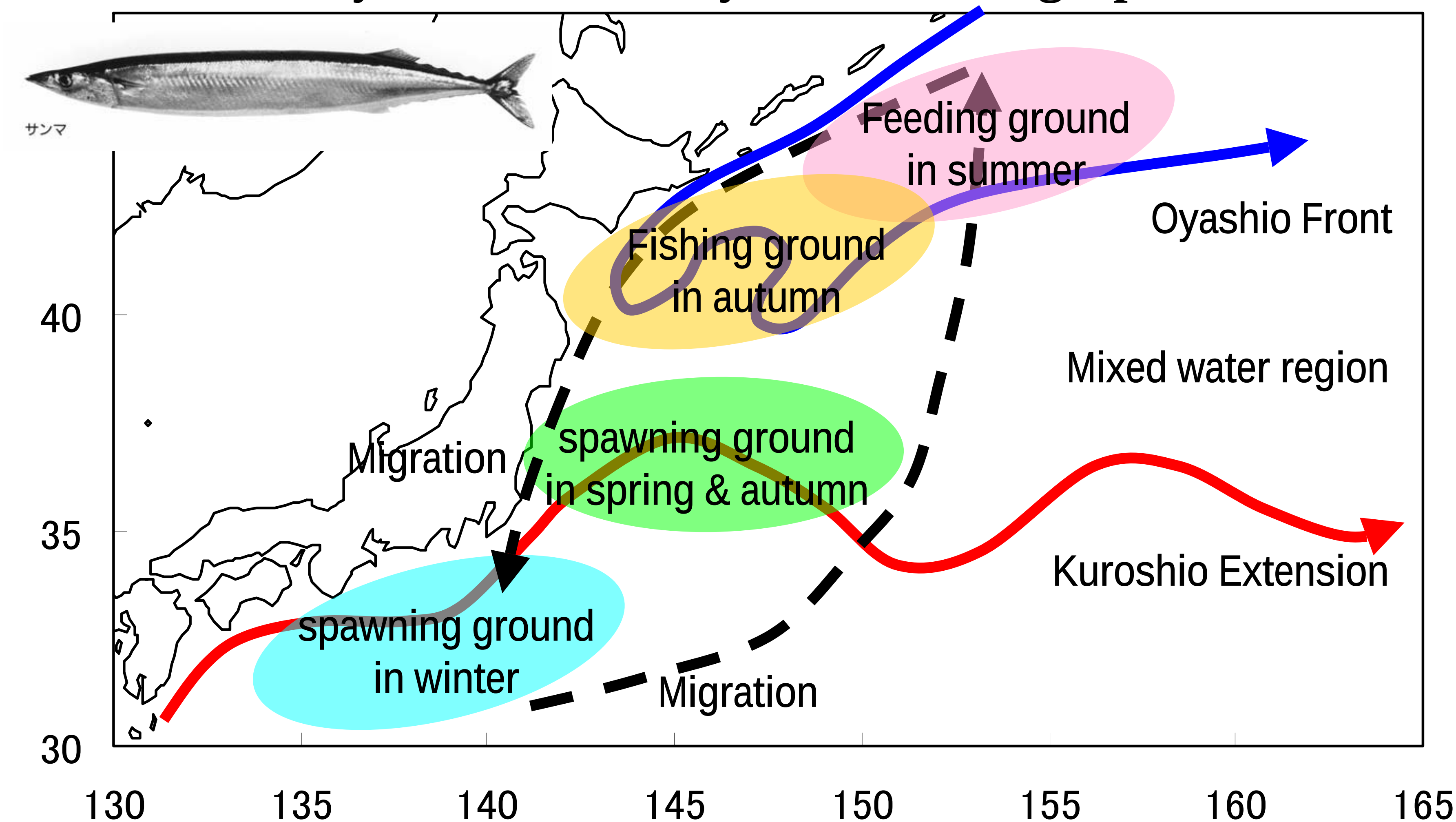
S: specific dynamic action (digesting food)

F: egestion

E: excretion

P: egg production

Life History of Pacific Saury with Oceanographic Features



Modified from Watanabe et al. (1989)

timing of migration

Jun. 15
KL<9.9cm 13°C
9.9<KL<19.9cm 9°C
19.9cm<KL independent

Feb. 1
15°C

Kuroshio → **mixed water region** → **Oyashio**

Kuroshio ← **mixed water region** ← **Oyashio**

Nov. 15
KL<24.0cm 13°C
24.0<KL<29.0cm 15.5°C
29.0cm<KL 18°C

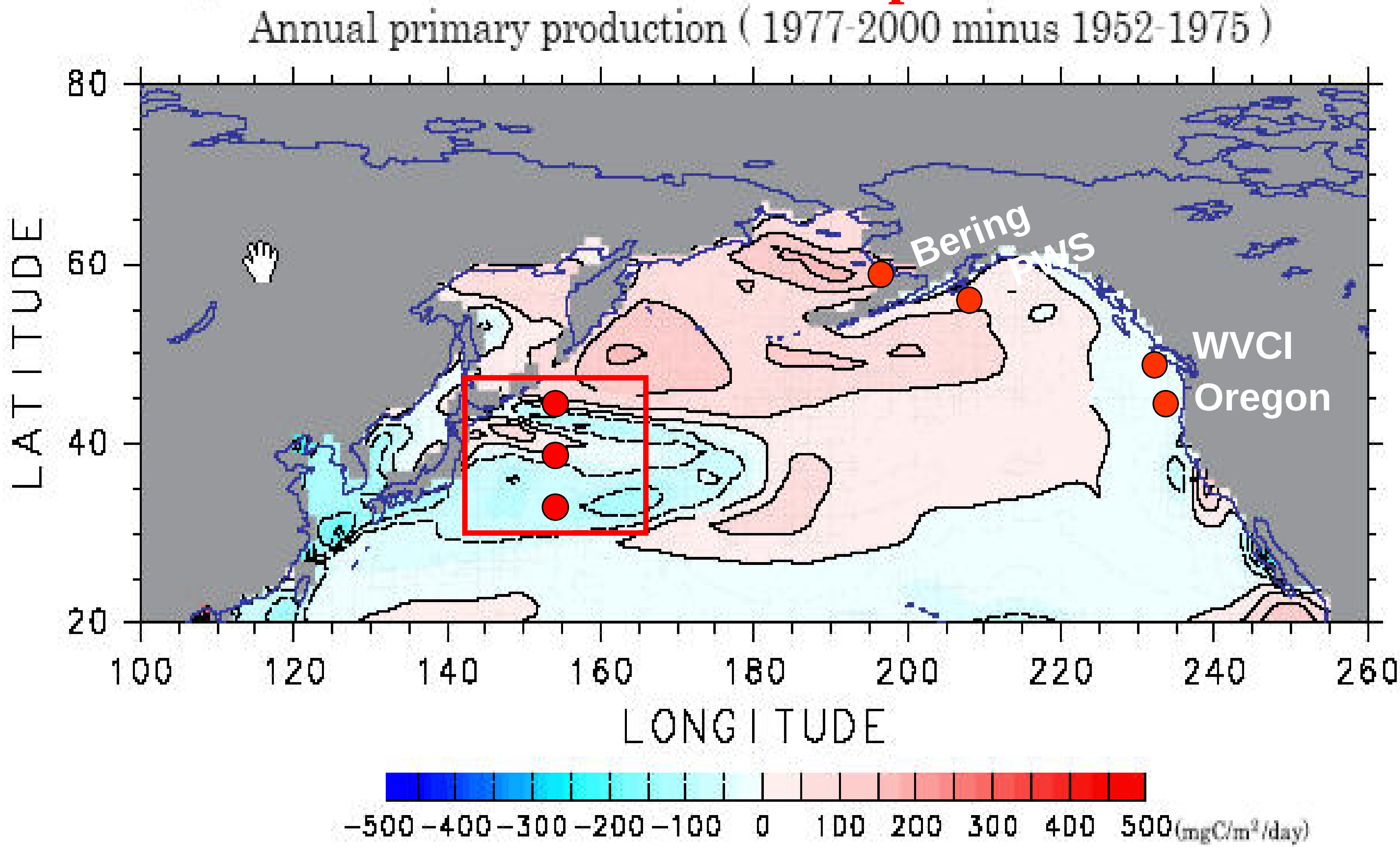
Oct. 1
KL<24.0cm 13°C
24.0<KL<29.0cm 15.5°C
29.0cm<KL 18°C

defined by KL and temperature
based on Fukushima (1987)
Kosaka (2000)

Ito et al. (2004): 3box model

Mukai et al. (submitted):
temperature dependent migration

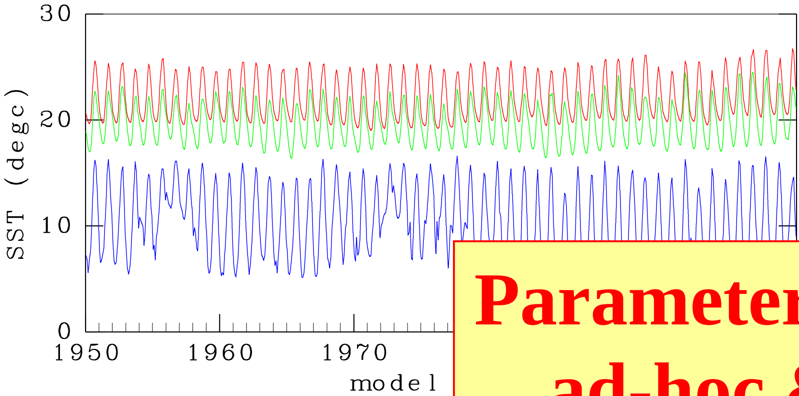
3D-NEMURO output

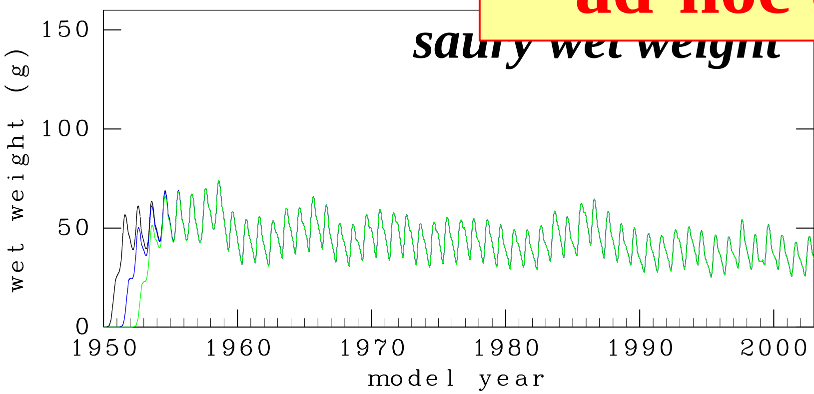


Noguchi-Aita et al. (2004)

3D-NEMURO forcing & result of NEMURO.FISH

3D-NEMURO mixed layer temp.

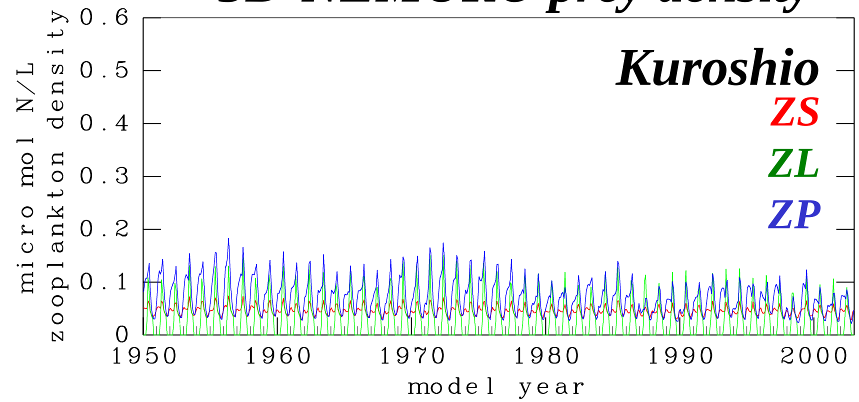


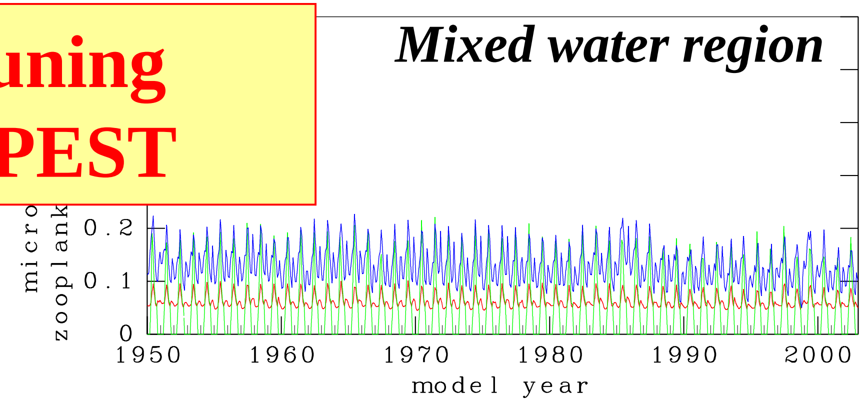


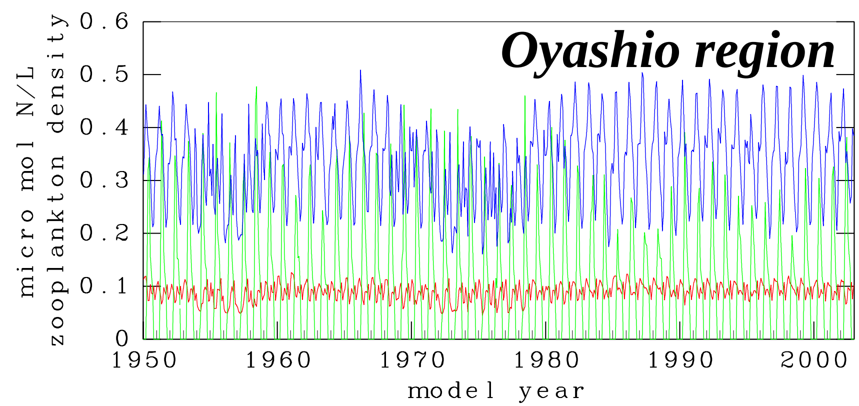
Parameter tuning
ad-hoc & PEST

saury cannot grow enough, because prey density is too low in the 3D-NEMURO.

3D-NEMURO prey density

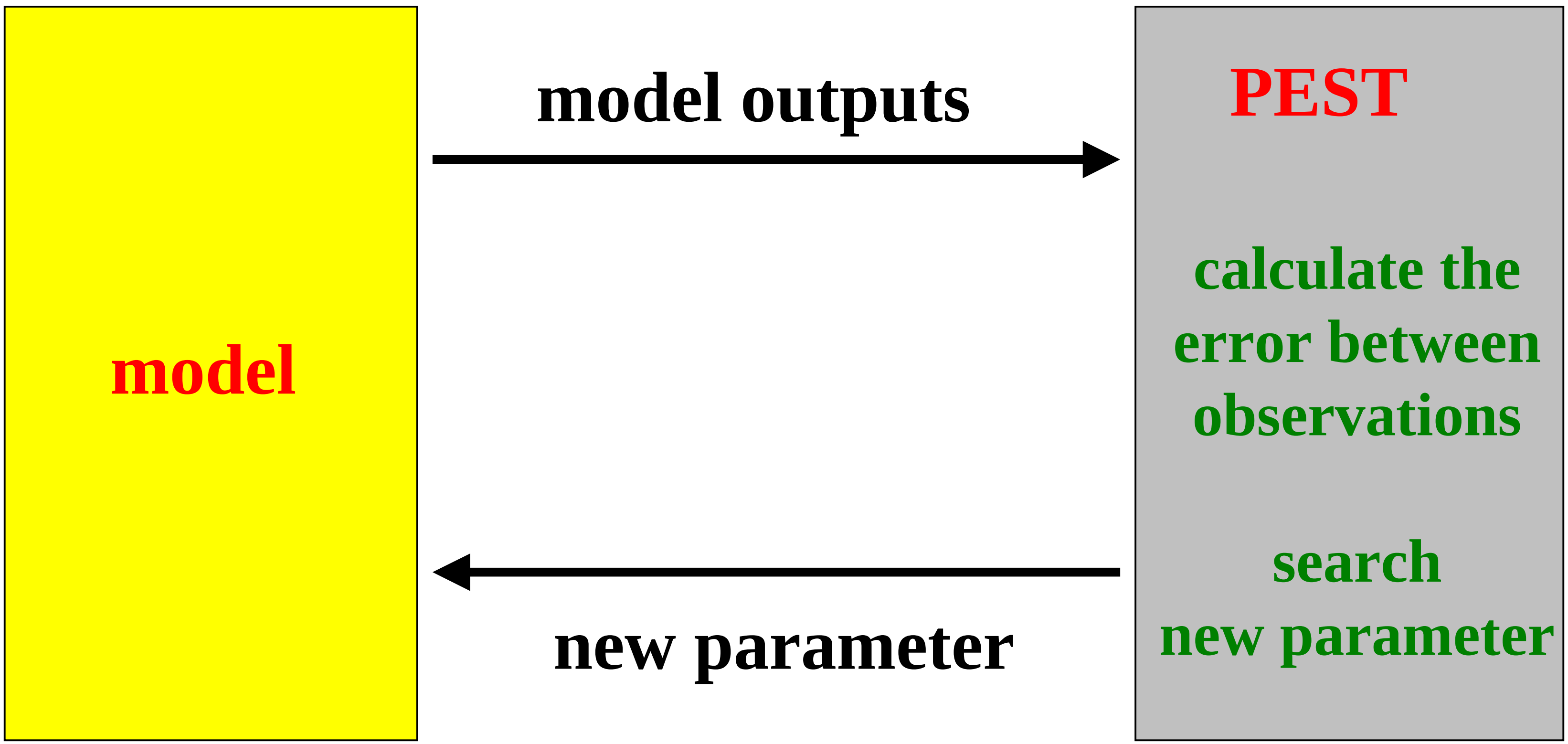






applied PEST Software to the saury model

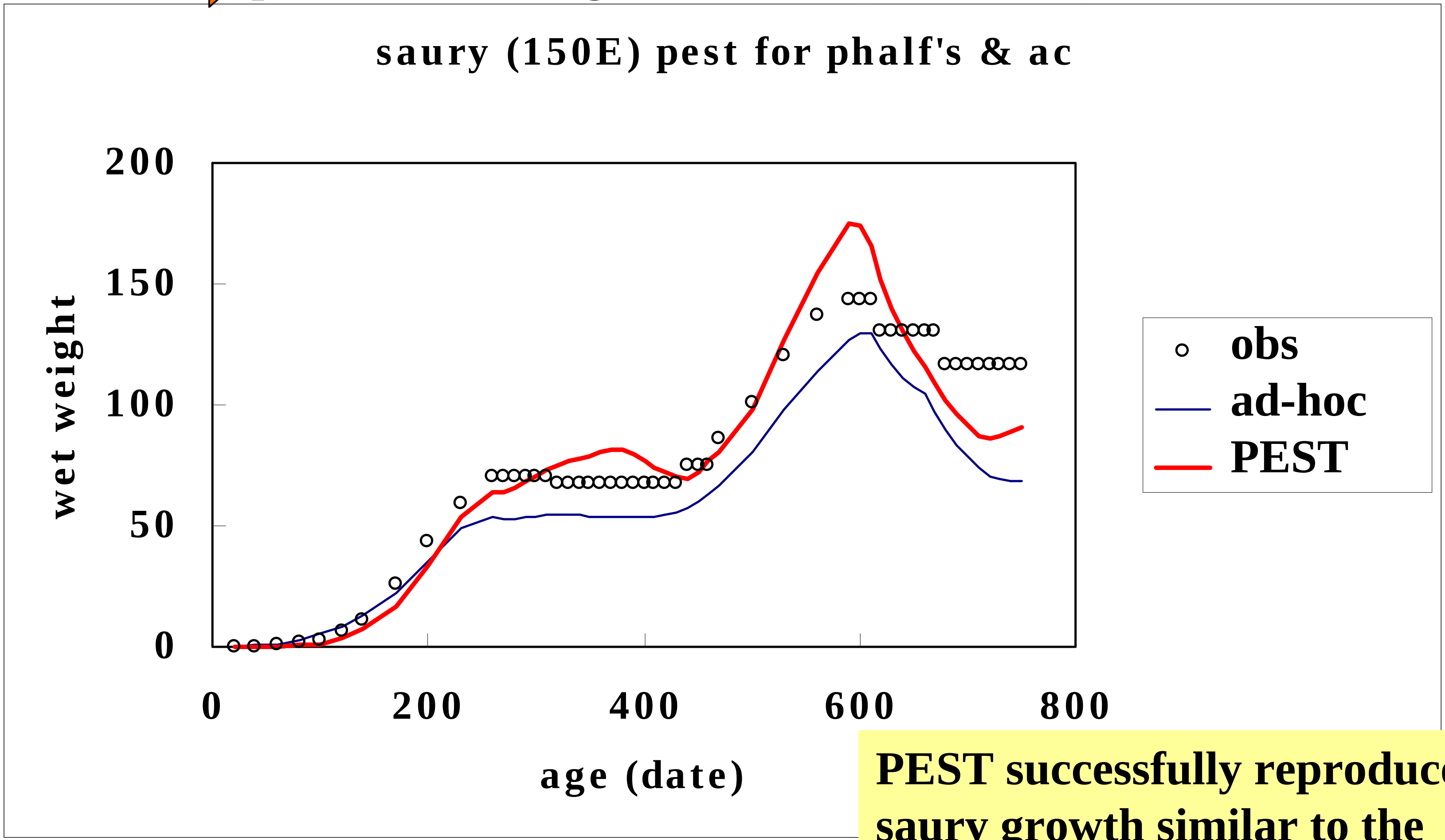
merit of the PEST is using PEST with no modification of the model source code.



parameter tuning

3D-NEMURO has a bias (low zooplankton biomass level).

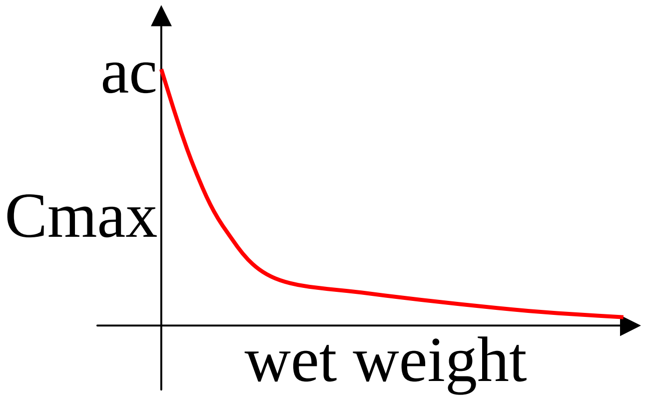
- **low growth of fish**
- **parameter tuning with ad-hoc (manual)**
- **parameter tuning with PEST (automated)**

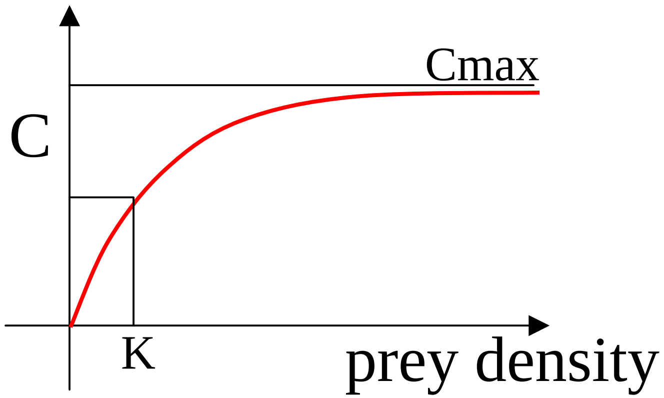


PEST successfully reproduce the saury growth similar to the observation.

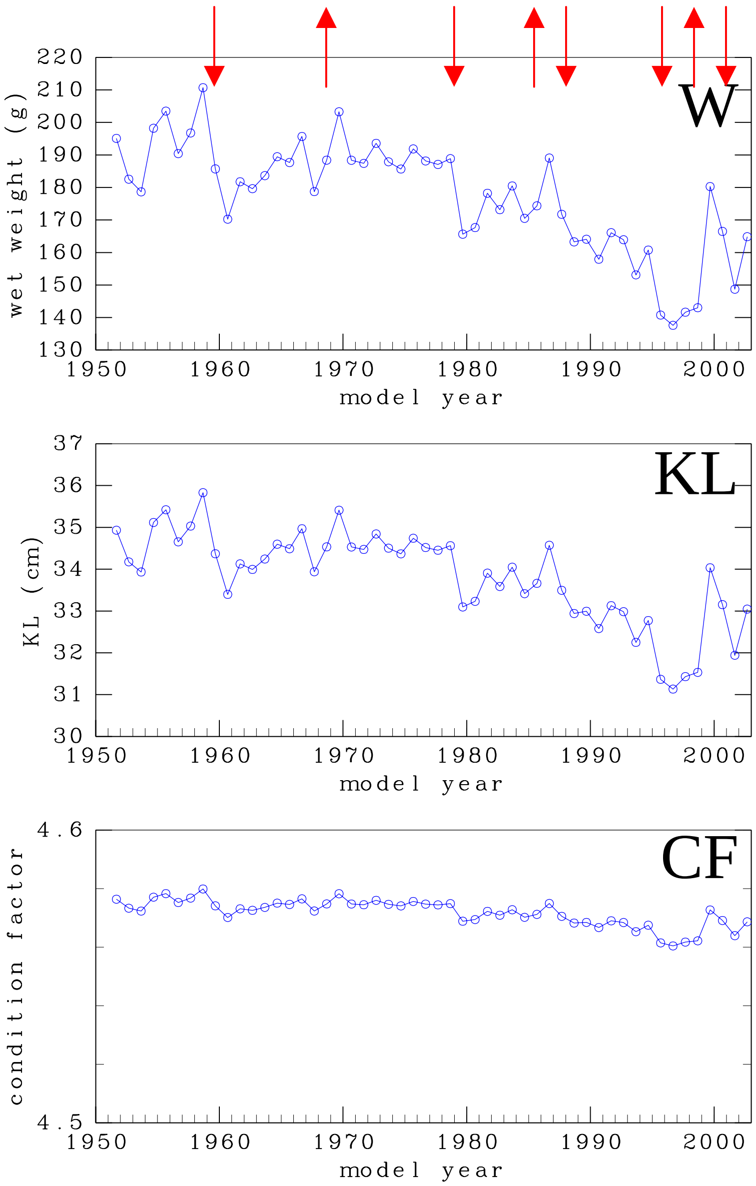
Table 1. Original and calibrated parameters; interception for the maximum consumption rate a_c and half-saturation constants K_{ij} for the saury bioenergetics model. i denotes fish type (1 for life stage 1, 2 for life stage 2 and 3 for life stage 3-9) and j denotes the prey type (1 for ZS, 2 for ZL and 3 for ZP).

parameters	original	precalibrated	postcalibrated
a_c	0.8	0.8	1.254080
K_{11}	0.30	0.10	0.339301
K_{21}	0.30	0.10	0.186160
K_{22}	0.30	0.10	0.292740
K_{32}	0.45	0.30	1.441980
K_{33}	0.45	0.30	0.348197





interannual run with PEST tuned parameter



distinctive shift

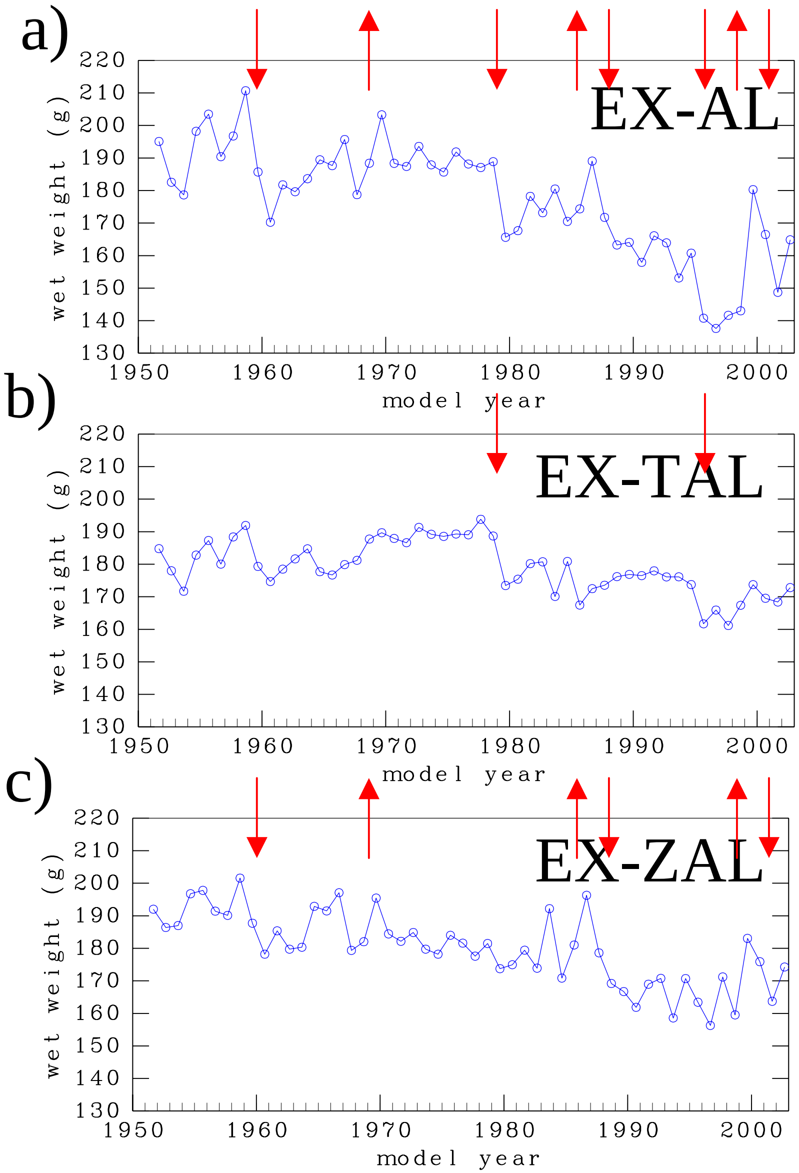
Decrease	**increase**
1958-60	**1967-69**
1978-79	**1985-86**
1986-88	**1998-99**
1994-95	
1999-2001	

Table 2. Forcing of numerical experiments. The model domains where interannual variations were prescribed as forcing factor are listed. The factors of no notification were fixed to climatological values. KR, MX, and OY denotes the Kuroshio area, mixed water region and Oyashio area, respectively.

experiment	T	ZS	ZL	ZP
EX-AL	all	all	all	all
EX-TAL	all	-	-	-
EX-ZAL	-	all	all	all
EX-ALKR KR	KR	KR	KR	
EX-ALMX	MX	MX	MX	MX
EX-ALOY OY	OY	OY	OY	
EX-TKR	KR	-	-	-
EX-TMX	MX	-	-	-
EX-TOY	OY	-	-	-
EX-ZKR	-	KR	KR	KR
EX-ZMX	-	MX	MX	MX
EX-ZOY	-	OY	OY	OY
EX-ZSAL	-	all	-	-
EX-ZLAL	-	-	all	-
EX-ZPAL	-	-	-	all
EX-ZPKR -	-	-	KR	
EX-ZPMX-	-	-	MX	
EX-ZPOY -	-	-	OY	

sensitivity analysis for forcing

In the model it is quite easy to divide the effect of forcing factors.
We performed additional 17 numerical experiments.



Temperature effect vs
zooplankton effect

6 of 8 distinctive shift were clearly reproduced by zooplankton varying case.

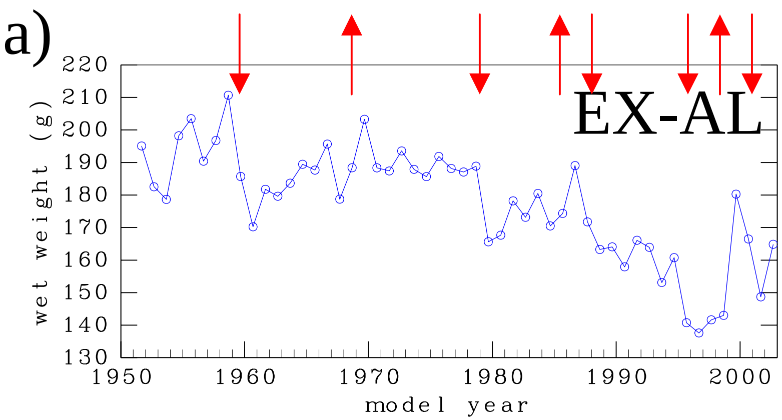
Only the 1978-79 and 1986-88 shifts are explained by temperature forcing.

Fig. 2.

Table 3. Response of saury wet weight in EX-AL, EX-TAL and EX-ZAL. The term "m." means major source for decrease of increase.

period	EX-AL	EX-TAL	EX-ZAL
1958-60	decrease	decrease	m. decrease
1978-79	decrease	m. decrease	decrease
1986-88	decrease	increase	m. decrearse
1994-95	decrease	m. decrease	decrease
1999-2001	decrease	decrease	m. decrease
1967-69	increase	increase	m. increase
1985-86	increase	increase	m. increase
1998-99	increase	increase	m. increase

The effects of temperature and zooplankton show same direction except for 1986-88.
6 of 8 distinctive shift were clearly reproduced by zooplankton varying case.



If look into the effect of each oceanic domain, the effects of the Oyashio area and mixed water region are important.
Especially the effect of the mixed water region is significant.

However, the effect of both domains showed opposite direction in 1986-88, 1999-2001 and 1985-86.

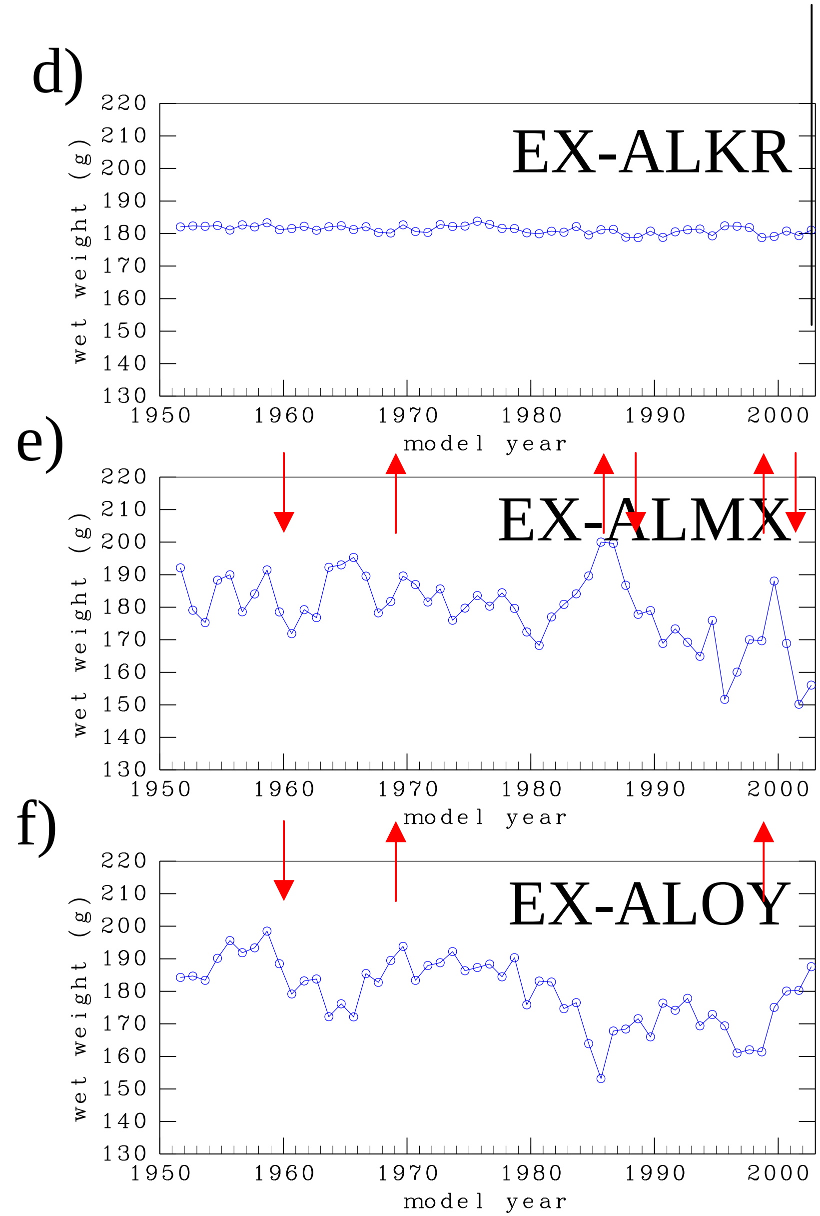
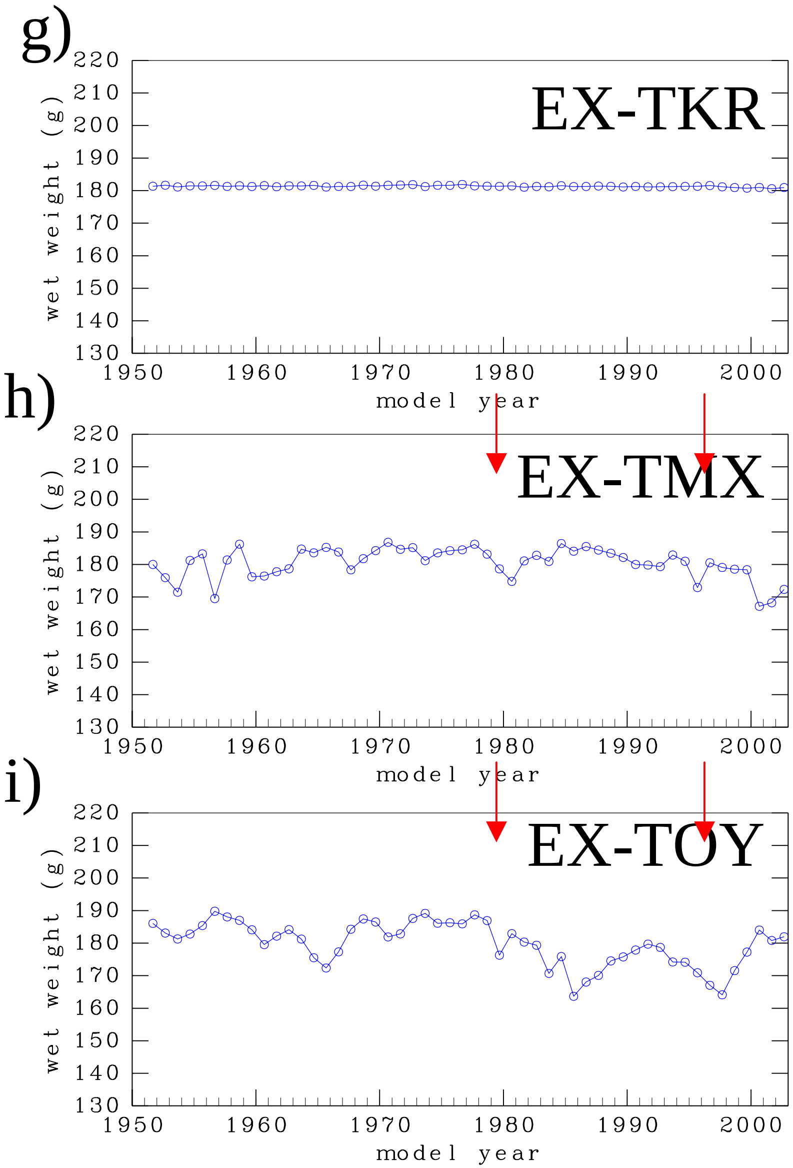


Fig. 2.



Concerning about the temperature effect, the effect of the Oyashio region was highest.

Although the temperature effect in the mixed water region was secondary important, it showed opposite direction except for 1978-79 and 1994-95. Only in these excepted case the temperature effects became major source for decrease

Concerning about zooplankton effects, the effect of the mixed water region was highest.

Although the zooplankton effect in the Oyashio region was secondary important, it showed almost same direction except for 1999-2001 and 1985-86.

Comparisons of effects of zooplankton species showed the importance of ZP (not show). Moreover, the ZP density in the mixed water region is the most effective (not shown).

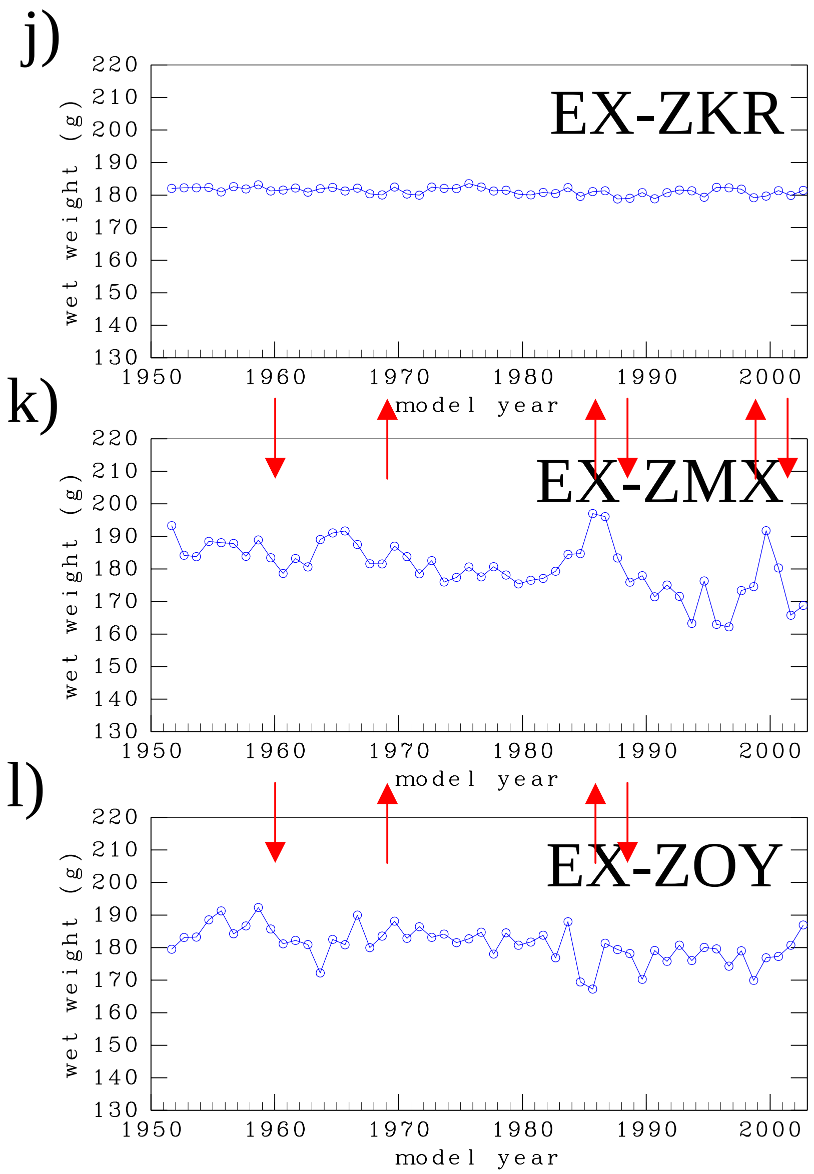
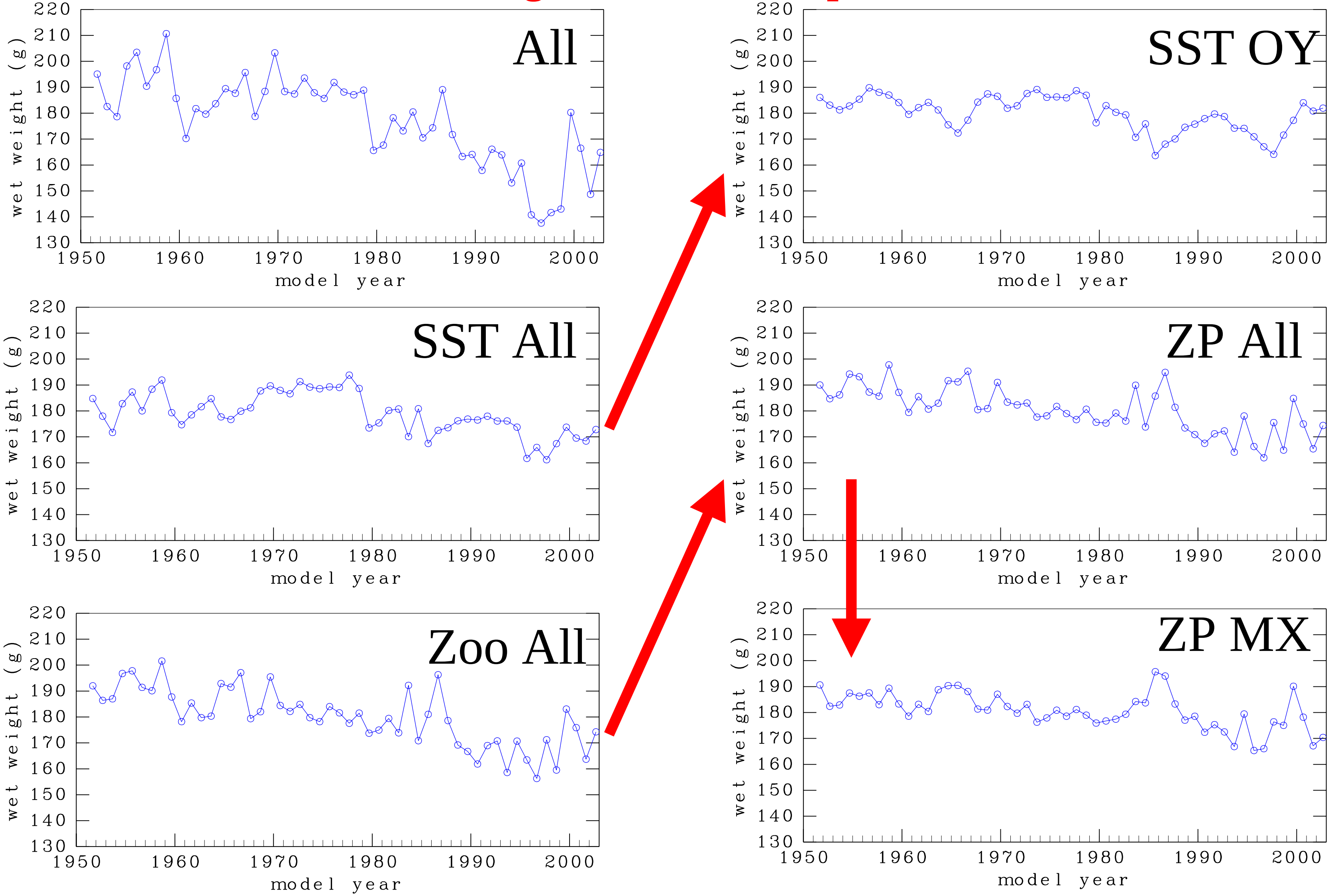


Fig. 2 continue.

For the saury growth, SST in the Oyashio region and ZP in the mixed water region are most important.



Summary

1. Parameter tuning with PEST
    successfully reproduce the realistic saury growth
    more observations are able to improve the model
2. For the saury growth, SST in the Oyashio region and ZP in the mixed water region are most important.
    However, in the actual ocean, there may be other effects, ex. competitions for prey zooplankton between other pelagic fishes.
    Especially, for saury, sardine predatory pressure on prey zooplankton is severe problem.

Future Perspectives

1. Construct multi-species model of NEMURO.FISH
    including sardine effects
    PEST parameter tuning

2. Geographical and species comparison

FRA/APN/IAI/GLOBEC/PICES Workshop

'*Global comparison of sardine, anchovy and other small pelagics – building towards a multi-species model* '

Date: 14-17 Nov. 2005

Objectives:

Summarize the response of sardine, anchovy and other small pelagic fishes to the global climate variability and seek effective model approaches to solve the mechanism of synchronicity and anti-synchronicity of them.

Agenda

14 (Mon) Review of variability of growth and biomass of sardine and anchovy in each region.

15 (Tue) Review of NEMURO.FISH and other models related to fish growth and population.

16 (Wed) NEMURO.FISH hands on.

17 (The) NEMURO.FISH hands on and discussion on future collaborations

Why the zooplankton shows same direction ?

The zooplankton effects in the mixed water region and Oyashio area showed almost same direction, on the other hand the effects of temperature showed opposite directions in almost case.

In primary, the zooplankton density, especially ZL and ZP, shows high value after severe winter because of higher nutrient supply.

Therefore, the zooplankton density in the mixed water region and Oyashio area has a tendency to show similar variation.

As a result, the zooplankton effects in both domains showed almost same direction.

Why the temperature effect shows opposite direction ?

The temperature effects to saury migration.

If the mixed layer temperature in the Oyashio area is low, the migration to the Oyashio area is delayed but the southward migration to the mixed water region is advanced. As the result, the period of staying in the Oyashio region is shorten and the wet weight of saury decreases.

On the other hand, if the temperature in the mixed water region is cold, although the southward migration to the Kuroshio region is advanced, the northward migration to the mixed water region is not changed.

Therefore the response of saury to the temperature in the mixed water region is not clear compared with that for the temperature in the Oyashio area.

Temperature & zooplankton effects

The basic effect of temperature in the Oyashio region has two opposite character.

One is positive effect to elongate the staying time in the Oyashio region; when the temperature in the Oyashio region is high, the saury can stay in there longer and grow up.

The other is negative effect through the primarily and secondary production; when the temperature in the Oyashio region is high, the zooplankton density decreases and the saury cannot grow fast.

In this sense, the wide migration of saruy may be one of the strategy to keep their growth stable.