A sardine growth model coupled with the NEMURO lower trophic level ecosystem model

Shin-ichi Ito
Akihiko Yatsu
Yasuhiro Yamanaka
Kenneth A. Rose
Carl D. vd Lingen
Lucho Cubillos
Salvador E. Lluch-Cota
Akinori Takasuka
Masahiko Noto
Taketo Hashioka
Bernard A. Megrey
Manuel Barange
Larry Jacobson
Goh Onitsuka
Yoshioki Oozeki
Michio J. Kishi
Maki Noguchi Aita
Francisco E. Werner
Yunne Shin
Vera N. Agostini
Yasuko Kamezawa

Motivation: failure of Pacific saury model

3-box version

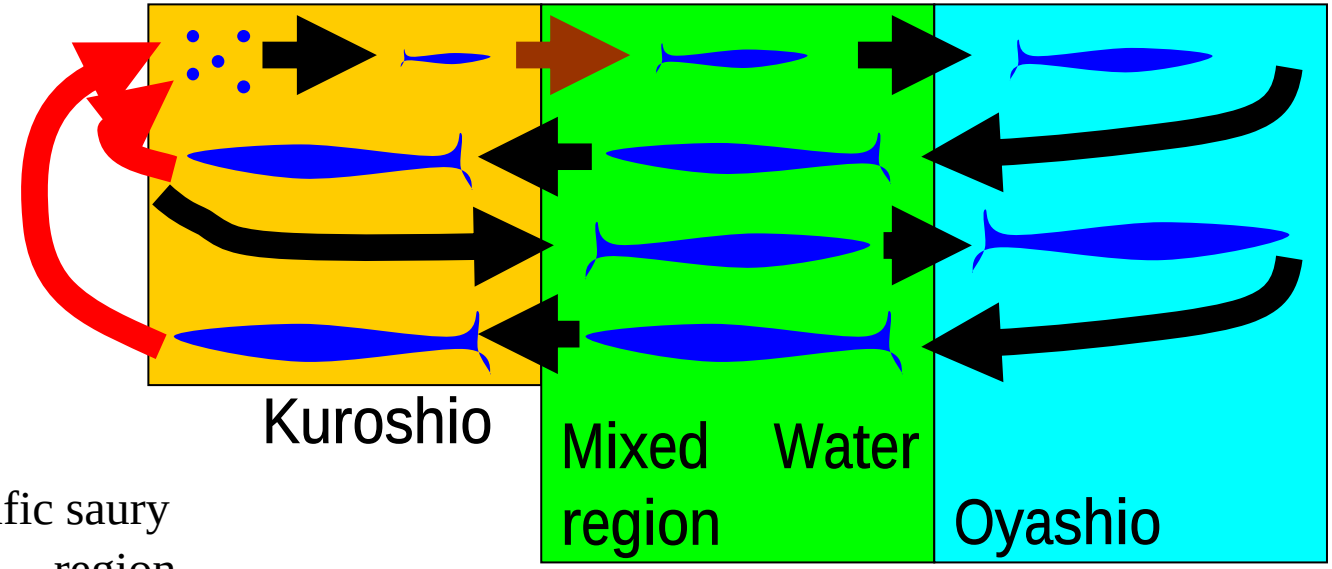
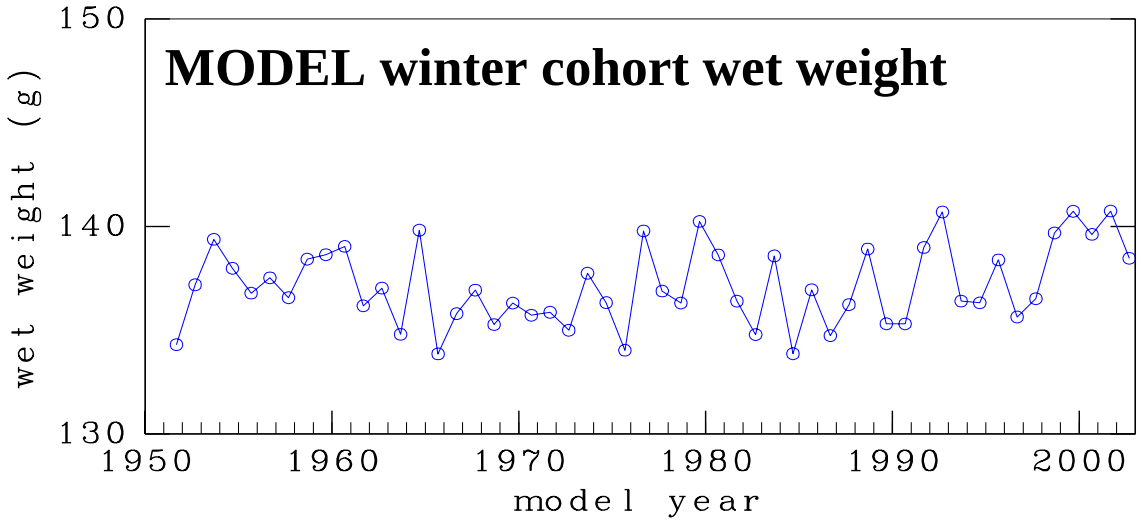


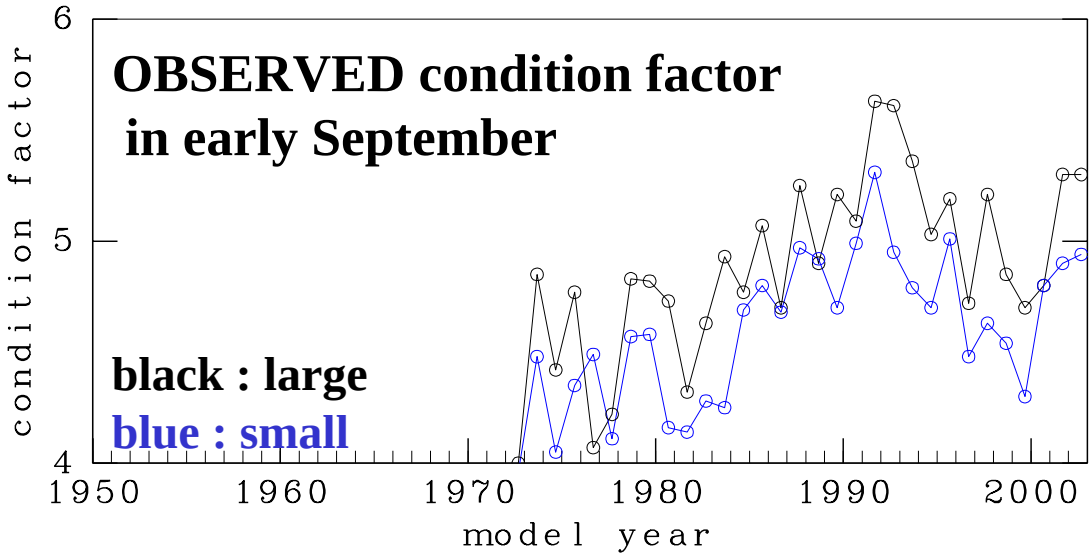
Table 2. Life stages of Pacific saury

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

NEMURO.FISH successfully reproduce realistic growth of saury (Ito et al., 2004). It also successfully reproduce growth difference between different seasonal cohorts (Mukai et al., in press). However, it could not reproduce realistic interannual variation of growth (Ito et al., in press).

Model vs Observation





The model result could not well reconstruct the observed variation.

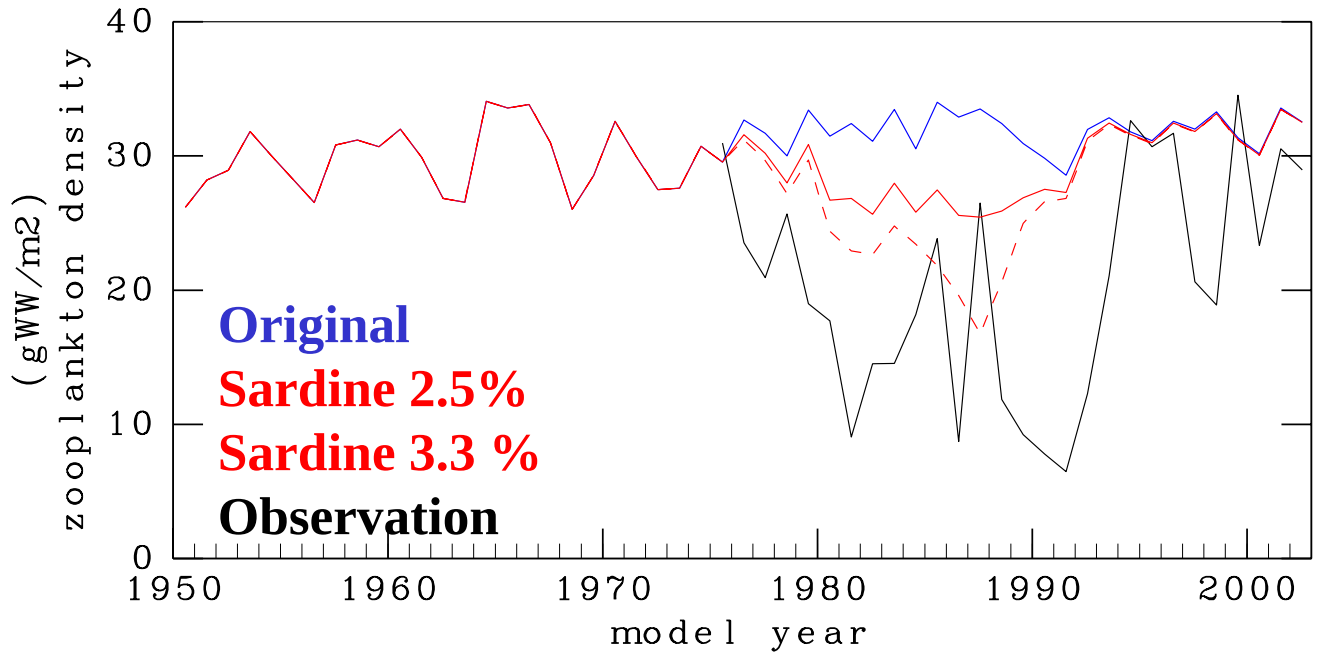
Ito et al. (in press)

Discussion

possibility 2 : sardine effect

sardine feeding : 2-3% of body weight (Noguchi et al.)

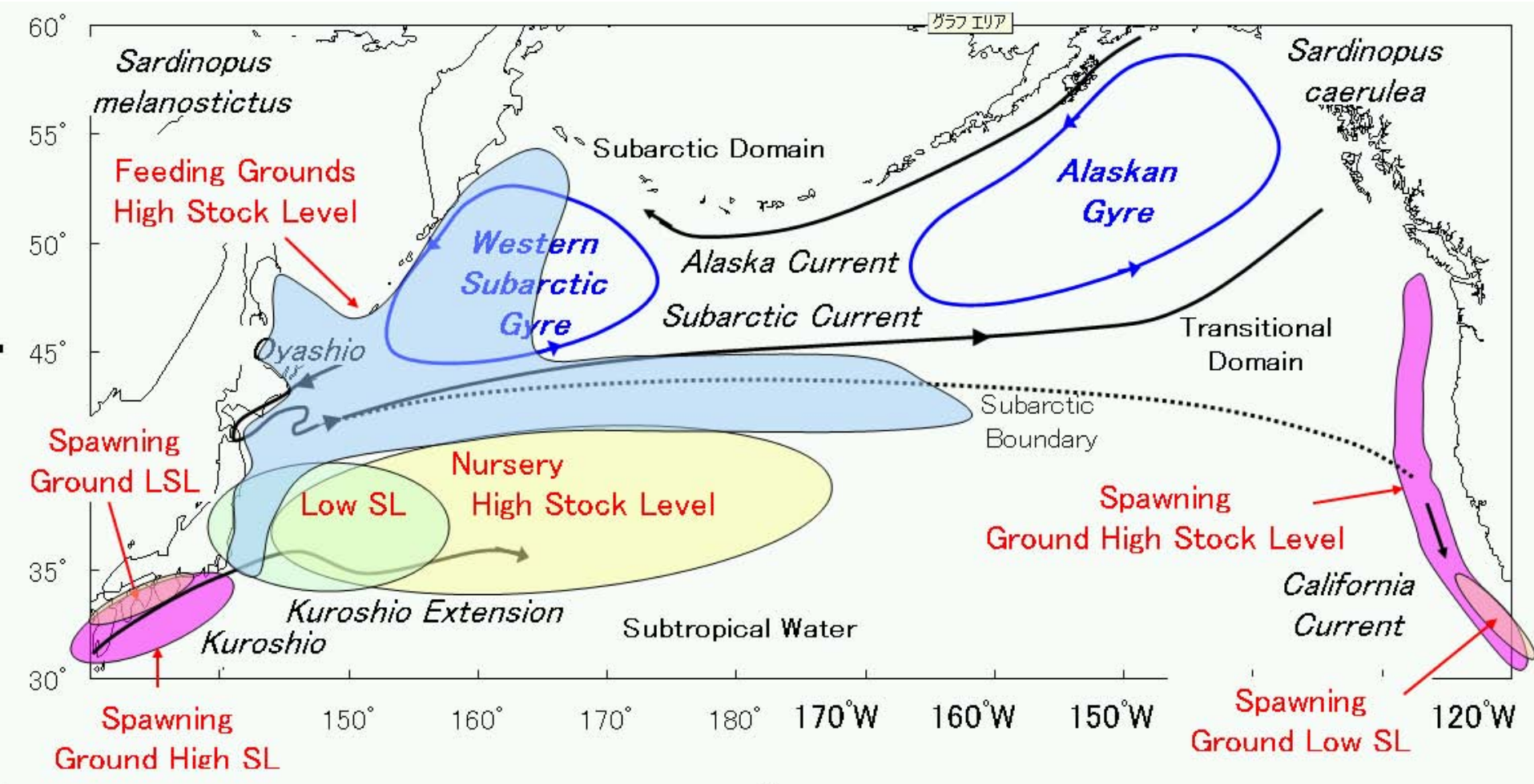
include sardine feeding pressure on ZL in NEMRUO



Ito et al. (in press)

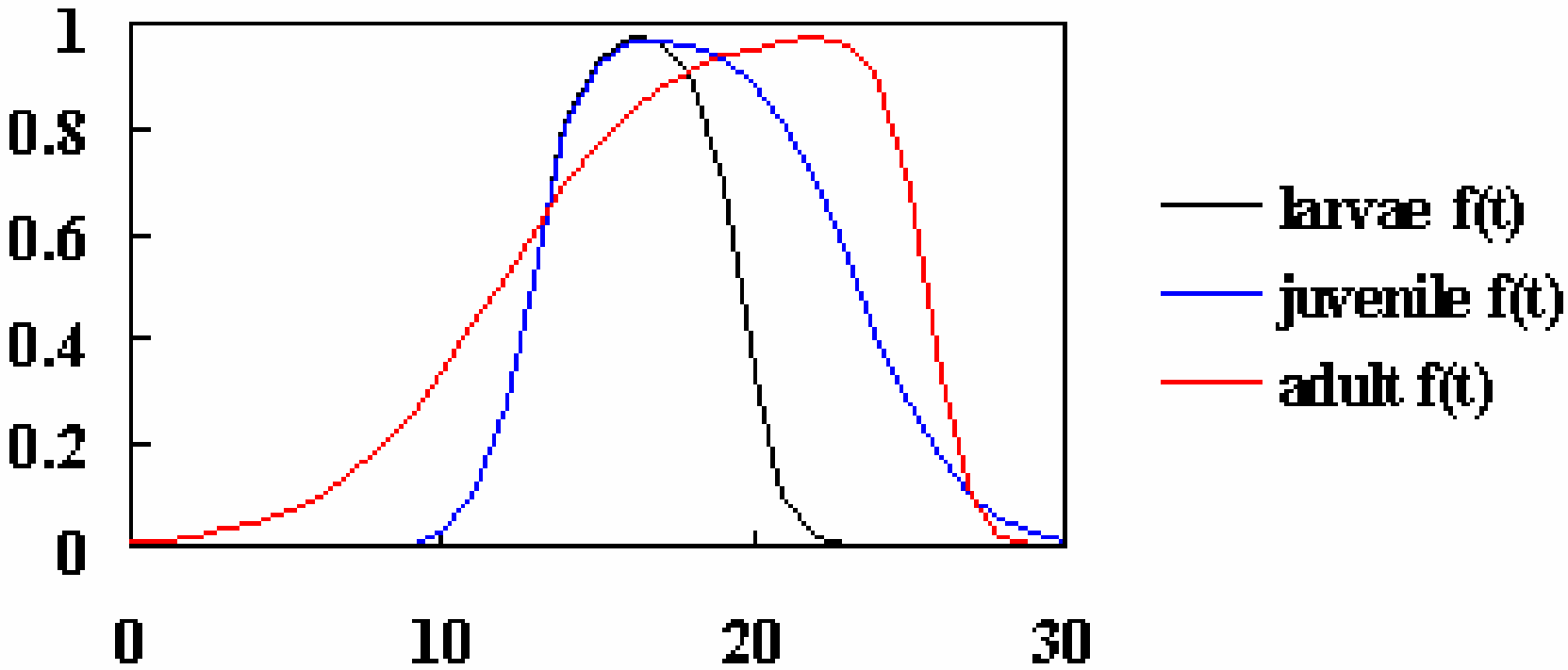
Model reproduced decreasing of ZL in 1980's
competition with sardine is important

NEMURO.FISH (sardine version)



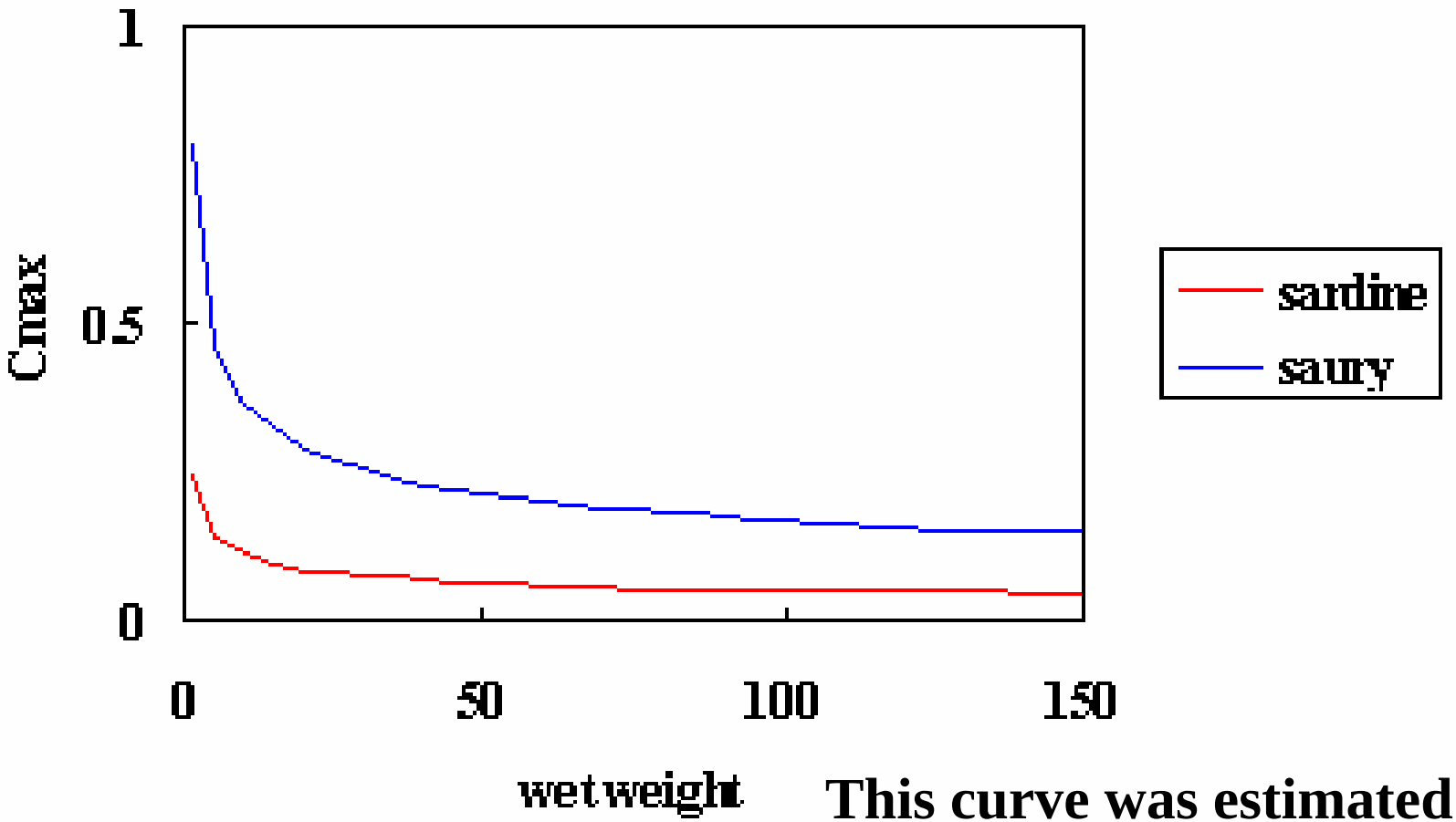
Courtesy of A. Yatsu

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



These curves were estimated from the results of Takasuka et al. (2005) and Takahashi et al. (2005)

Maximum consumption rate



This curve was estimated from the results of Noguchi et al. (1990)

2-box version

Table 2. Life stages of Pacific sardine in the sardine bioenergetics model

Stage	age(day)	period	region
Larva	1- 59	Feb.01-Mar.31	Kuroshio
juvenile & young	60-300	Apr.01-Dec.31	mixed
adult mature 1	300-420	Jan.01-Apr.30	Kuroshio
Adult	421-700	May.01-Dec.31	mixed
adult mature 2	-	Jan.01-Apr.30	Kuroshio
Adult	-	Mar.01-Dec.31	mixed
adult mature 3	-	Jan.01-Apr.30	Kuroshio
Adult	-	Mar.01-Dec.31	mixed
adult mature 4	-	Jan.01-Apr.30	Kuroshio
Adult	-	Mar.01-Dec.31	mixed
adult mature 5	-	Jan.01-Apr.30	Kuroshio
Adult	-	Mar.01-Dec.31	mixed
adult mature 6	-	Jan.01-Apr.30	Kuroshio
Adult	-	Mar.01-Dec.31	mixed
adult mature 7	-	Jan.01-Apr.30	Kuroshio
Adult	-	Mar.01-Dec.31	mixed
adult mature 8	-	Jan.01-Apr.30	Kuroshio

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

Symbol	Parameter description	Value
Consumption, C_{MAX}		
a_C	Intercept for C_{MAX} at (*te2*+*te3*)/2	0.240, 0.240
b_C	coefficient for C_{MAX} versus weight	-0.342, -0.342
te1	Temperature for *xk1* (in ºC)	11[a] , 11[b], 6[c], 6[d]
te2	Temperature for *xk2* (in ºC)	16[a] , 16[b], 22[c], 22[d]
te3	Temperature for *xk3* (in ºC)	17[a] , 17[b], 23[c], 23[d]
te4	Temperature for *xk4* (in ºC)	21[a] , 27[b], 27[c], 27[d]
xk1	Proportion of C_{MAX} at *te1*	0.1
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*	0.1
Metabolism, R		
a_R	Intercept for *R*	0.0033
b_R	Coefficient for *R* versus weight	-0.227
c_R	Coefficient for *R* versus temperature	0.020
d_R	Coefficient for *R* versus swimming speed	0.026
S	Coefficient for Specific Dynamic Action	0.150*, 0.175[#]

* values for stage 1 saury, [#] values for stage 2 and higher saury

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

Symbol	Parameter description	Value
Swimming Speed, U		
a_A	Intercept *U* (< 6 ºC) (in cm/s)	2.0
a_A	Intercept *U* (≥ 6 ºC) (in cm/s)	9.52, 8.69
b_A	Coefficient *U* versus weight	0.33, 0.33
c_A	Coefficient *U* versus temperature (< 6 ºC)	0.149
c_A	Coefficient *U* versus temperature (≥ 6 ºC)	0.0
Egestion and Excretion, F and E		
a_F	Proportion of consumed food egested	0.16
a_E	Proportion of consumed food excreted	0.10

* values for stage 1 saury, # values for stage 2 and higher saury

Table 4. Vulnerability coefficients v_{ij} for the sardine bioenergetics model.

Vulnerability coefficients for each zooplankton compartment

Stage	Region	PL	ZS	ZL	ZP
1	Kuroshio	0.0	1.0	0.0	0.0
2	mixed water	1.0	1.0	0.0	0.0
3	Kuroshio	1.0	1.0	0.0	0.0
4	mixed water	1.0	1.0	0.0	0.0

Table 5. Half-saturation constants K_{ij} for the sardine bioenergetics model. Values were adjusted to provide the best fit between model-predicted growth and observed growth.

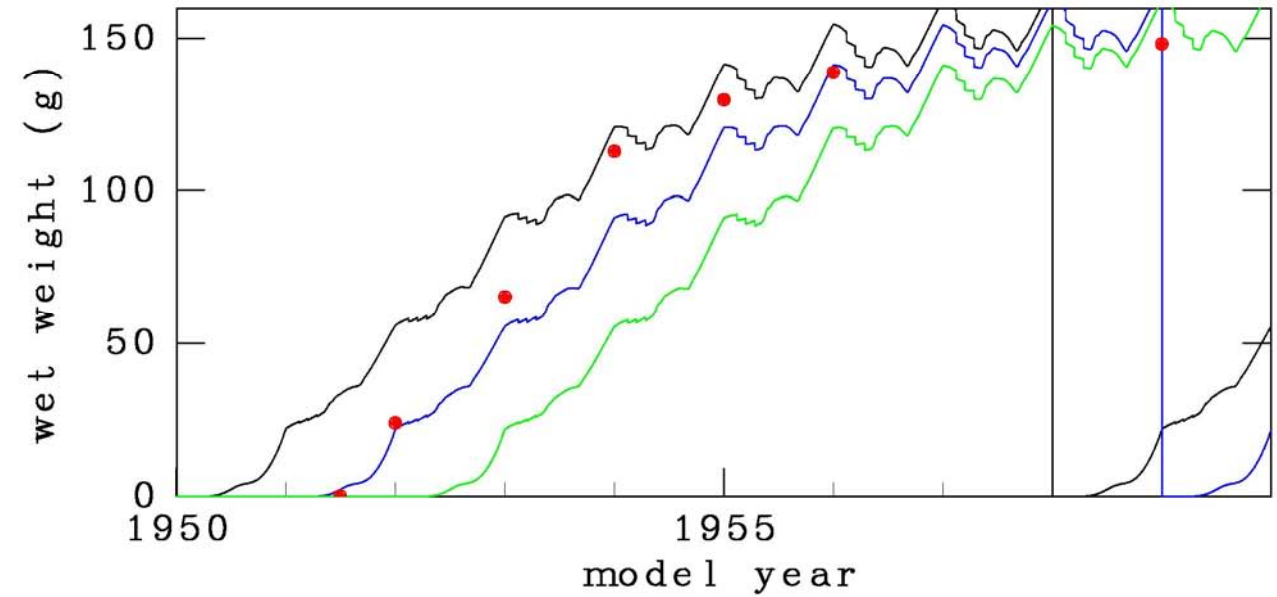
Half-saturation constants for each zooplankton compartment

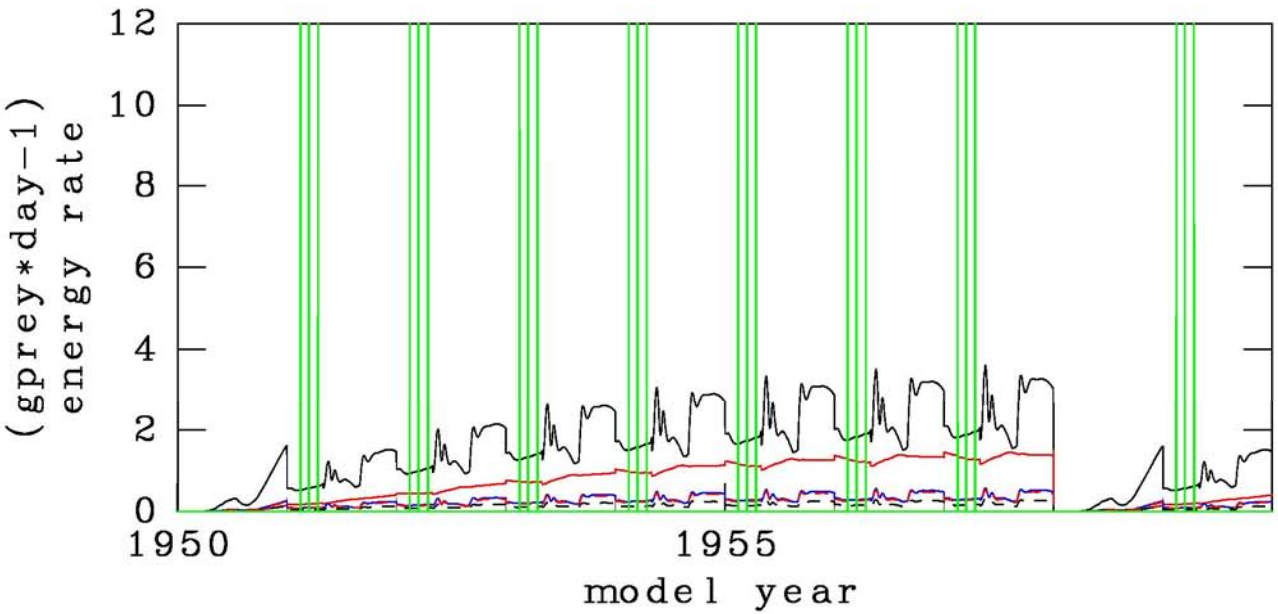
Stage	Region	PL	ZS	ZL	ZP
1	Kuroshio	-	0.30	-	-
			0.05		
2	mixed water	0.30	0.30	-	-
		0.05	0.05		
3	Kuroshio	0.45	0.45	-	-
		0.60	0.60		
4	mixed water	0.45	0.45	-	-
		0.60	0.60		

Table 1. Bottom boundary conditions for temperature and nutrients in NEMURO

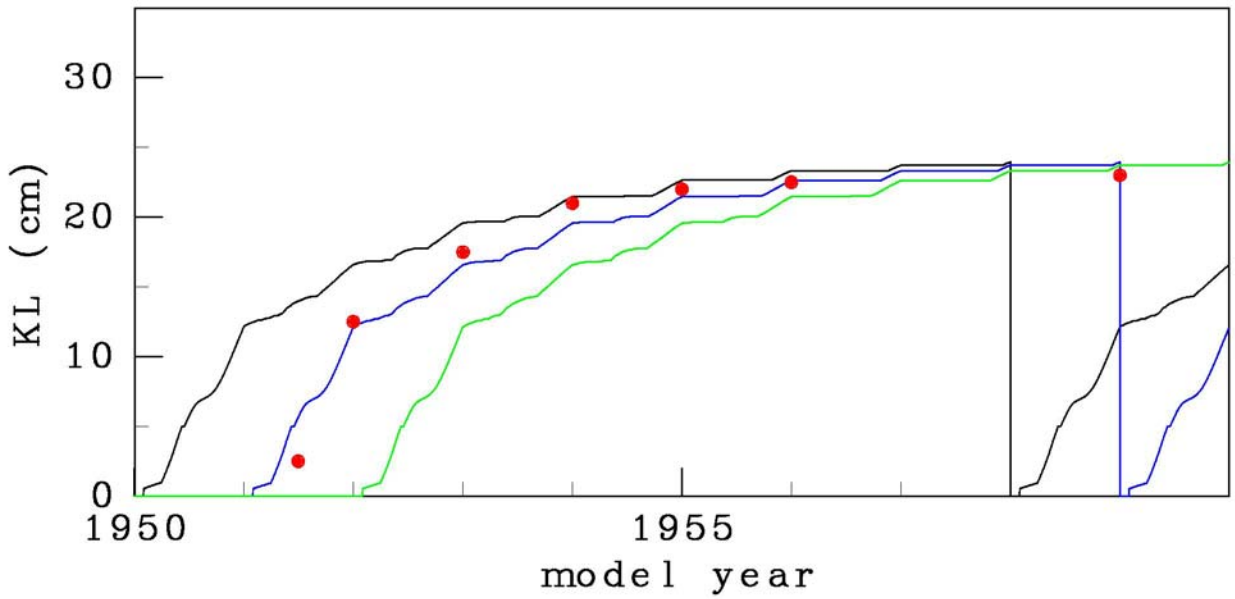
boundary condition	Kuroshio	mixed water	Oyashio
water temperature (ºC)	19.10	14.70	4.58
nitrate (molN/l)	6.0×10^{-6}	18.0×10^{-6}	25.0×10^{-6}
silicate (molSi/l)	6.0×10^{-6}	25.0×10^{-6}	30.0×10^{-6}

result from NEMURO.FISH



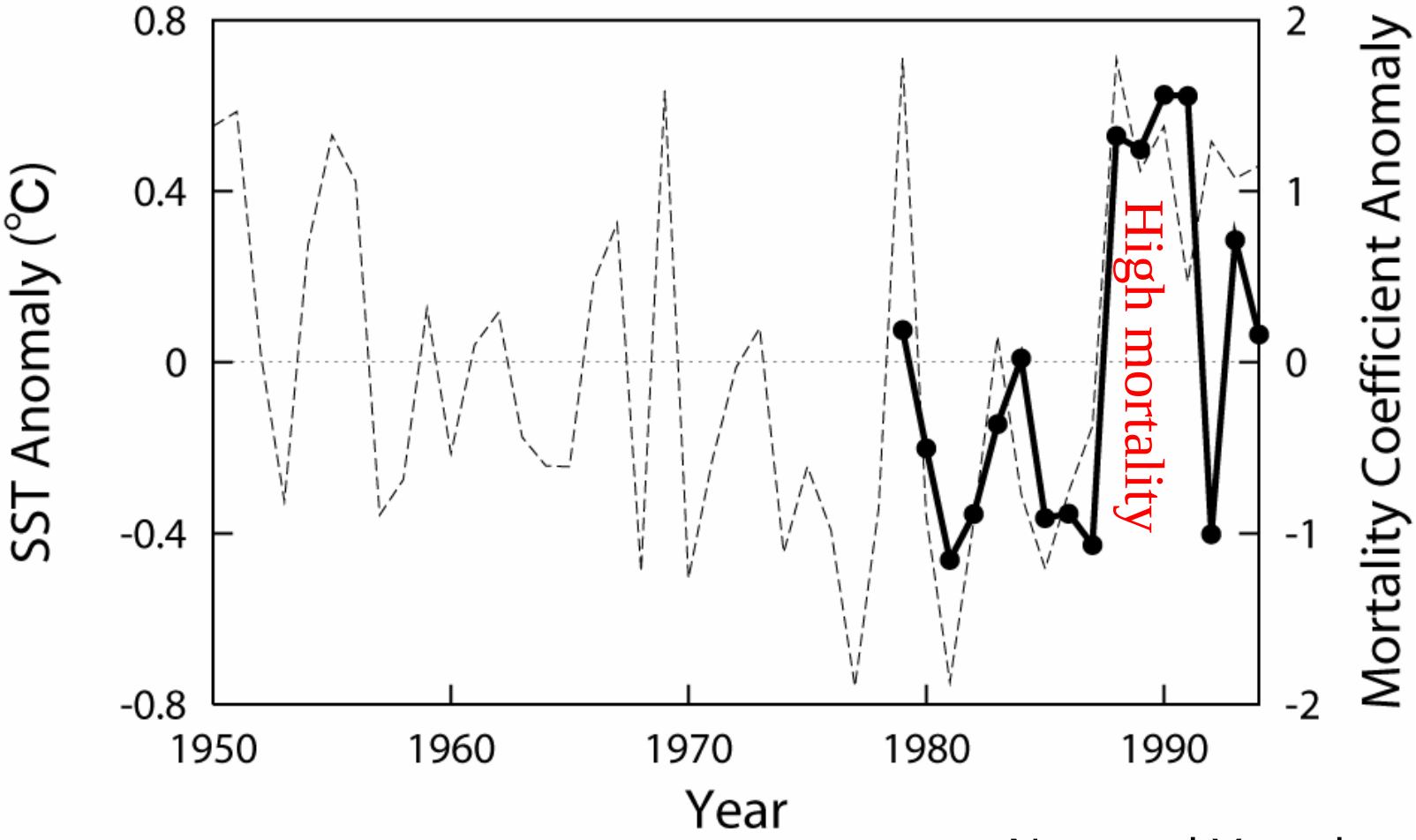


result from NEMURO.FISH



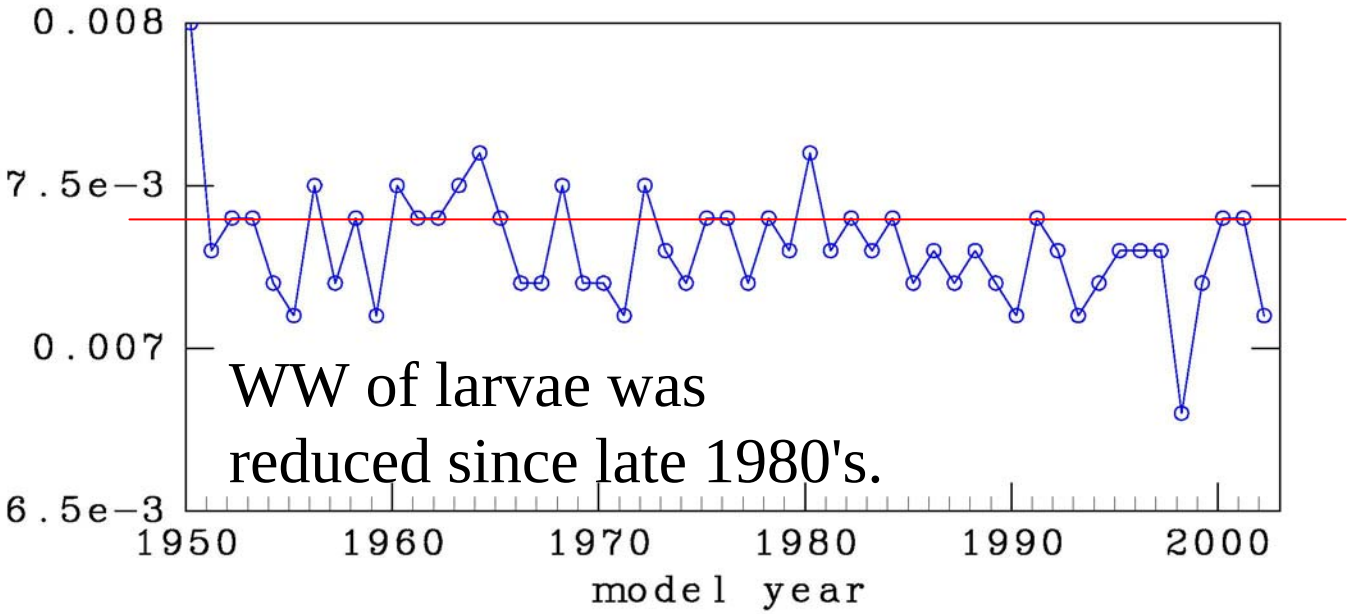
This model is two box version and coupled with LTL model.

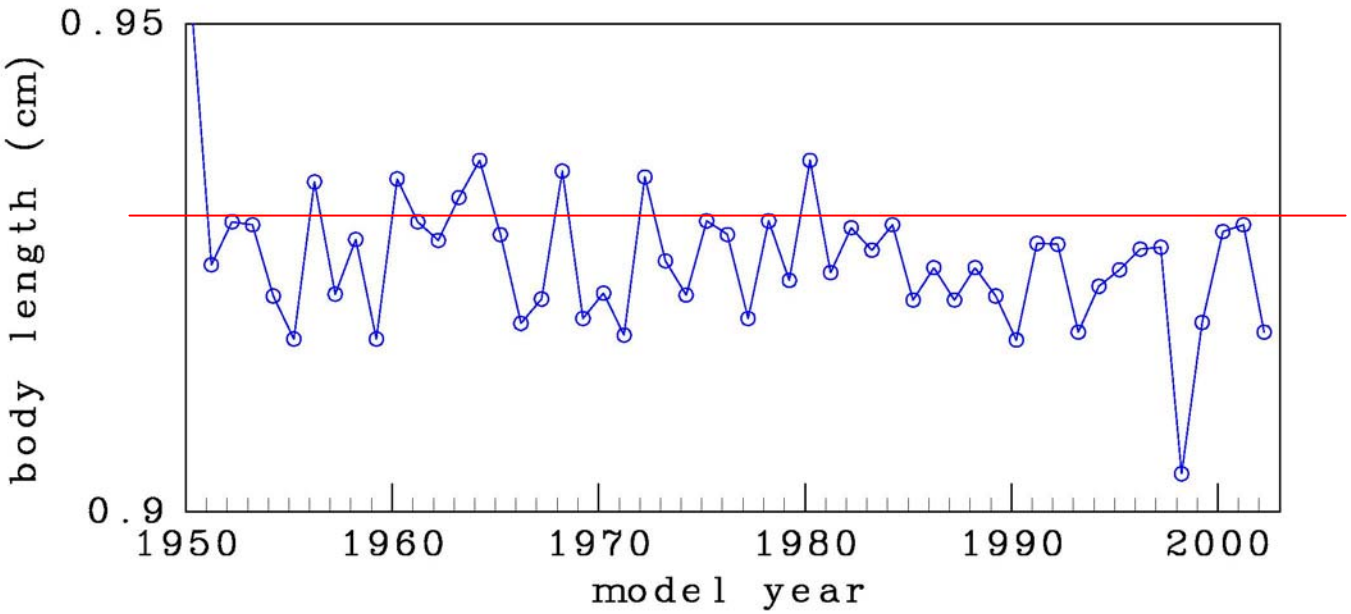
February-SST anomaly (℃) averaged in the KESA (broken) and natural mortality coefficient anomaly during the period from post larva to age-1(solid).



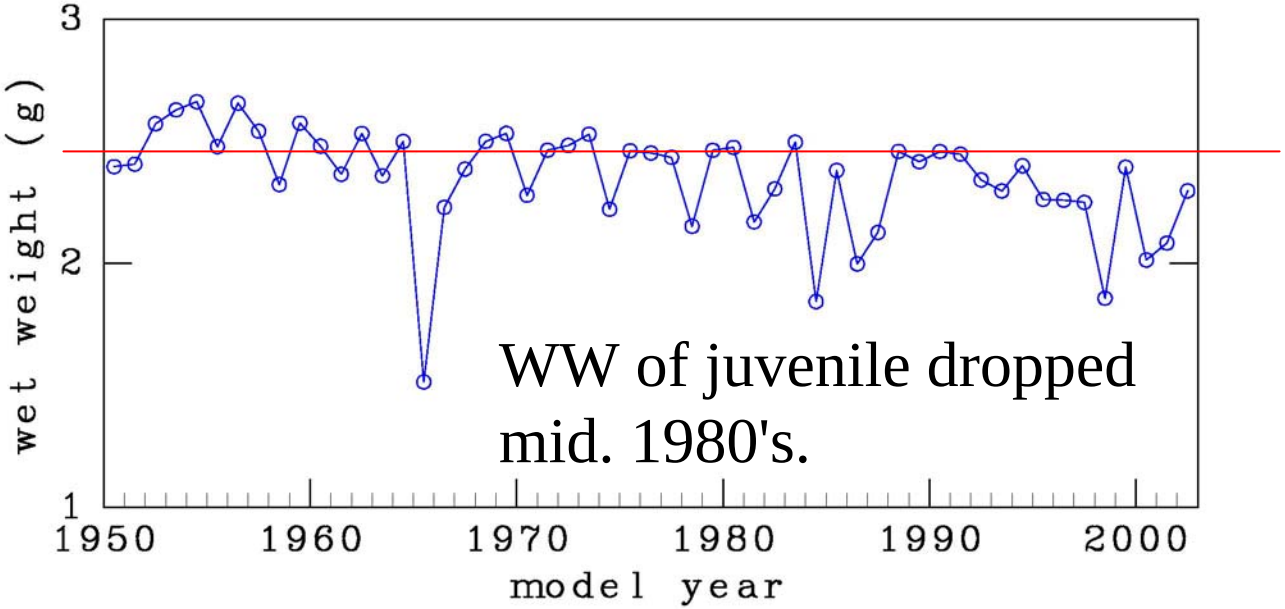
Noto and Yasuda (CJFAS, 1999)

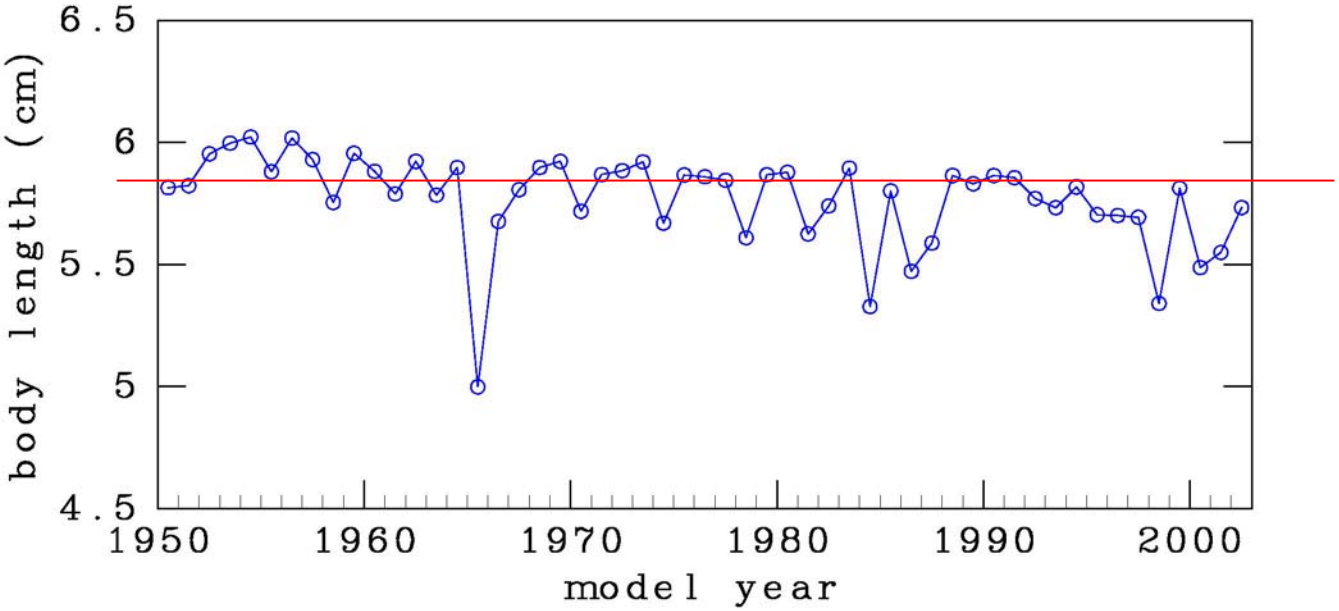
Mar. 30 (about 60 days after spawned: just before moving to MWR)



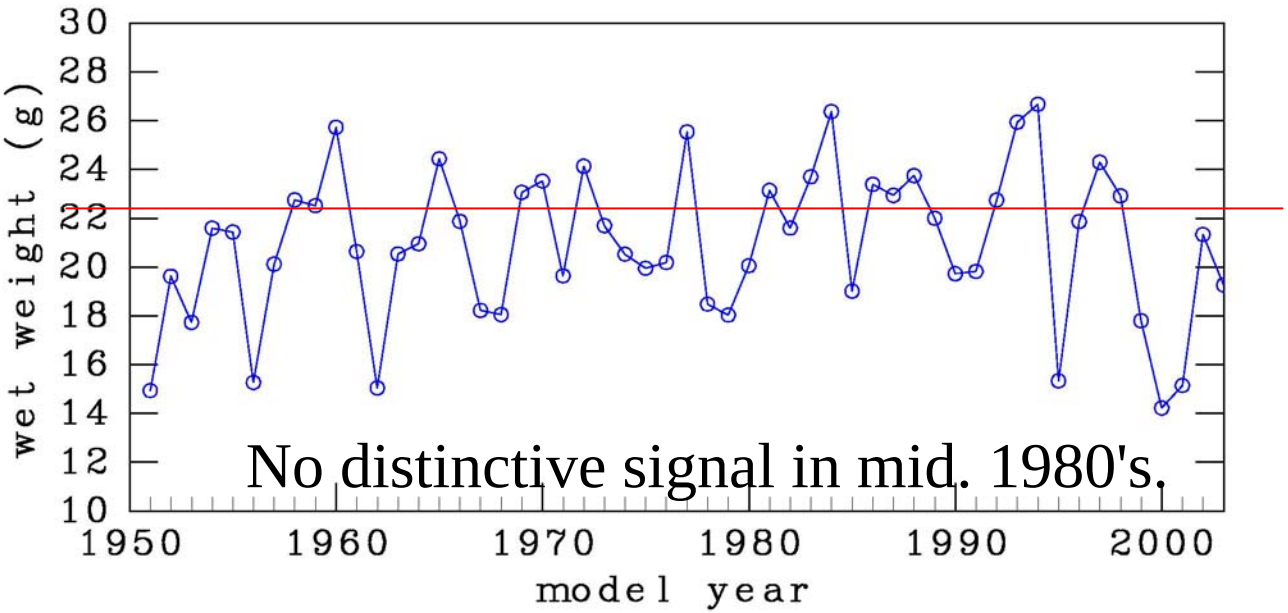


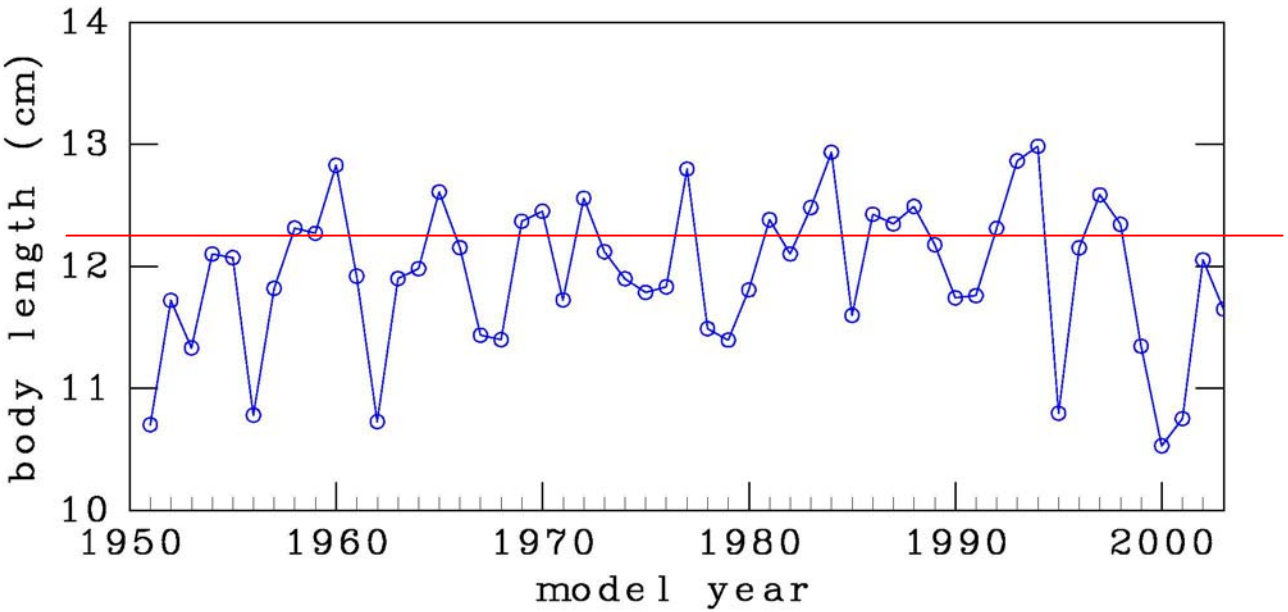
Jul. 5 (about 155 days after spawned: end of high prey density season)





Dec. 30 (about 300 days after spawned: just before spawning)





A sardine growth model coupled with the NEMURO lower trophic level ecosystem model

1. sardine version NEMURO.FISH was coded.
2. appropriate growth of Japanese sardine was available.
3. need to improve the estimation of parameters.
   especially in early life stages
4. slow down of sardine growth was found in early life stages.
   mainly by temperature effect

Future Tasks

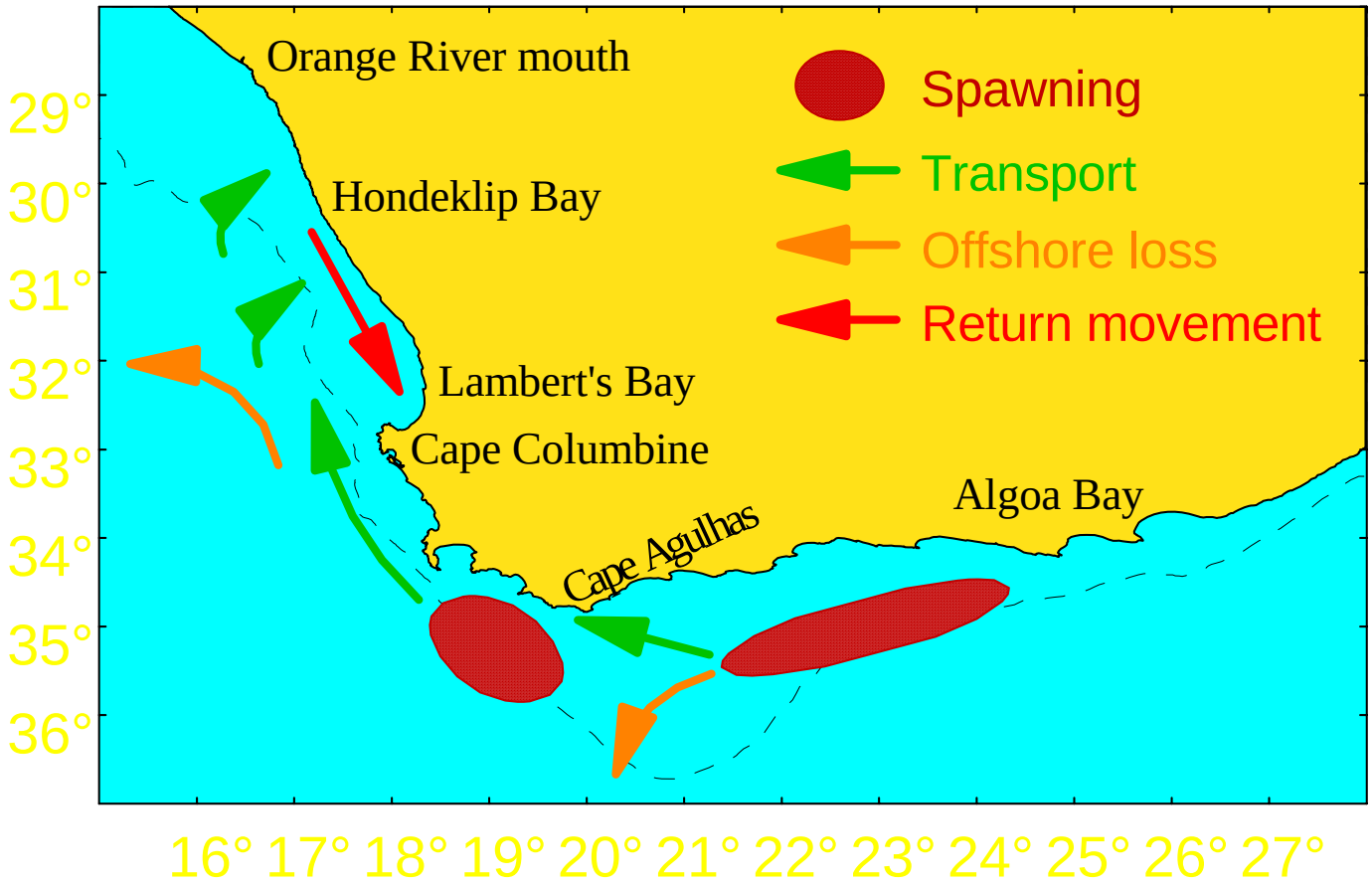
California Current System
Benguela Current System
Humboldt Current System
Kuroshio/Oyashio Current System

Benguela Current System

Courtesy of C. V. Lingen

Life history cycle of SB anchovy and sardine:

Separate spawning and nursery areas, transport from south coast spawning area to west coast nursery area is considered a critical determinant of recruitment success;

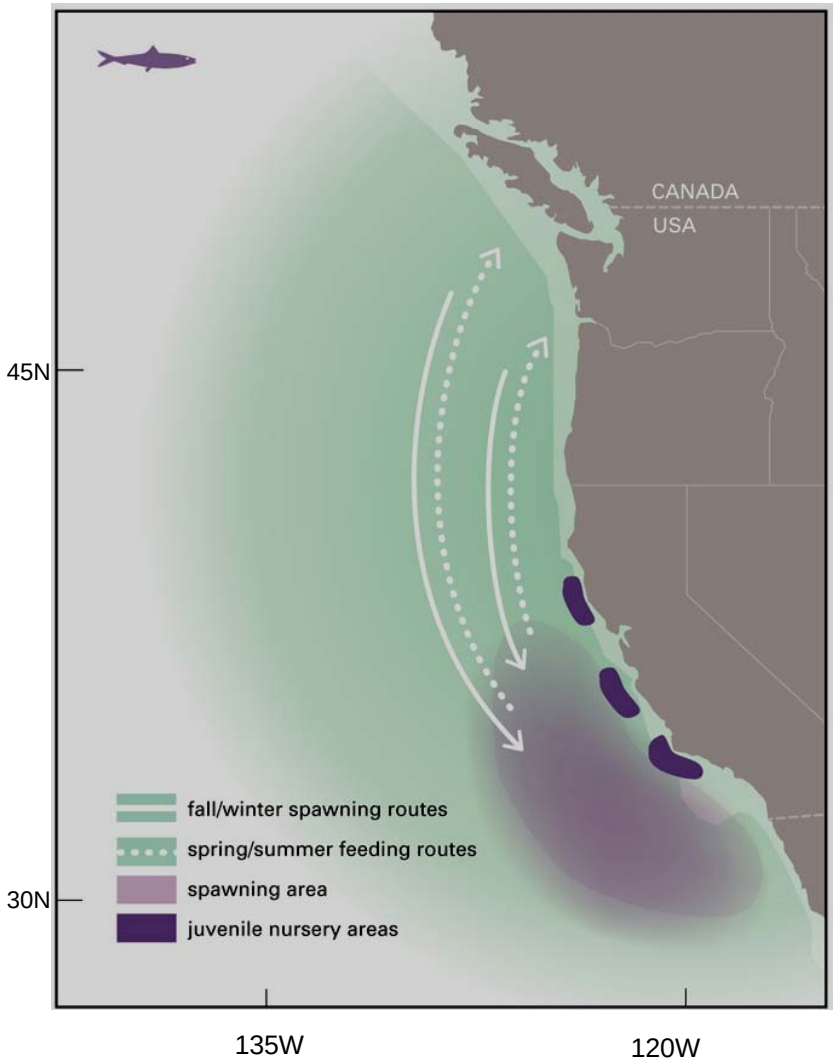


South coast may act as a sardine nursery area on occasion.

BOX2: 16E, 32S
BOX1: 18E, 35S

California Current System

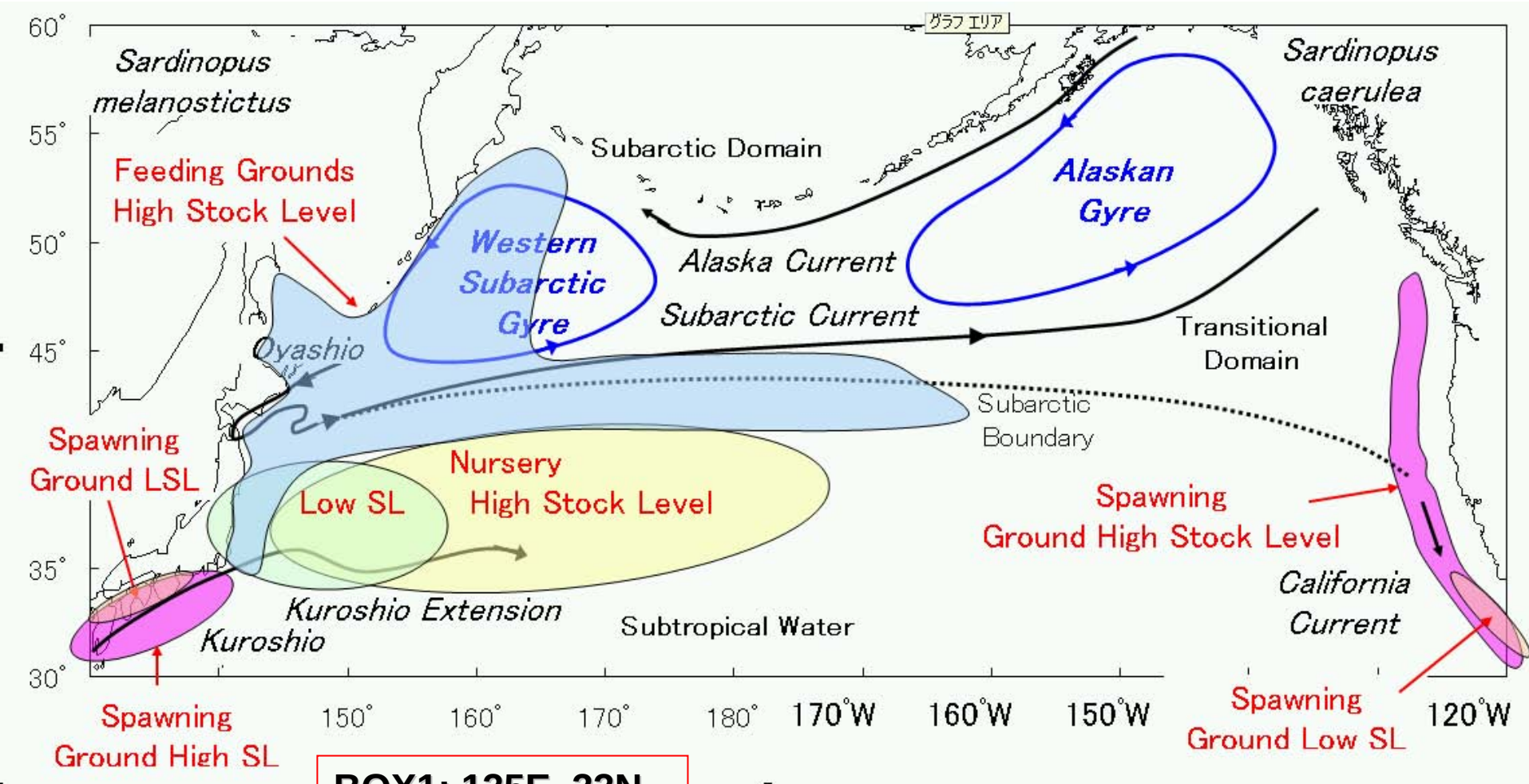
Courtesy of Jacobson & Agostini



BOX1: 122W, 33N
BOX2: 126W, 45S

Kuroshio/Oyashio Current System

Courtesy of Yatsu



BOX1: 135E, 33N
BOX2: 148E, 37N