Two-species of population dynamics model for Japanese sardine and chub mackerel using object oriented modelling

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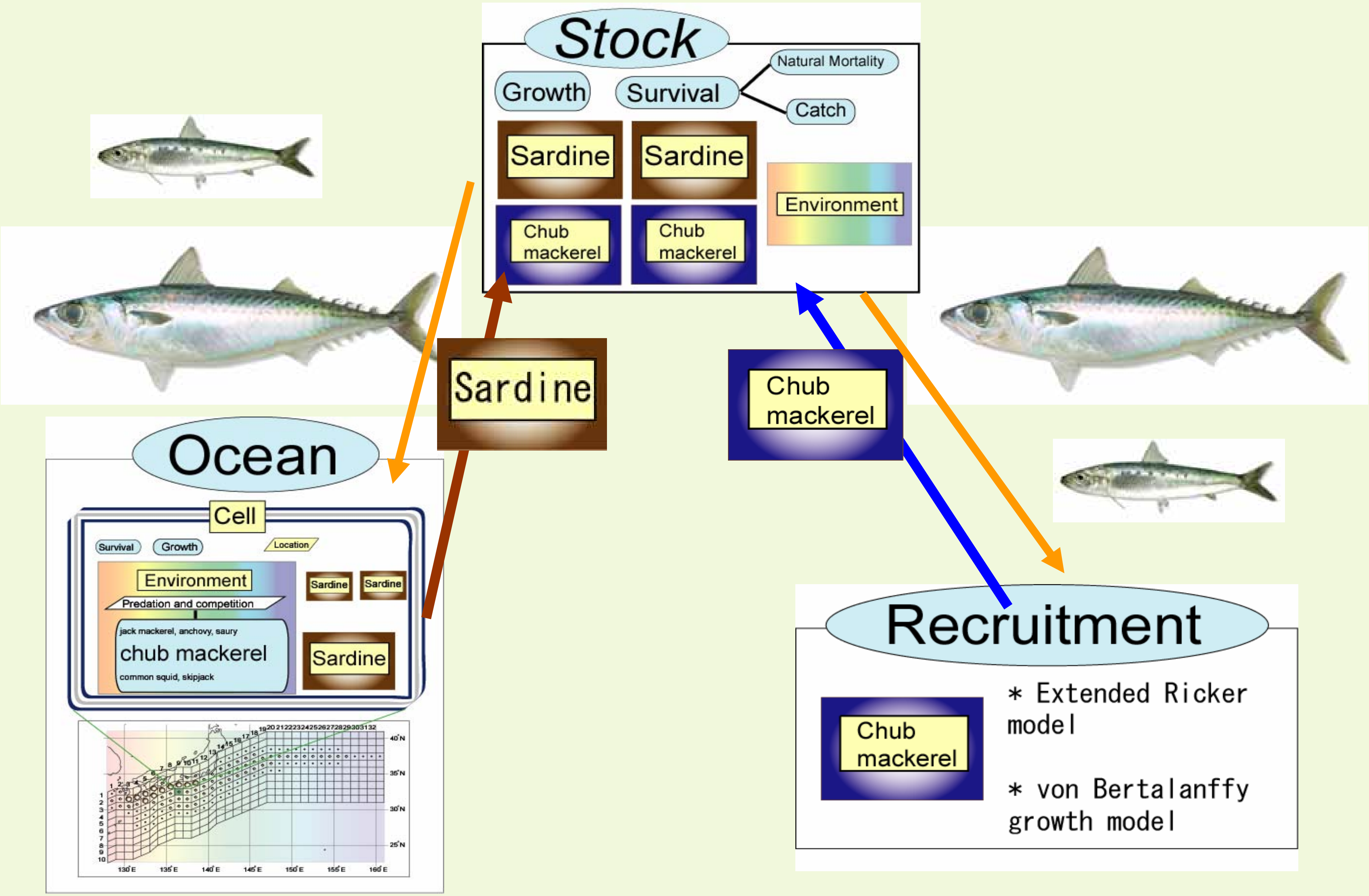
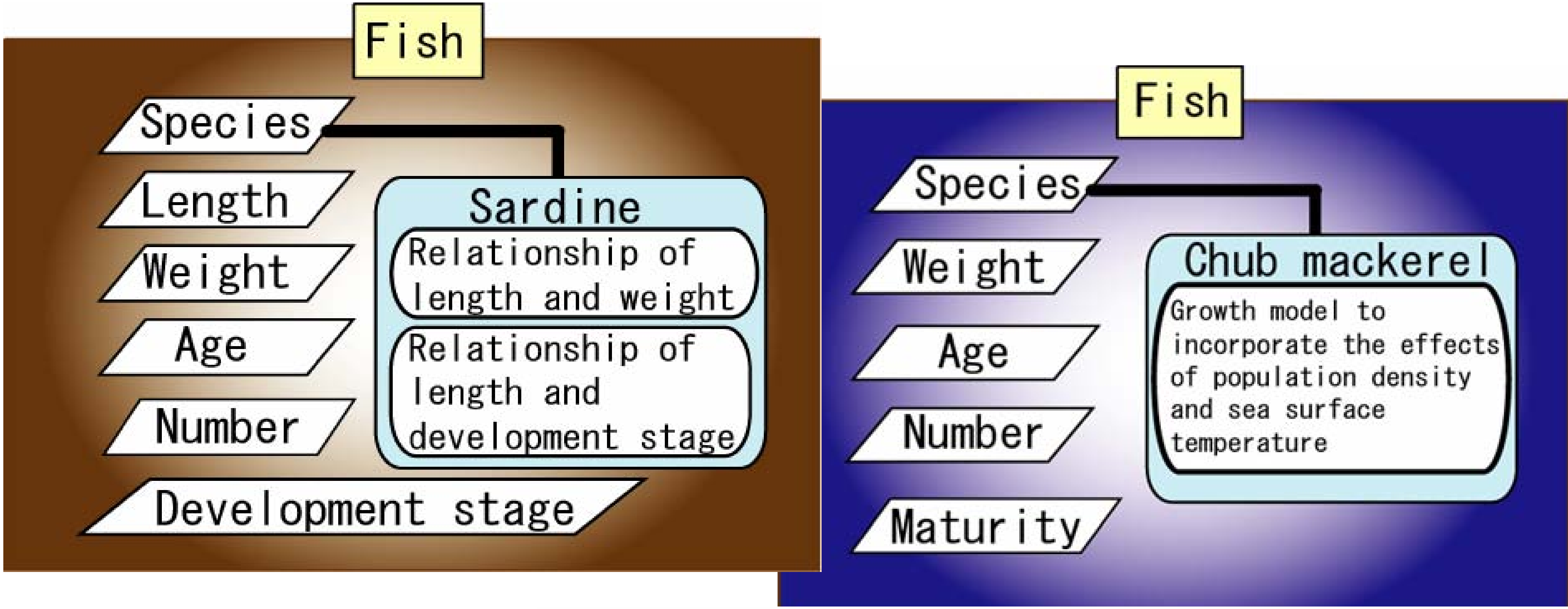
Concepts of model



FISH object



A group of fish

Contents

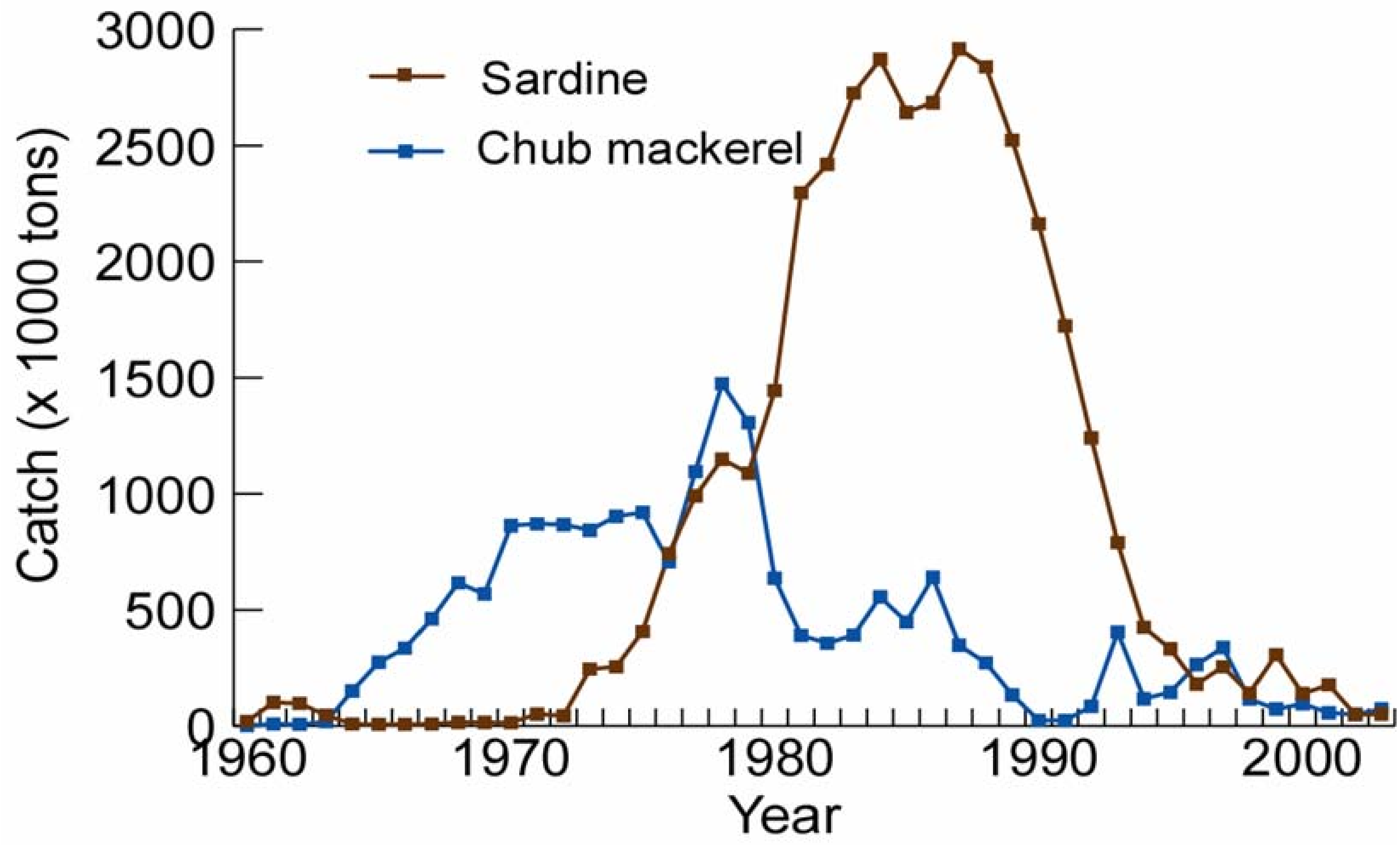
1 Stock fluctuation s of Japanese sardine and chub mackerel

2 Life cycle models for Japanese sardine and chub mackerel

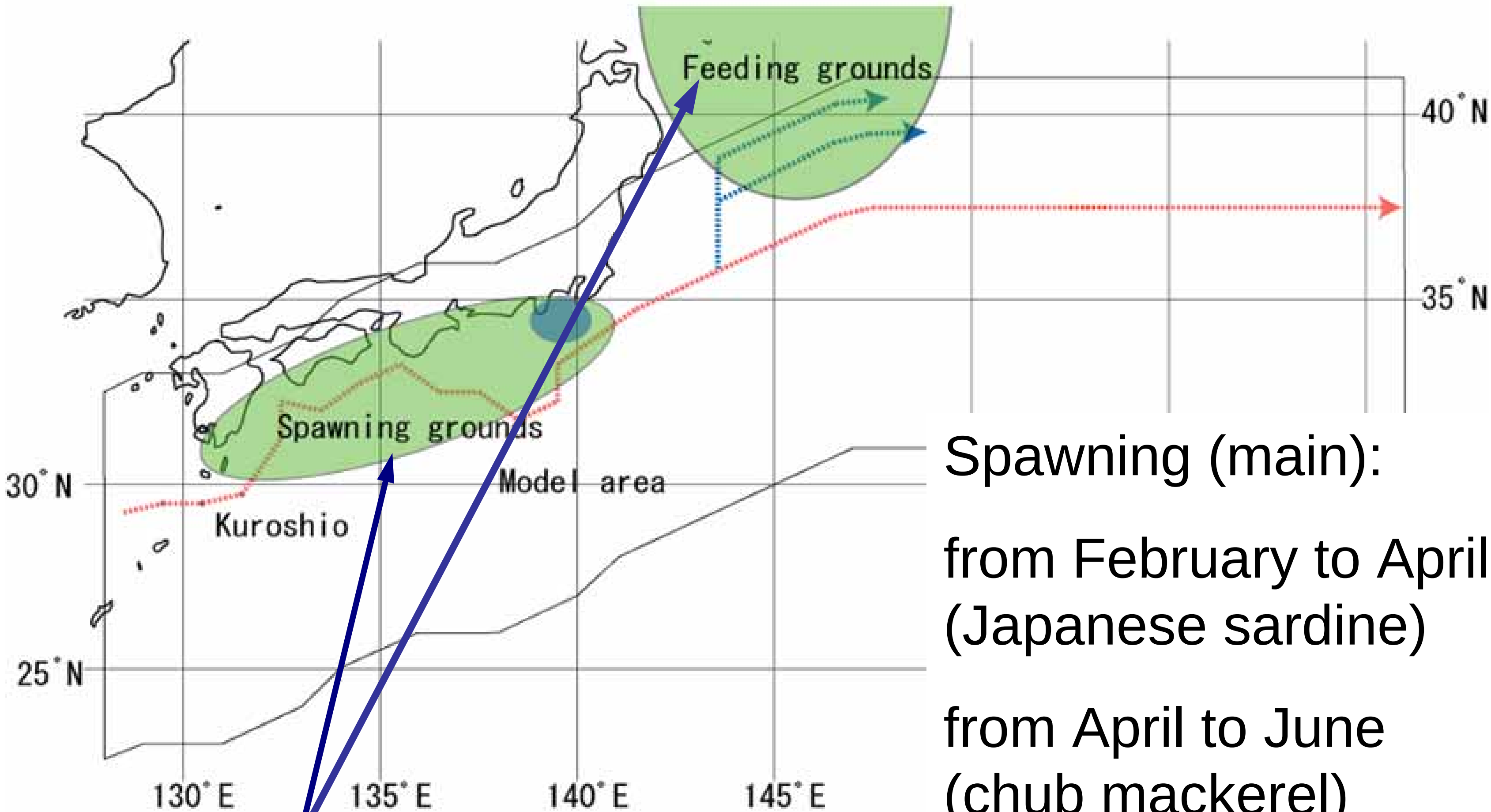
3 Example of the simulation

Time series of catches

for Japanese sardine and chub mackerel off the Pacific coast of Japan



Japanese sardine (*Sardinops melanostictus*) and chub mackerel (*Scomber japonicus*)



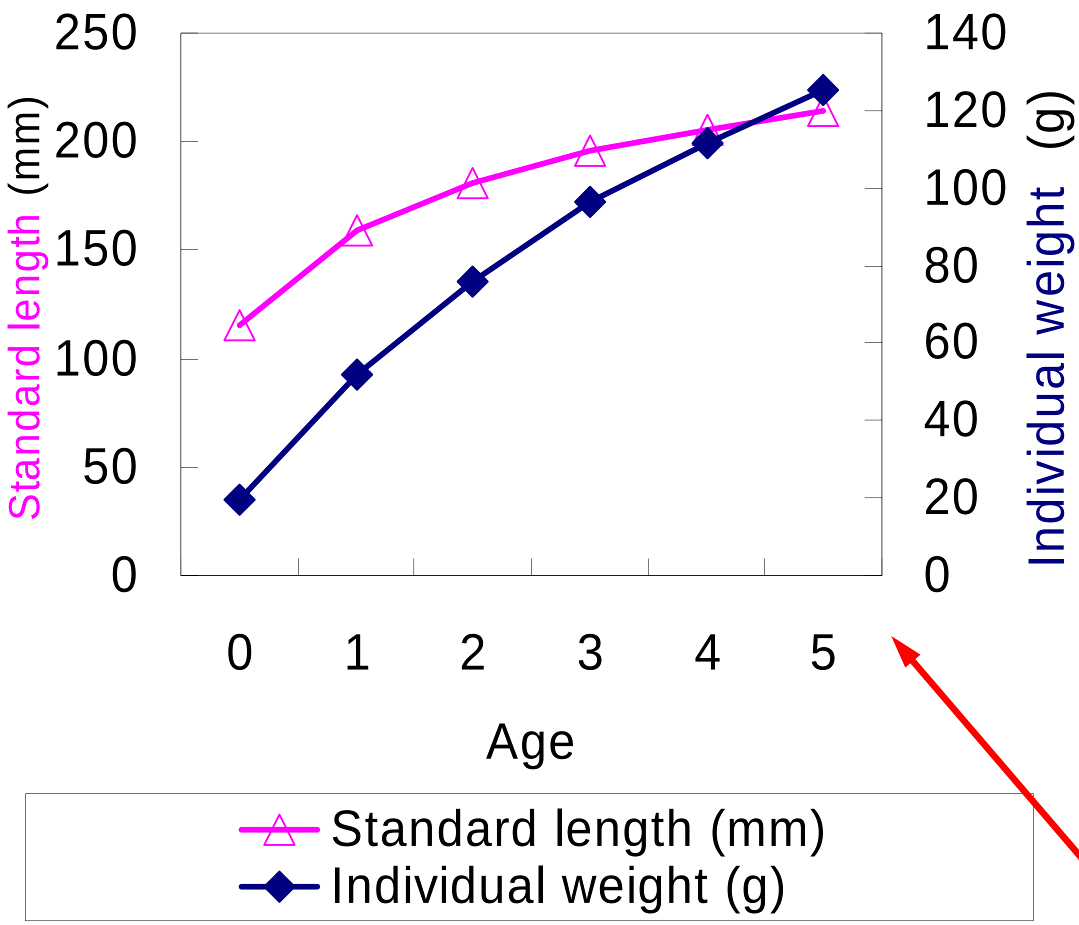
Spawning (main):

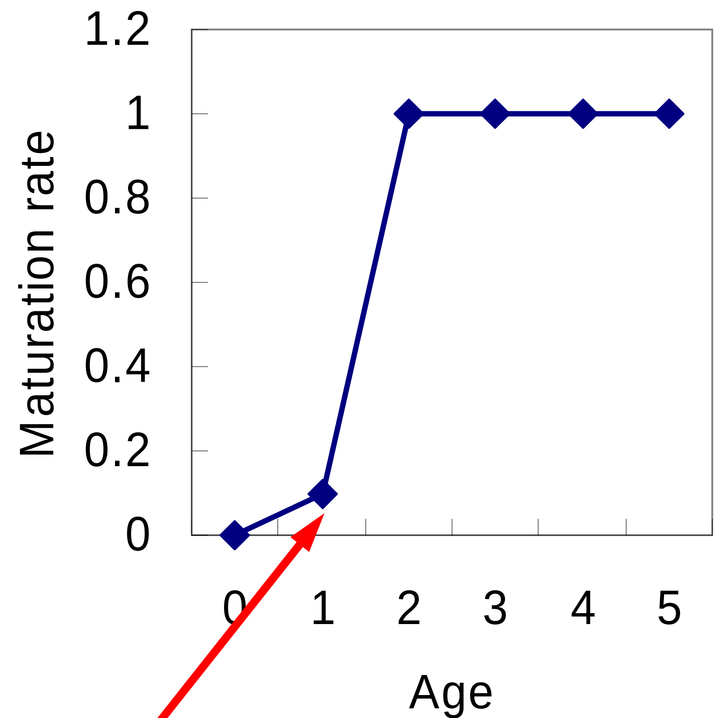
from February to April (Japanese sardine)

from April to June (chub mackerel)

vary according to the level of stock abundance (high and low)

Japanese sardine



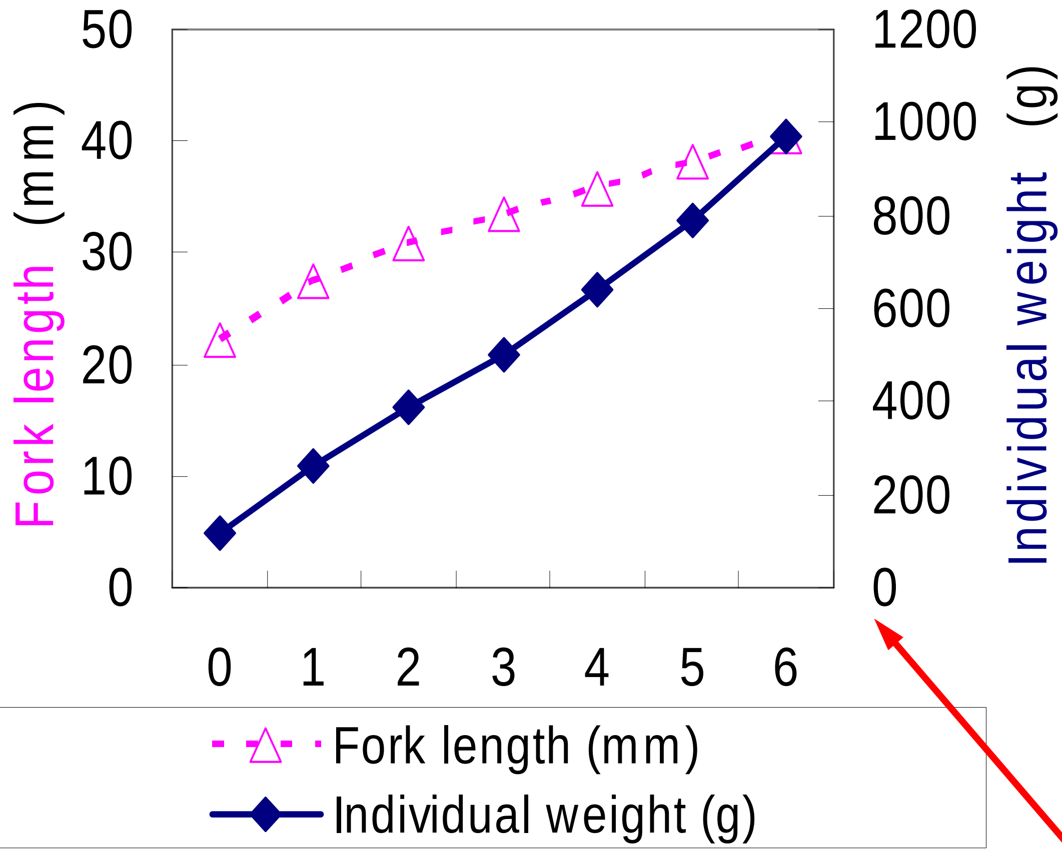


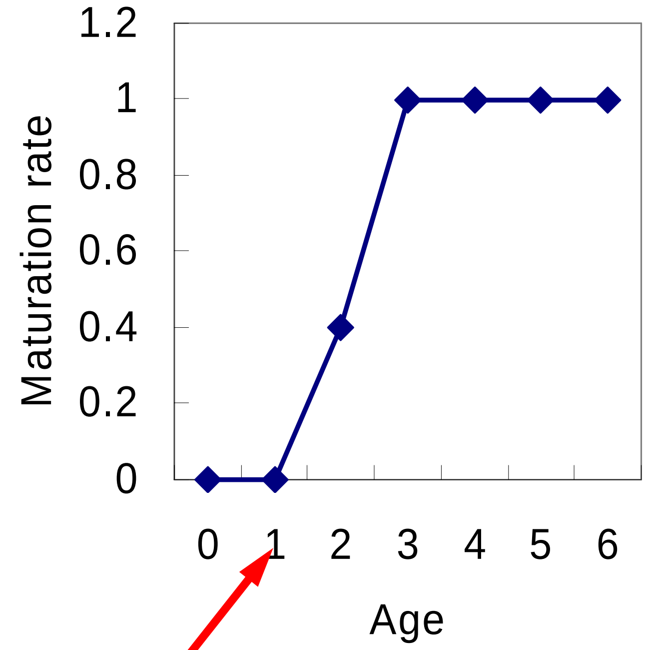
Maturation rate

Individual growth
(by the catch data)

vary according to the level of
stock abundance (high and low)

Chub mackerel





Maturation rate

Individual growth

vary according to the level of stock abundance (high and low)

Influence on the stock fluctuations

- Fishing mortality
- Environmental factors
  (Water temperature)
- Interspecific-relationship

Model planning

Extended model of

Japanese sardine population dynamics model

consisting

the spatial early- life stage model and

age structured adult sub model

and

Chub mackerel population dynamics model

consisting

extended Ricker spawner-recruit model

age structured model

Using object oriented modelling

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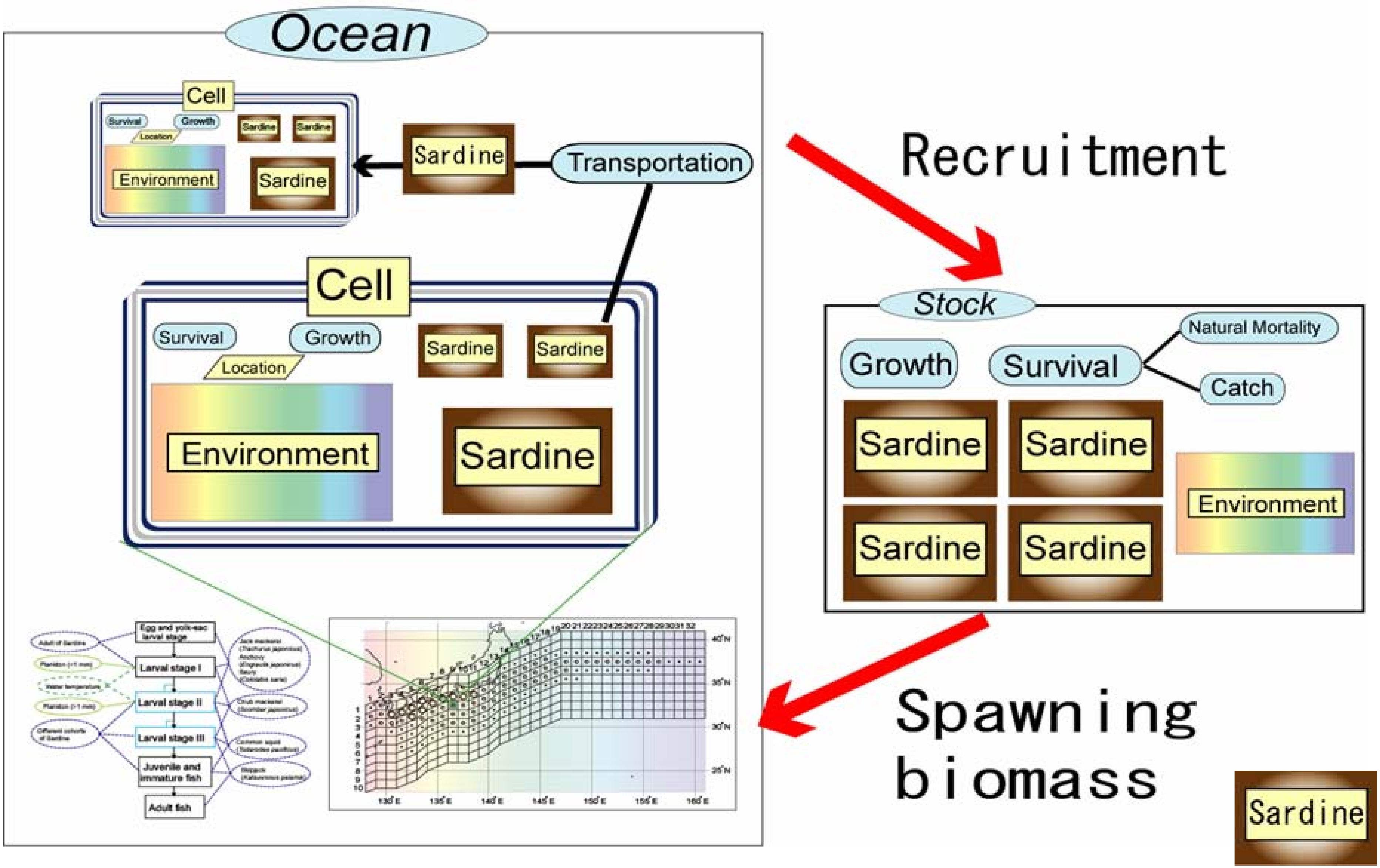
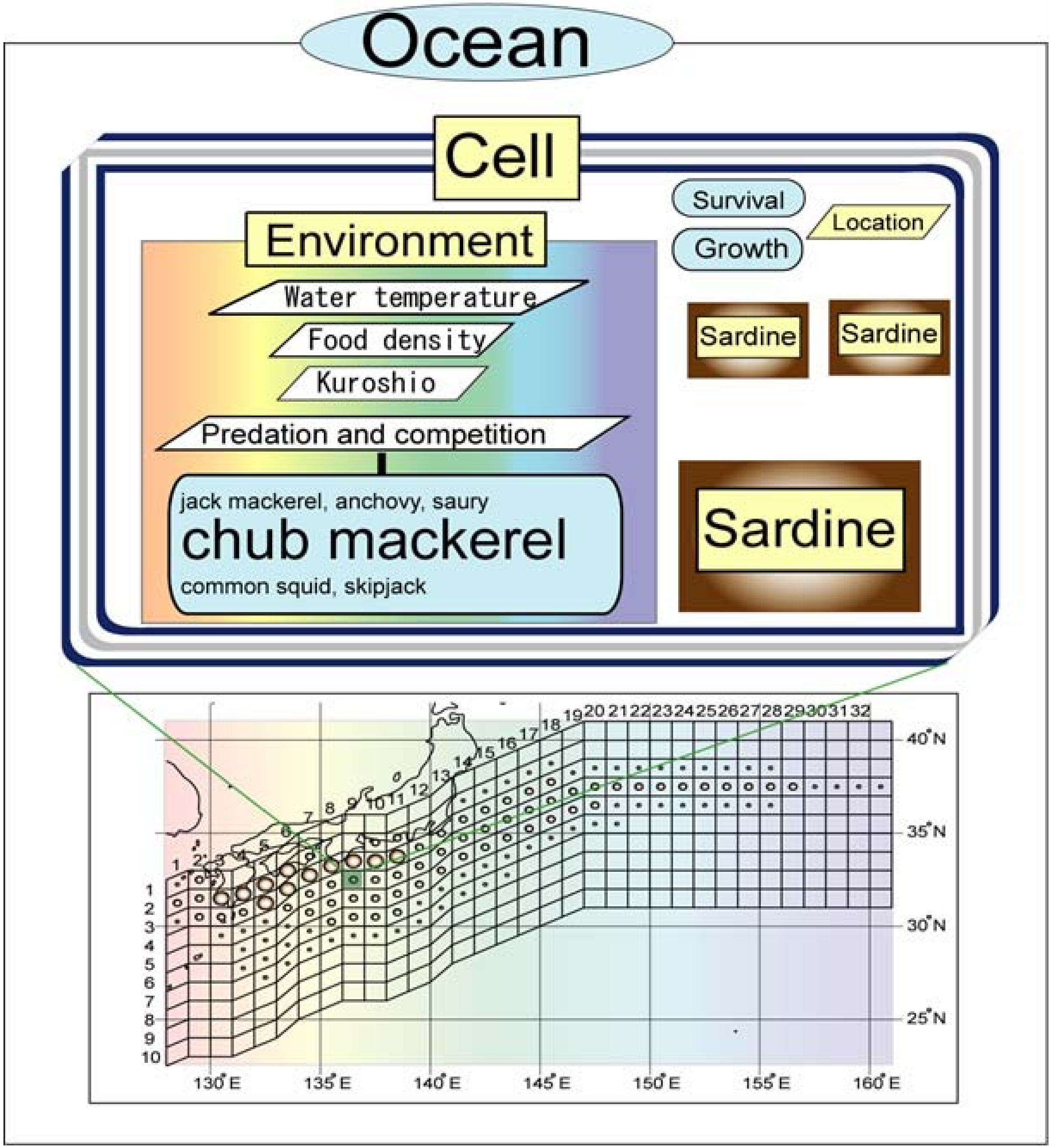
Concepts of model Sardine

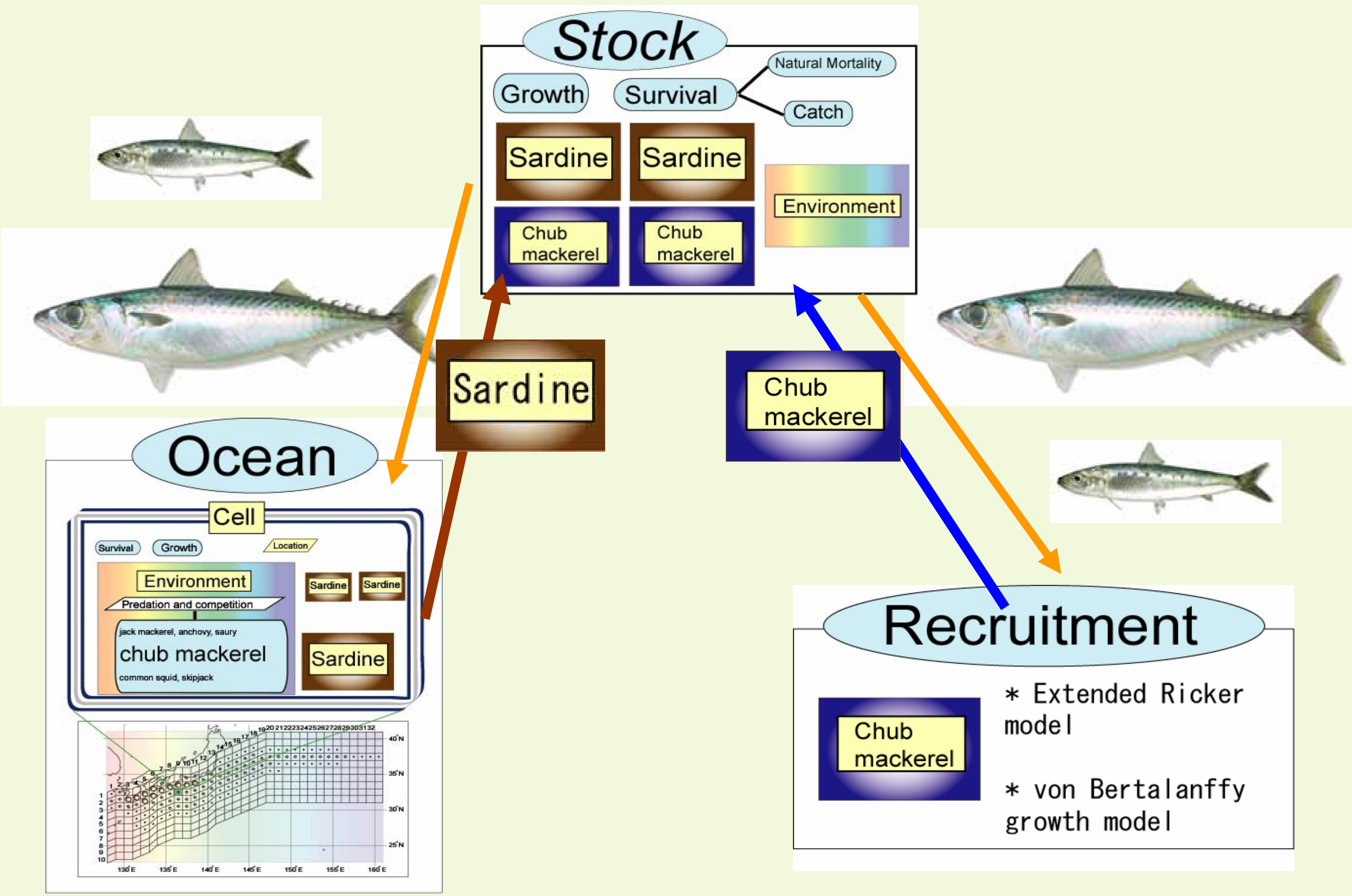




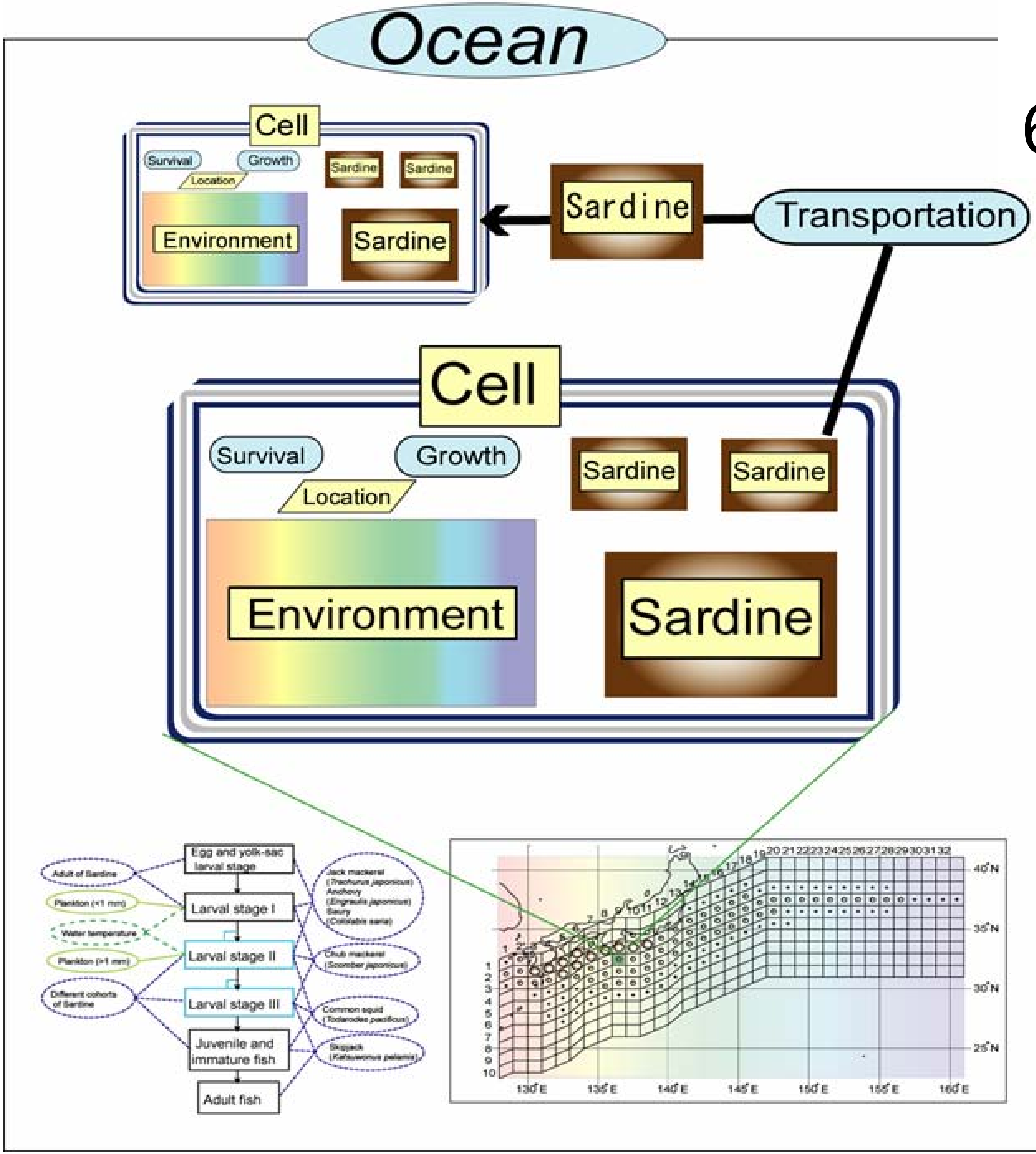
Ocean
Cell
Environment
Water temperature
Food density
Kuroshio
Predation and competition
jack mackerel, anchovy, saury
chub mackerel
common squid, skipjack
Survival
Growth
Location
Sardine
Sardine
Sardine
40°N
35°N
30°N
25°N
130°E
135°E
140°E
145°E
150°E
155°E
160°E

Sardine

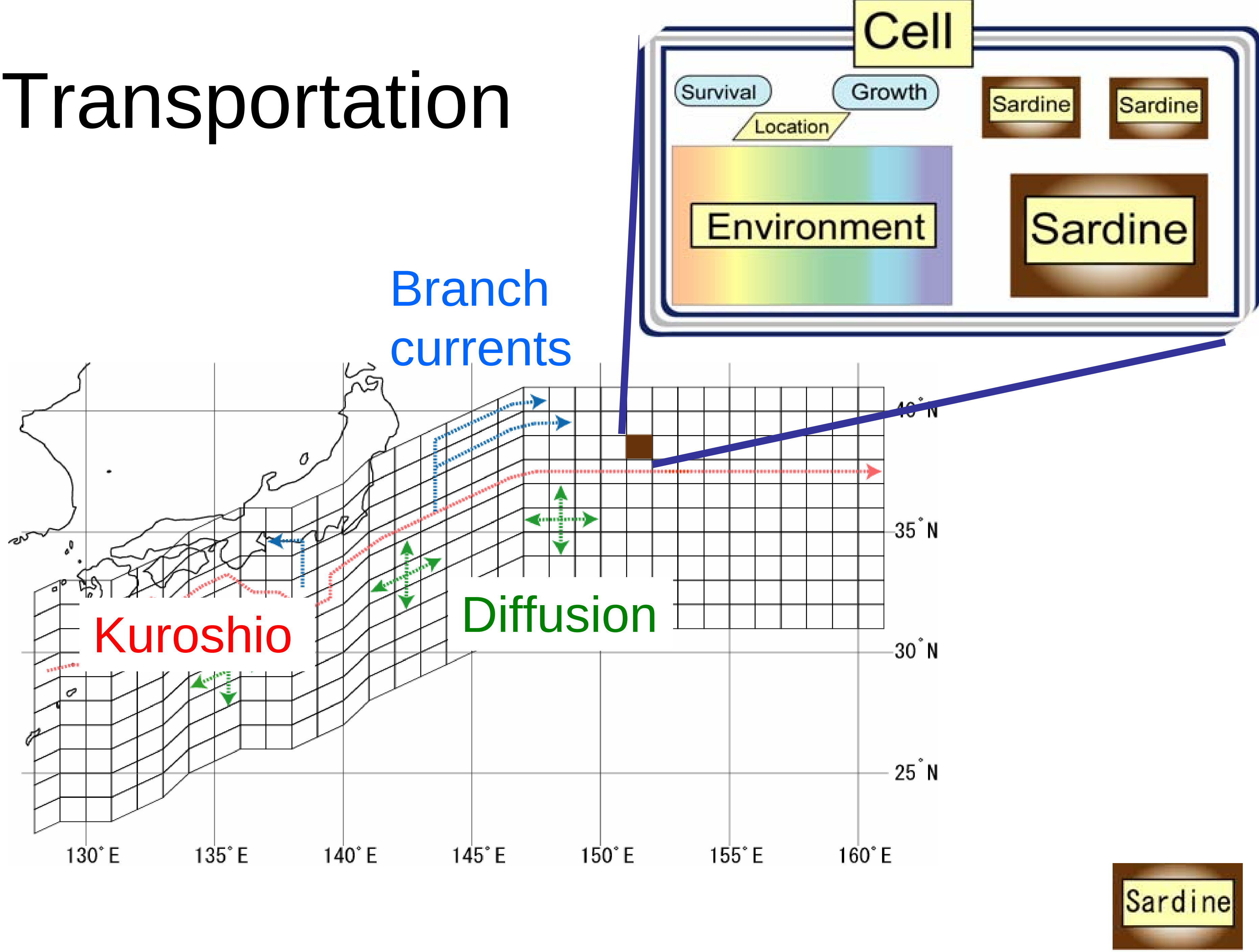
Concepts of model



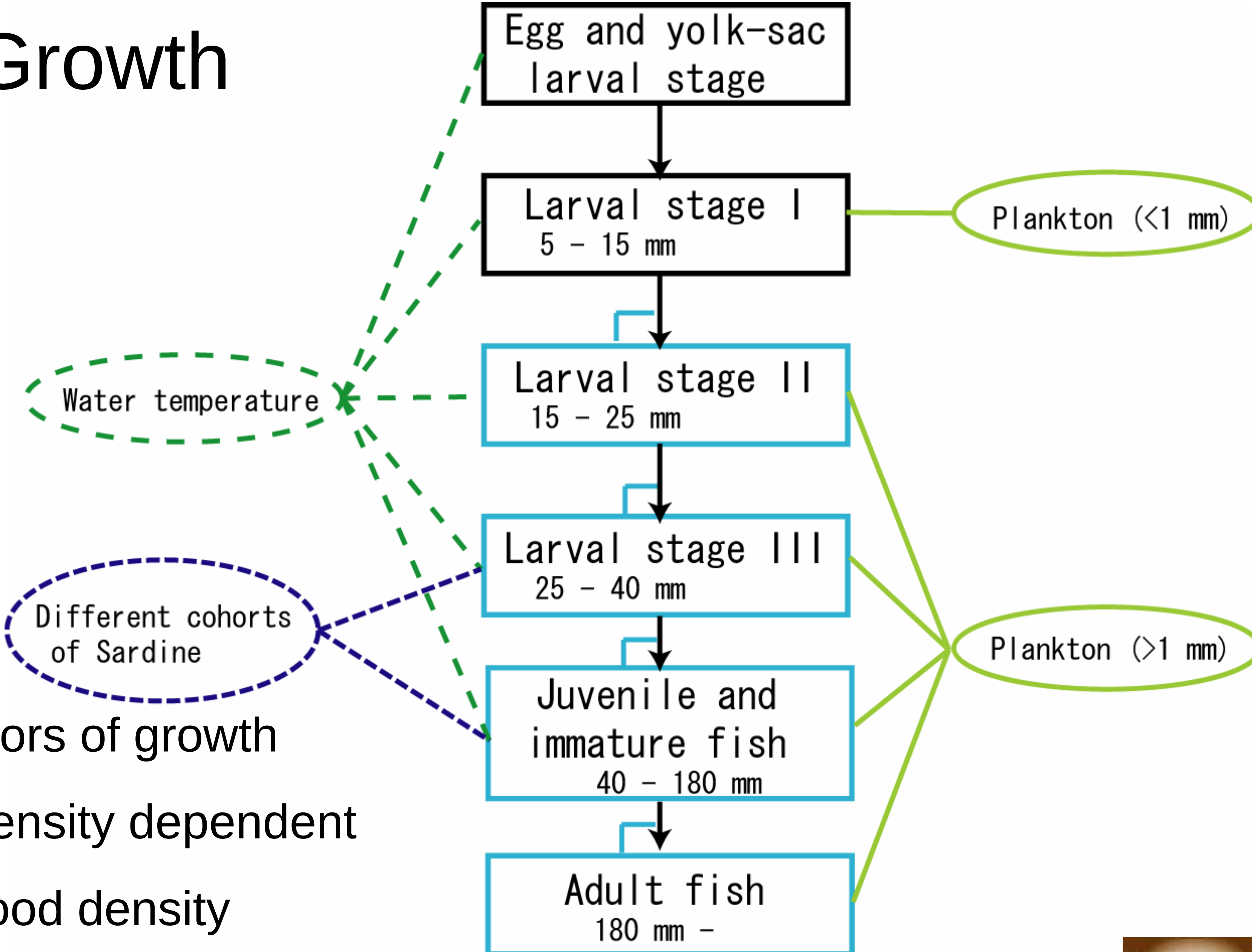
From egg to 60-day sardine



Transportation



Growth

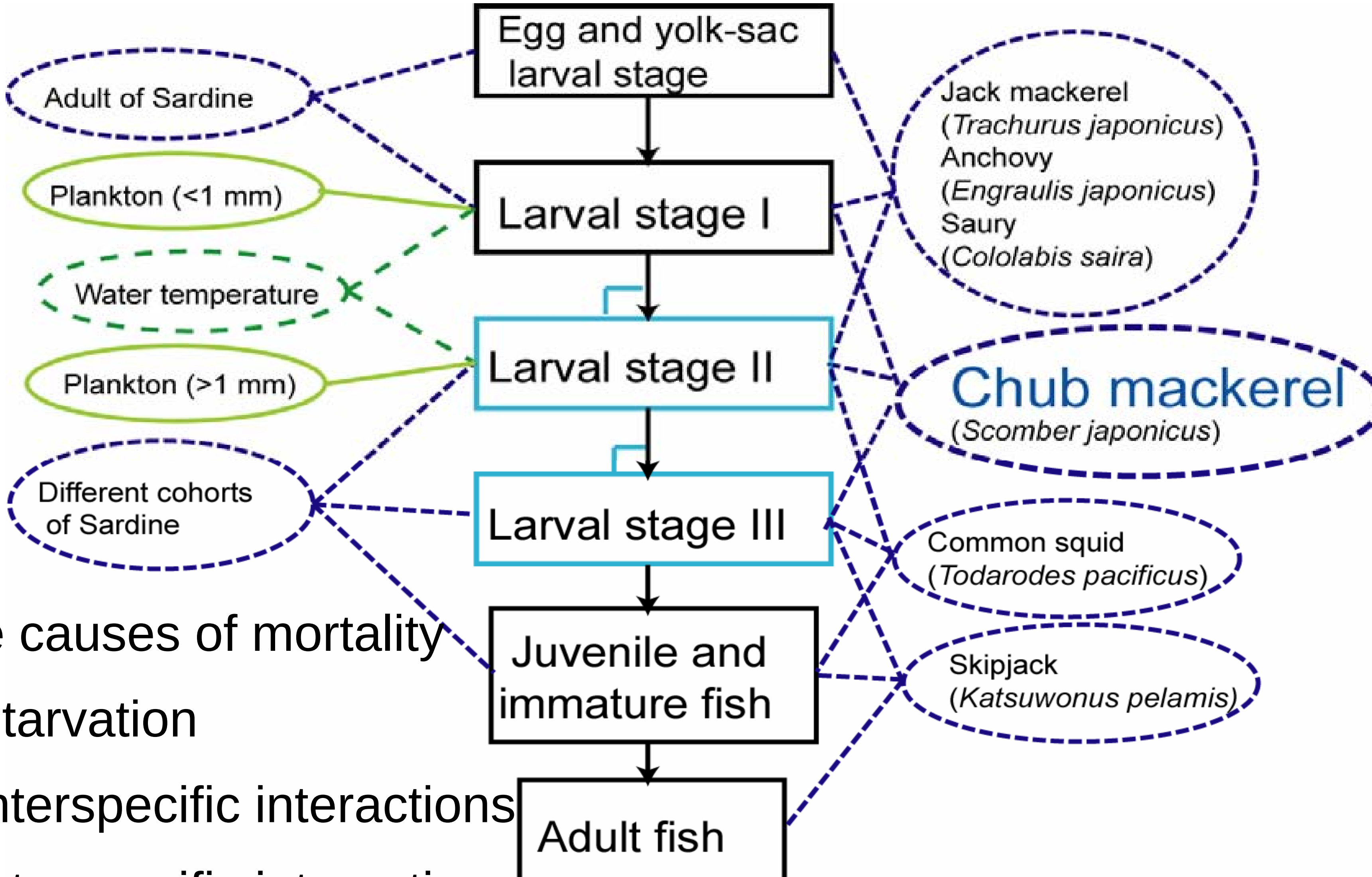


Factors of growth

- Density dependent
- Food density
- Water temperature

Sardine

Survival

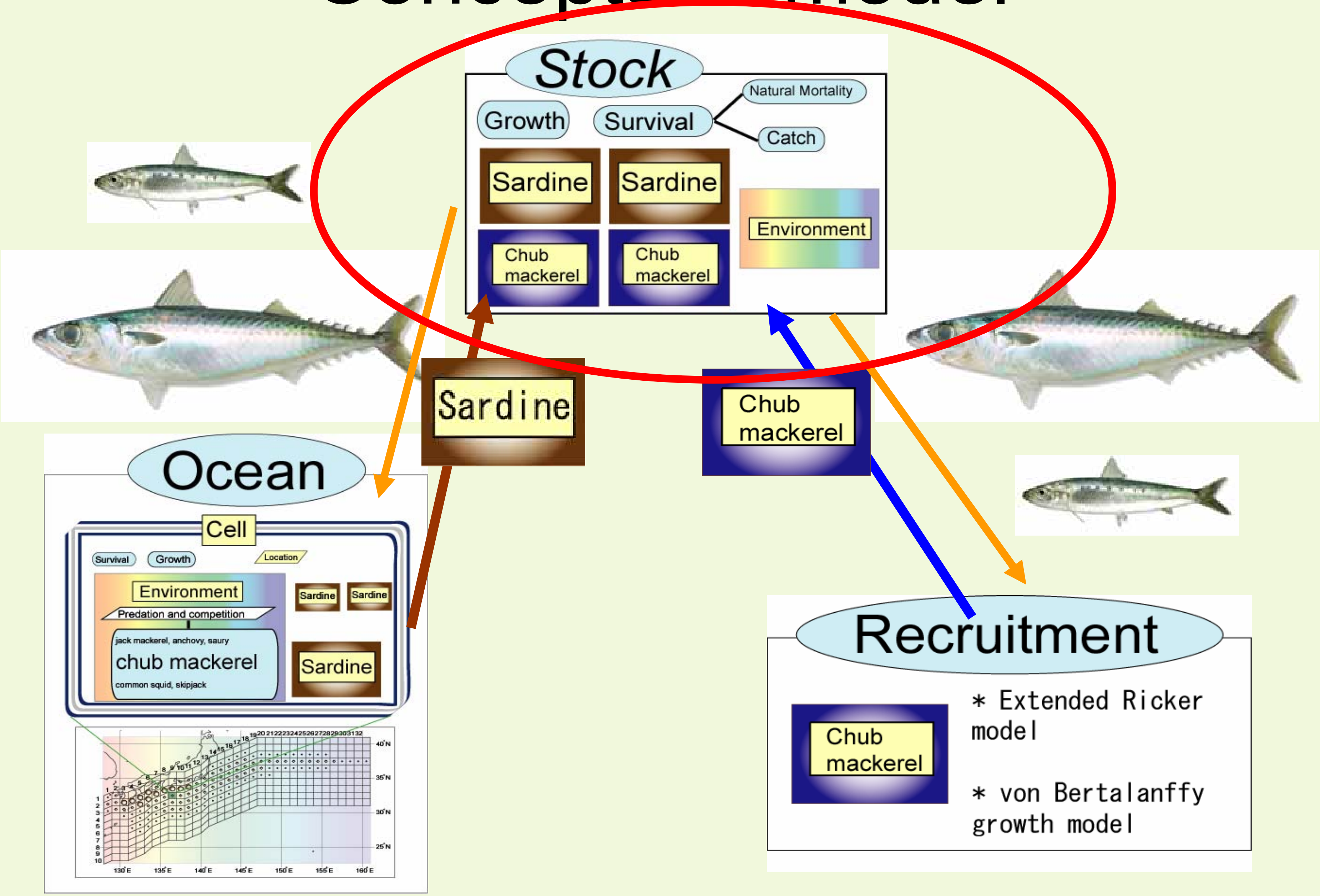


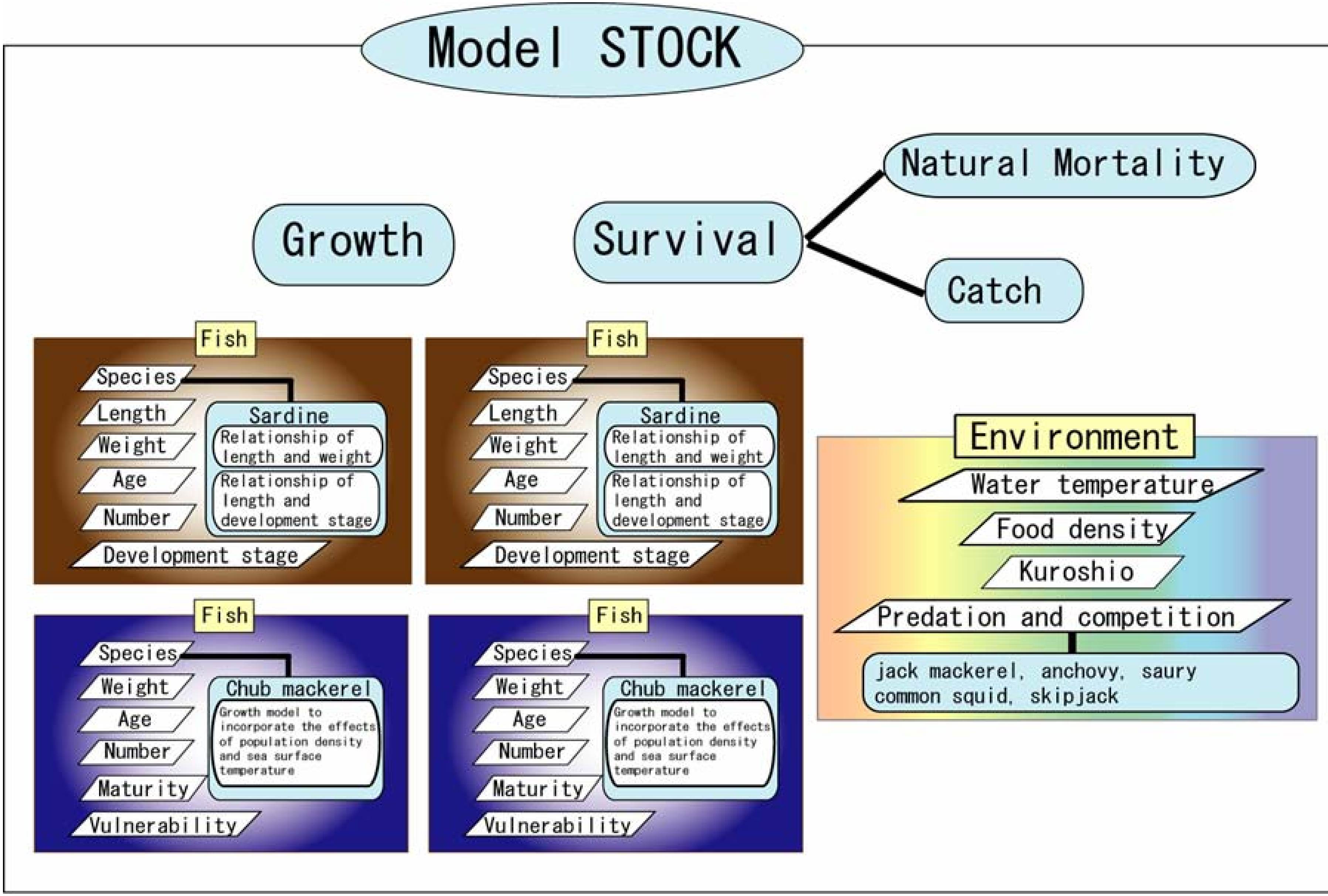
The causes of mortality

- Starvation
- Interspecific interactions
- Intraspecific interactions
- Water temperature effects

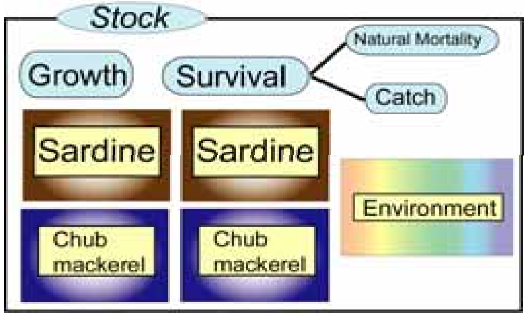
Sardine

Concepts of model




Model STOCK
Growth
Survival
Natural Mortality
Catch
Fish
Species
Length
Weight
Age
Number
Development stage
Sardine
Relationship of length and weight
Relationship of length and development stage
Fish
Species
Length
Weight
Age
Number
Development stage
Sardine
Relationship of length and weight
Relationship of length and development stage
Fish
Species
Weight
Age
Number
Maturity
Vulnerability
Chub mackerel
Growth model to incorporate the effects of population density and sea surface temperature
Fish
Species
Weight
Age
Number
Maturity
Vulnerability
Chub mackerel
Growth model to incorporate the effects of population density and sea surface temperature
Environment
Water temperature
Food density
Kuroshio
Predation and competition
jack mackerel, anchovy, saury
common squid, skipjack

Age structured model



- N_t : the number of a *Fish* object at t days after spawning

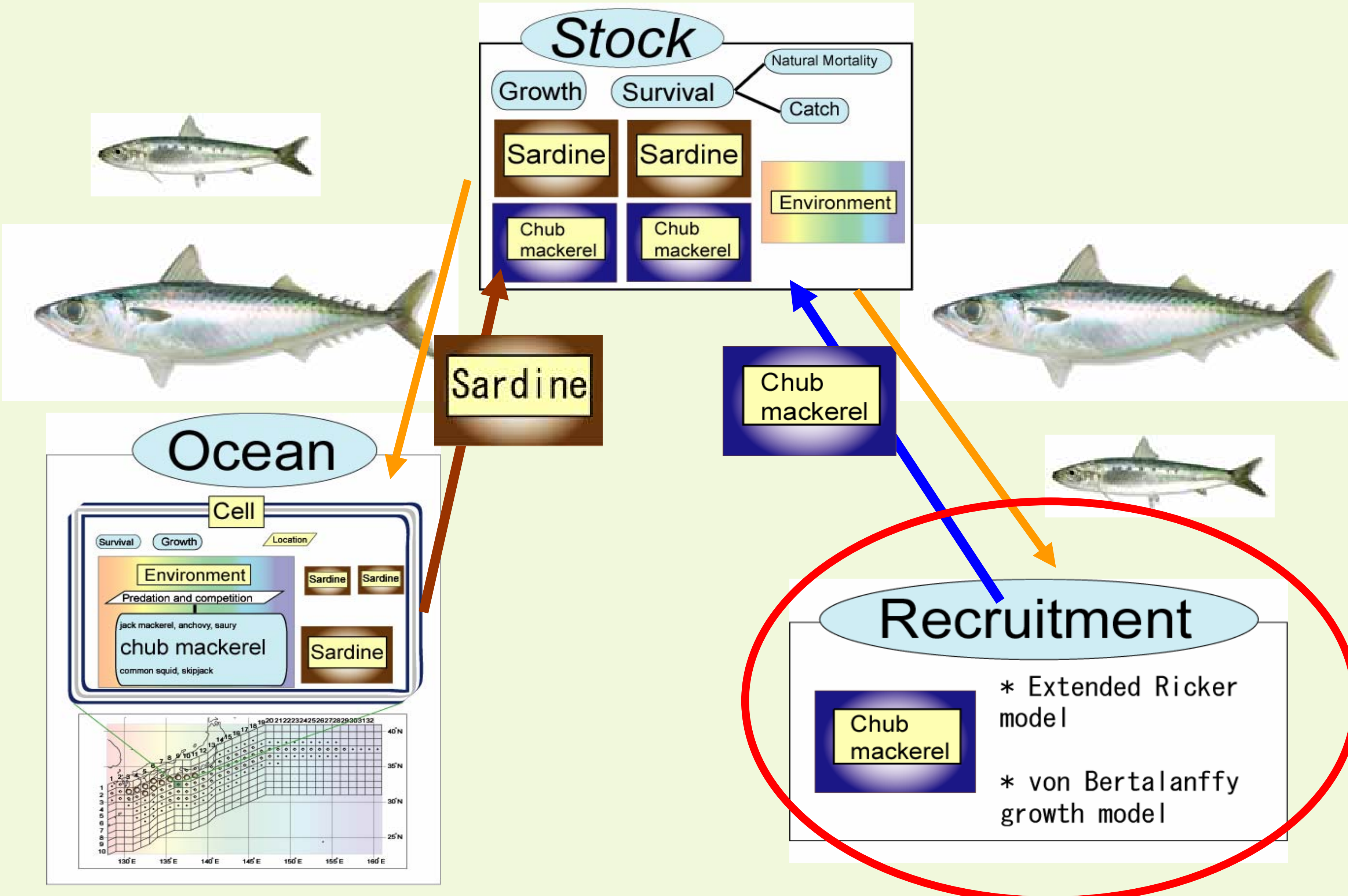
$$N_{t+1}=N_t \exp(-M)$$

- Assuming the catch at once t_0 for each year

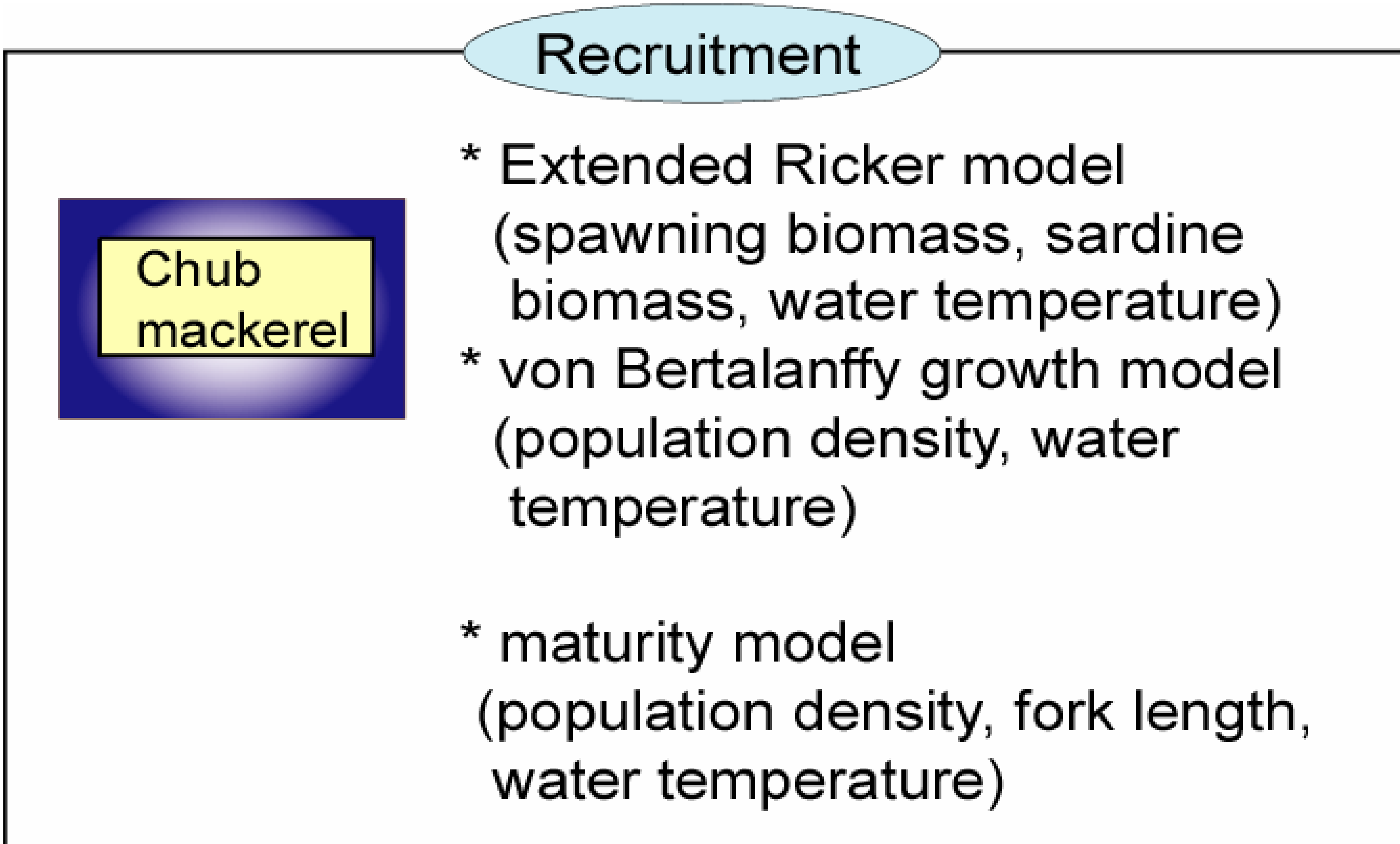
$$Catch=N_{t_0}(1-\exp(-F))$$

$$N_{t_0+1}=(N_{t_0}-Catch)\exp(-M)$$

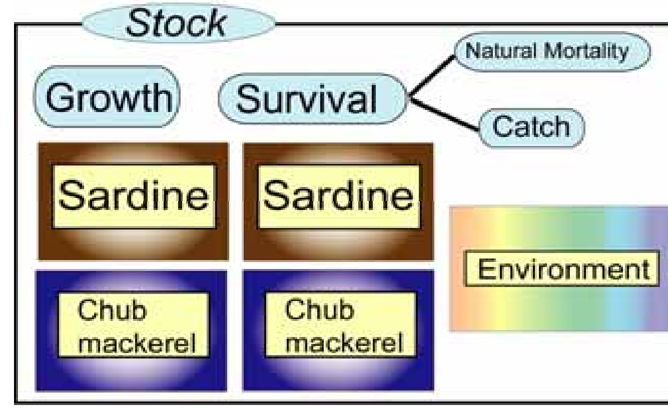
Concepts of model



Concepts of recruitment model for chub mackerel



Recruitment model for chub mackerel



- Extended Ricker model (by Yatsu et al., 2005)
- ln(R/S)

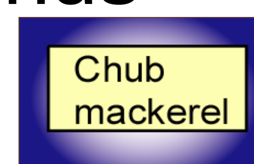
$$= - 0.00043\ S - 0.794\ W - 0.00006\ B + 18.64$$

R: recruitment of chub mackerel

S: spawning stock biomass of chub mackerel

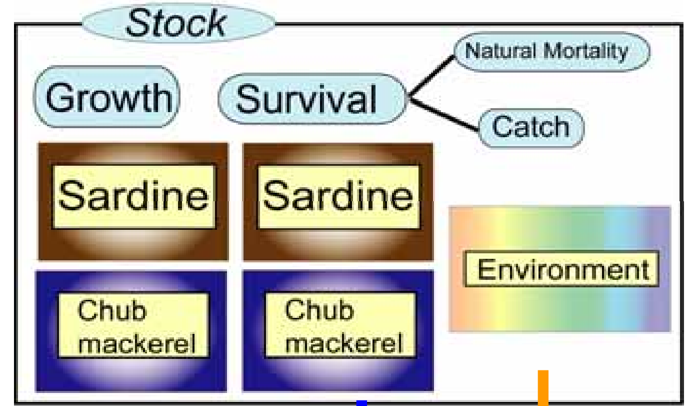
W: water temperature of spawning grounds

B: sardine biomass



Individual growth model for chub mackerel

(by Watanabe and Yatsu, 2004)



- $L_{0,y} = 43.98\{1\text{-}\exp(-2.585k_{i,0})\}$
- $L_{i+1,y} = L_{i,y} + (43.98 - L_{i,y})\{1 - \exp(-k_{i,y})\}$
- $k_{i,y} = 0.271 - 0.008T_{i+y} - 0.021D_{i,y}$

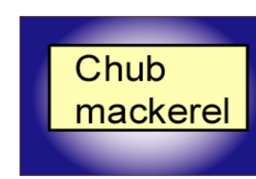
$L_{i,y}$: Fork length at age *i* of year-class *y*

T:Standardized sea surface temperature

(during April-June in the waters bounded by 38-40° N and 141-143° E)

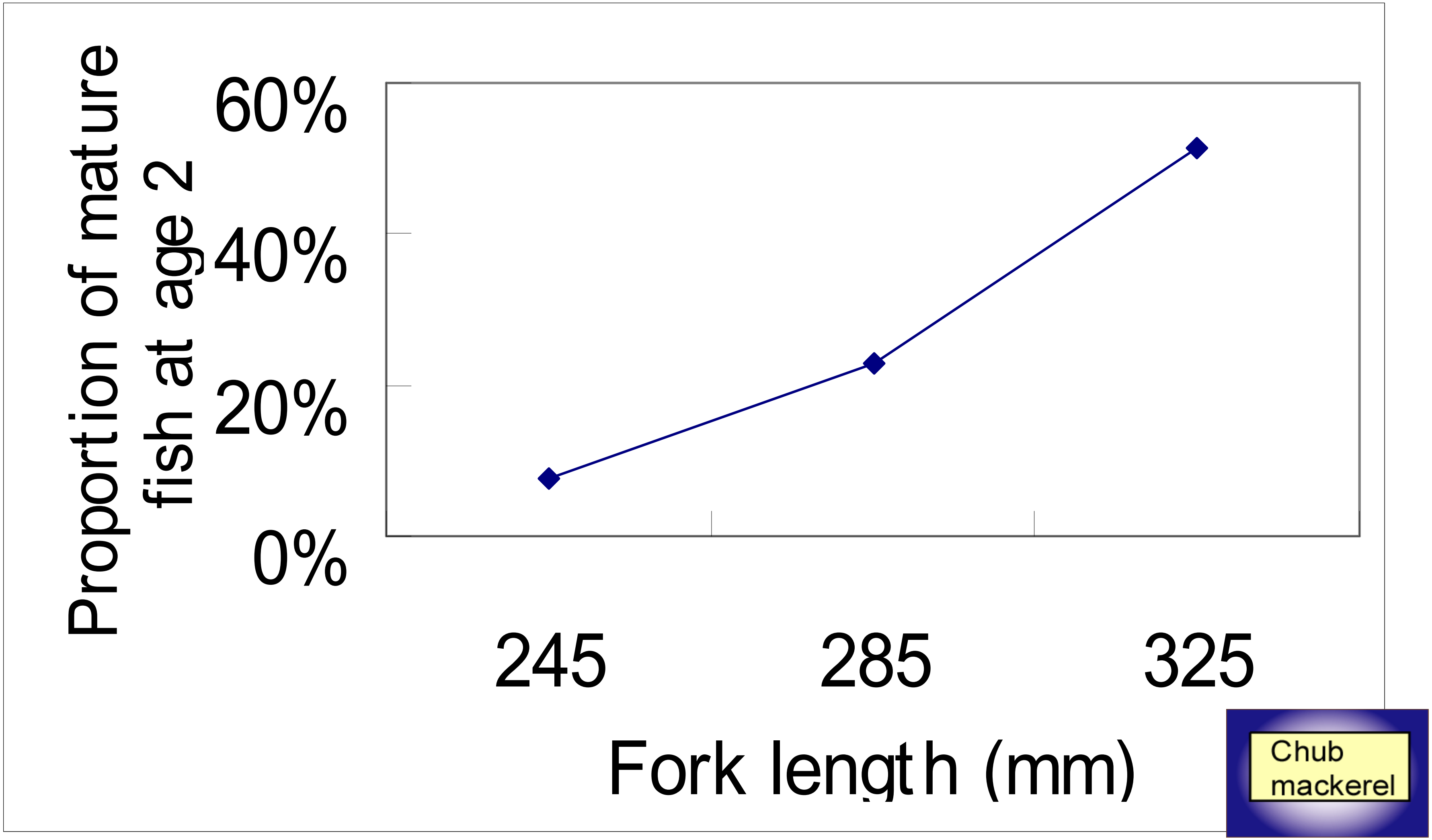
$D_{i,y}$:Standardized population density

(the number of stock at age *i* of year-class *y*)



Maturation model for chub mackerel

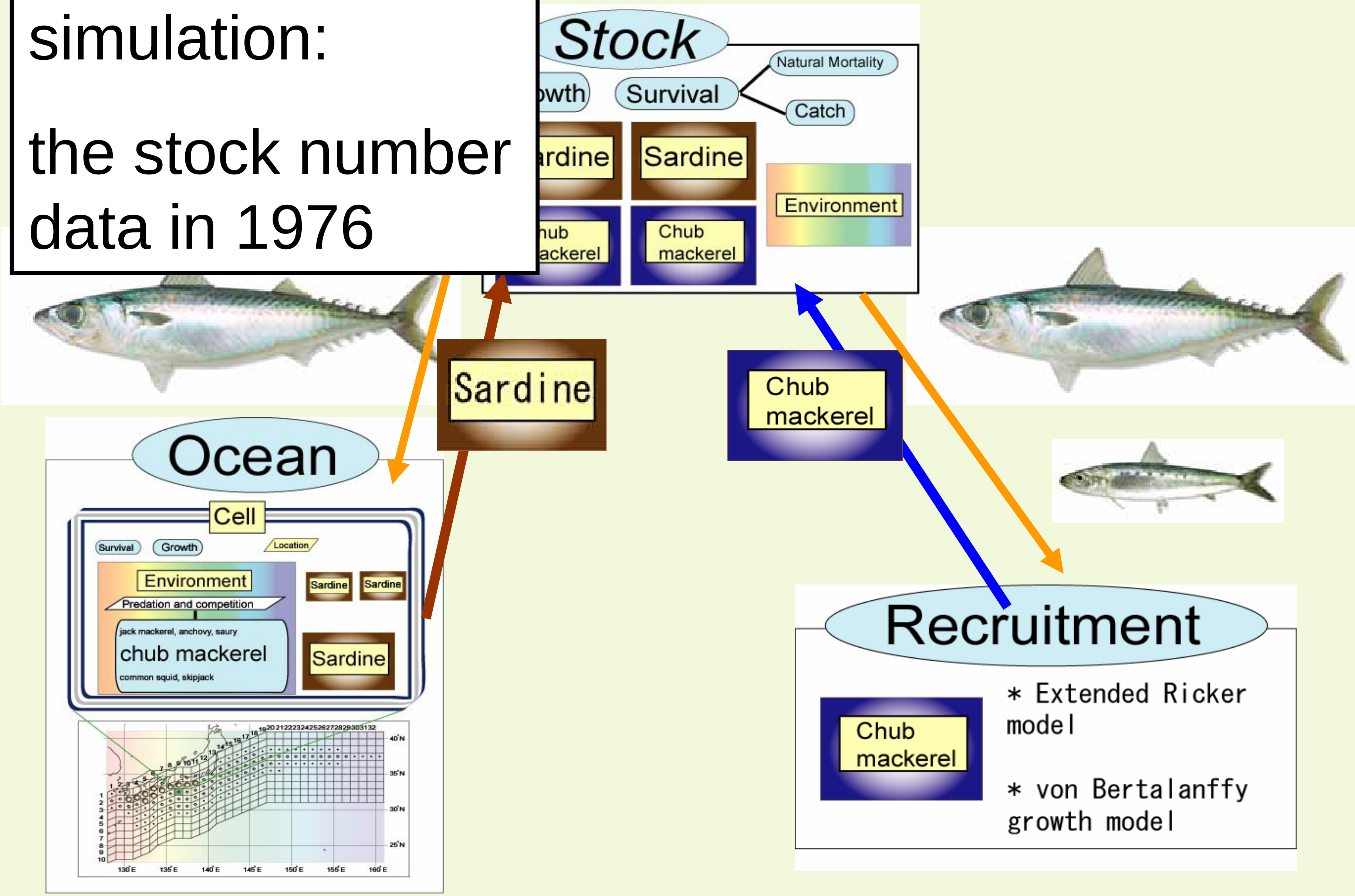
(by Watanabe and Yatsu, 2006)



epts of model

Initial value of the simulation:

the stock number data in 1976



Input Data

- Sea surface temperature

  Oceanographic normals and analyses for the period 1971-2000 published by the Meteorological Agency

- Location of Kuroshio axis, Ocean current statistics

  Prompt Report of Oceanographic Conditions, published by the Japan Coast Guard

- Stock abundance index of jack mackerel, anchovy, saury, common squid and skipjack

  Catch data compiled by the Ministry of Agriculture, Forestry and Fisheries

- Zooplankton biomass

  Nakata et al. (2001), Nakata and Koyama (2003), Odate (1994)

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Simulation planning

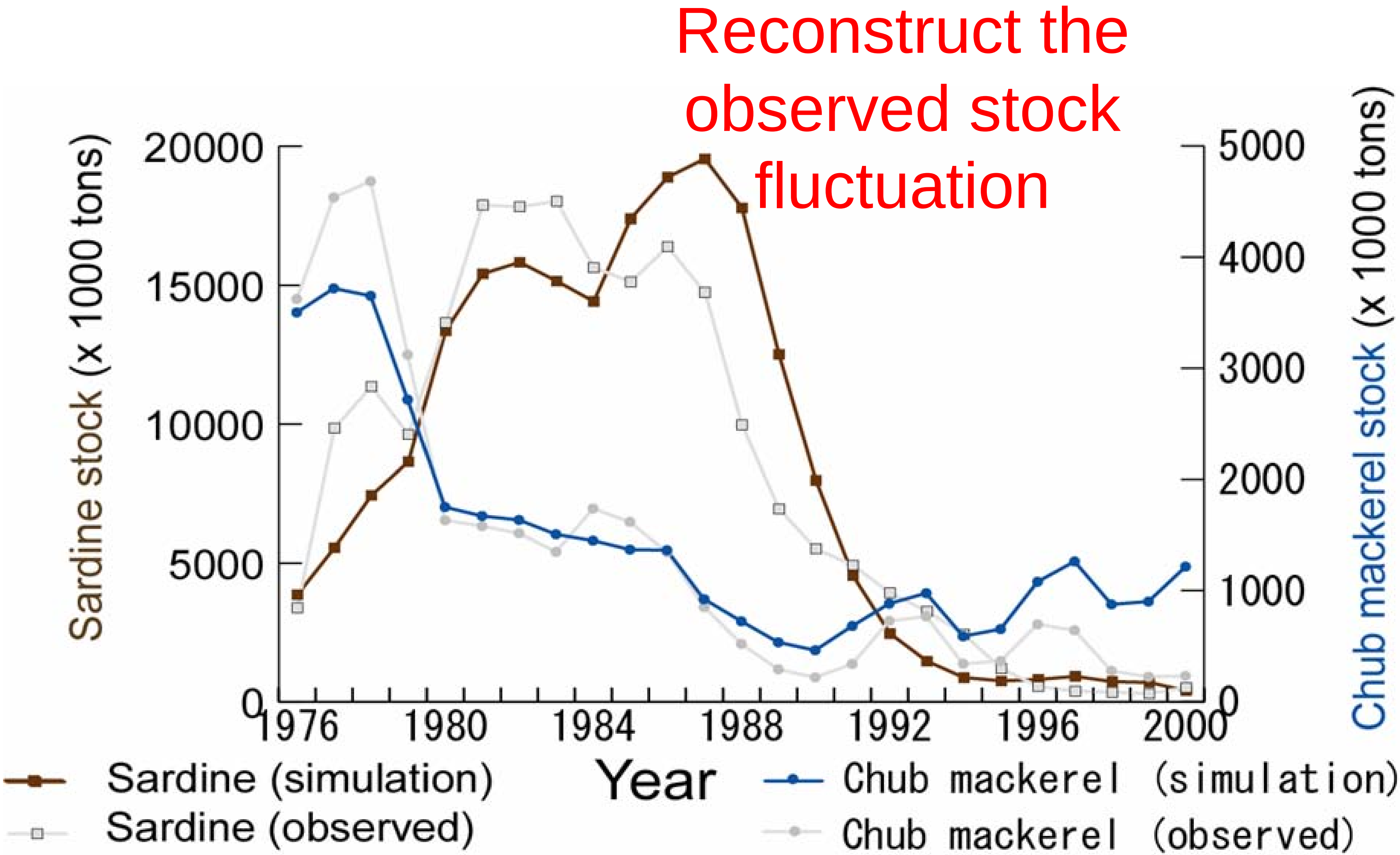
A. Reconstruct the observed stock fluctuation (using observed data)

B. Set the fishing mortality 0

C. Investigate the influence of the water temperature

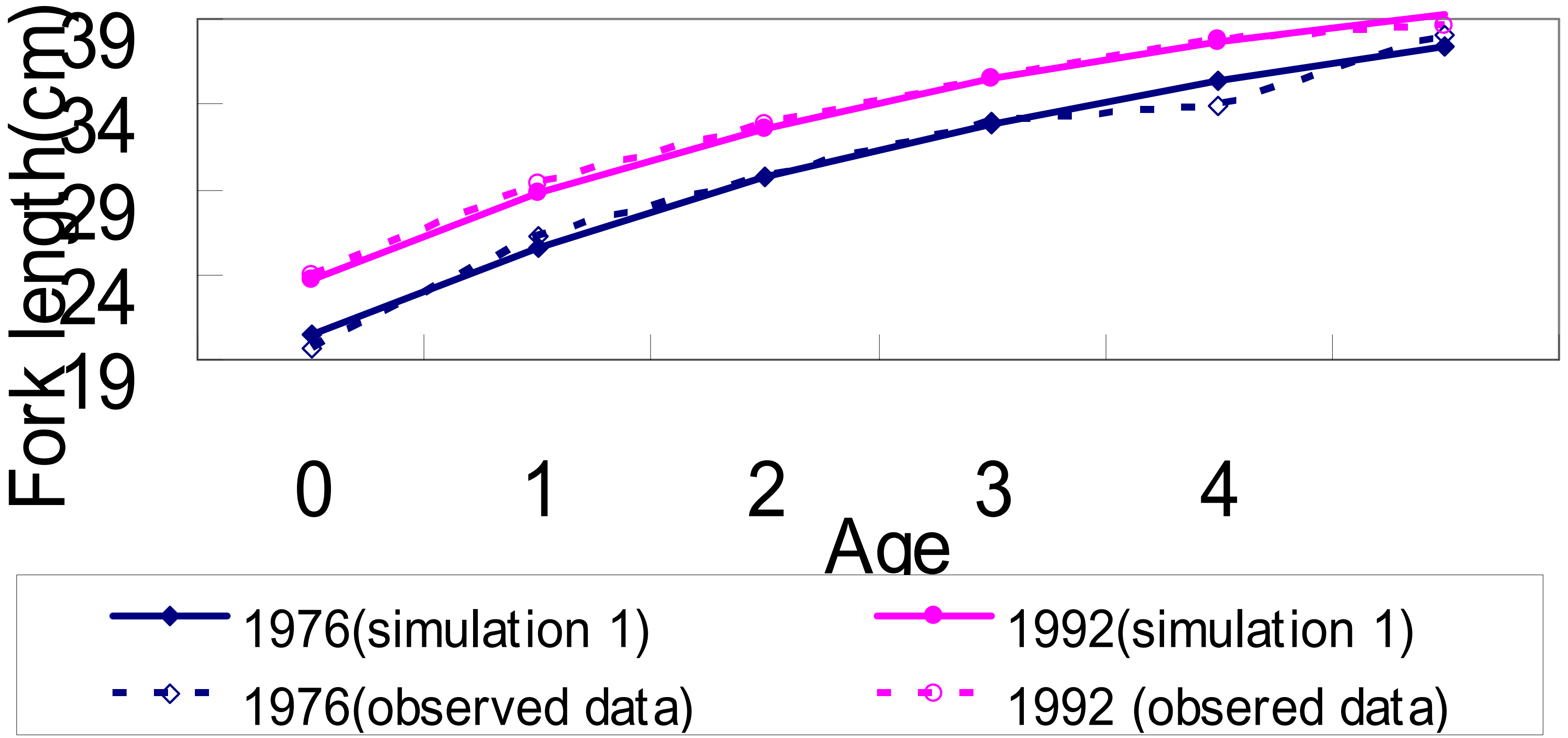
(using normal water temperature +0.5°C and normal water temperature -0.5°C)

Result (Stock in simulation A)



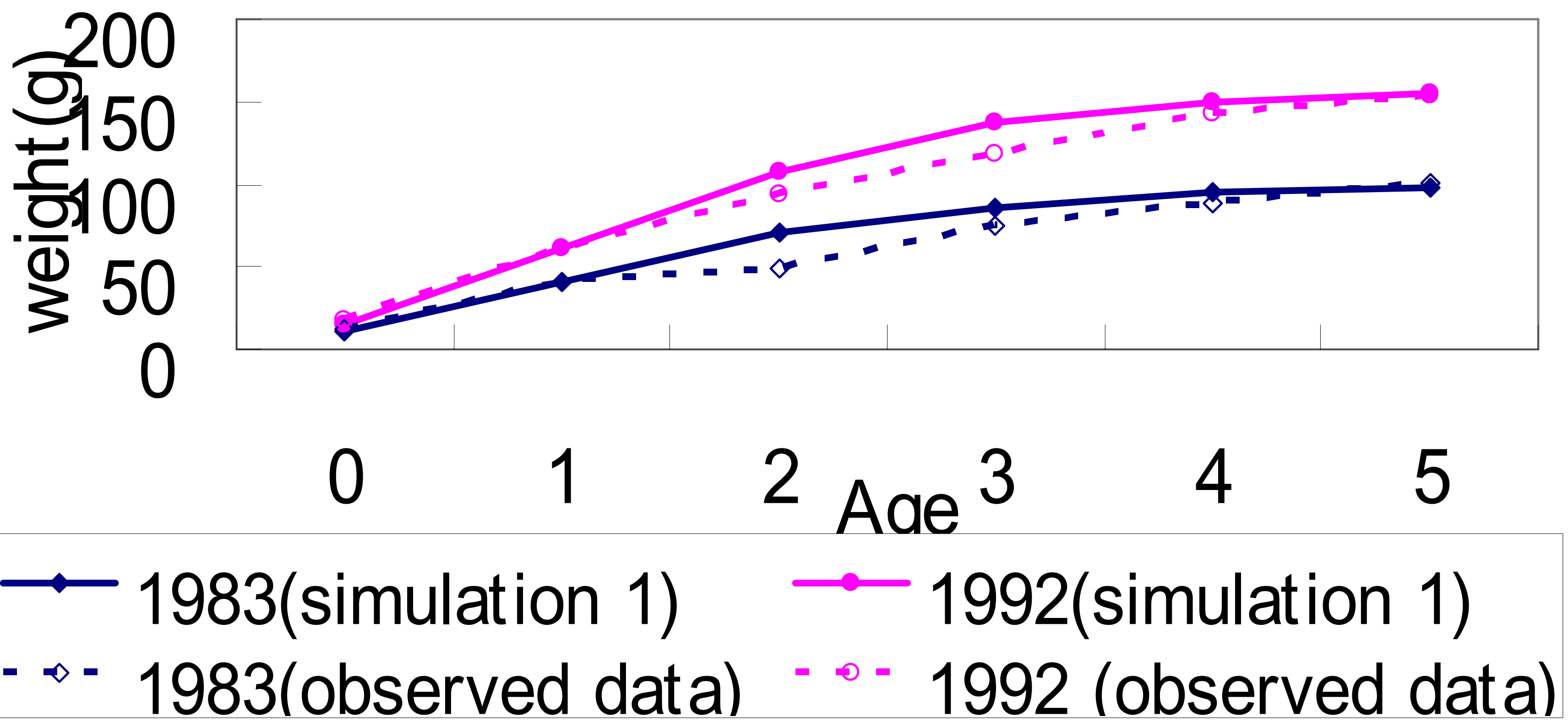
Chub mackerel

Result (Fork length in simulation A)



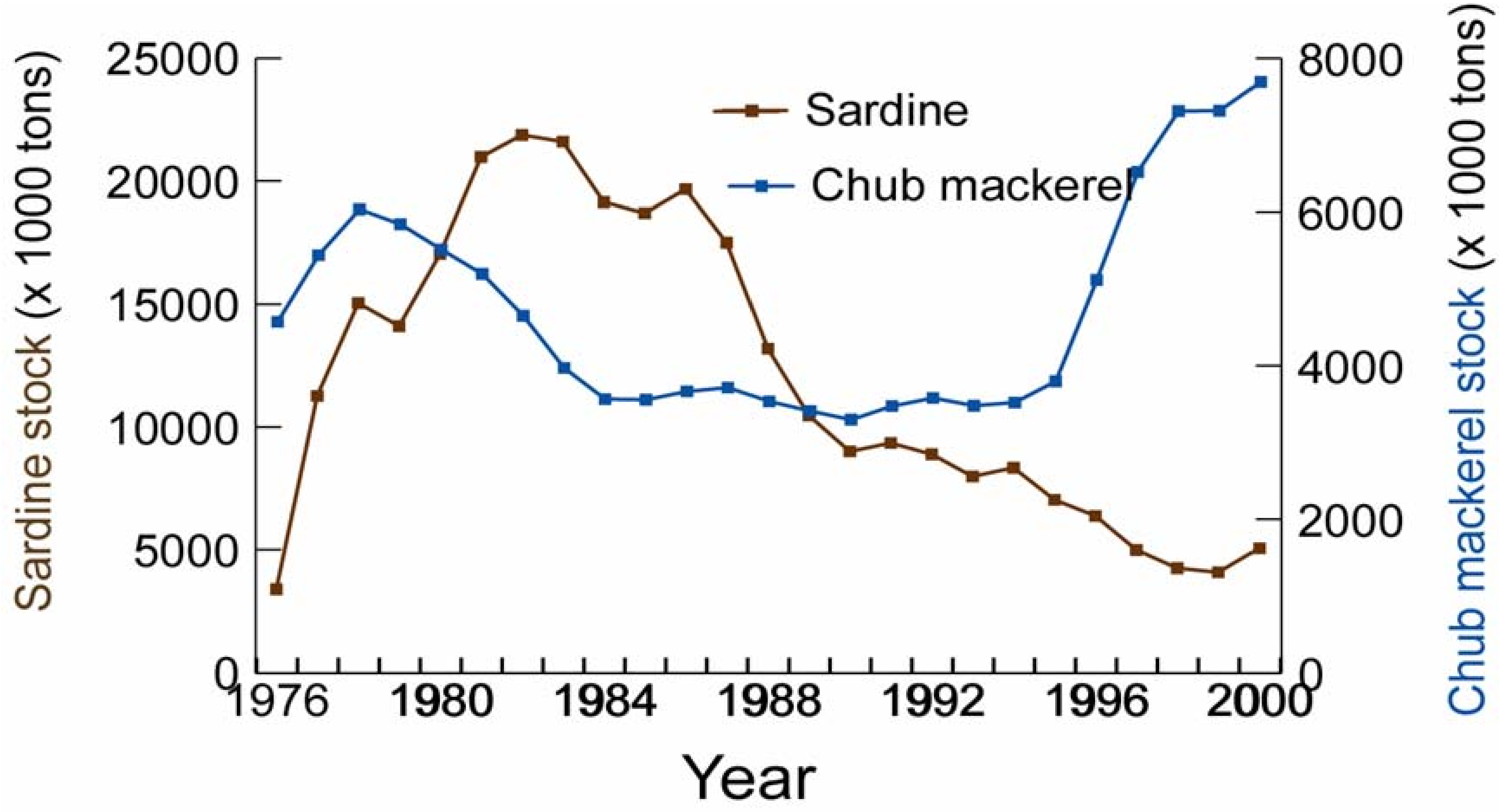
Sardine

Result (Individual weight in simulation A)

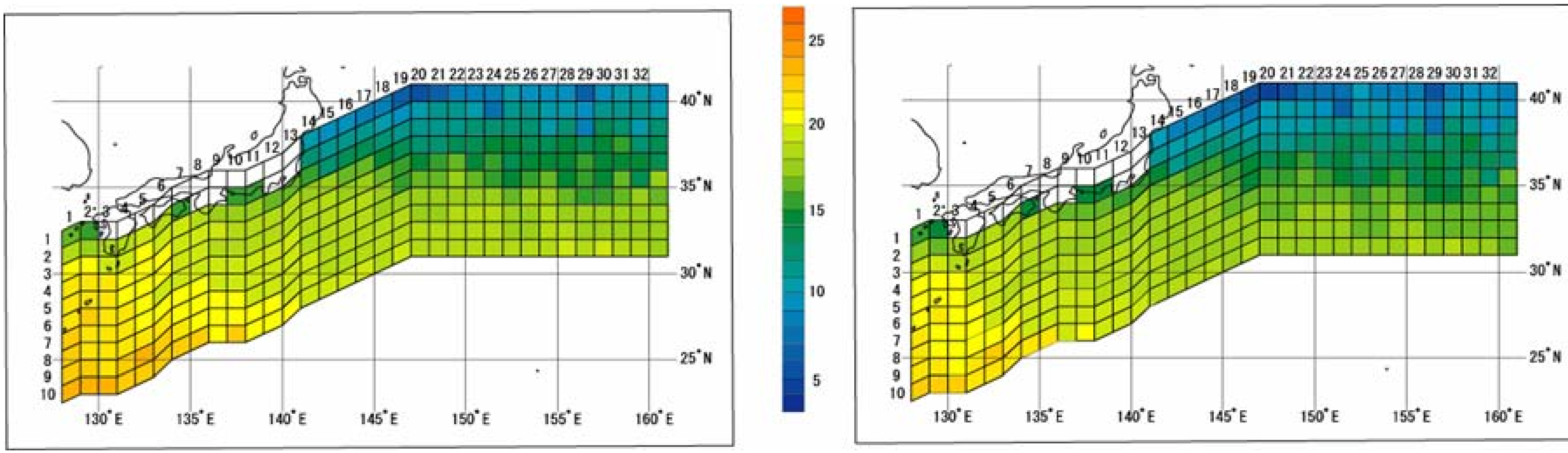


Result (Stock in simulation B)

No-catch simulation



Data of water temperature in the simulation C



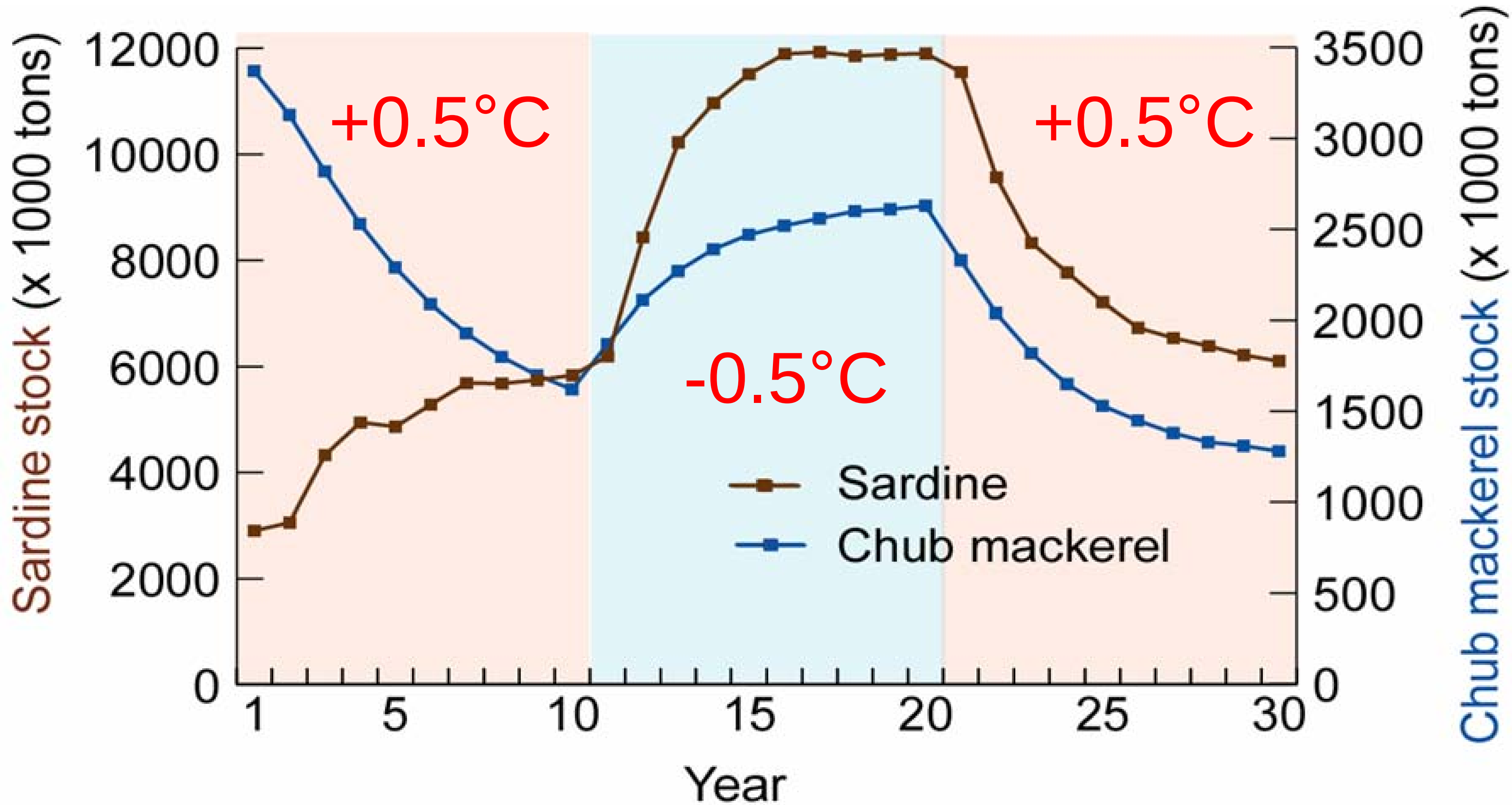
Normal water temperature +0.5

Normal water temperature -0.5

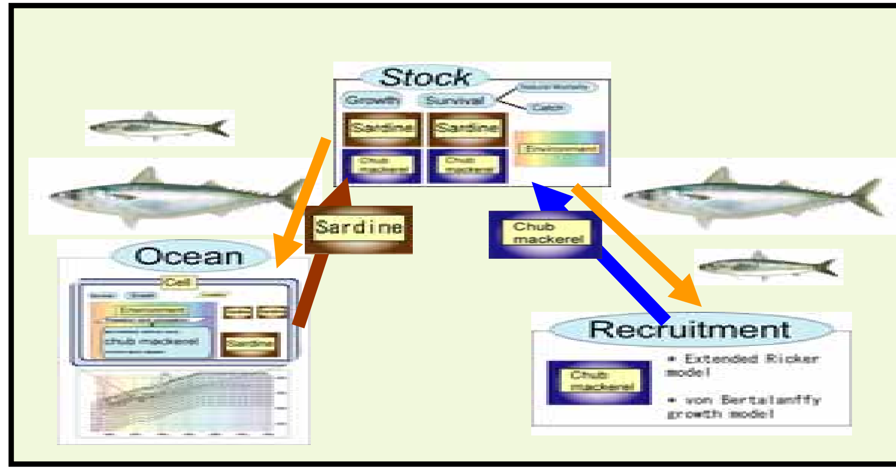
February

Result (Stock in simulation C)

the influence of the water temperature



Summary



- Development of two-species population dynamics model for Japanese sardine and chub mackerel
- Object oriented modeling to link the spatial stage-based model with the population-based model
- Flexibility and extensibility in the model

Future version:

Sardine recruitment model using FRA/JCOPE