Ecological functions of a kelp community as an indicator of anthropogenic nutrient stressors

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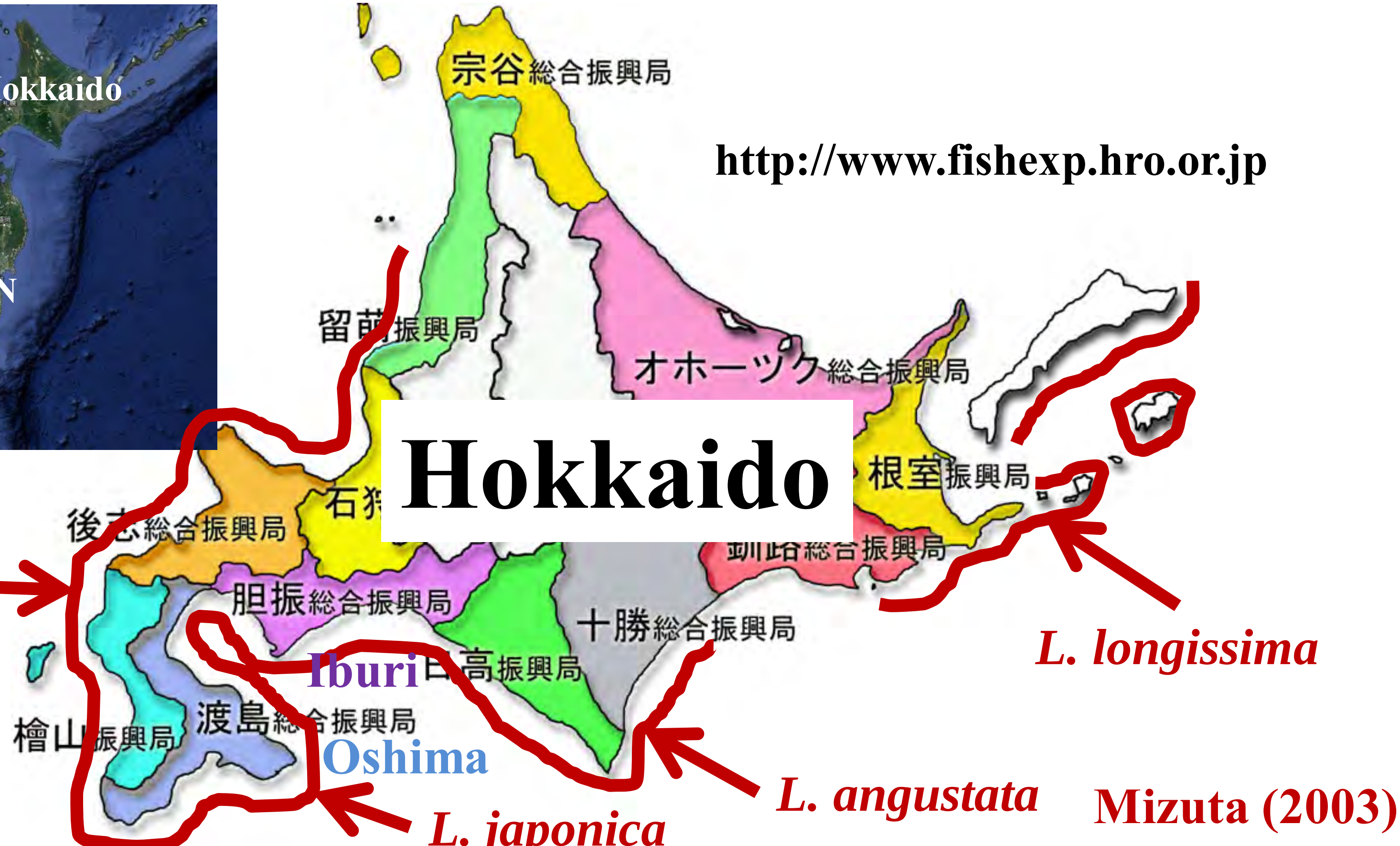
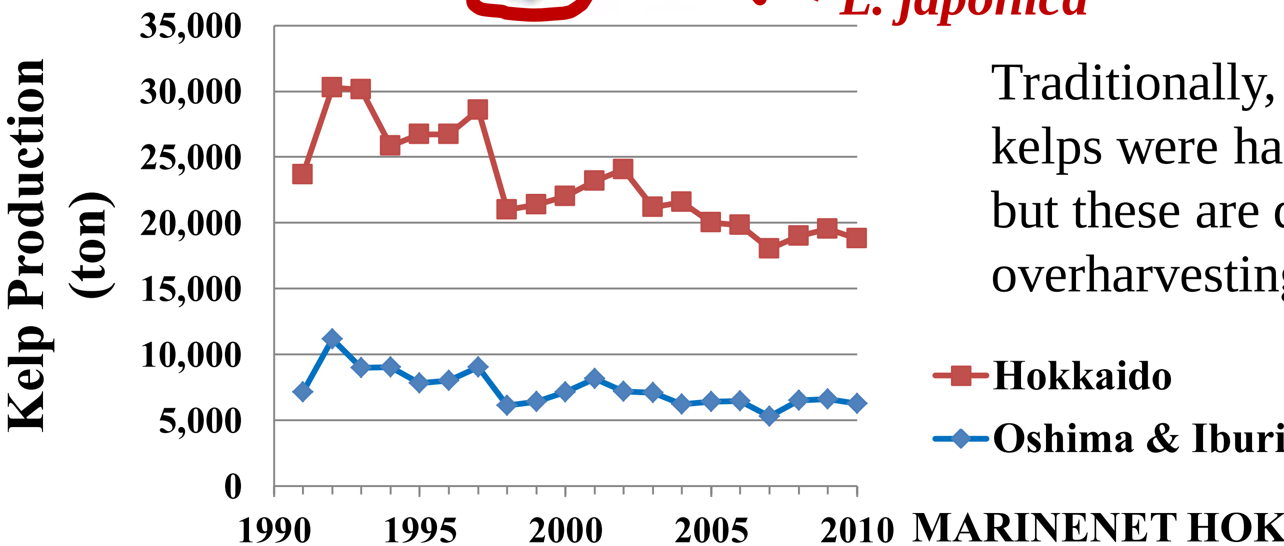
Today's contents

- Kelp Growth Model
- Coupling to NEMURO
- Coupling to 3D OGCM+HaRUM
- Conclusions

Google map





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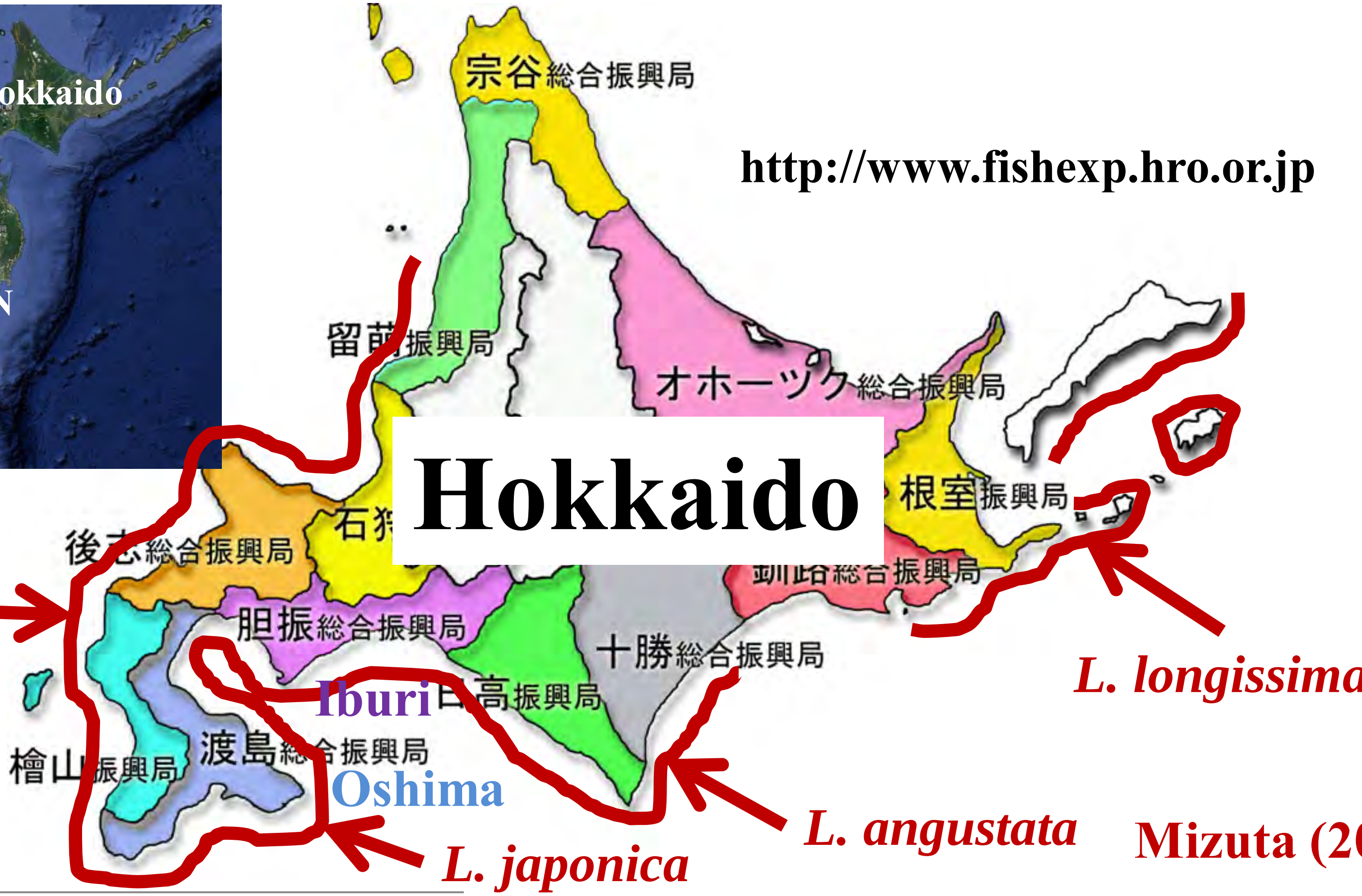
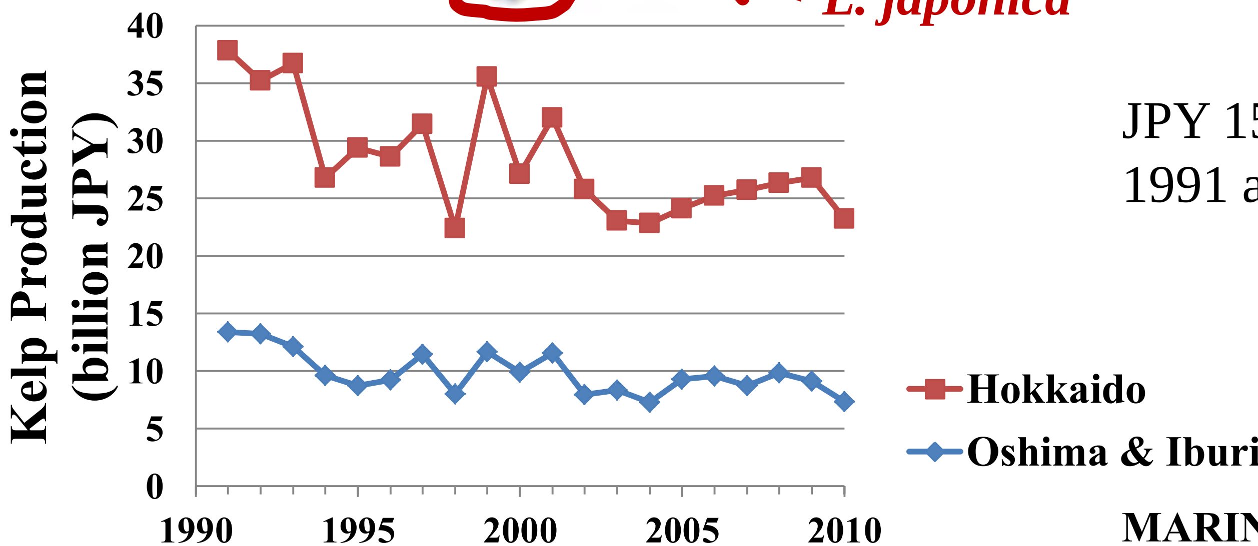
Traditionally,
kelps were harvested from wild stocks, but these are declining because of overharvesting.

Google map



http://www.fishexp.hro.or.jp

Mizuta (2003)



JPY 15B decreased between 1991 and 2010 in Hokkaido.

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Objectives

- To estimate the standing stock of kelp for efficient stock management

- To evaluate the ecological functions of kelp community as an indicator of anthropogenic stressors associated with riverine nutrient loading

⇒ We developed an ecosystem model by coupling a kelp growth model with a lower trophic-level model for the North Pacific marine ecosystem (NEMURO; Kishi et al., 2007).

Kelp nutrient uptake

Nitrate uptake [μmolN g dry weight^{-1} h^{-1}]

$$UpNO_3 = V_{max_{NO_3}} \times \frac{NO_3}{NO_3 + K_{s_{NO_3}}} \times f_T(T) \times f_L(L)$$

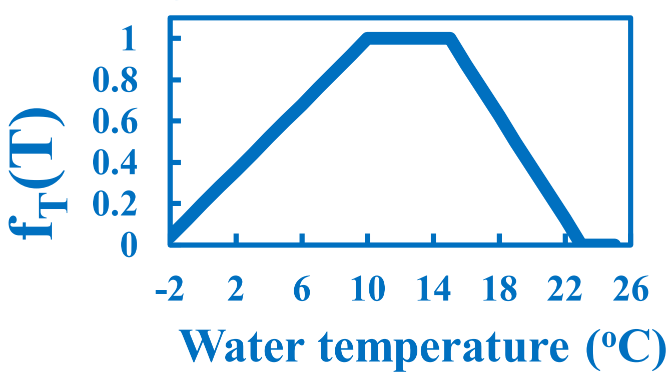
Ammonium uptake [μmolN gDW^{-1} h^{-1}]

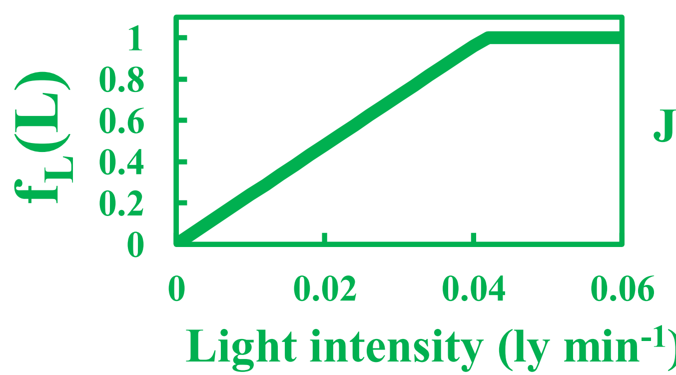
$$UpNO_3 = V_{max_{NH_4}} \times \frac{NO_3}{NO_3 + K_{s_{NH_4}}} \times f_T(T) \times f_L(L)$$

Braga and Yoneshigue-Valentin (1996)

	NO_3	NH_4	
V_{max}	5.0	2.0	[μmolN gDW^{-1} h^{-1}]
K_s	14.0	4.6	[μmolN l^{-1}]

Broch and Slagstad (2012)





Jackson (1987)

Growth rate of an individual kelp

[g dry weight day^{-1}]

$$\frac{dW}{dt} = (Up - R - E) \times W$$

[day^{-1}] [µmolN g dry weight^{-1} h^{-1}] [h^{-1}] to [day^{-1}]

$$Up = (UpNO_3 + UpNH_4) \times 24 \times \frac{1\ \text{g dry weight}}{1.61 \times 10^3\ \mu\text{molN}}$$

[day^{-1}]

$$R = ar \times fr(T)$$

0.0002 day^{-1}

Ren et al. (2012)

[day^{-1}]

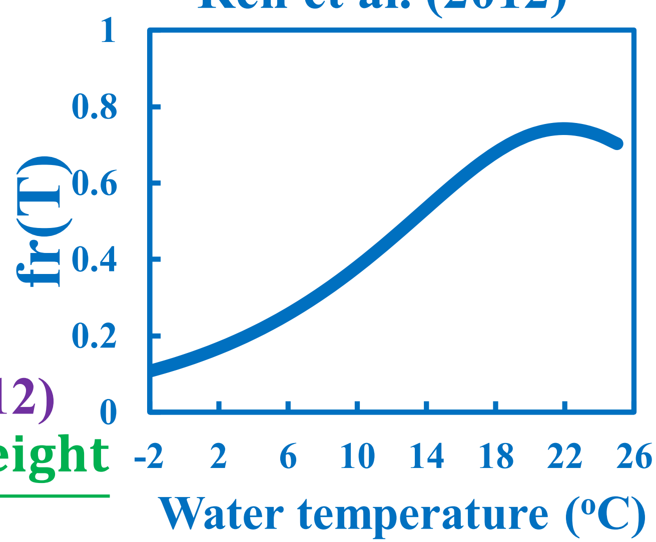
$$E = ae \times fe(A)$$

0.000001 day^{-1}

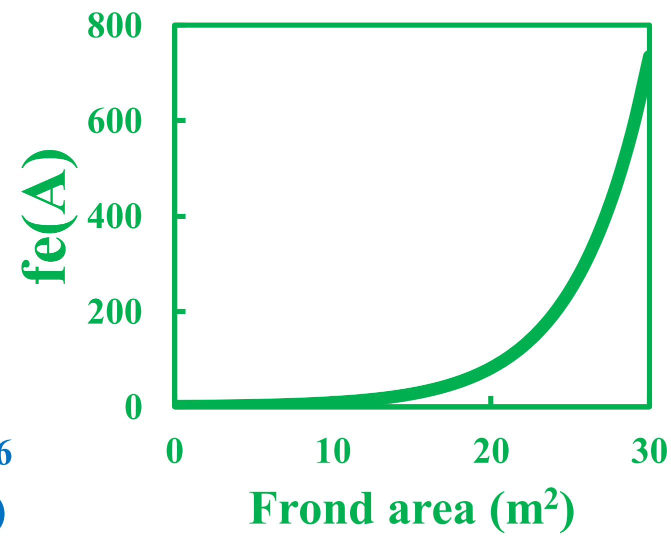
Broch and Slagstad (2012)

$$W = A \times \frac{0.6\ \text{g dry weight}}{10\ \text{cm}}$$

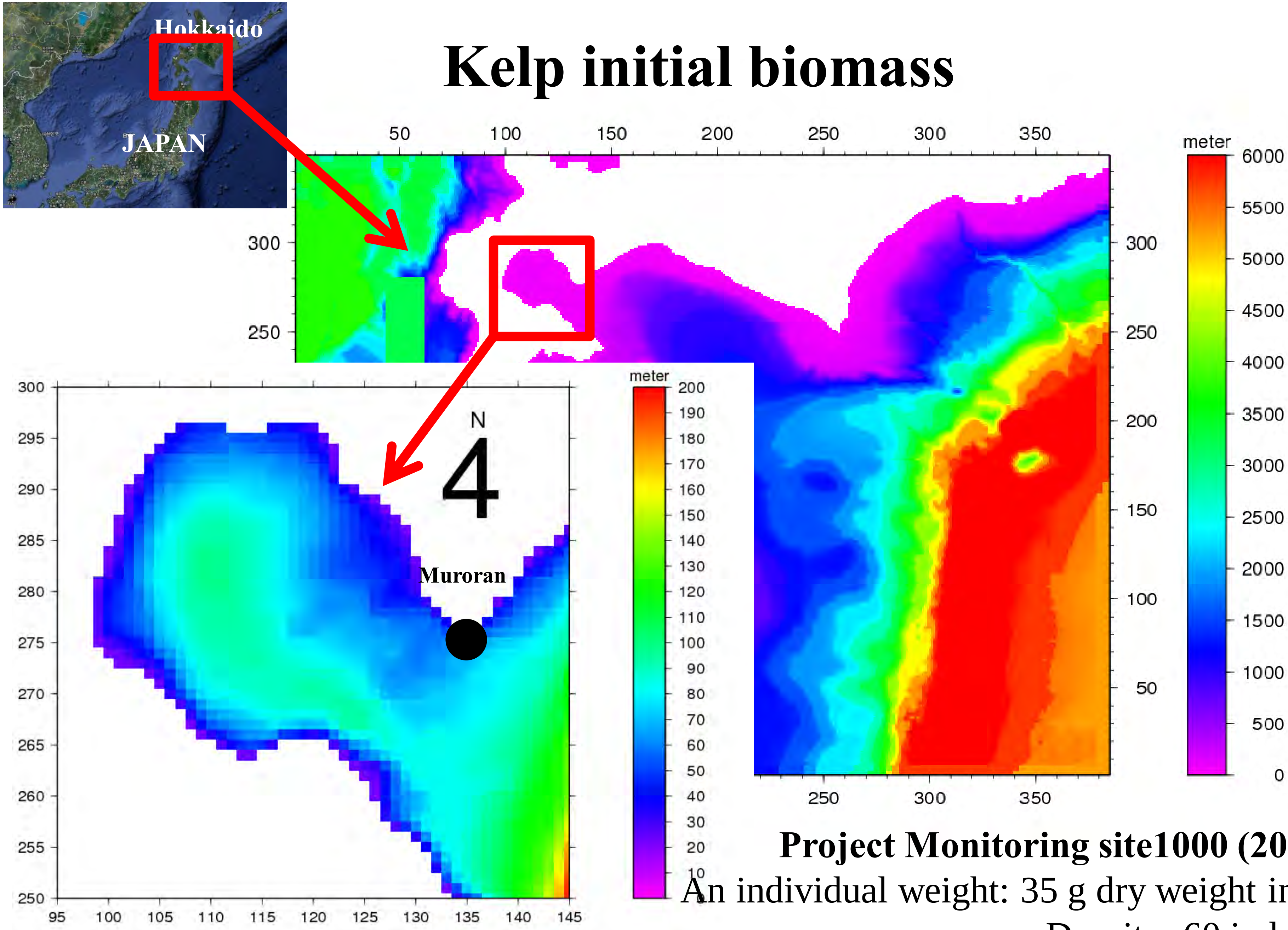
Ren et al. (2012)



Broch and Slagstad (2012)



Kelp initial biomass



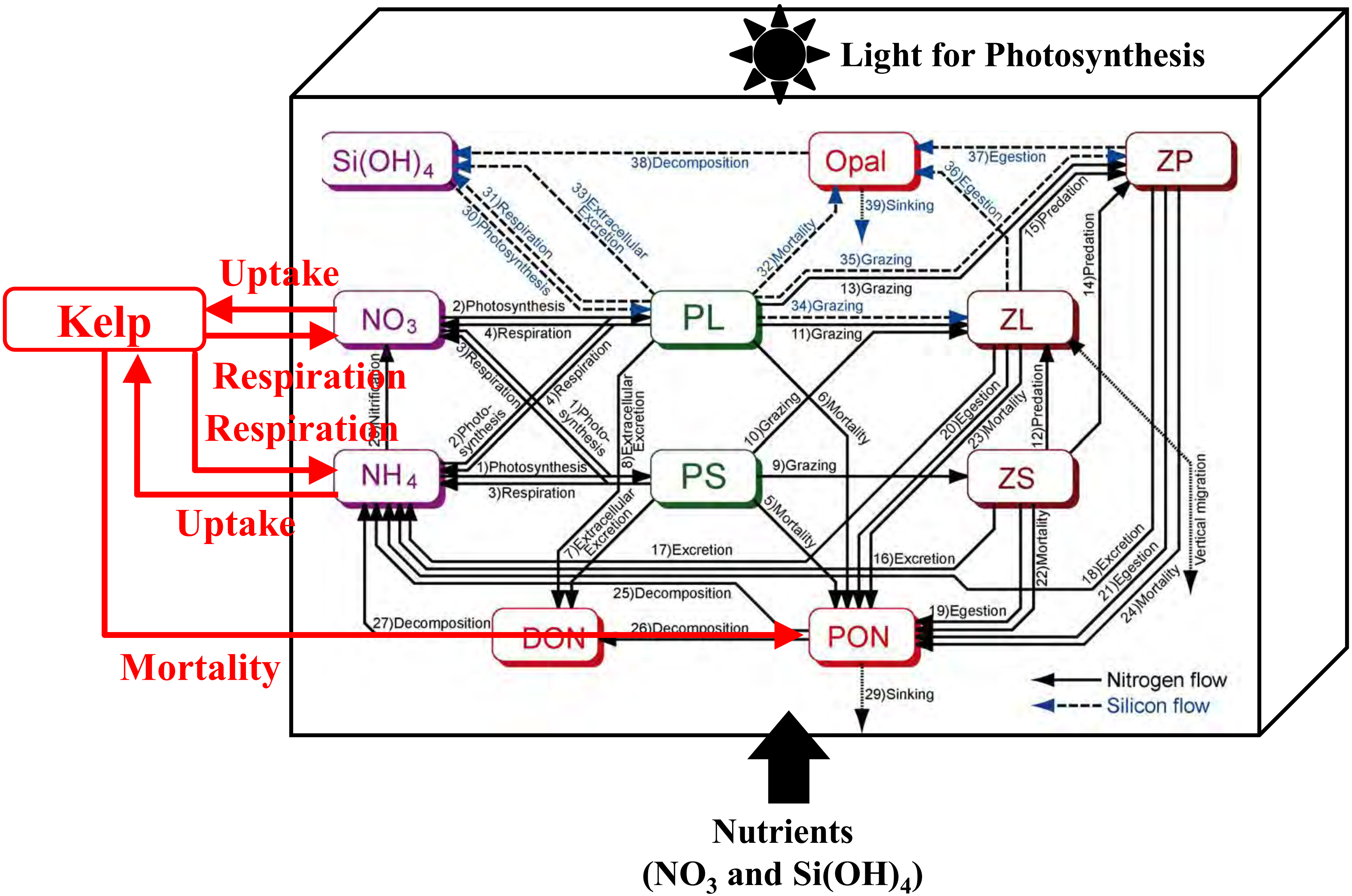
Project Monitoring site1000 (2011)

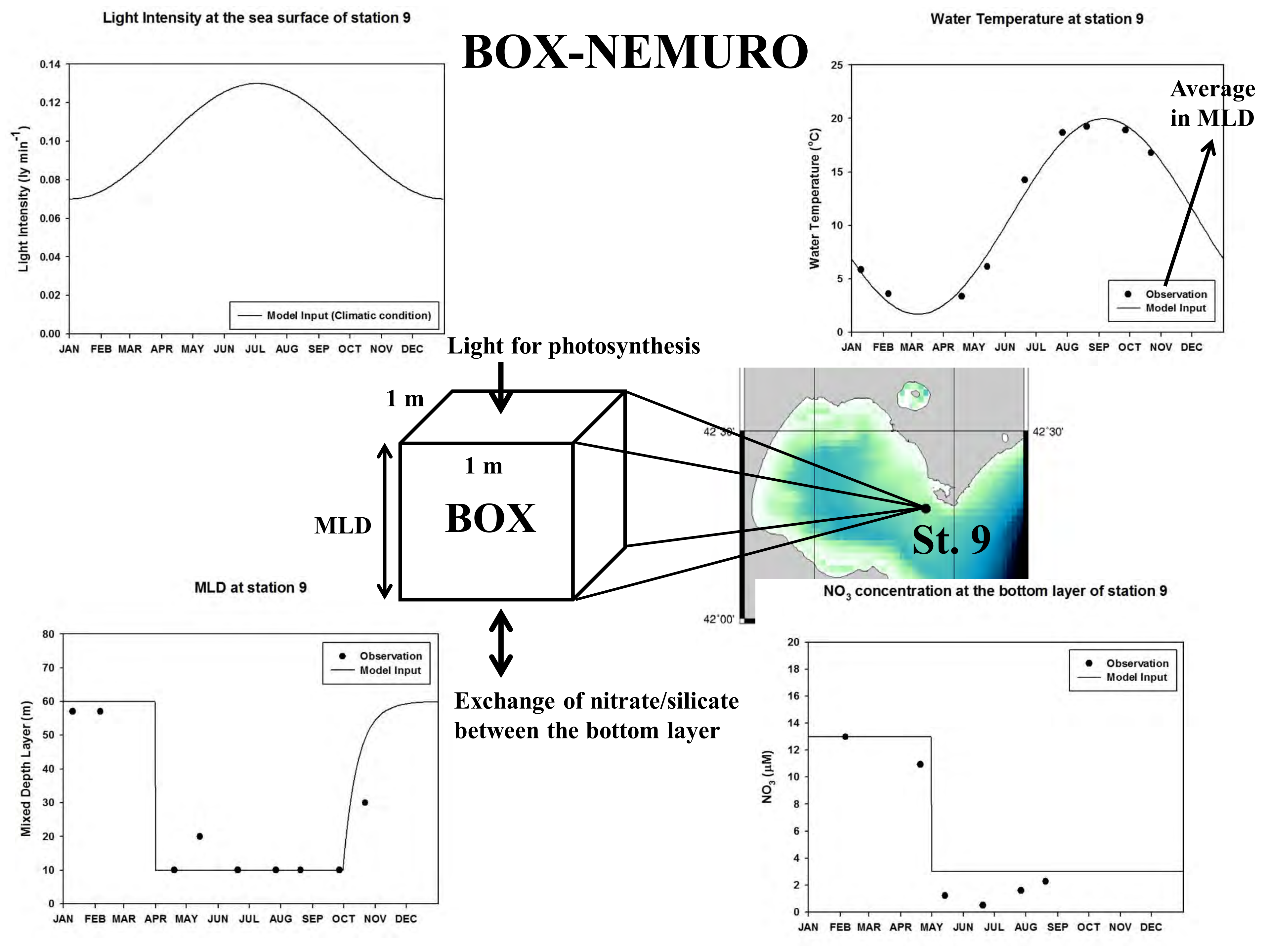
An individual weight: 35 g dry weight ind^{-1}

Density: 60 ind m^{-2}

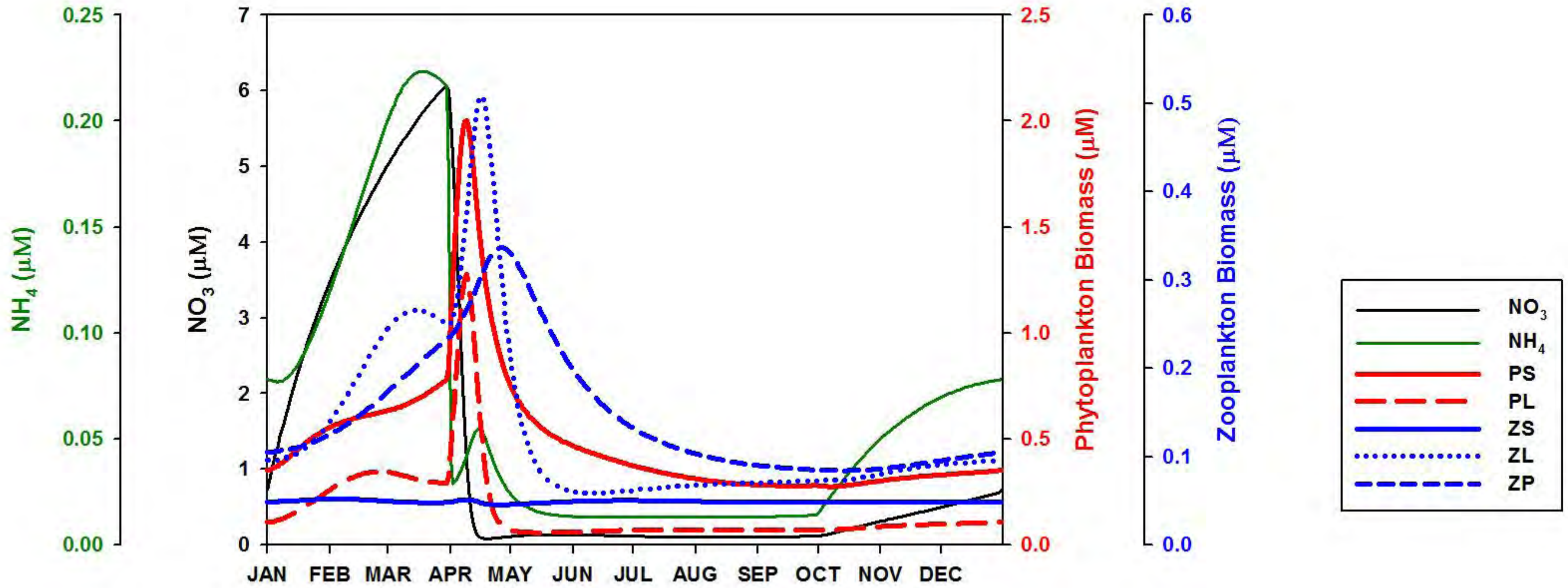
Biomass: 2100 g dry weight m^{-2}

NEMURO + Kelp Growth Model (KGM)

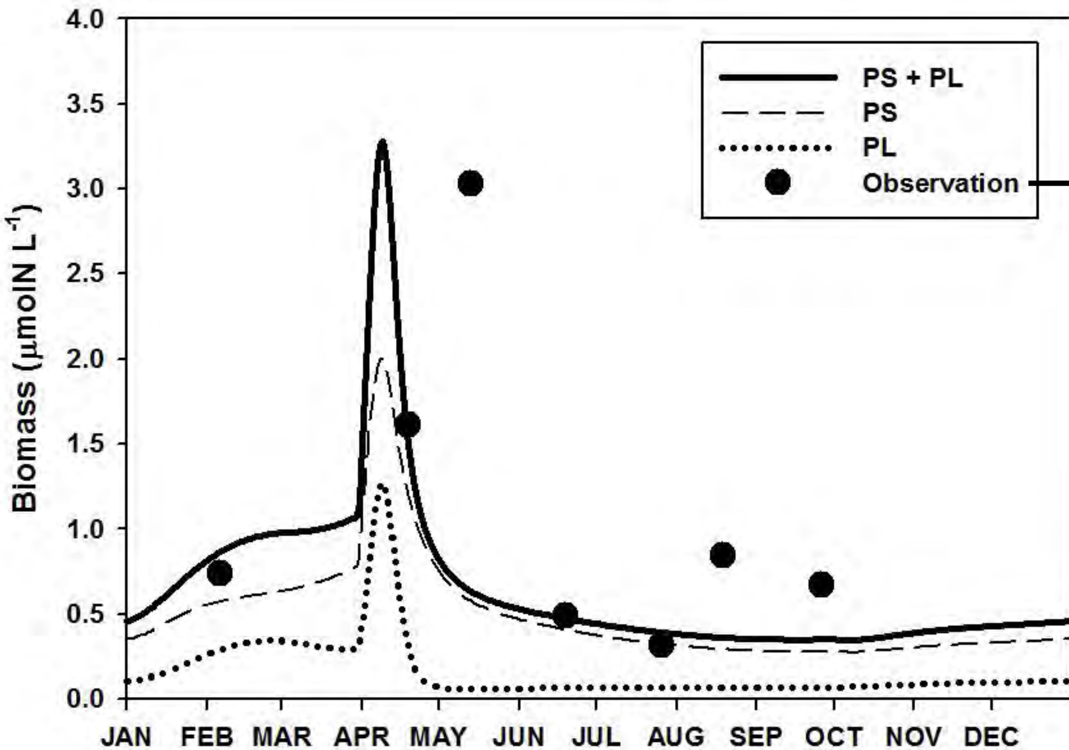



BOX-NEMURO
Light Intensity at the sea surface of station 9
Light Intensity (ly min^{-1})
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
Model Input (Climatic condition)
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Water Temperature at station 9
Water Temperature (°C)
0
5
10
15
20
25
Observation
Model Input
Average in MLD
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Light for photosynthesis
1 m
1 m
MLD
BOX
42°30'
42°30'
42°00'
St. 9
Exchange of nitrate/silicate between the bottom layer
MLD at station 9
Mixed Depth Layer (m)
0
10
20
30
40
50
60
70
80
Observation
Model Input
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
NO_3 concentration at the bottom layer of station 9
NO_3 (μM)
0
2
4
6
8
10
12
14
16
18
20
Observation
Model Input
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

BOX-NEMURO
Model Results



BOX-NEMURO
Model Results vs Observation

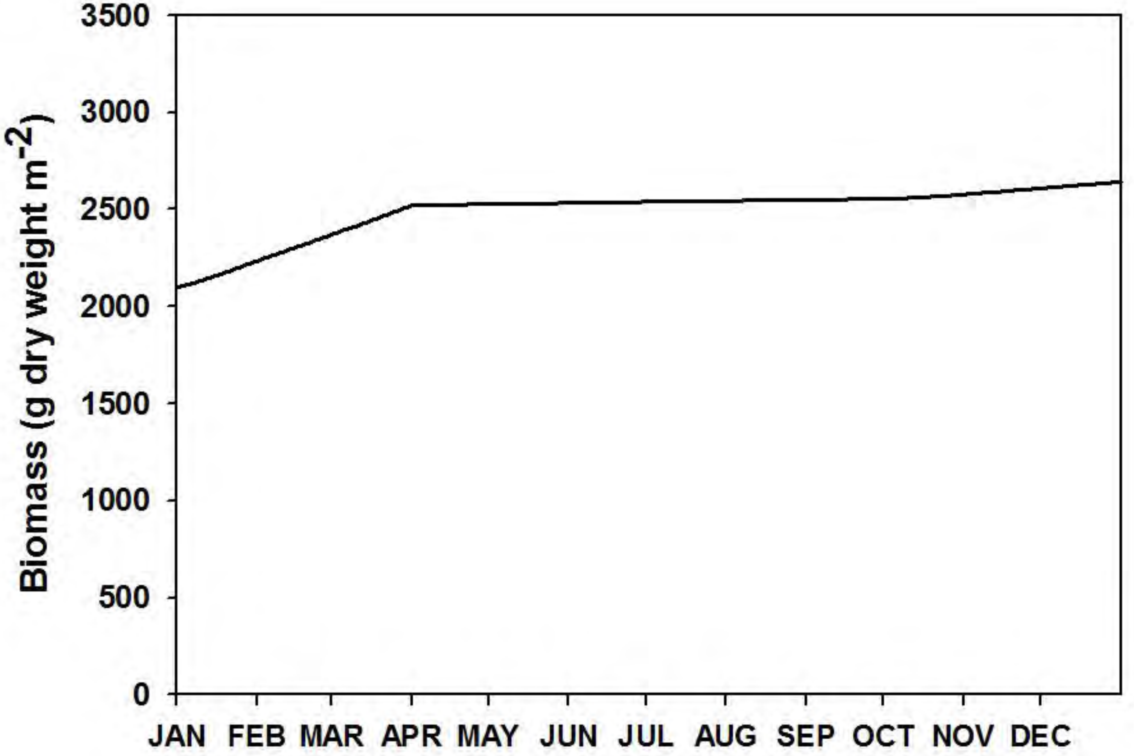


→ **Average in MLD**

[μgChl.a L^{-1}] into [μmolN L^{-1}]

$$\frac{50\ \mathrm{gC}}{1\ \mathrm{gChl.a}} \times \frac{1\ \mathrm{molC}}{12\ \mathrm{gC}} \times \frac{16\ \mathrm{molN}}{106\ \mathrm{molC}}$$

BOX-NEMURO + Kelp Growth Model
Model Results

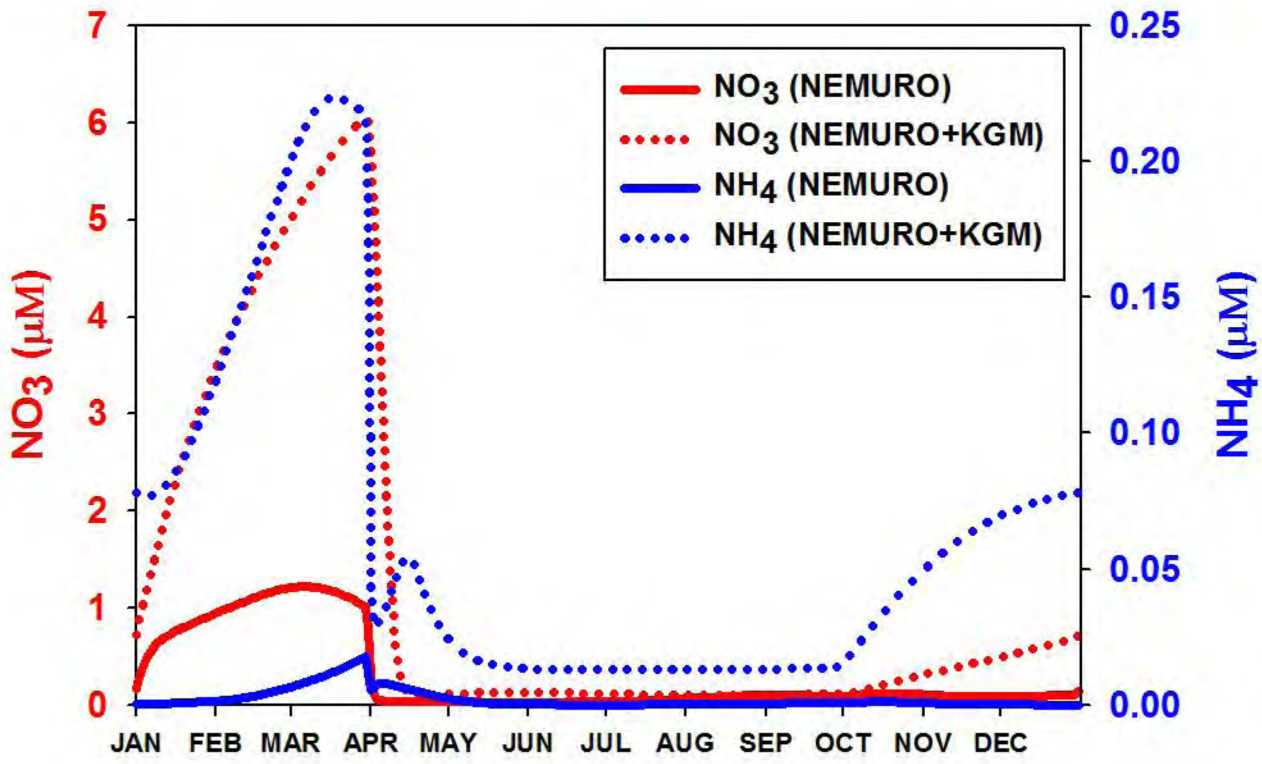


Biomass of kelp

$$\frac{dB}{dt} = \frac{dW}{dt} \times N$$

→ 60 ind m^{-2}

BOX-NEMURO
versus
BOX-NEMURO + Kelp Growth Model



Need to couple to three-dimensional physical model

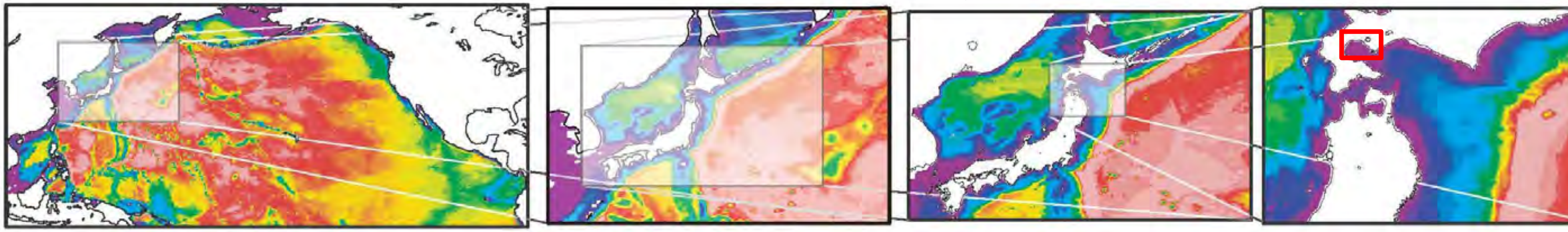
OGCM + Hydrometeological and Runoff Utility Model

Nest0
North Pacific
climatological model

Nest1
Norhwestern Pacific
DA model

Nest2
Around Japan
Adjacent sea model

Nest3
Hokkaido-Tohoku
Coastal model

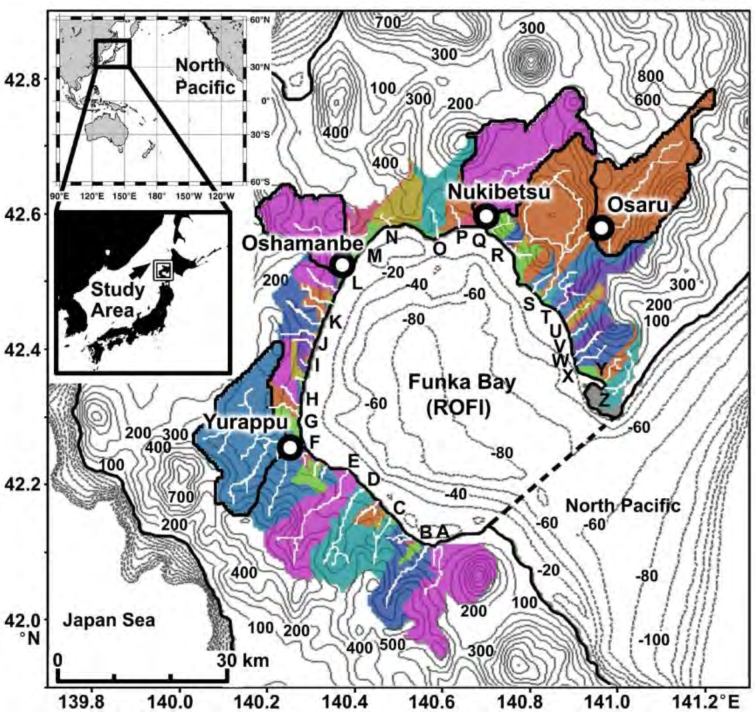


1/6 degree x 1/8 degree
Climatological surface flux

1/6 degree x 1/8 degree
(longitude) (latitude)
4D-Var

1/18 degree x 1/24 degree
(longitude) (latitude)

1/72 degree x 1/54 degree
(longitude) (latitude)
(1.55 km x 1.55 km grid size)

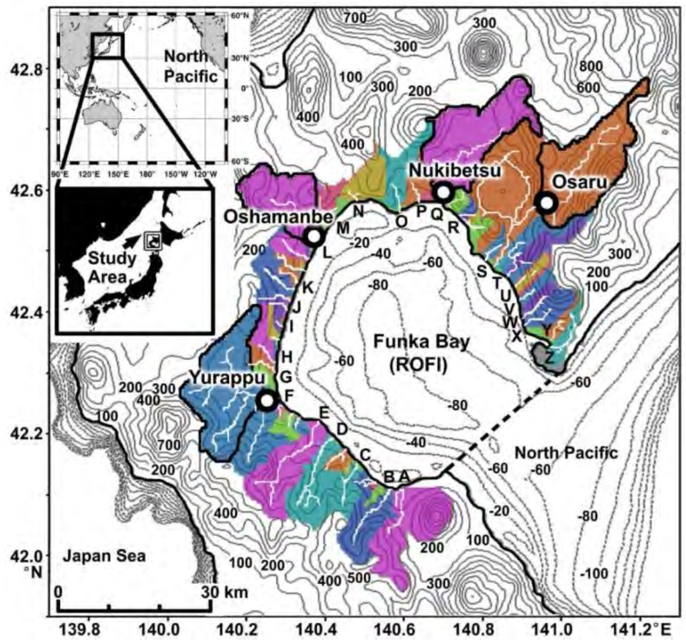


→ lateral open boundary & initial conditions

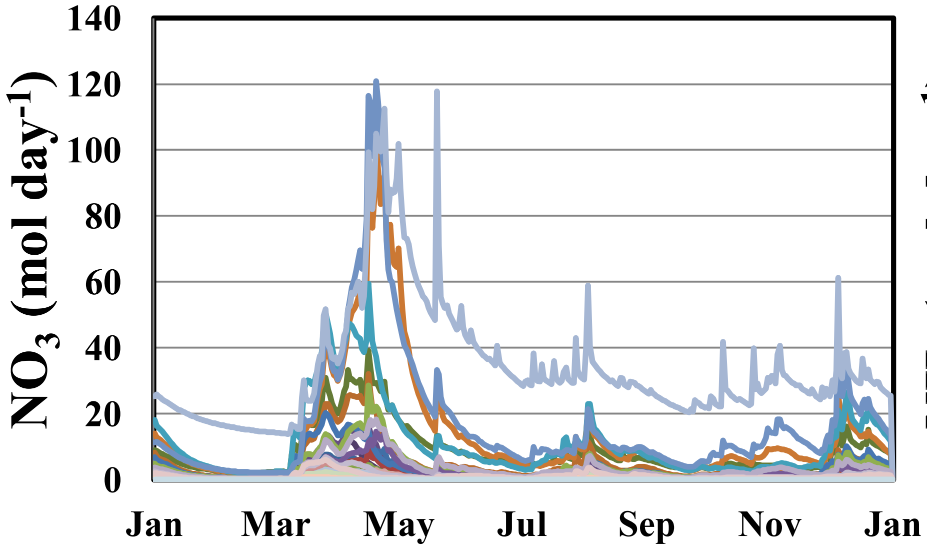
→ lateral open boundary condition

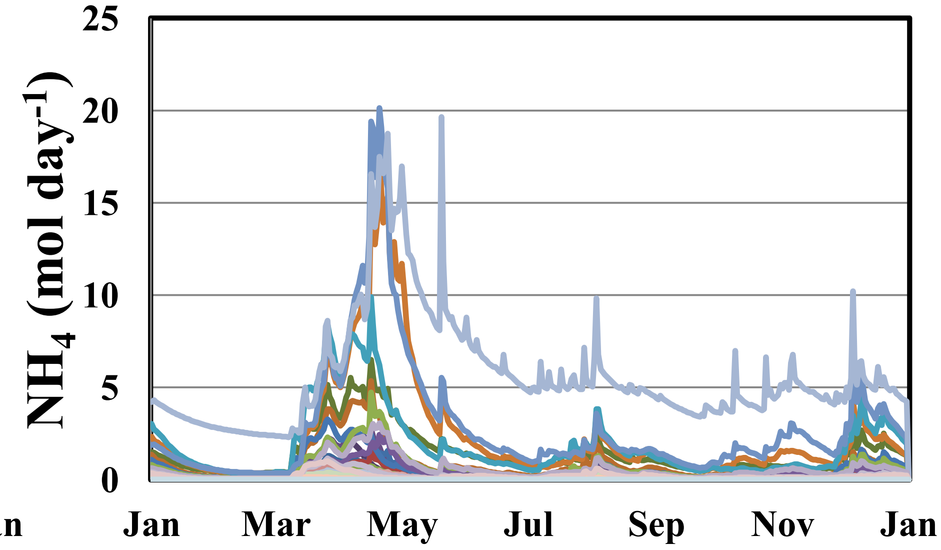
← Locally Coupled with ocean and hydrological models around Funka Bay (Nakada et al., 2012)

Riverine nutrient loads



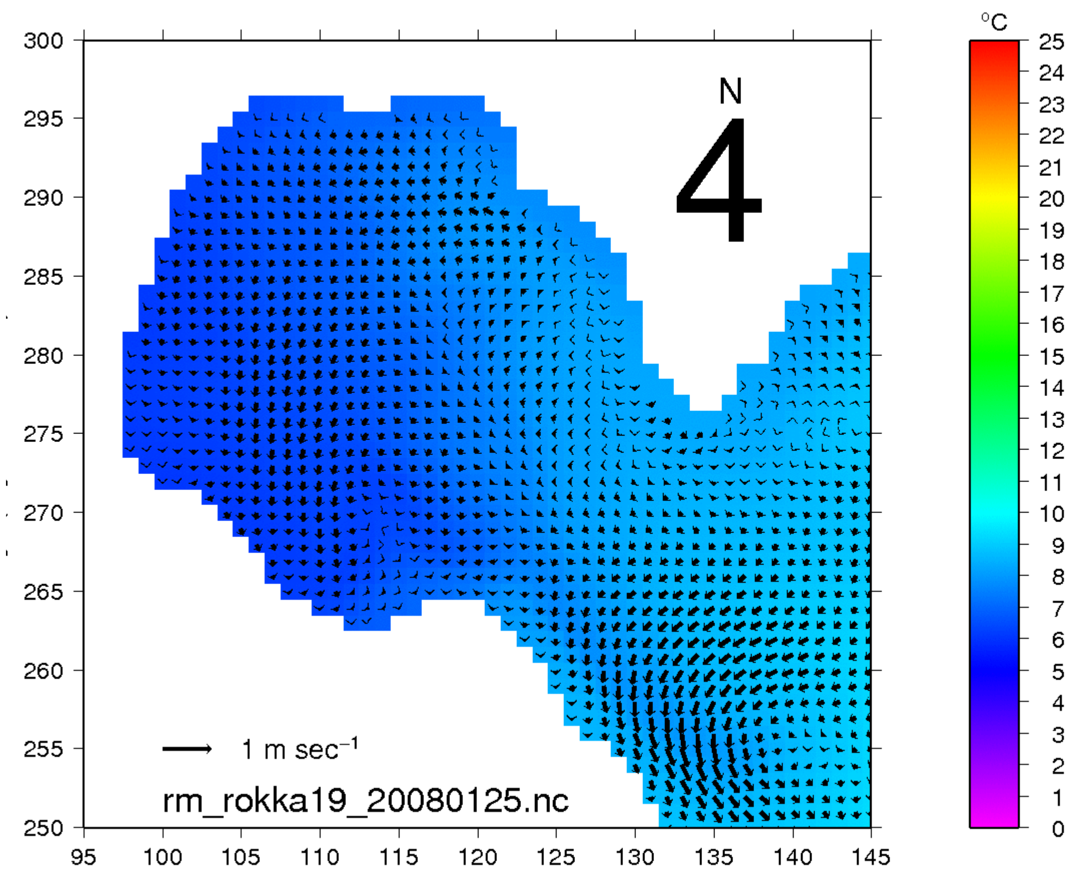
Total nutrient loads
Nitrate: 45164 molN year^{-1}
Ammonium: 7498 molN year^{-1}



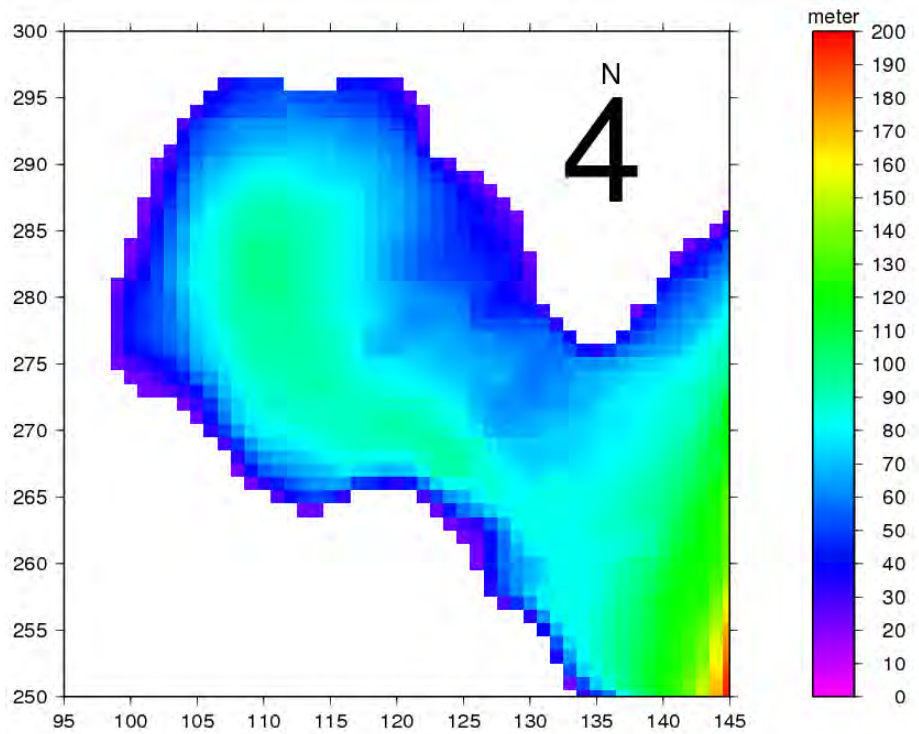


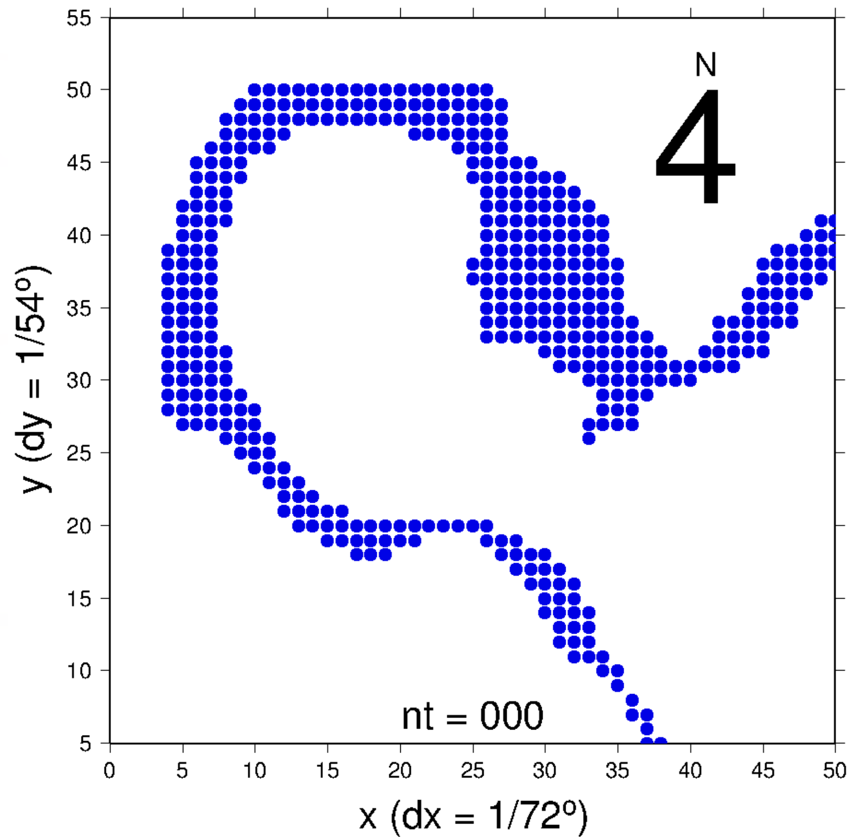
OGCM+HaRUM

Horizontal water temperature & current vector at surface layer



Kelp initial biomass and distribution in 3D model





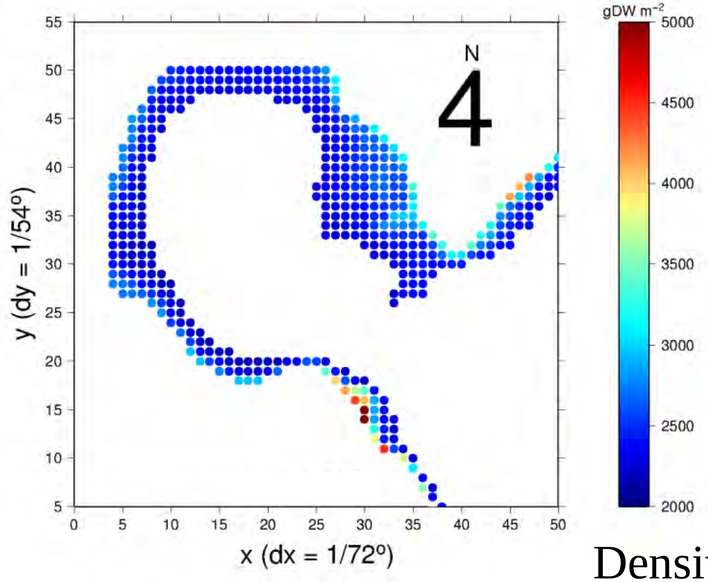
Project Monitoring site1000 (2011)
An individual weight: 35 g dry weight ind^{-1}
Density: 60 ind m^{-2}
Biomass: 2100 g dry weight m^{-2}

Distribution
At the bottom below 50 m depth

3D modeling results

CASE01

Riverine NO3: 45164 molN yr^{-1}
Riverine NH4: 7498 molN yr^{-1}
Initial weight: 35 gDW ind^{-1}
Density: 60 ind m^{-2}
Initial biomass: 2100 gDW m^{-2}

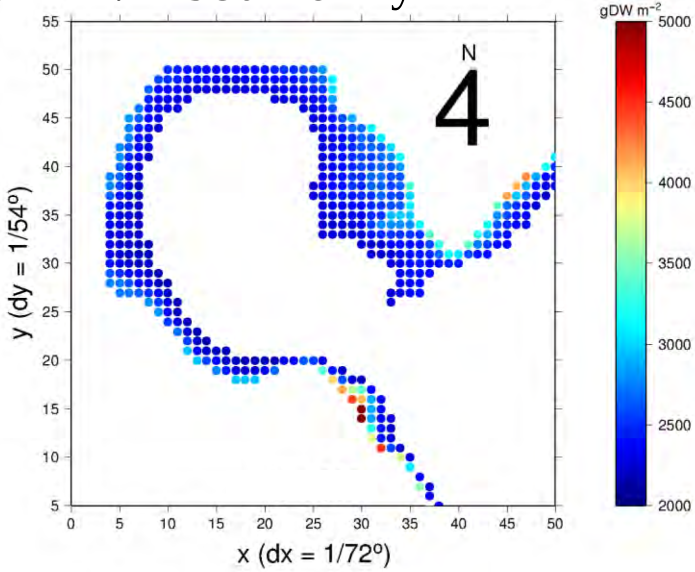


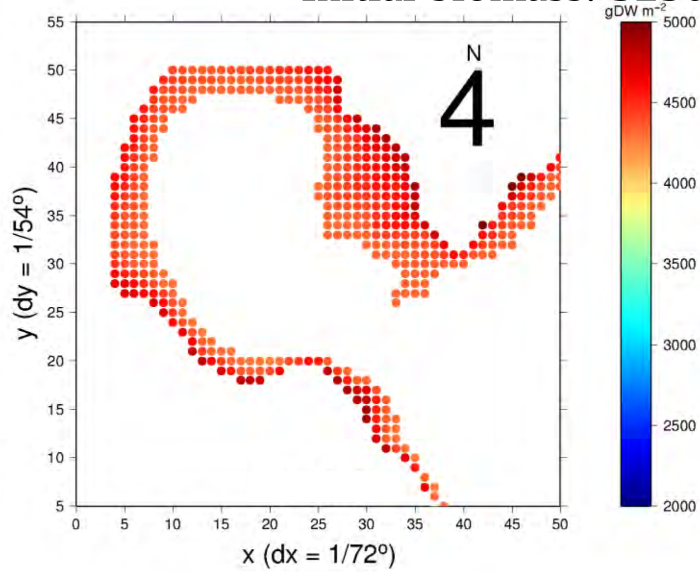
CASE02

Riverine NO3: 451640 molN yr^{-1}
Riverine NH4: 74980 molN yr^{-1}

CASE03

Density: 150 ind m^{-2}
Initial biomass: 5250 gDW m^{-2}





Conclusions

- We developed an ecosystem model by coupling a kelp growth model with 3D NEMURO.

- Though riverine nutrient loads increased, kelp biomass was almost same because those did not reach to the bottom where kelps inhabit.

- When kelp density increased, the individual weight decreased due to nutrients deficiency.