Can we explain and predict stock fluctuations of Japanese common squid, *Todarodes pacificus* related to climatic regime shifts?

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Background

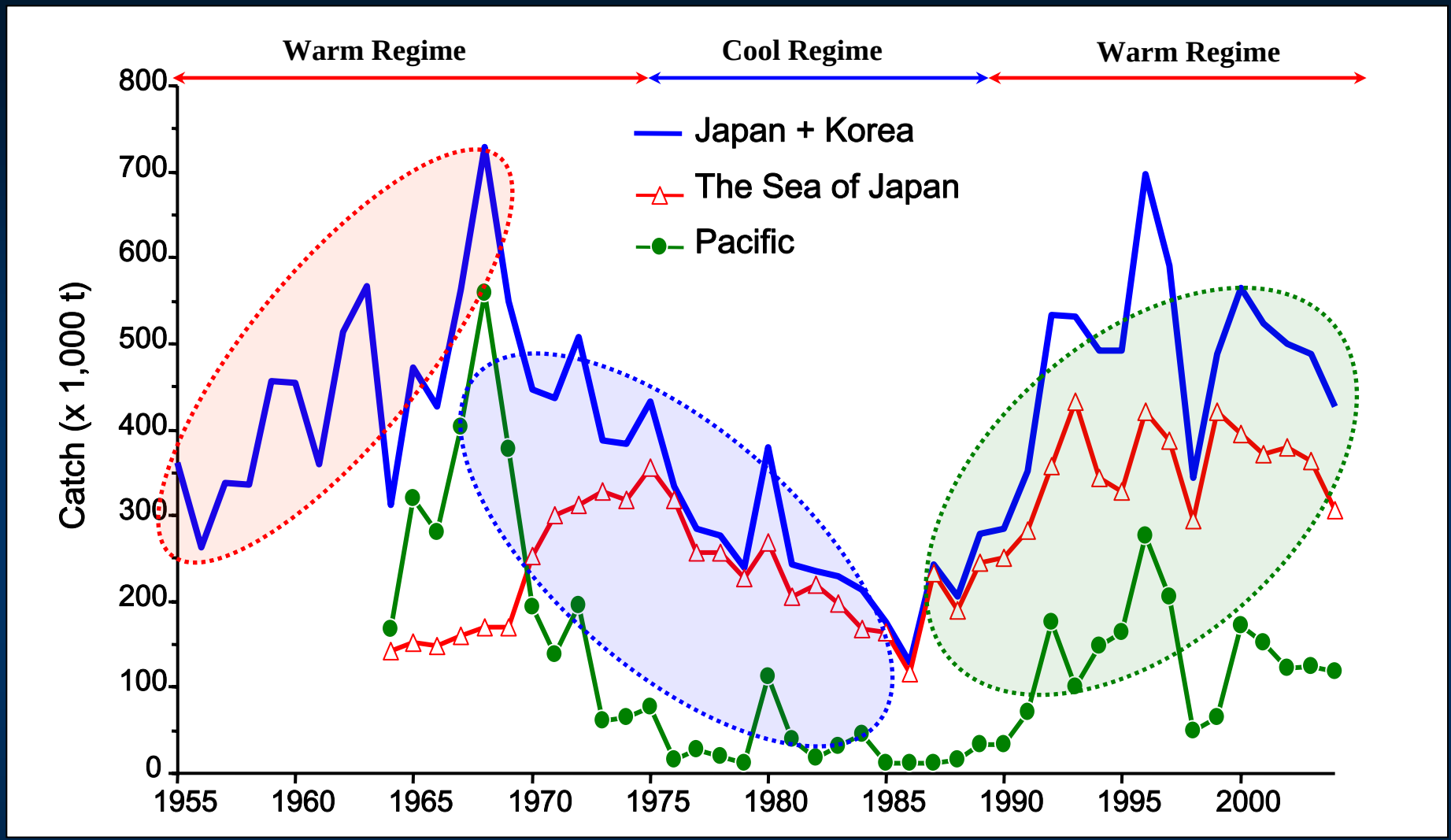
• Recruitment success in squids depends largely on environmental conditions at the spawning and nursery grounds

・ Stock size in Japanese common squid, *Todarodes pacificus* might fluctuate due to environmental factors such as the winter wind stress, air temperature, and mixed layer depth at the spawning grounds.

Objective

・ How to predict stock fluctuation of common squid related to climate change, based on the new reproduction and recruitment scenario.

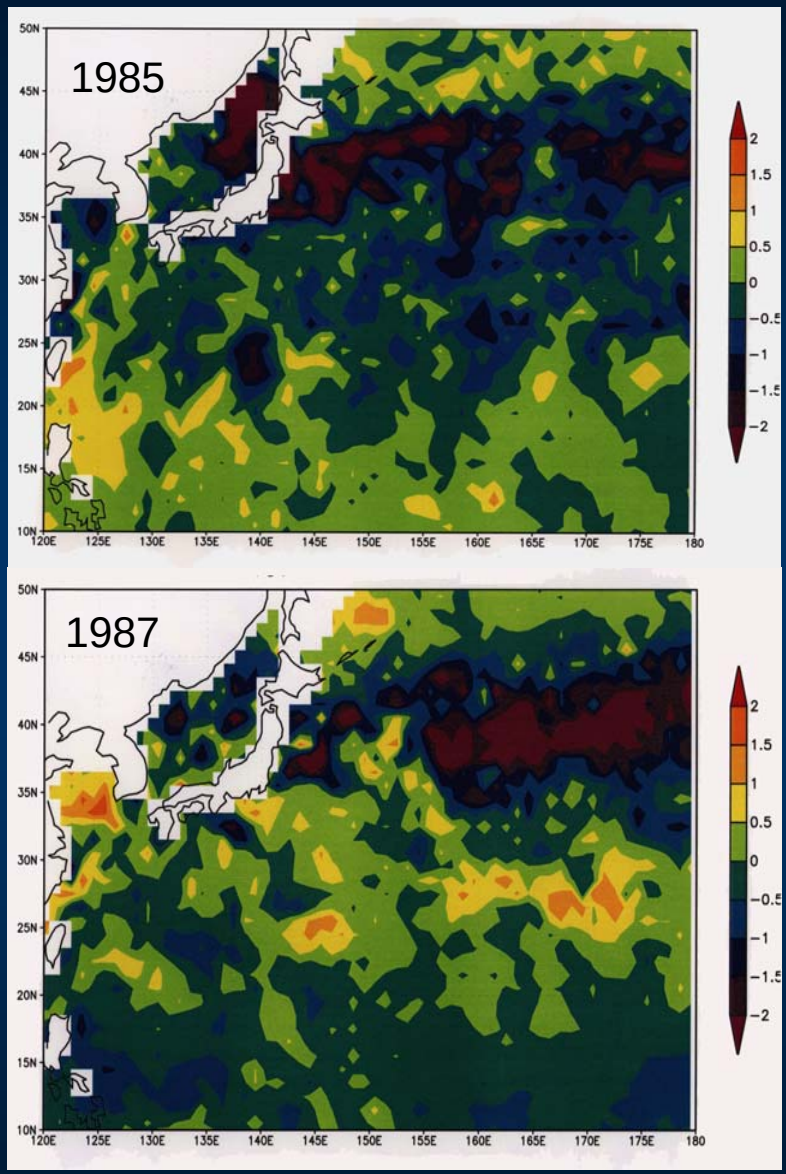
Spawning grounds and migration routes of *T. pacificus*



Annual fluctuation in common squid, *T. pacificus* catches of Korea and Japan during 1955 - 2004.

(Data derived from the Japan Sea Research Institute, Japan and the National Fisheries Research and Development Institute, Korea).

Regime shift

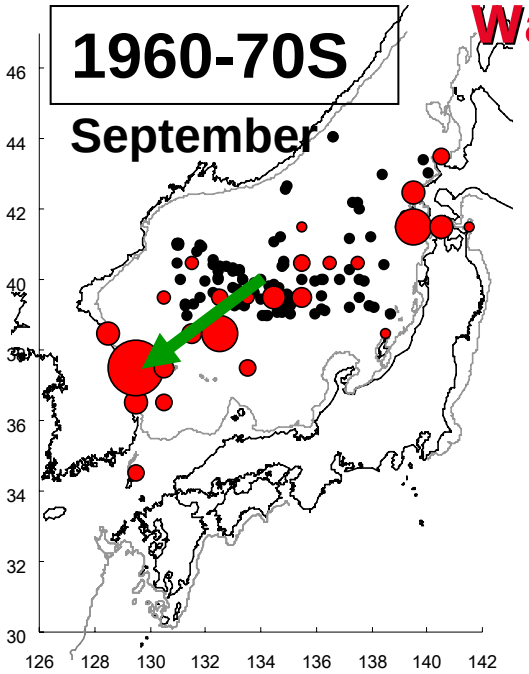


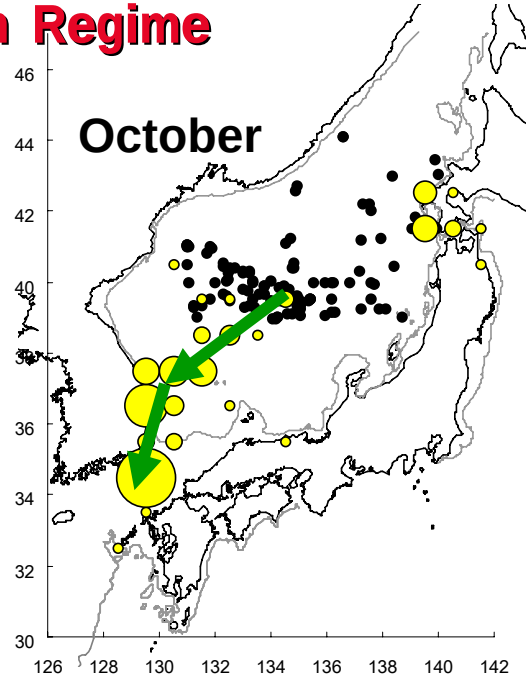
Sea surface temperature anomaly in February

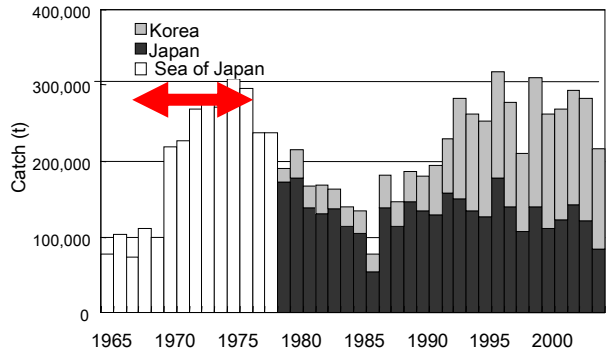
(Noto & Yasuda, 1999)

Routes of spawning migration based on the release & catch data of tagged squids

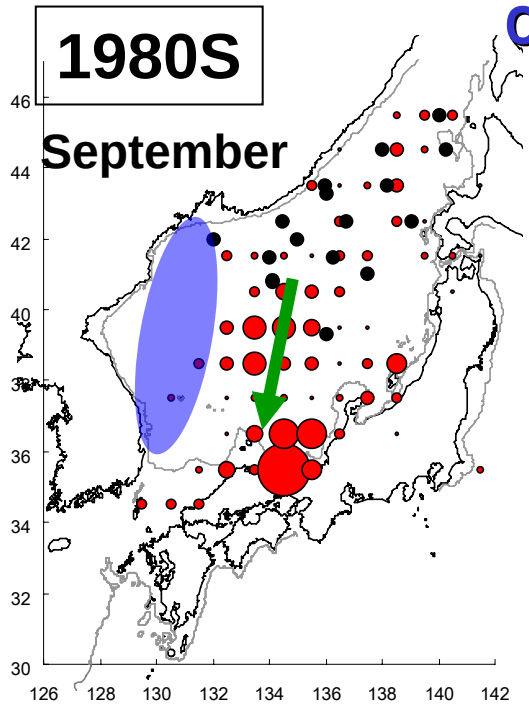
Warm Regime

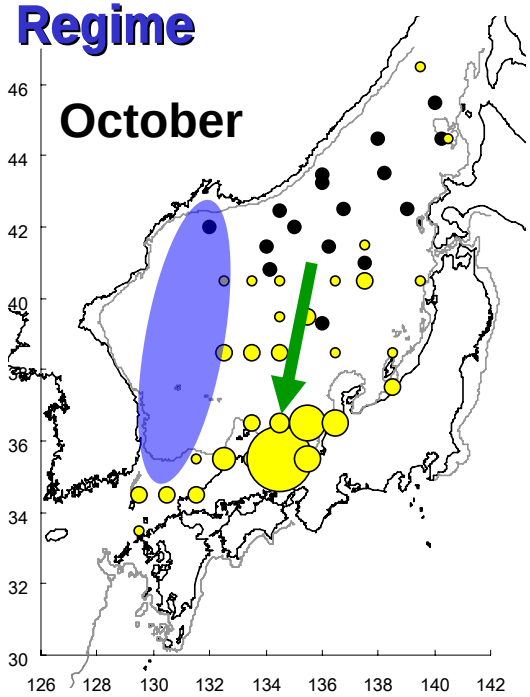


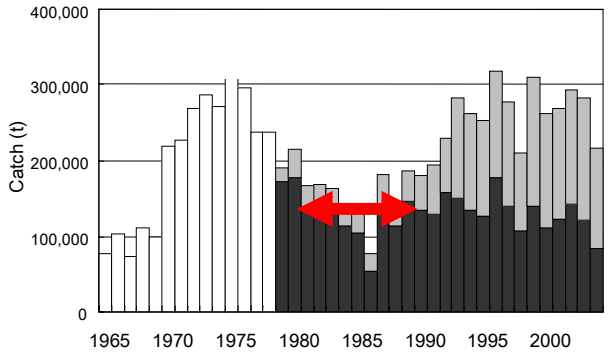




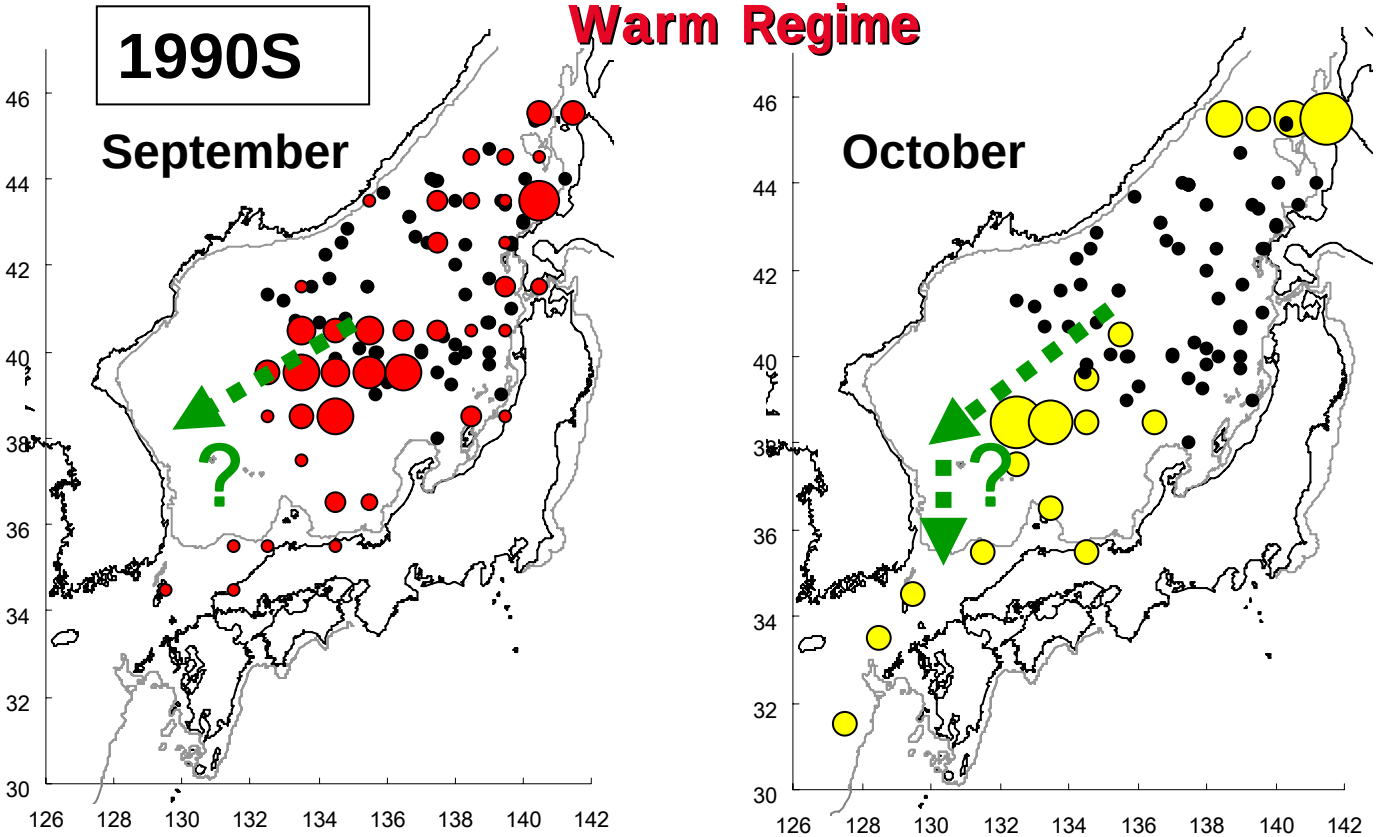
Cool Regime



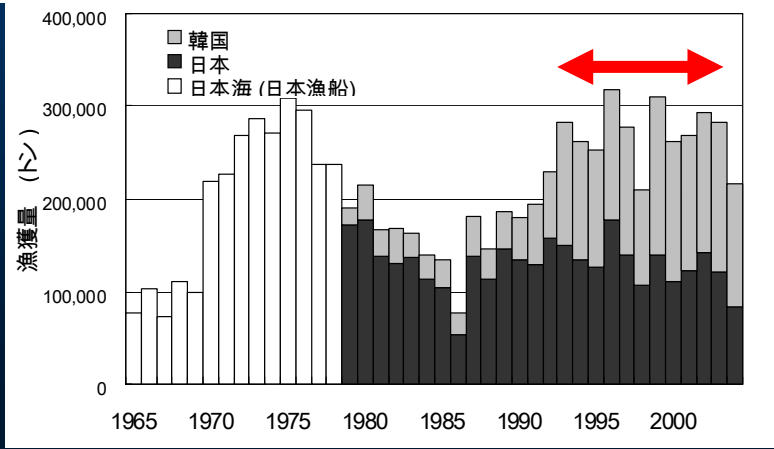




Kidokoro (Pers. Com.)



Routes of spawning migration based on the release & catch data of tagged squids



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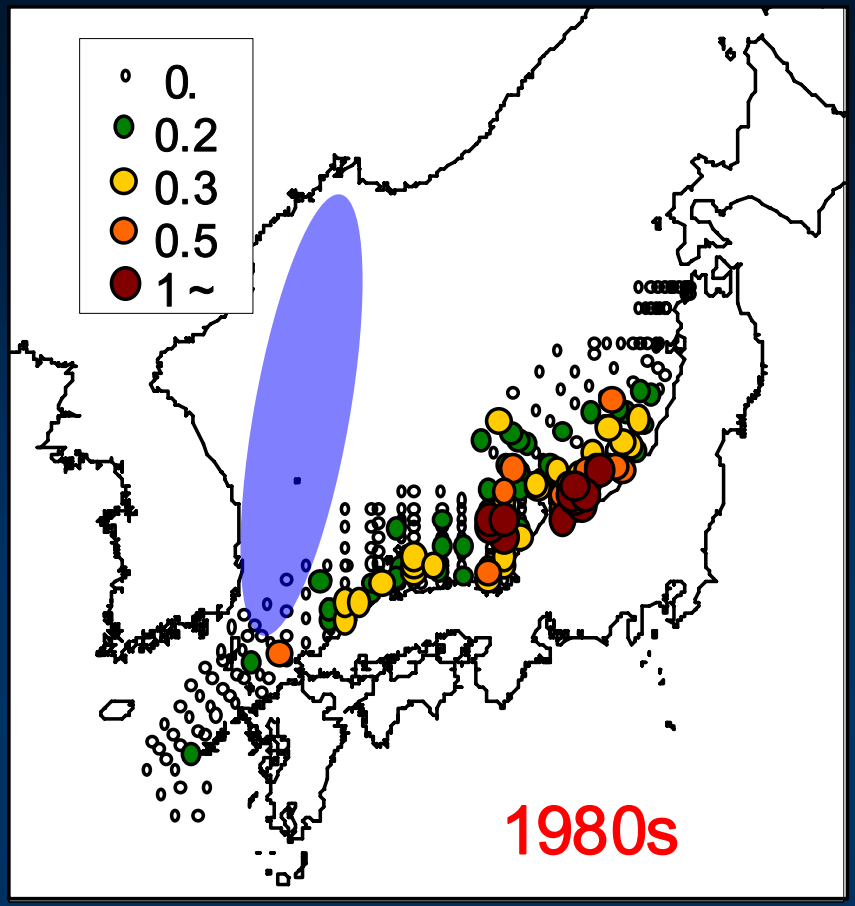
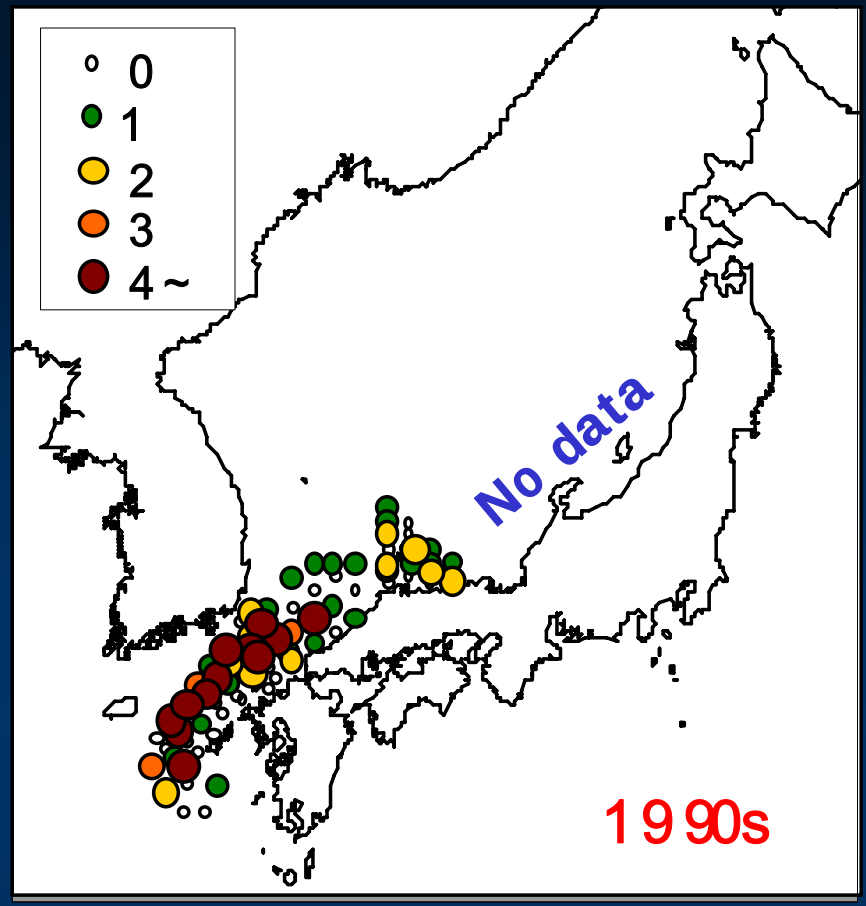




Changes of distribution patterns of *T. pacificus* paralarvae of autumn spawning group in 1980's (cool regime) and 1990's (warm regime). (No. of paralarvae/tow).

(T. Goto et al., 2005)

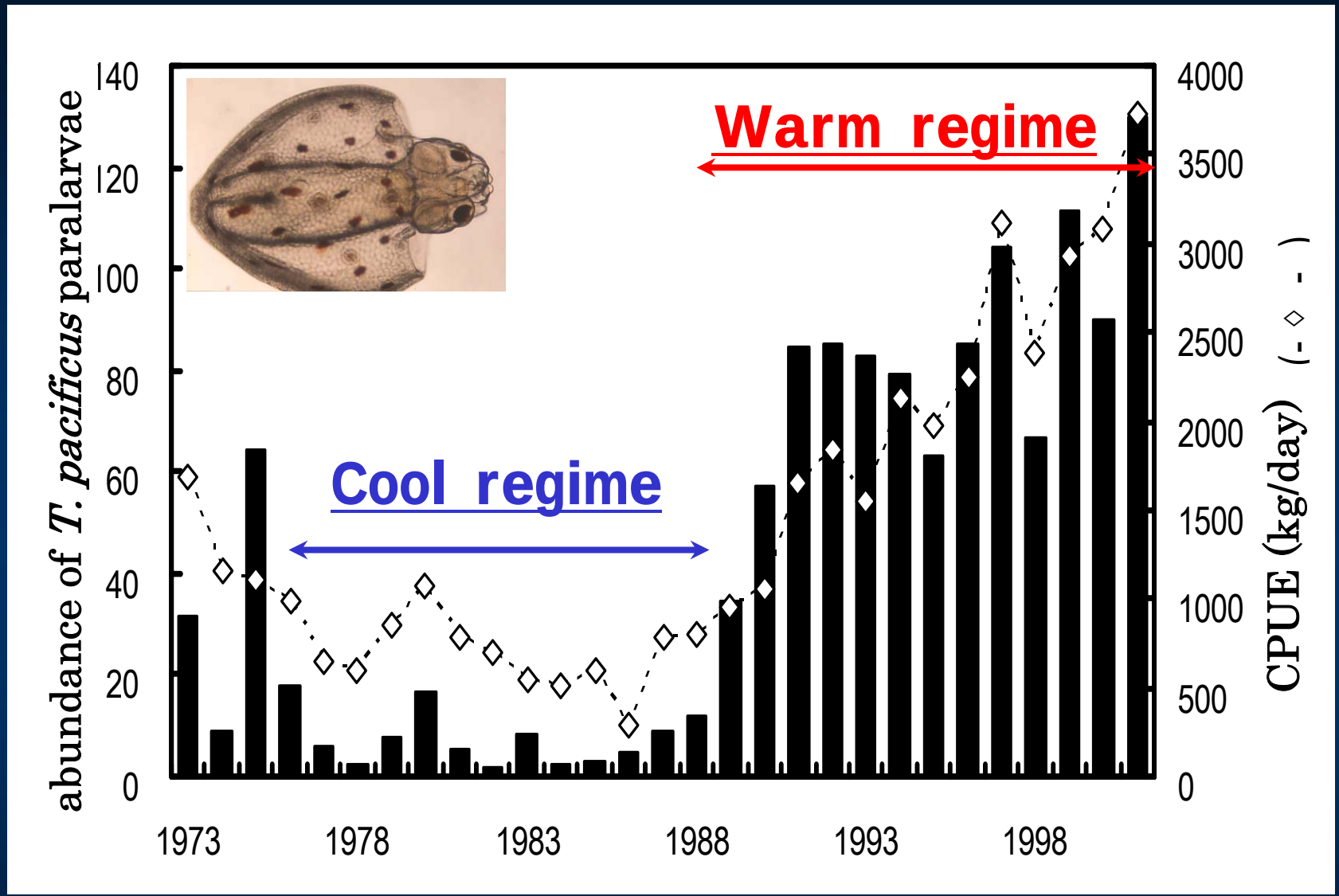
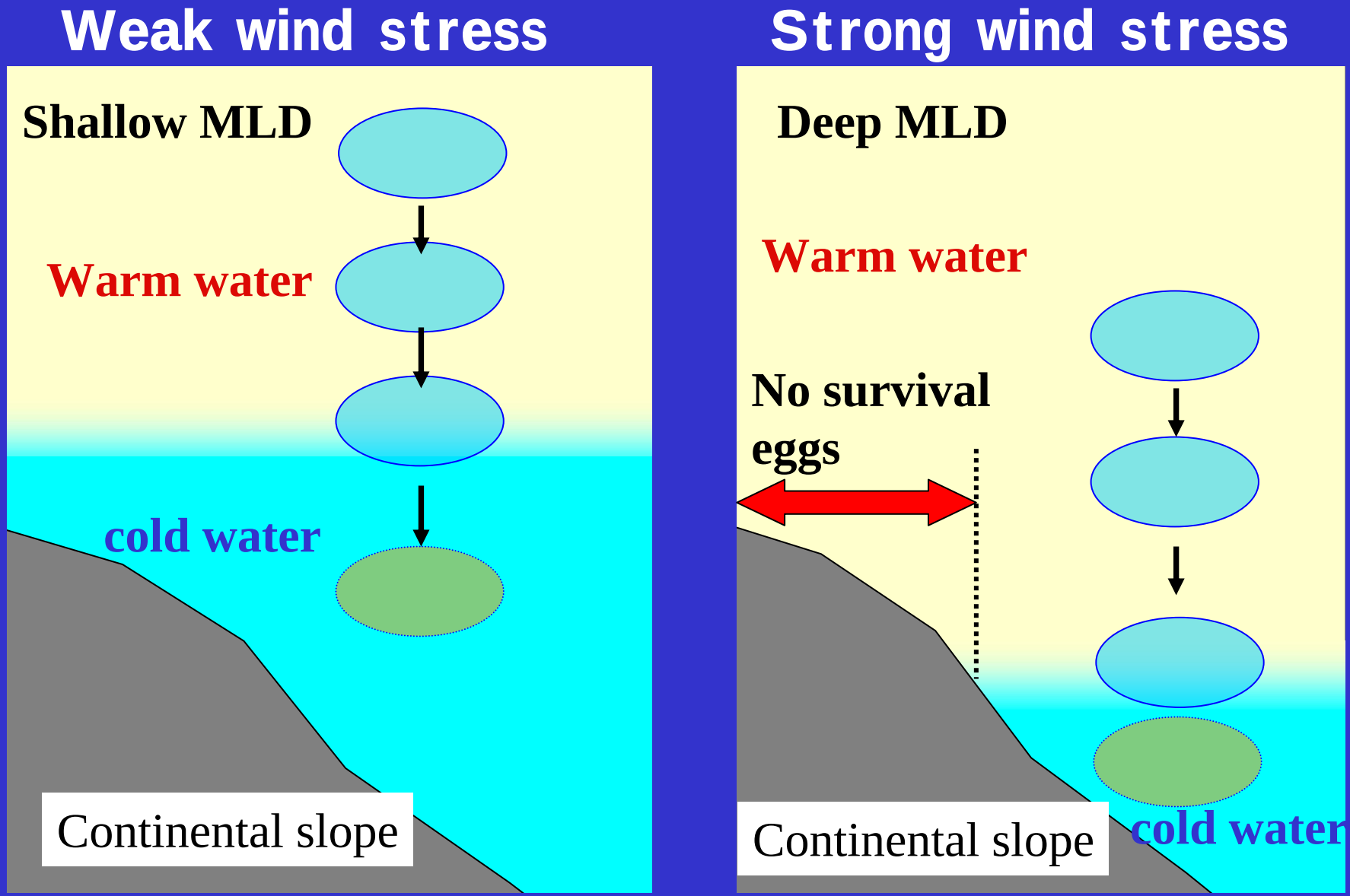


Fig. Annual changes of abundance of *T. pacificus* paralarvae / 1000m^3 (Oct-Nov) and CPUE (kg/day , May-Oct, Japan Sea) (Goto *et al*, 2002)

Stock fluctuations of Japanese common squid (*Todarodes pacificus*) related to climate change

*How do climatic changes affect stock size through the reproduction and recruitment process? Is it sea water temperature, wind stress or MLD ?

*How do changes of wind stress, sea and air temperature or MLD affect the success of reproduction?


Weak wind stress
Shallow MLD
Warm water
cold water
Continental slope
Strong wind stress
Deep MLD
Warm water
No survival
eggs
Continental slope
cold water

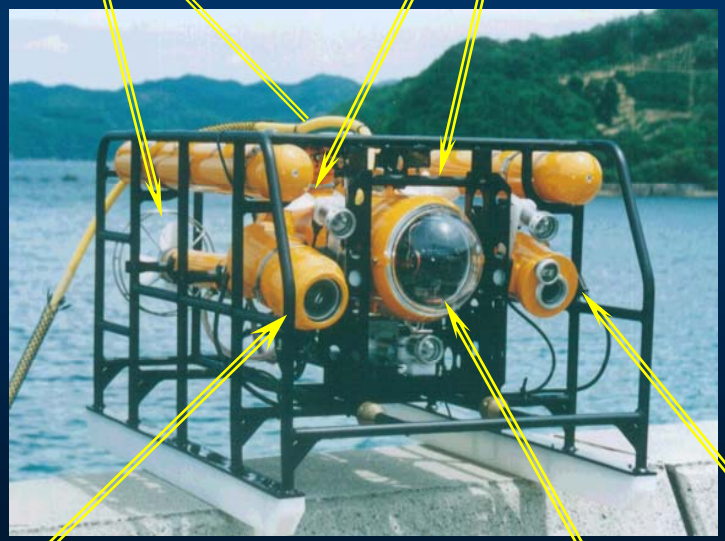
Natural egg mass survey using ROV

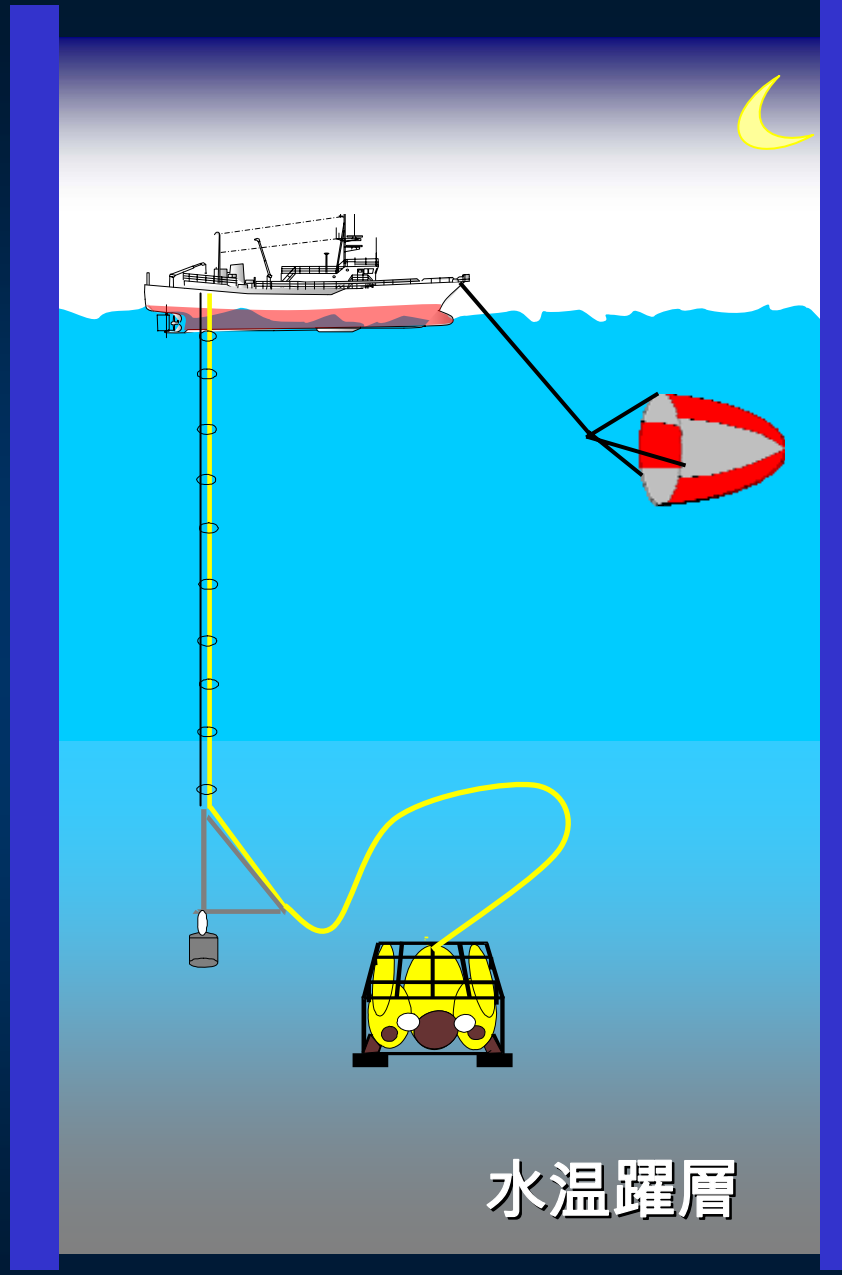
ROV (Expert Nova System , KOWA Co.Ltd.)

Equipments :

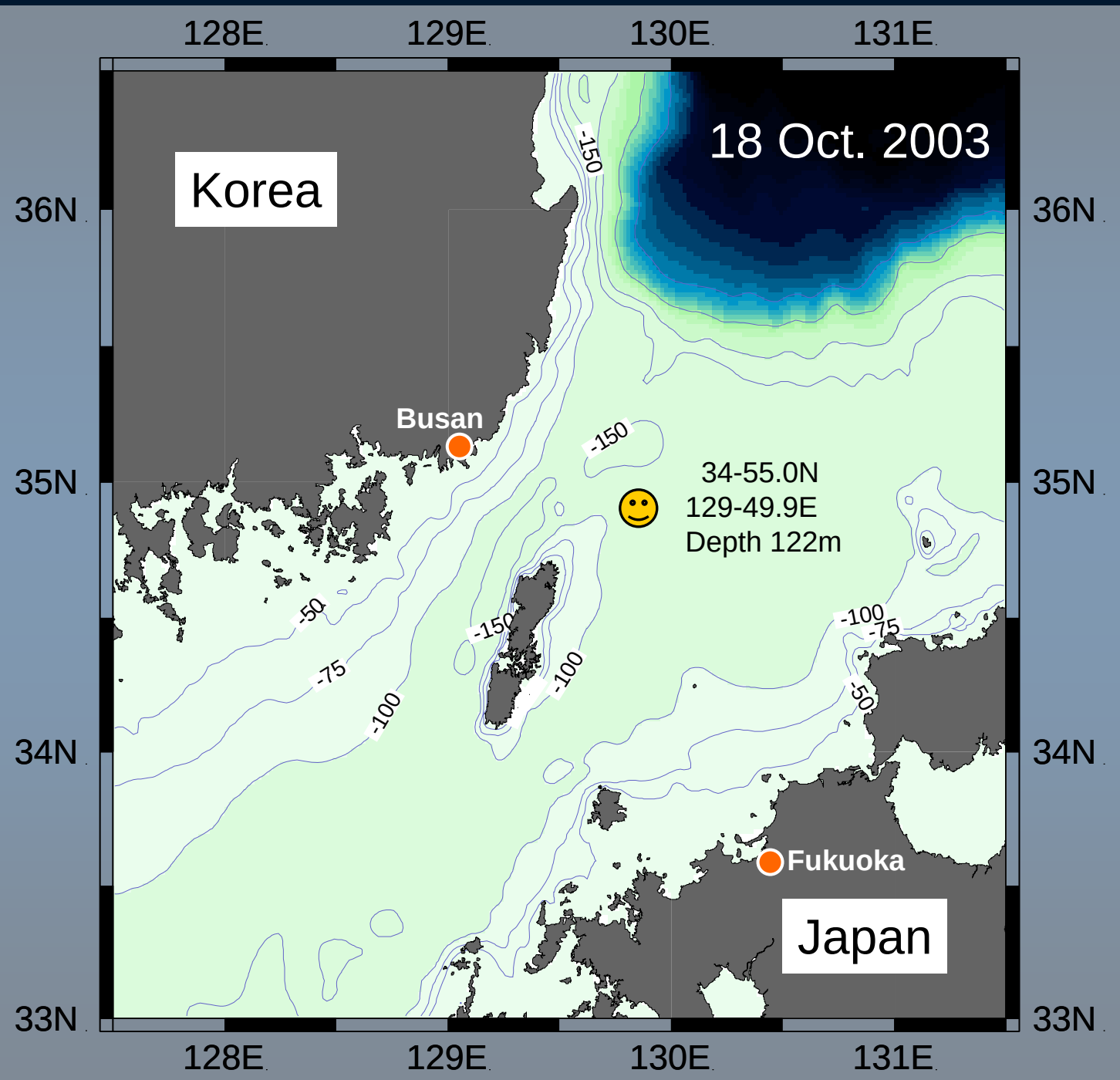
- Two pairs of thrusters
  Horizontal and Vertical
- 3 Cameras
  3CCD, video and 35-mm

Capacity to resist depth : 400m





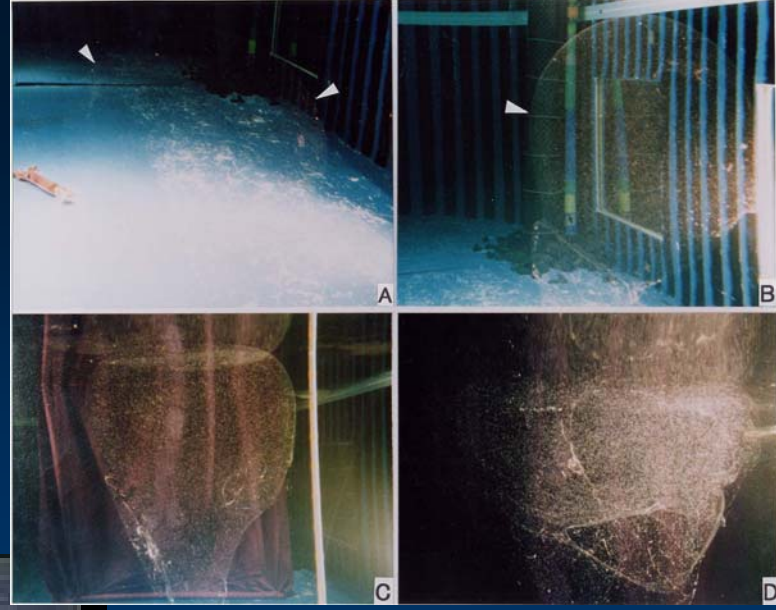
Schema of ROV observation


128E
129E
130E
131E
36N
35N
34N
33N
18 Oct. 2003
Korea
Japan
Busan
Fukuoka
34-55.0N
129-49.9E
Depth 122m
-150
-50
-75
-100

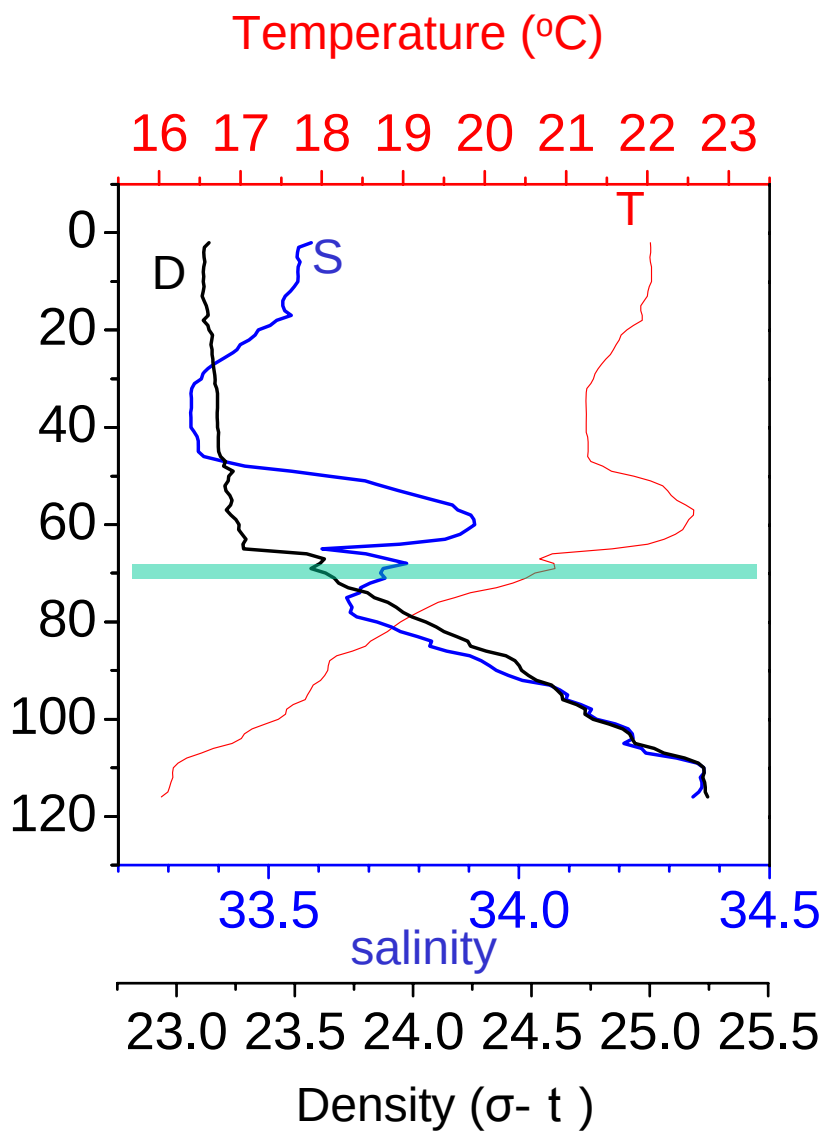
Gelatinous sphere mass resembling *T. pacificus* egg mass observed by J. Yamamoto

（Depth:80m, Temp:21℃, Oct. 18, 2003）

Gelatinous sphere mass resembling *T. pacificus* egg mass （Depth:80m, Temp:21℃，Oct. 18, 2003）



Egg mass of *T. pacificus* in captivity

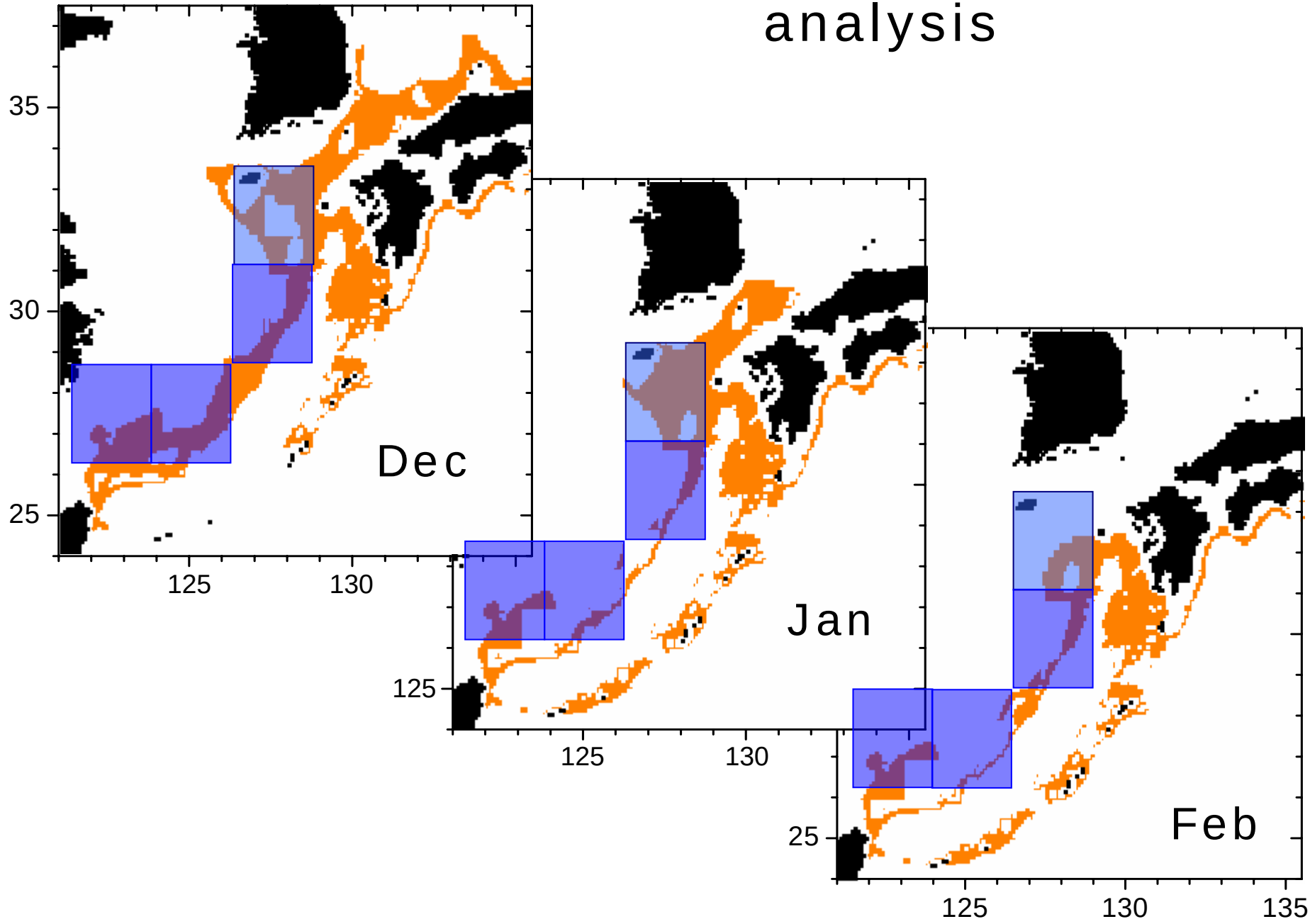


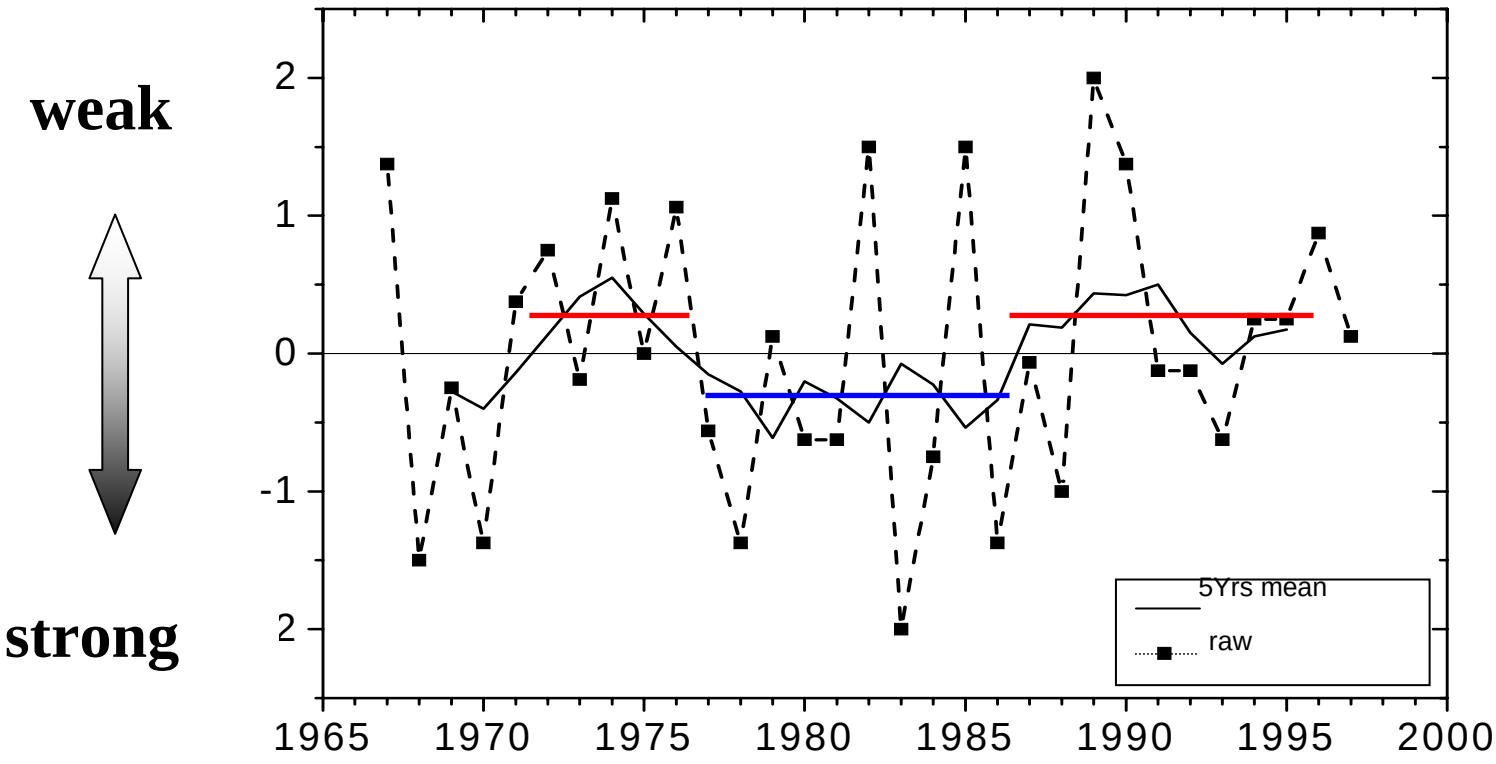
Vertical hydrographic features at the ROV station

The egg masses of *T. pacificus* are thought to occur within or above the pycnocline at temperatures suitable for egg development (15-23℃)

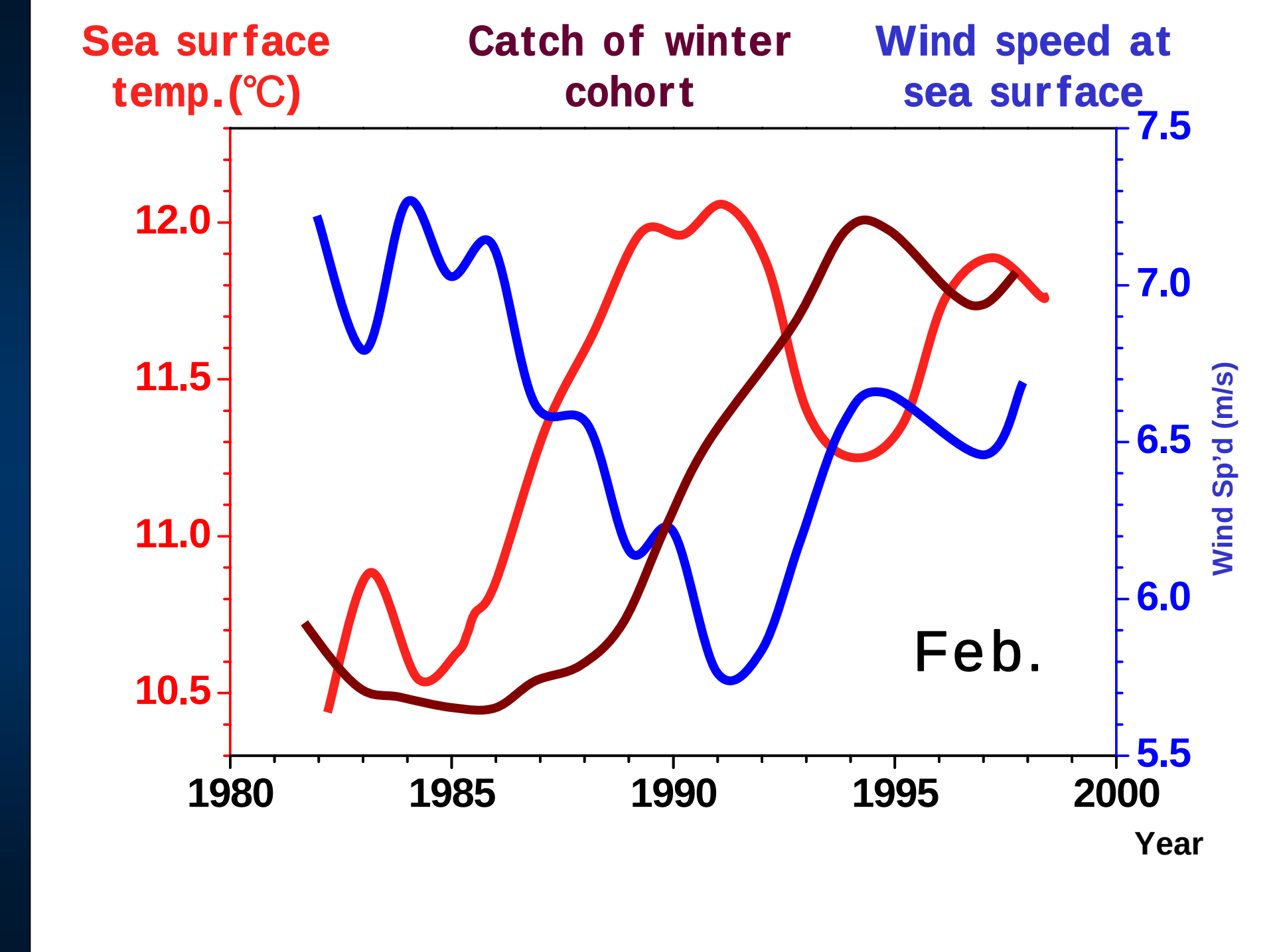
However, we found a jelly-like mass at 21℃, not in cold water.

Survey areas for meteorological and MLD analysis





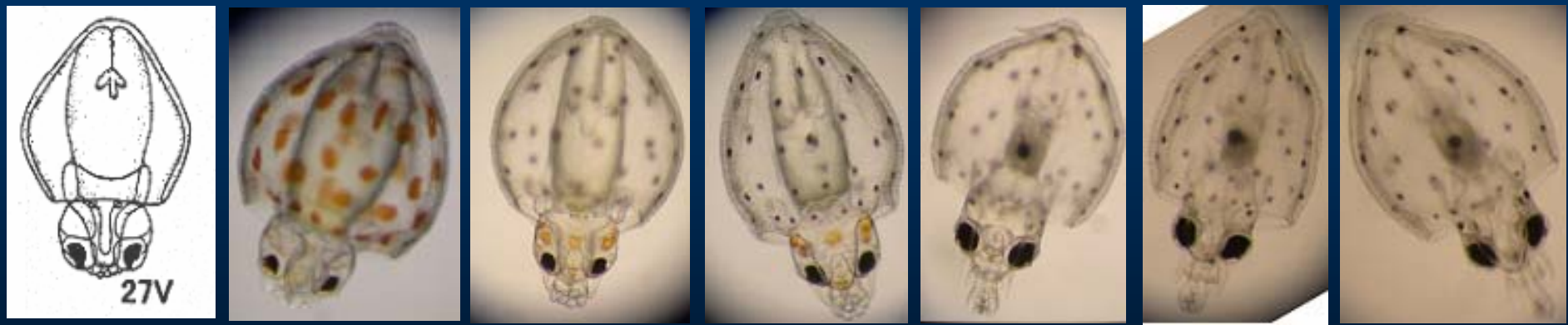
Annual change of Aleutian low pressure index. **(Nakamura and Honda, 2002)**


Sea surface temp.(℃)
Catch of winter cohort
Wind speed at sea surface
12.0
11.5
11.0
10.5
7.5
7.0
6.5
6.0
5.5
Wind Sp'd (m/s)
1980
1985
1990
1995
2000
Year
Feb.

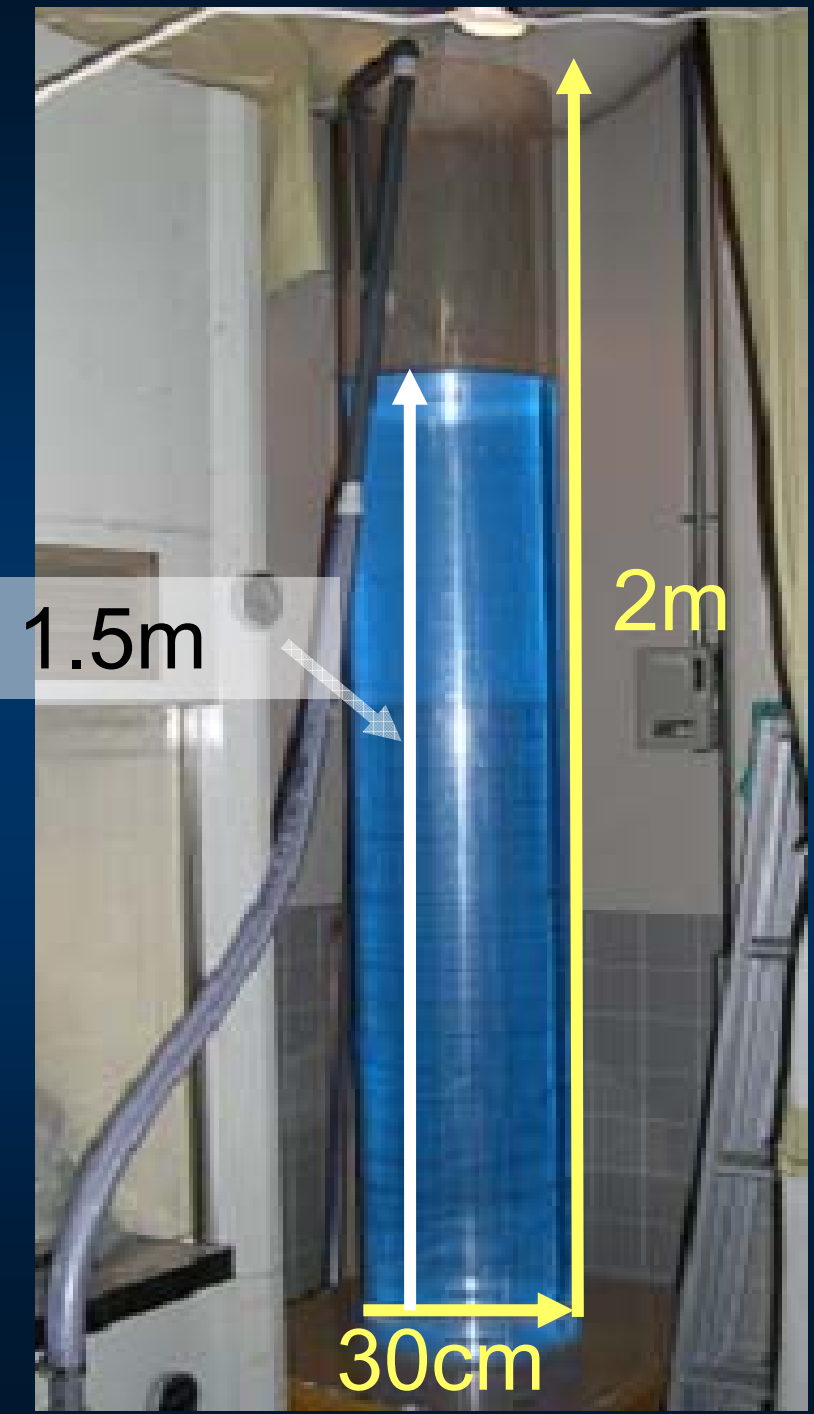
What development stage can hatchlings ascend from near thermocline to the surface in the same temperature range of 15-23℃ for normal embryonic development?

(Miyanaga et. al., 2006)

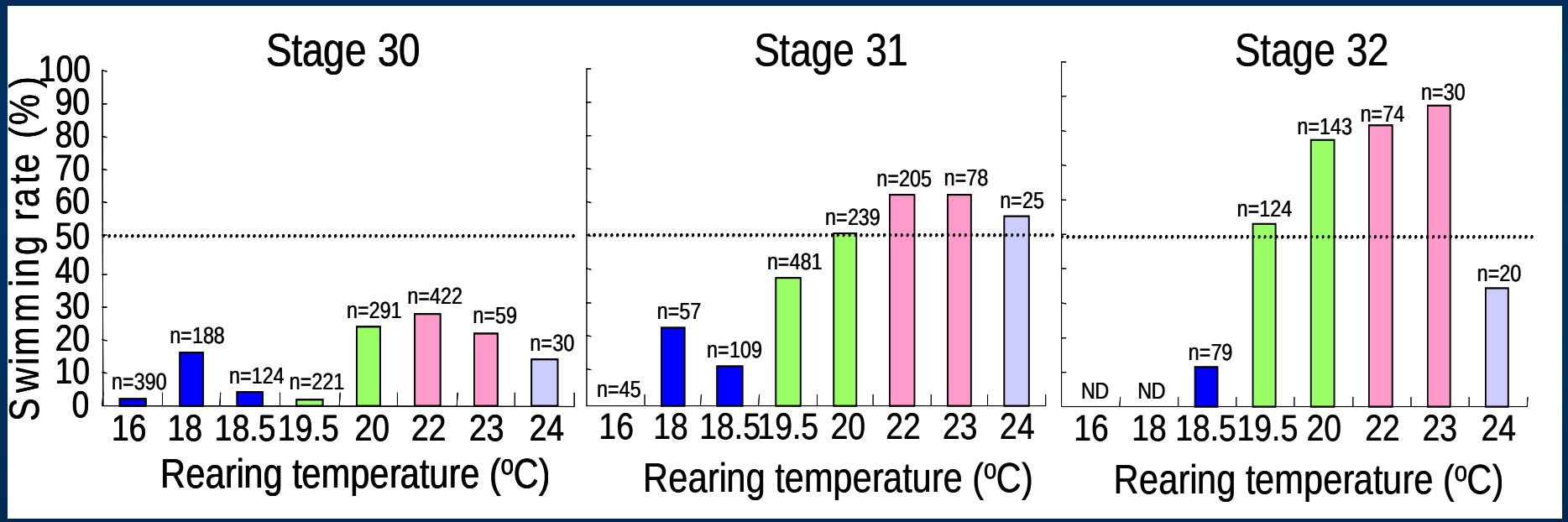
Development stage of hatchling (Watanabe *et al.*, 1996)



stage27 stage28 stage29 stage30 stage31 stage32 stage33

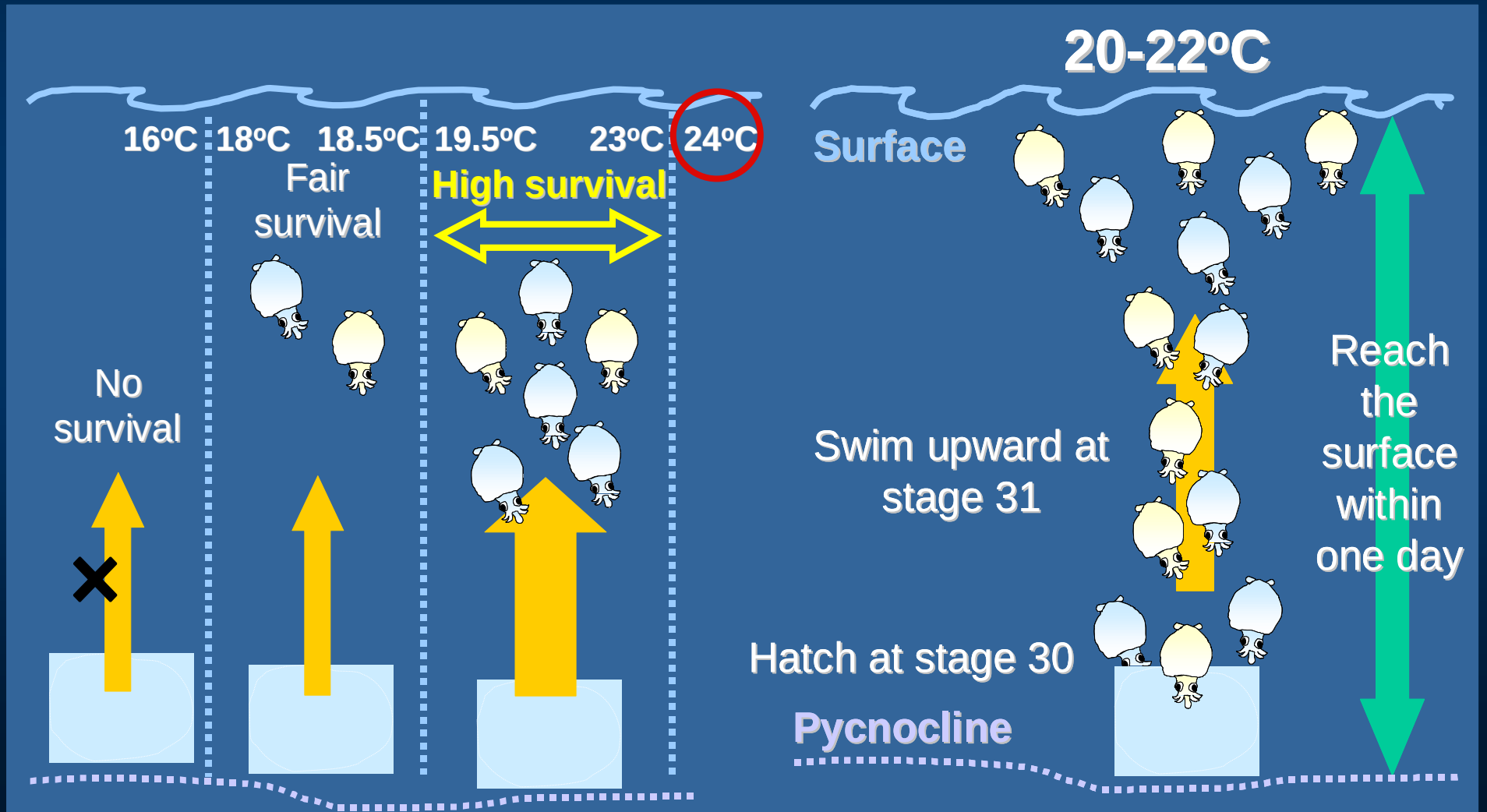


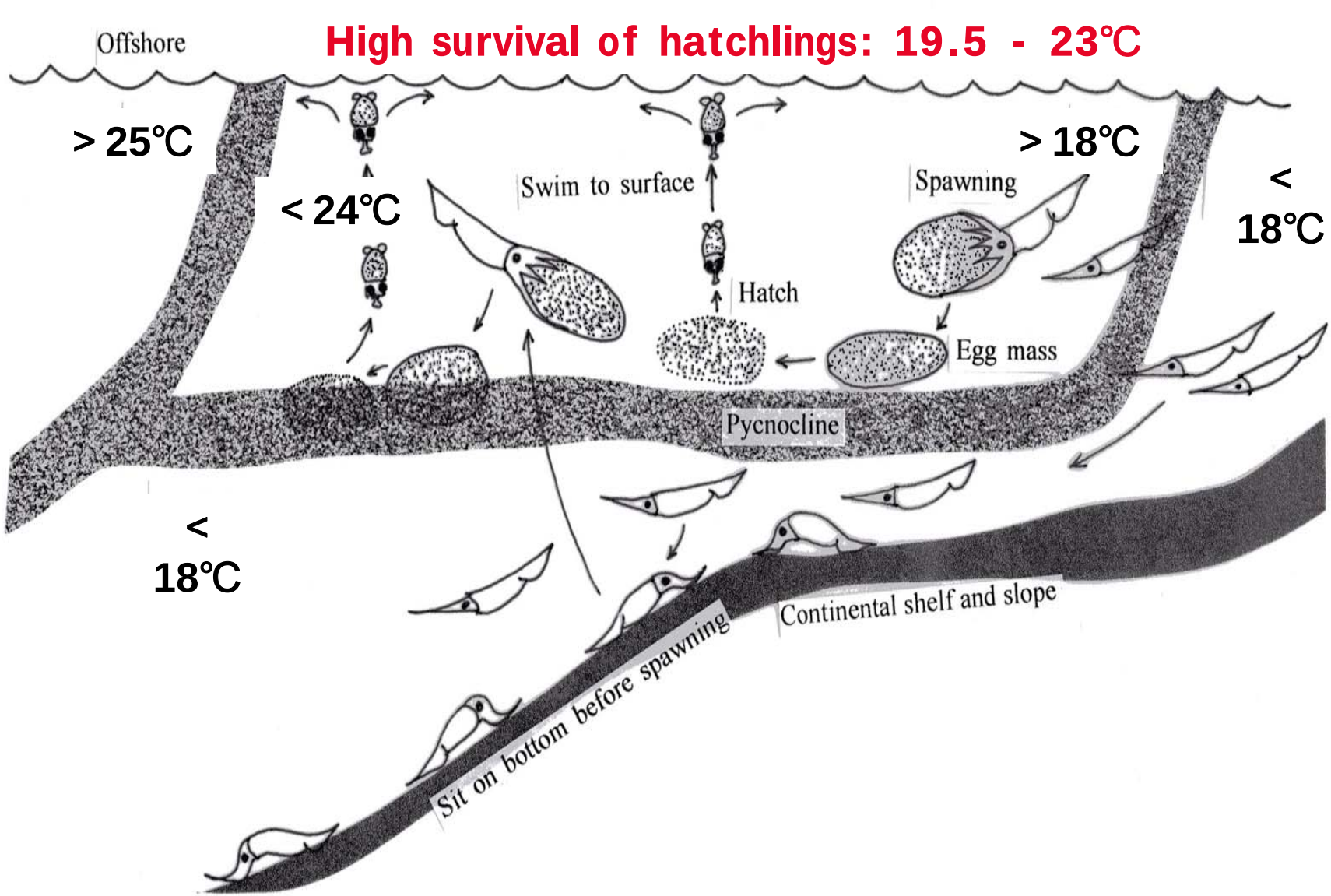
Measurement of vertical swimming speed of hatchling at different development stage and temperature (15-23℃) using a transparent columnar tank.



For paralarvae reared at 19.5-23℃, swimming rates were higher at stage 31 than at stage 28-30. Swimming began at stage 31.

Fair and high survival of eggs and hatchlings occur at 18-23℃, and 19.5-23℃, and can survive at the surface layer of 24℃. Hatch occurs at stage 28-29. Hatchlings stay near the egg mass by stage 30 and ascend to sea surface after stage 31 within one day from a few hundred meters in deep.

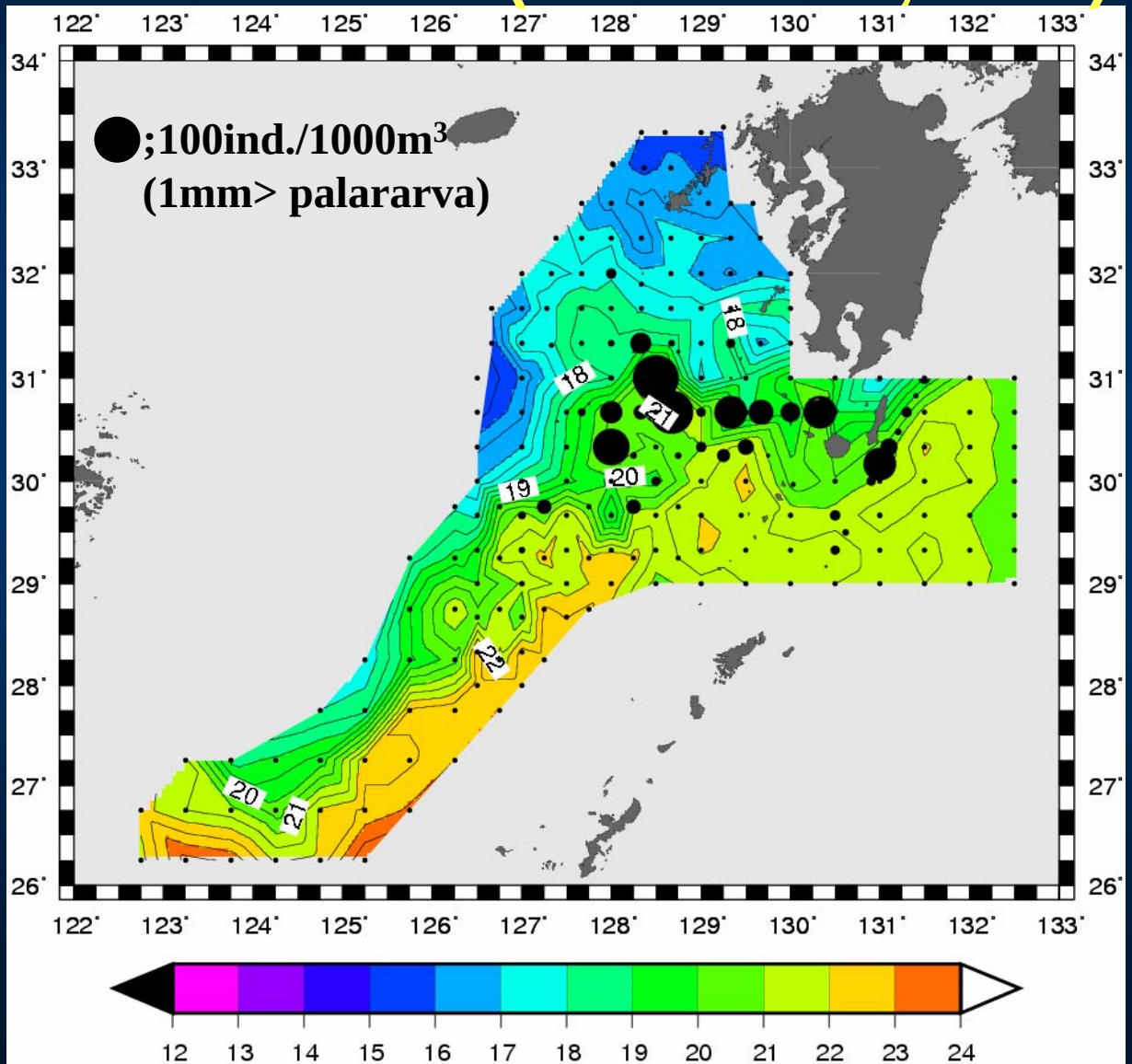




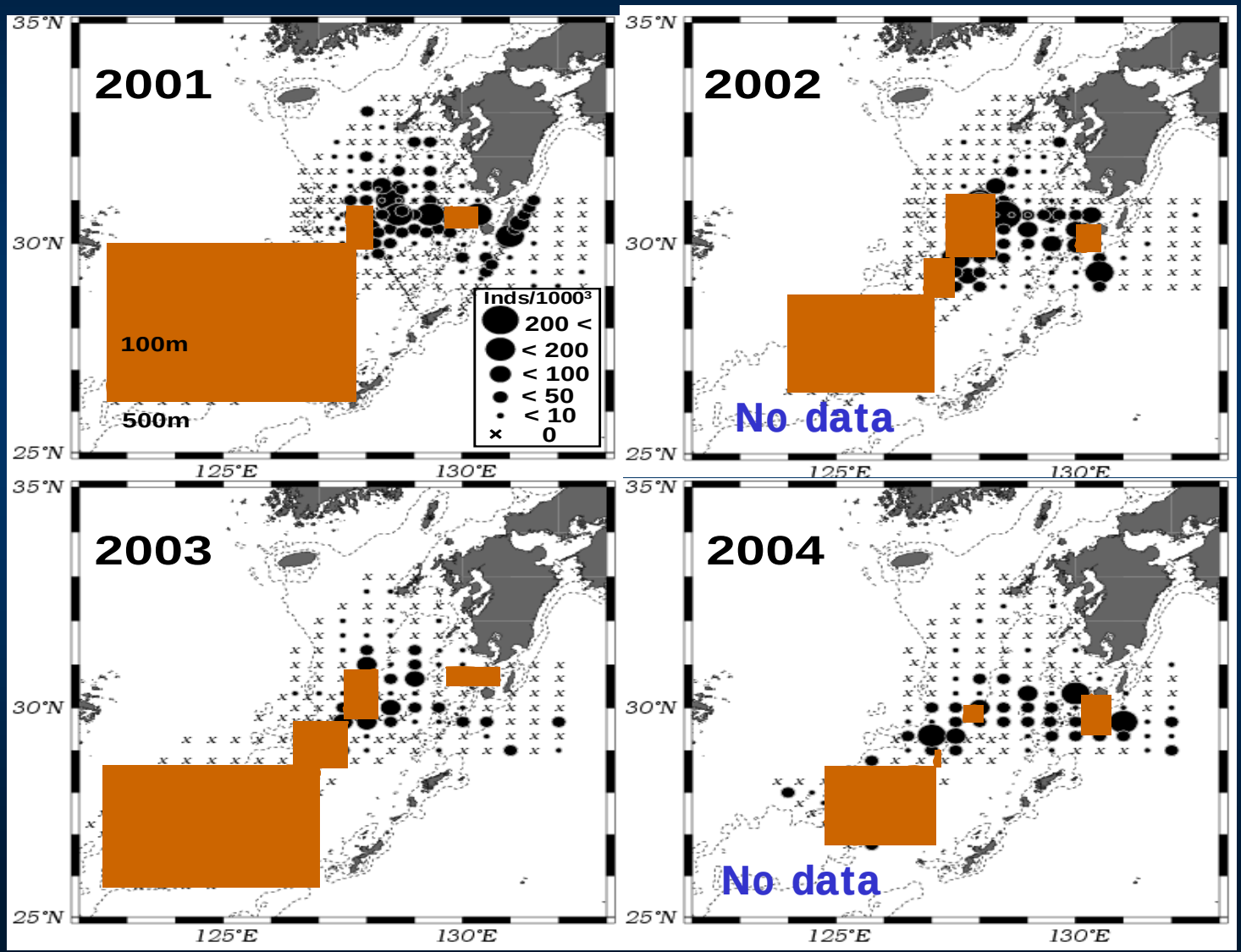
New Schematic view of reproductive processes of *T. pacificus*

Occurrence of *T. pacificus* hatchlings (<1mm DML) at the sea surface layer in the East China Sea, February 2001

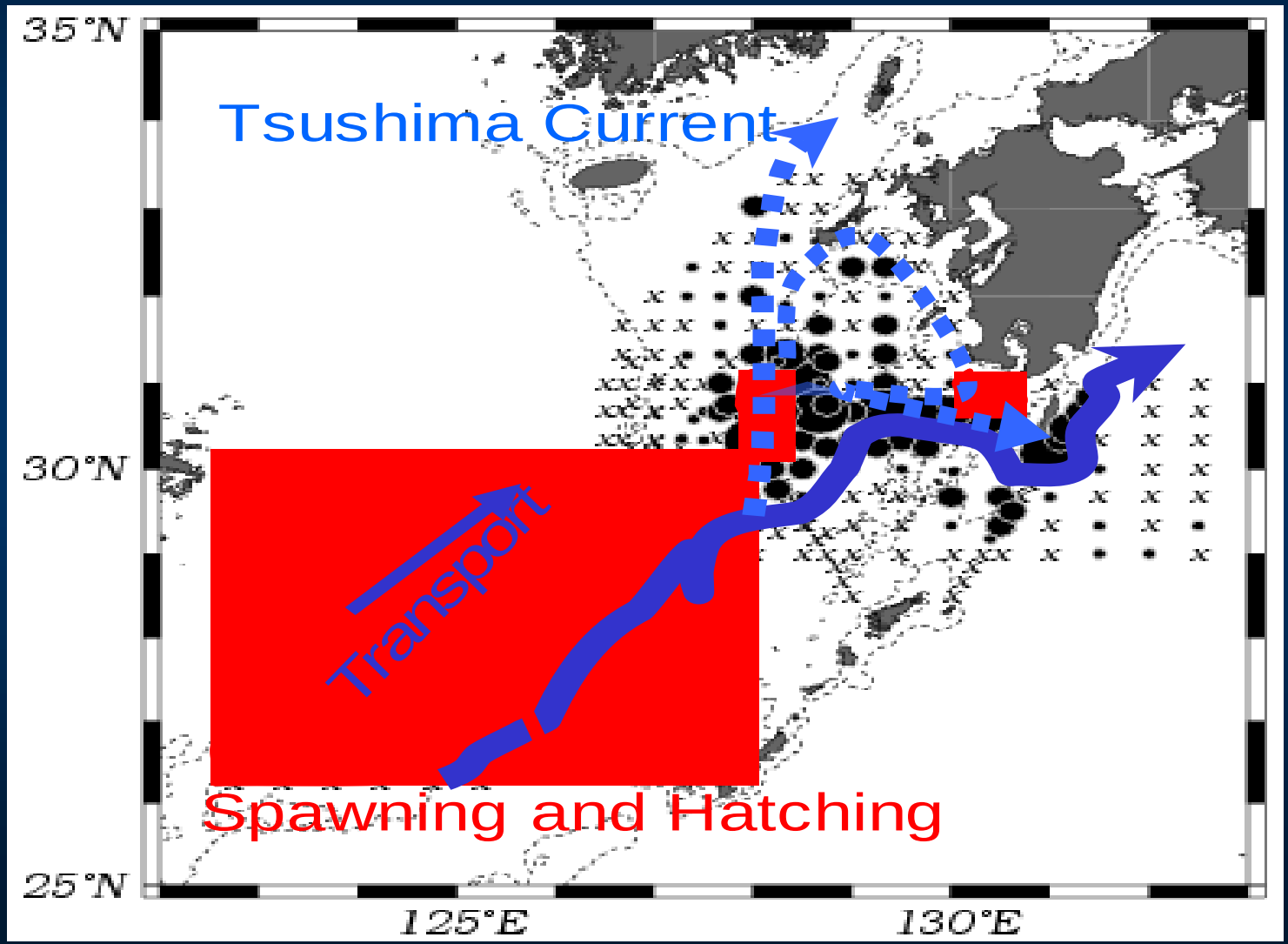
(Sakai et. al., 2006)



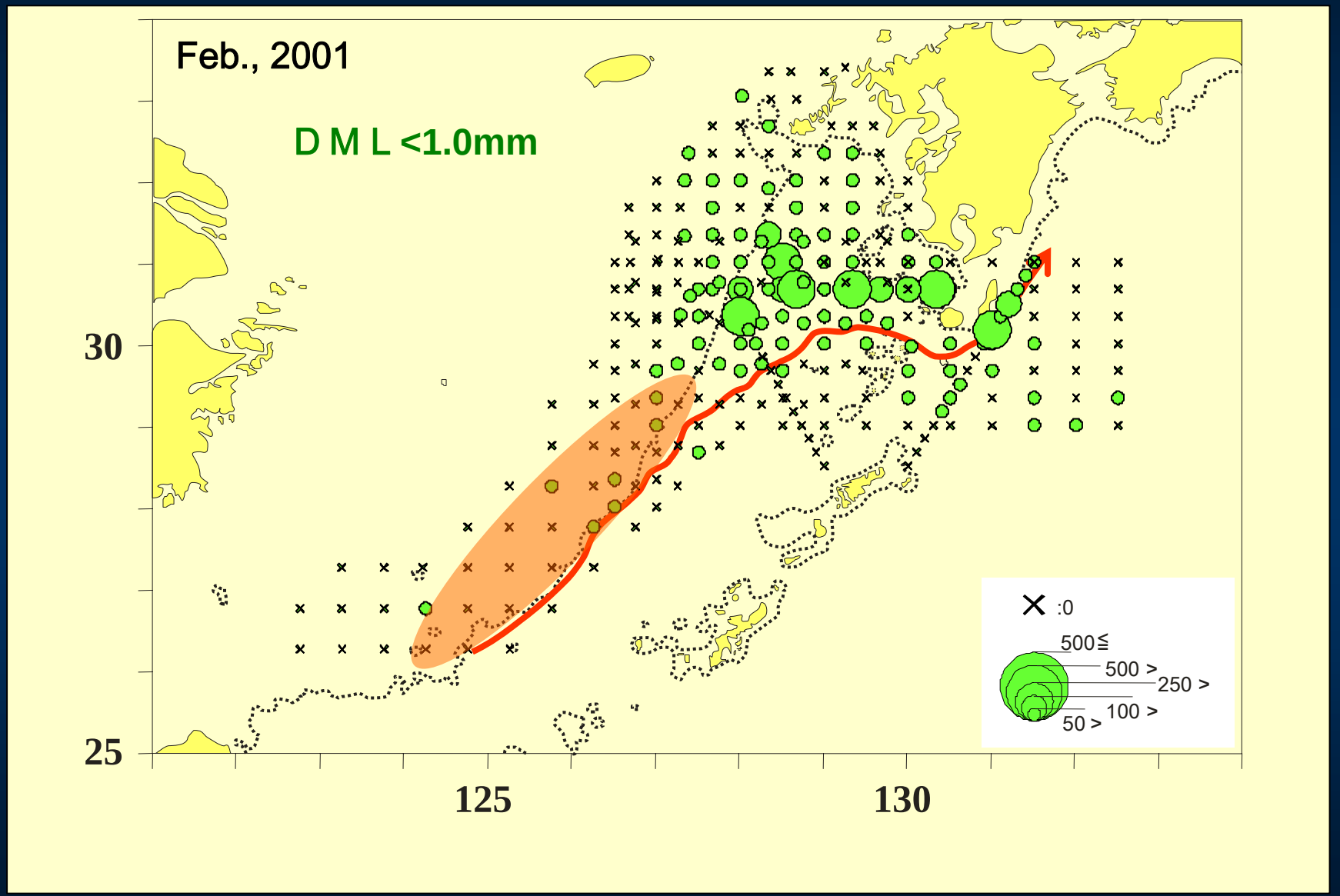
Inferred spawning areas of winter cohort of *T. pacificus* (orange) and distribution of hatchlings (< 1mm DML) during 2001-2004 (Sakai et. al., 2006)



Hatchlings will be transported northeastward by the inner current of Kuroshio along the continental edge and trapped in Kuroshio frontal eddies . (Sakai et. al., 2006)



Distribution patterns of *T. pacificus* hatchlings ranged from 1 mm to 5 mm DML



(K. Mori, Ph.D. Thesis, Hokkaido University,2006)

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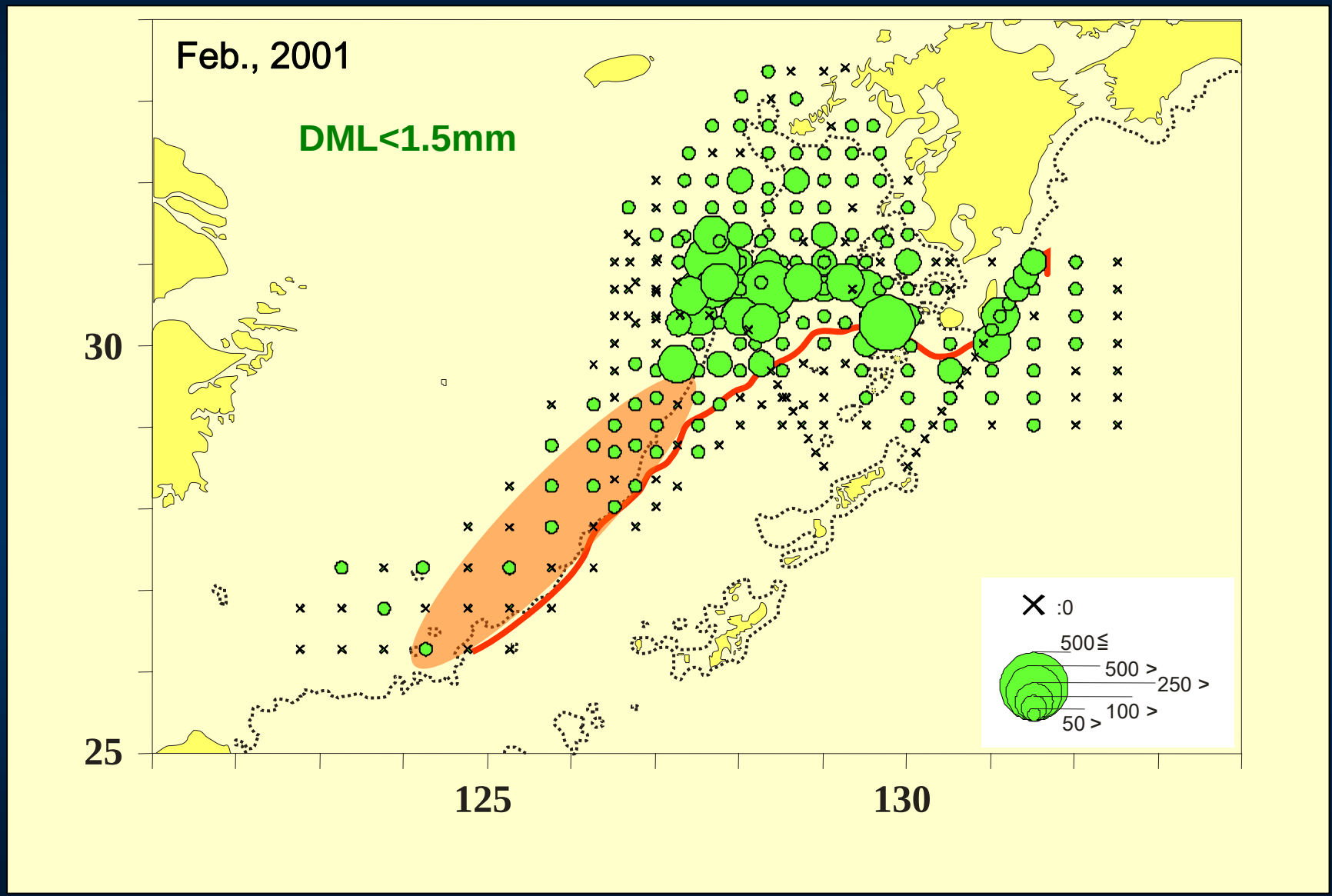

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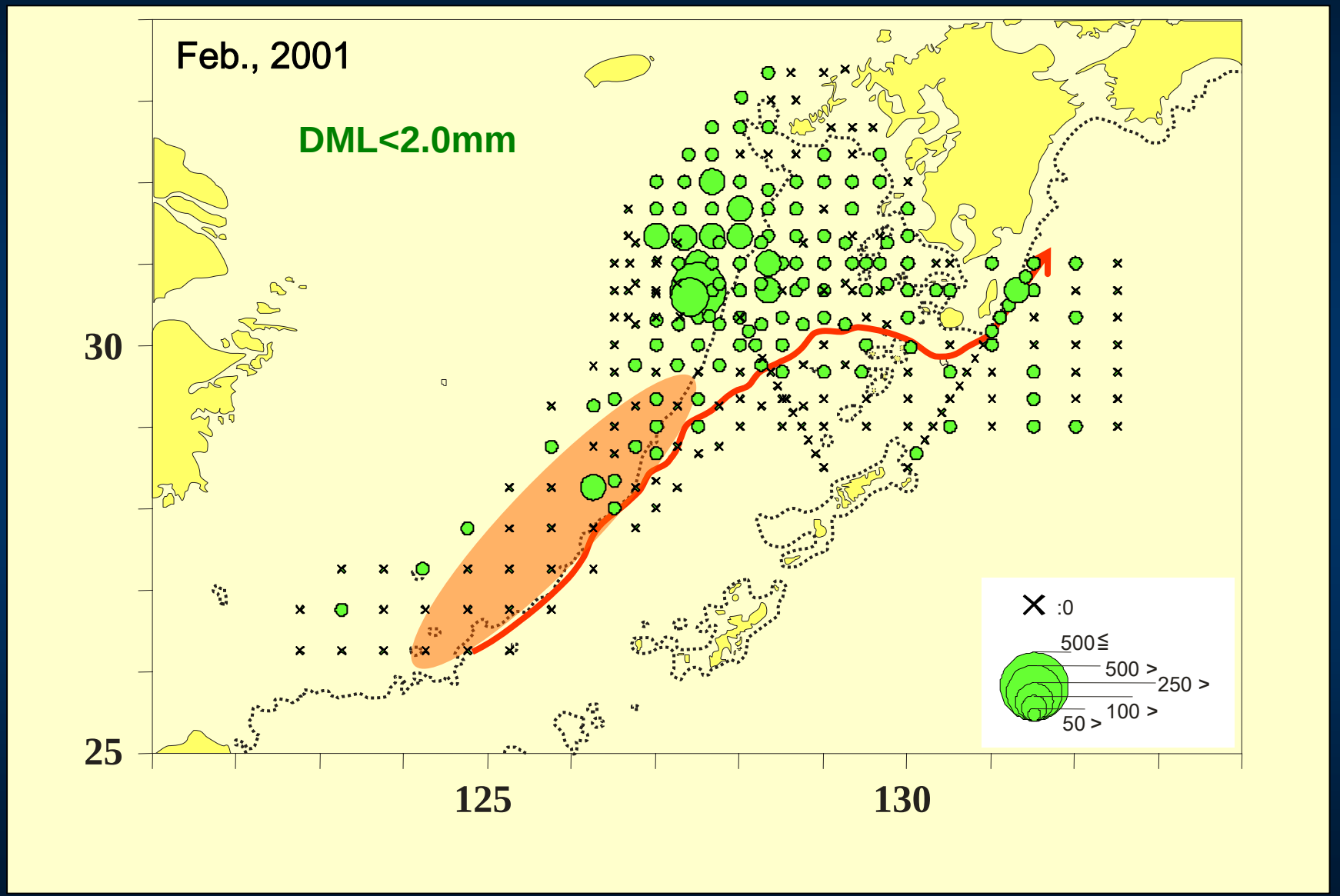

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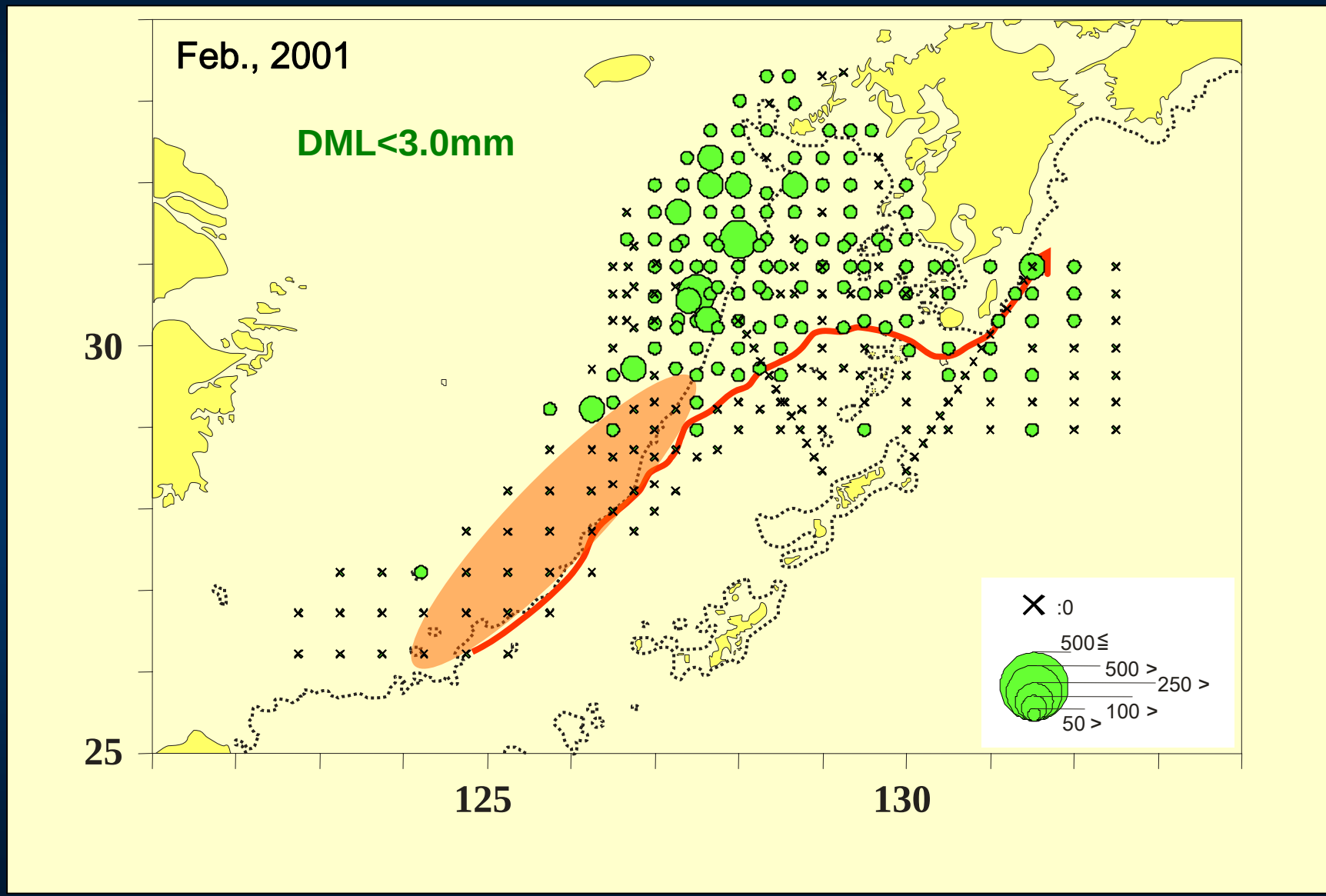

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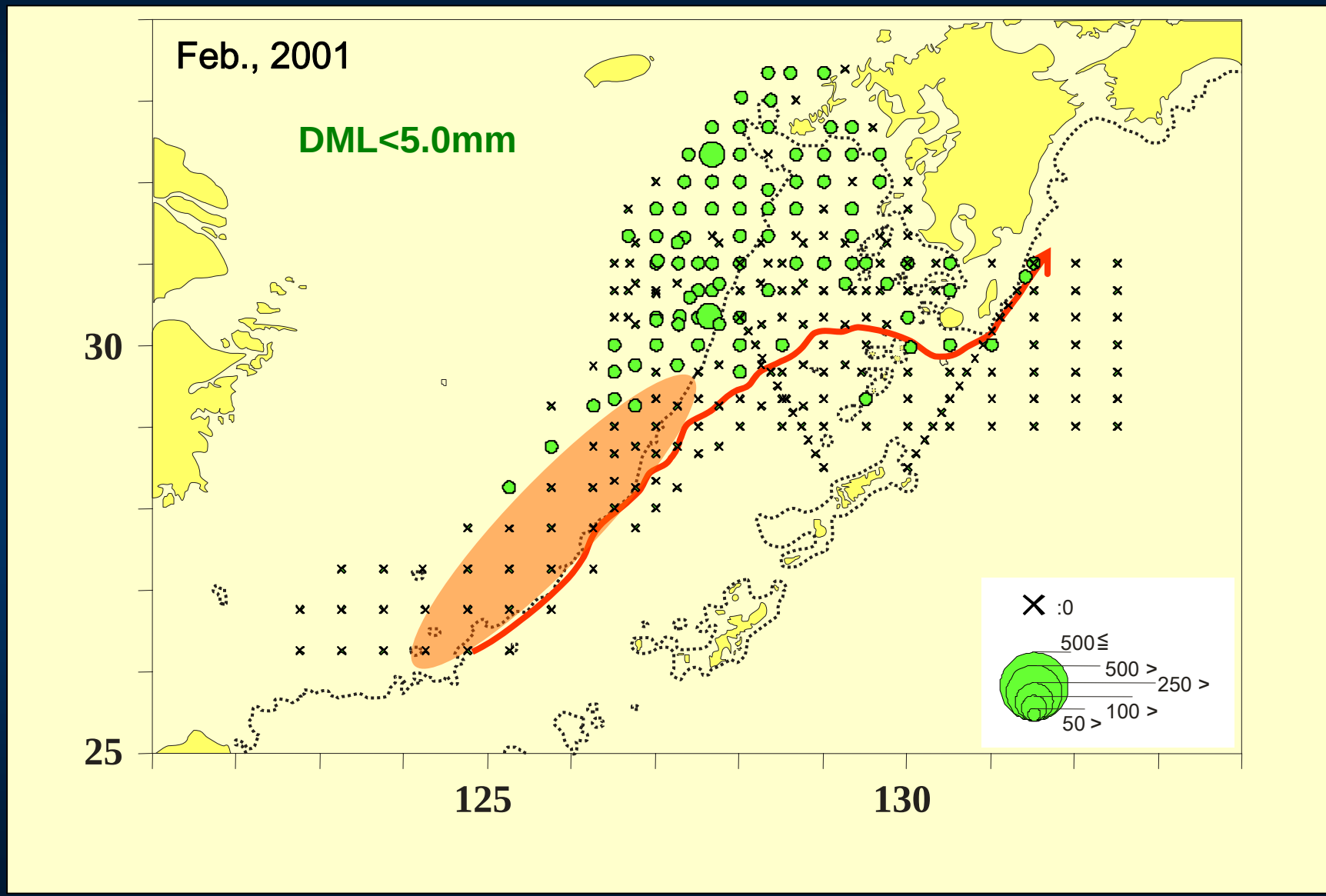

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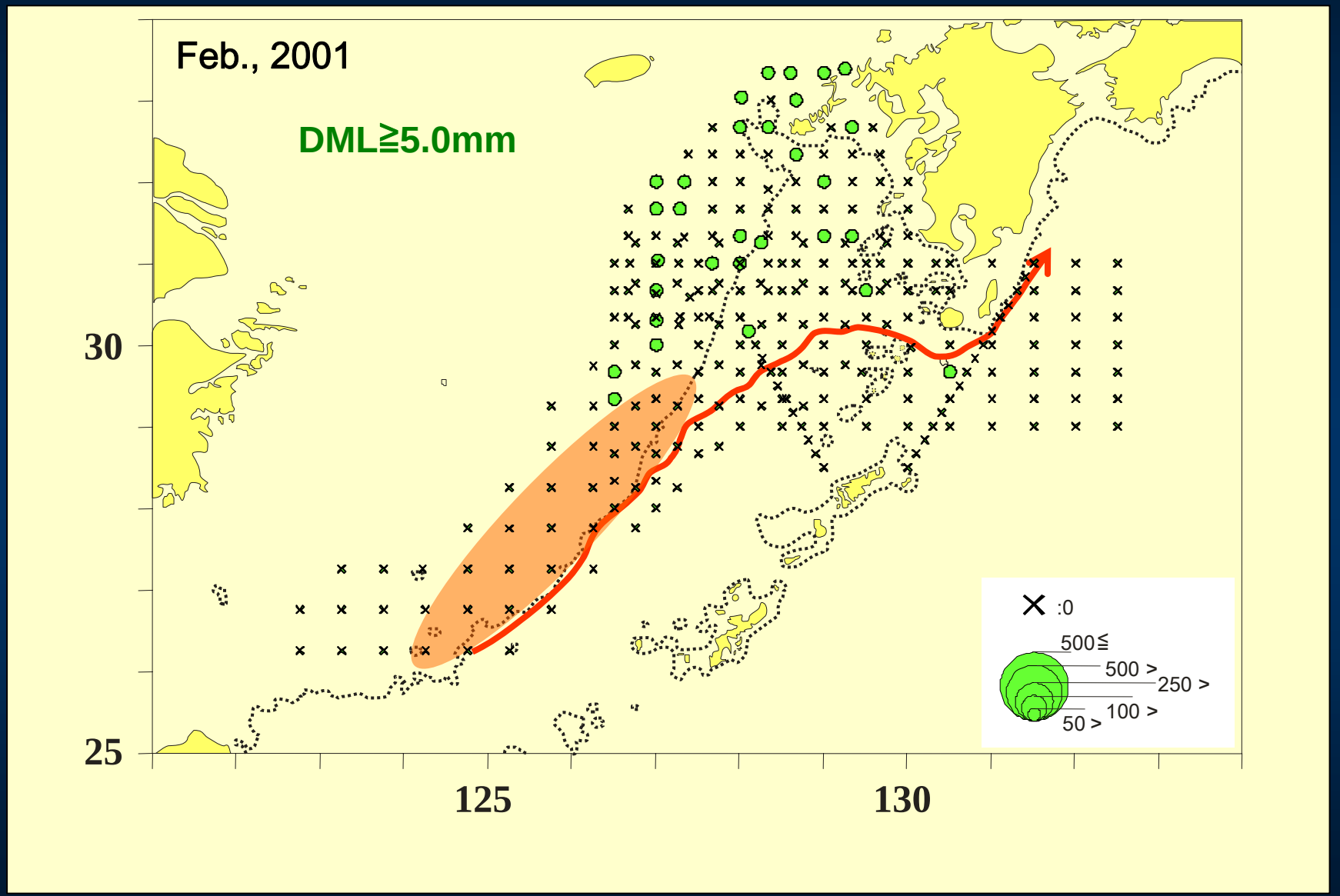
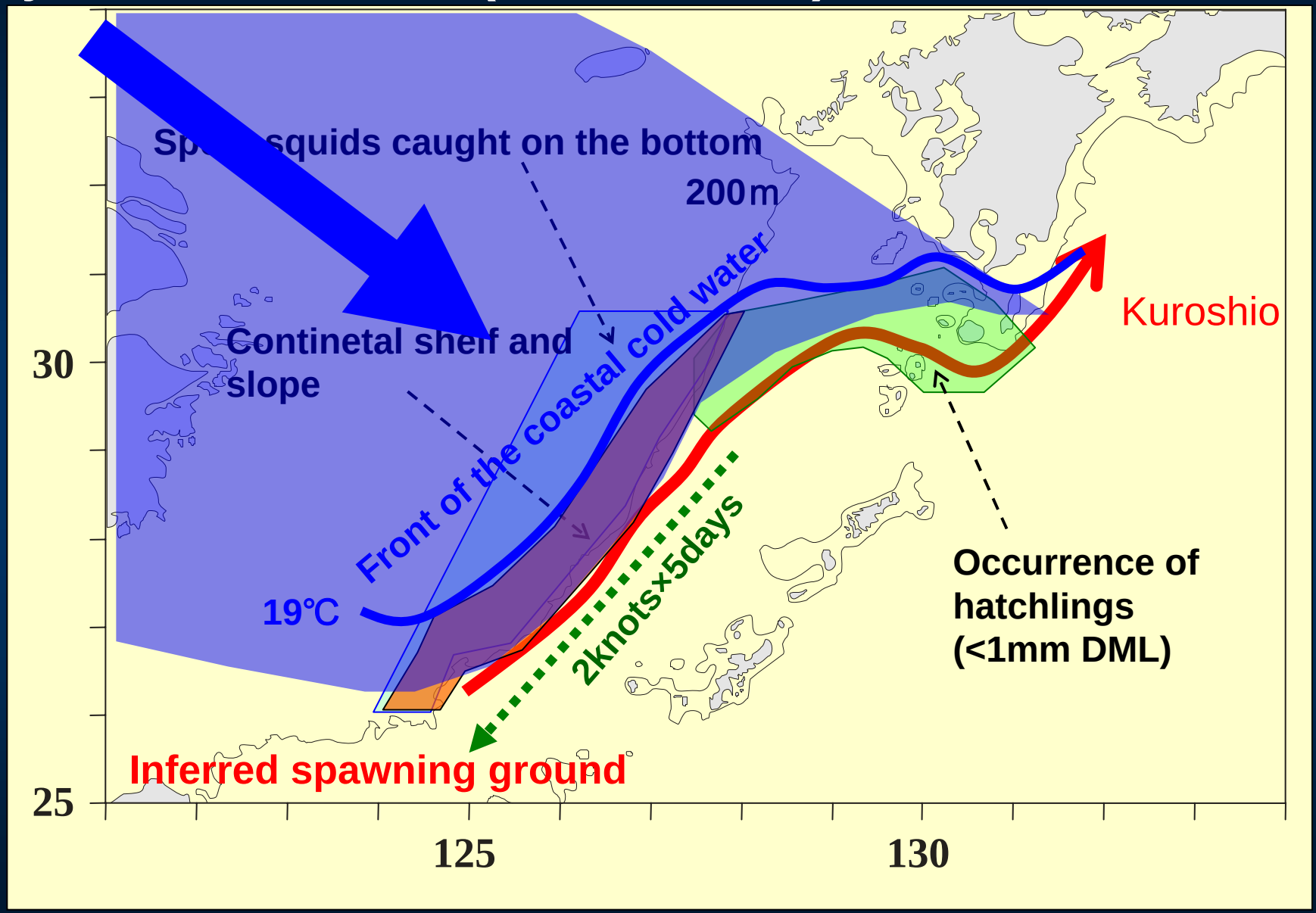


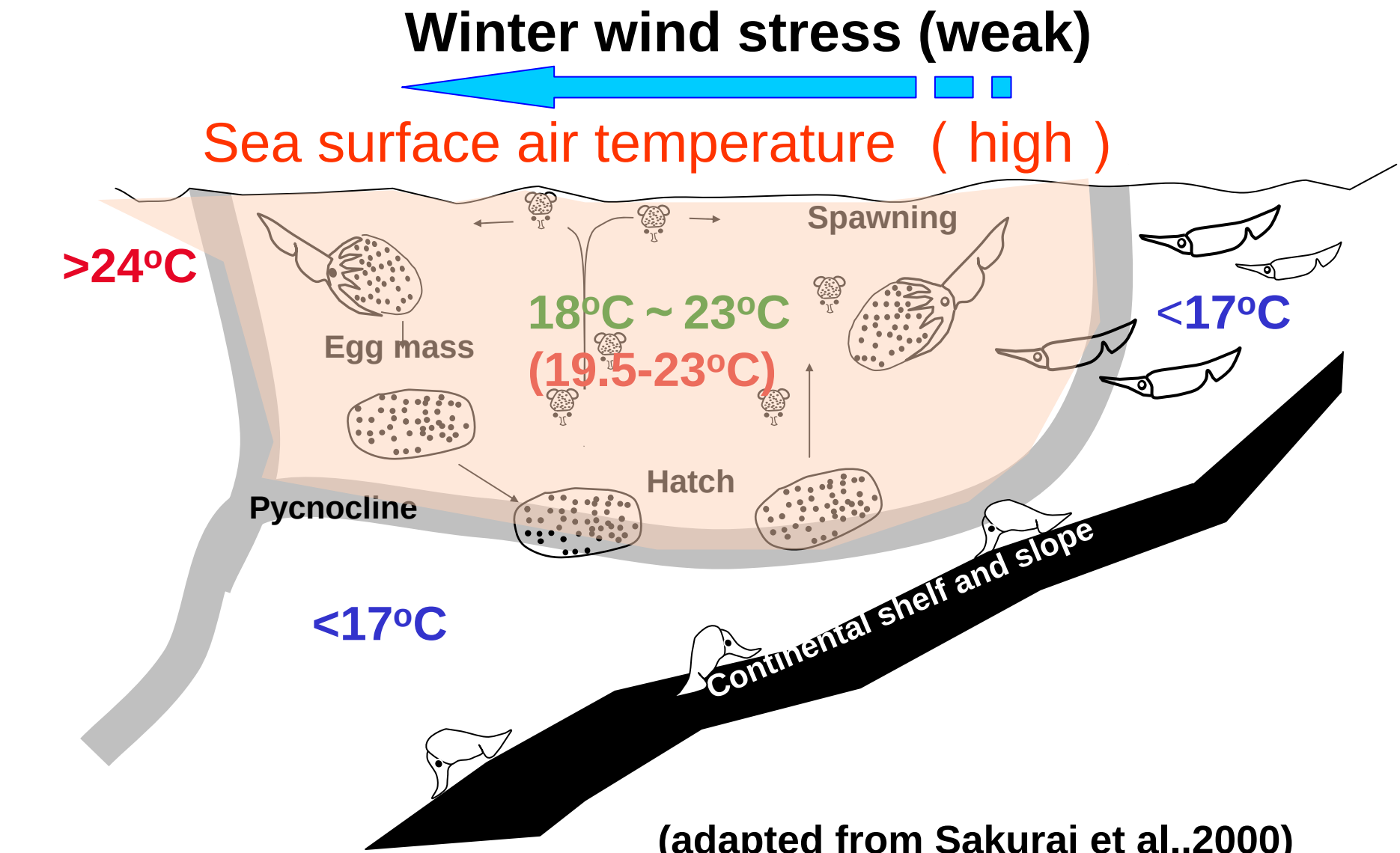
(K. Mori, Ph.D. Thesis, Hokkaido University,2006)

Inferred spawning area of *T. pacificus* during recent years, 2001-2004 (winter cohort).



(Modified from K. Mori, Ph.D. Thesis, Hokkaido University,2006)

During warm regime

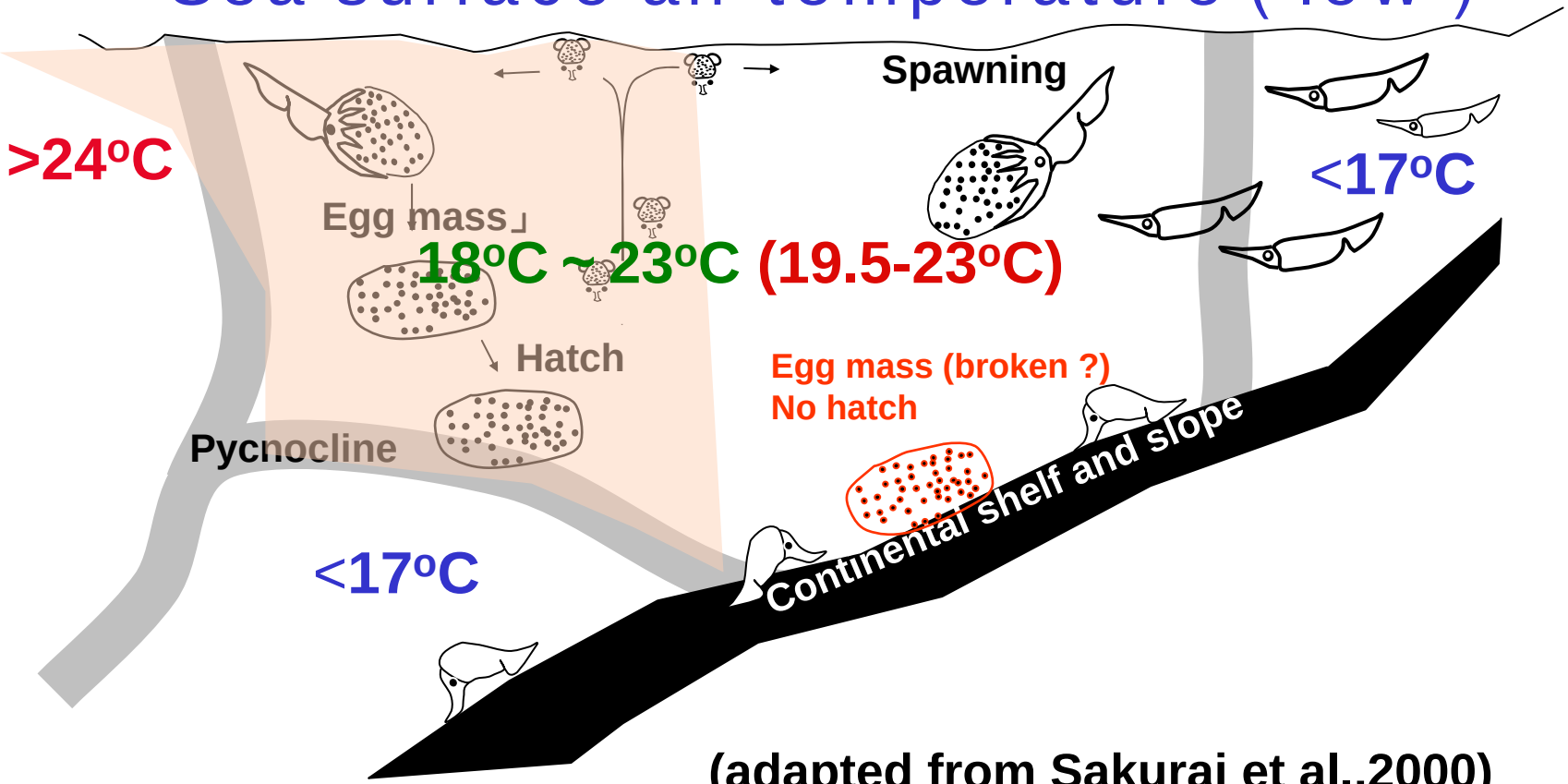


(adapted from Sakurai et al.,2000)

Start of cool regime

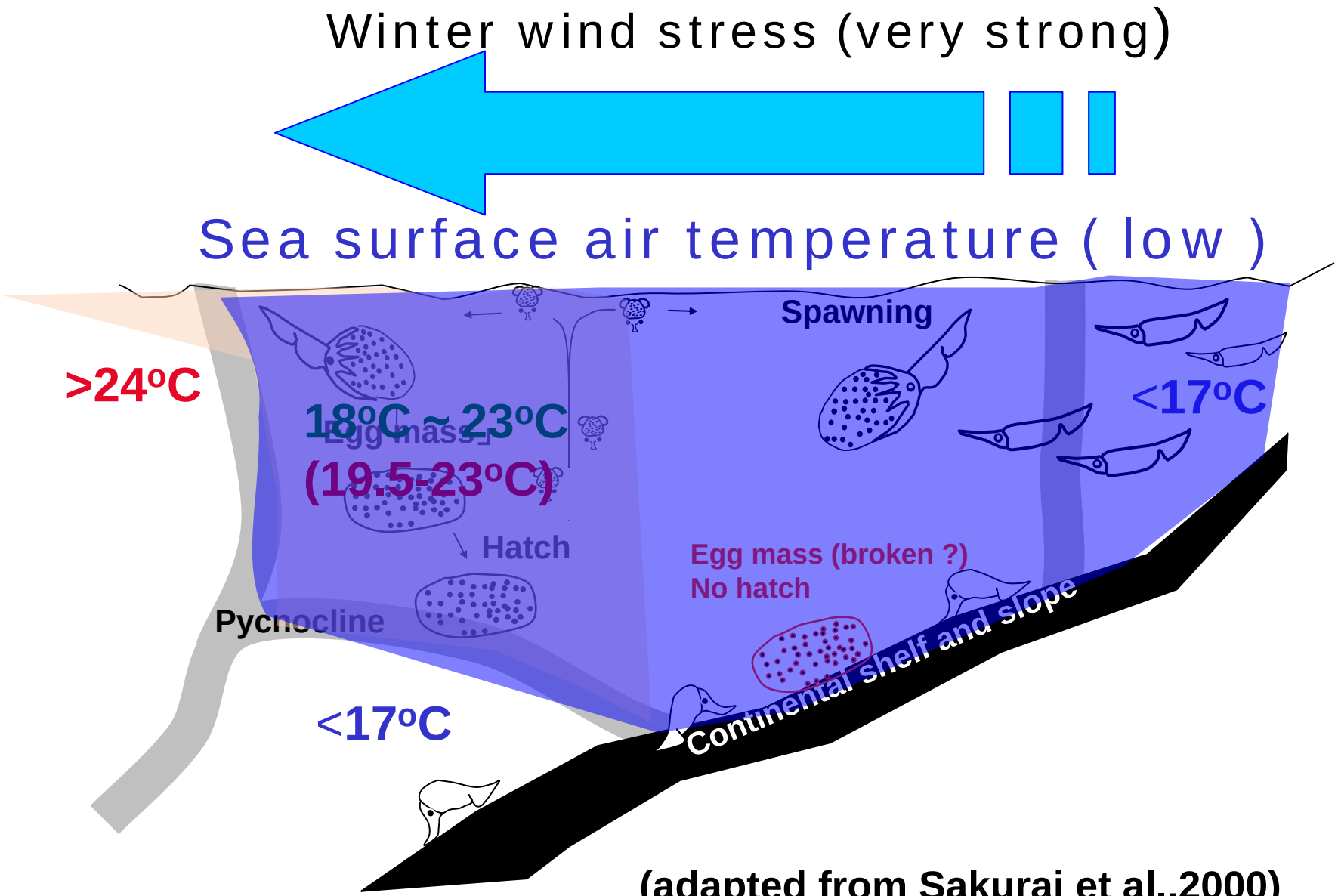
Winter wind stress (gradually strong)

Sea surface air temperature (low)

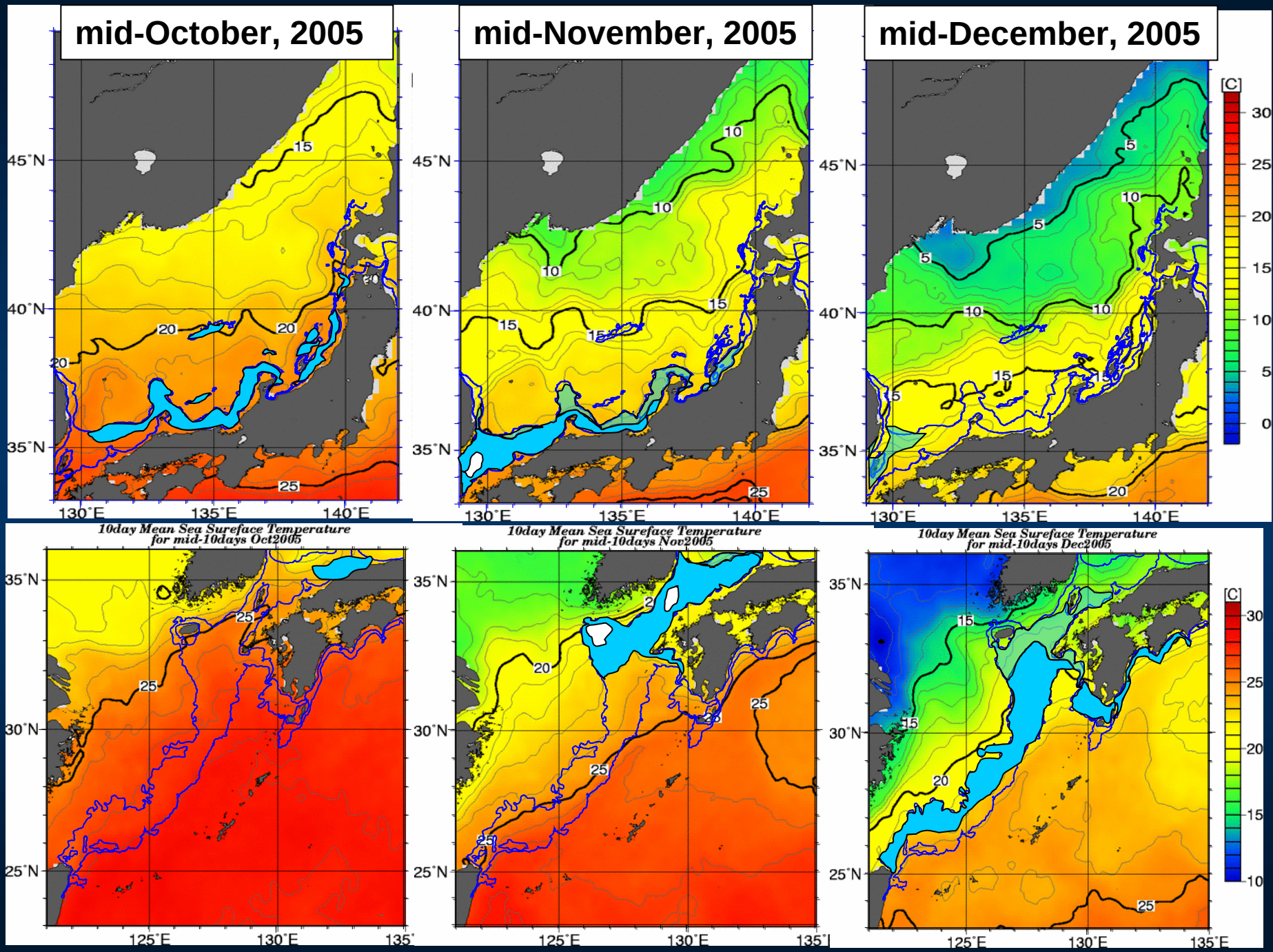


(adapted from Sakurai et al.,2000)

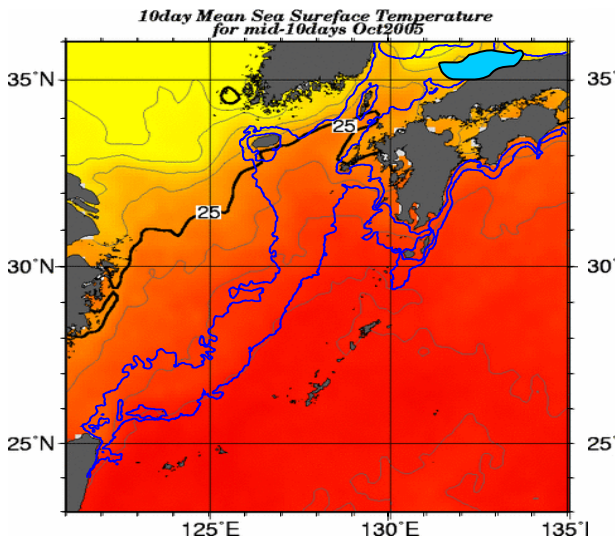
During cool regime



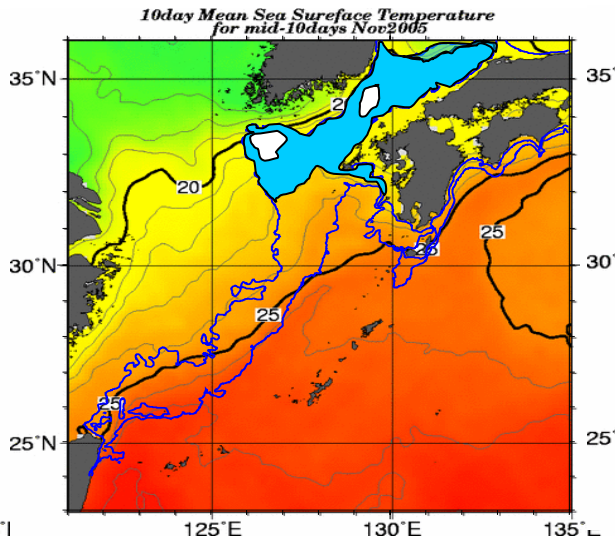
(adapted from Sakurai et al.,2000)


mid-October, 2005
mid-November, 2005
mid-December, 2005
10day Mean Sea Sureface Temperature
for mid-10days Oct2005
10day Mean Sea Sureface Temperature
for mid-10days Nov2005
10day Mean Sea Sureface Temperature
for mid-10days Dec2005
[C]
45°N
40°N
35°N
30°N
25°N
130°E
135°E
140°E
125°E

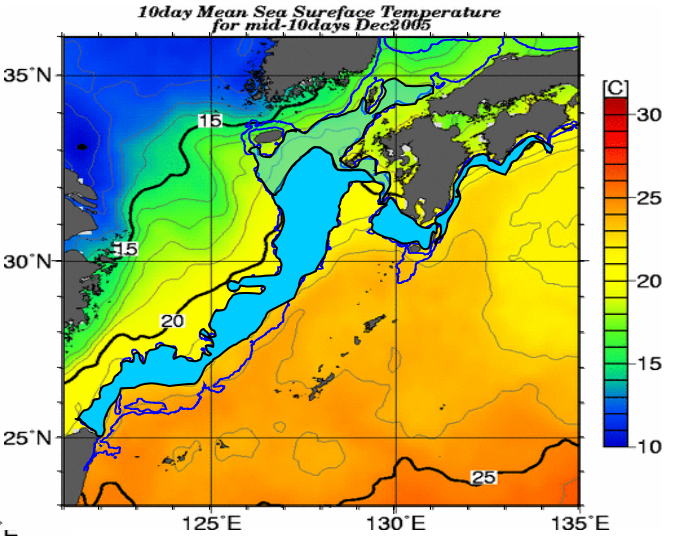
mid-October, 2005



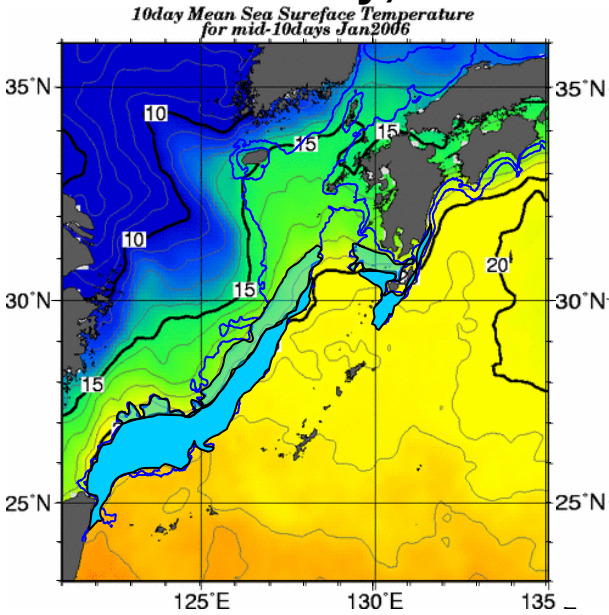
mid-November, 2005



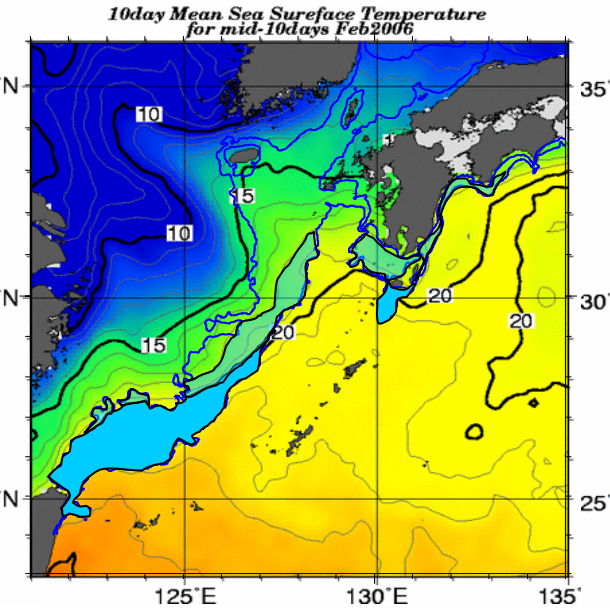
mid-December, 2005



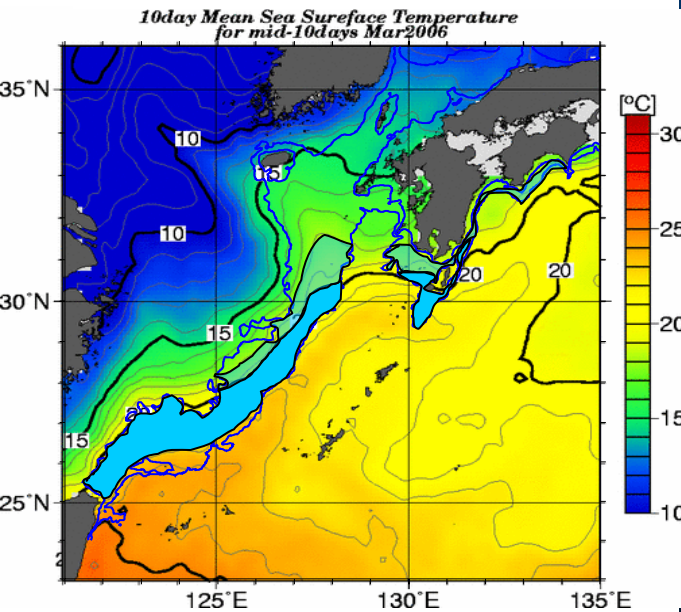
mid-January, 2006

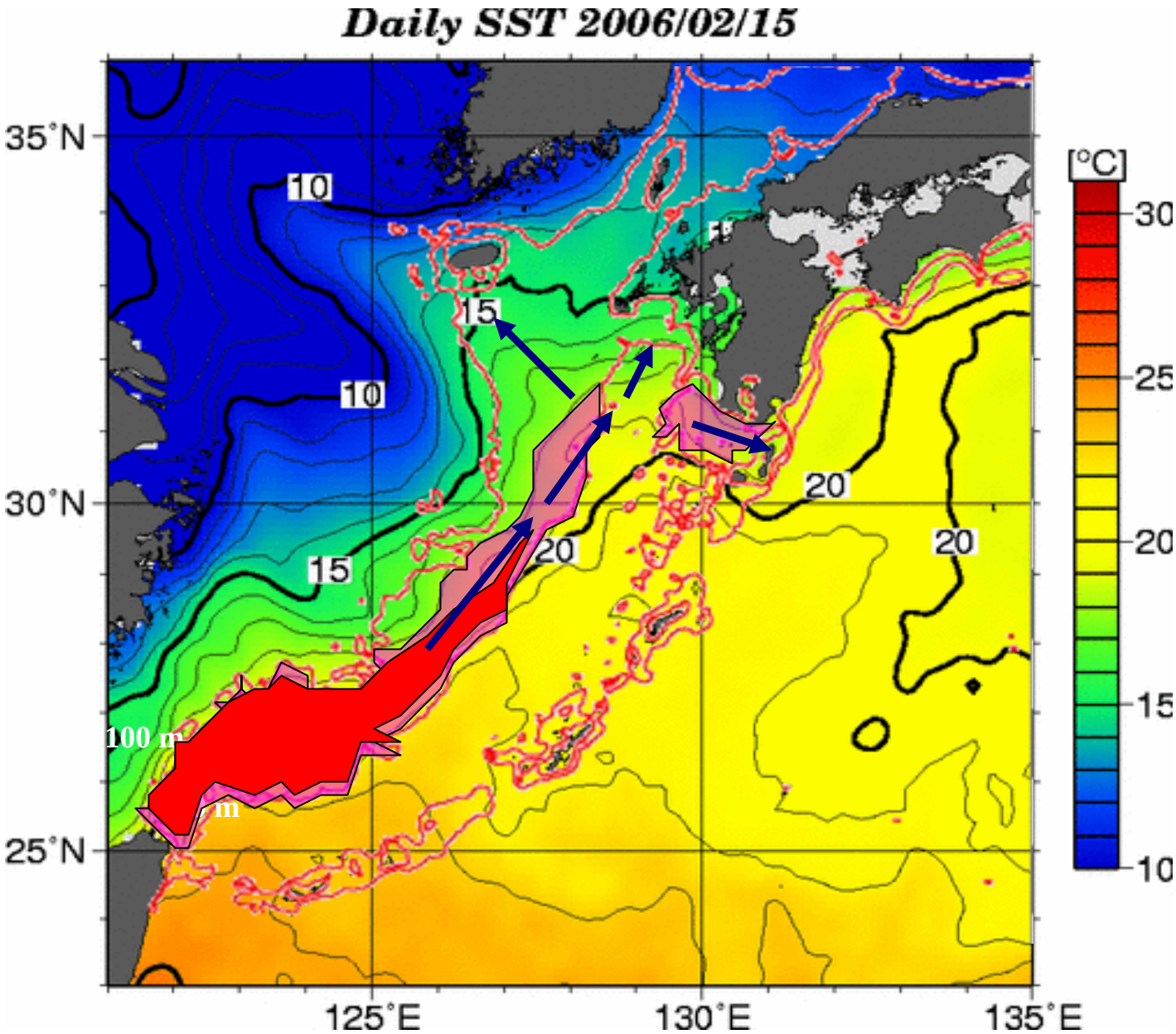


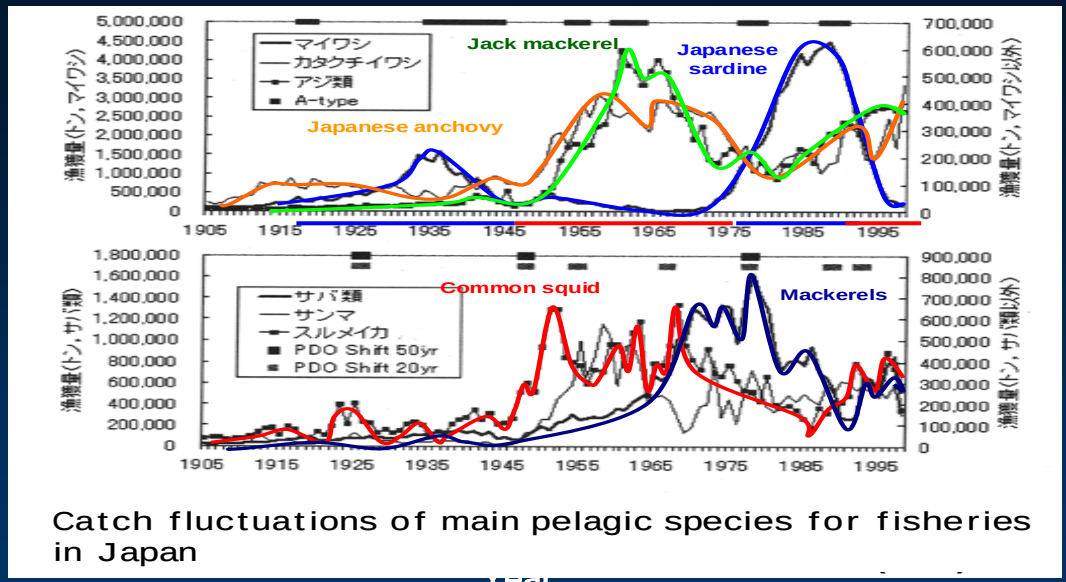
mid-February, 2006



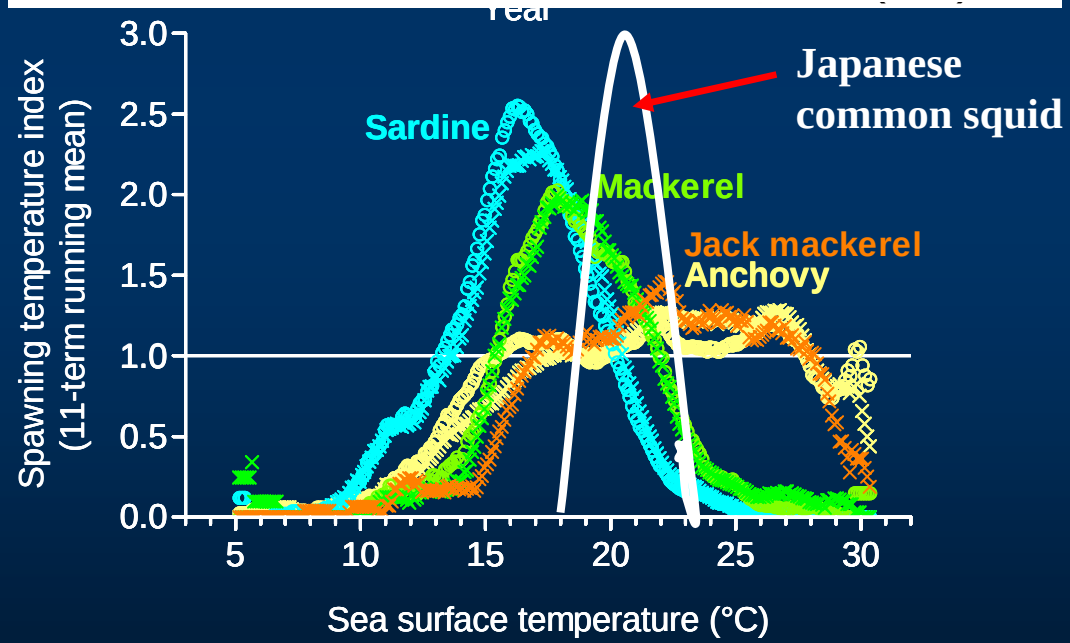
mid-March, 2006




Daily SST 2006/02/15
35°N
30°N
25°N
125°E
130°E
135°E
10
10
15
15
20
20
20
100 m
m
[°C]
30
25
20
15
10



Catch fluctuations of main pelagic species for fisheries in Japan




Anchovy


Sardine

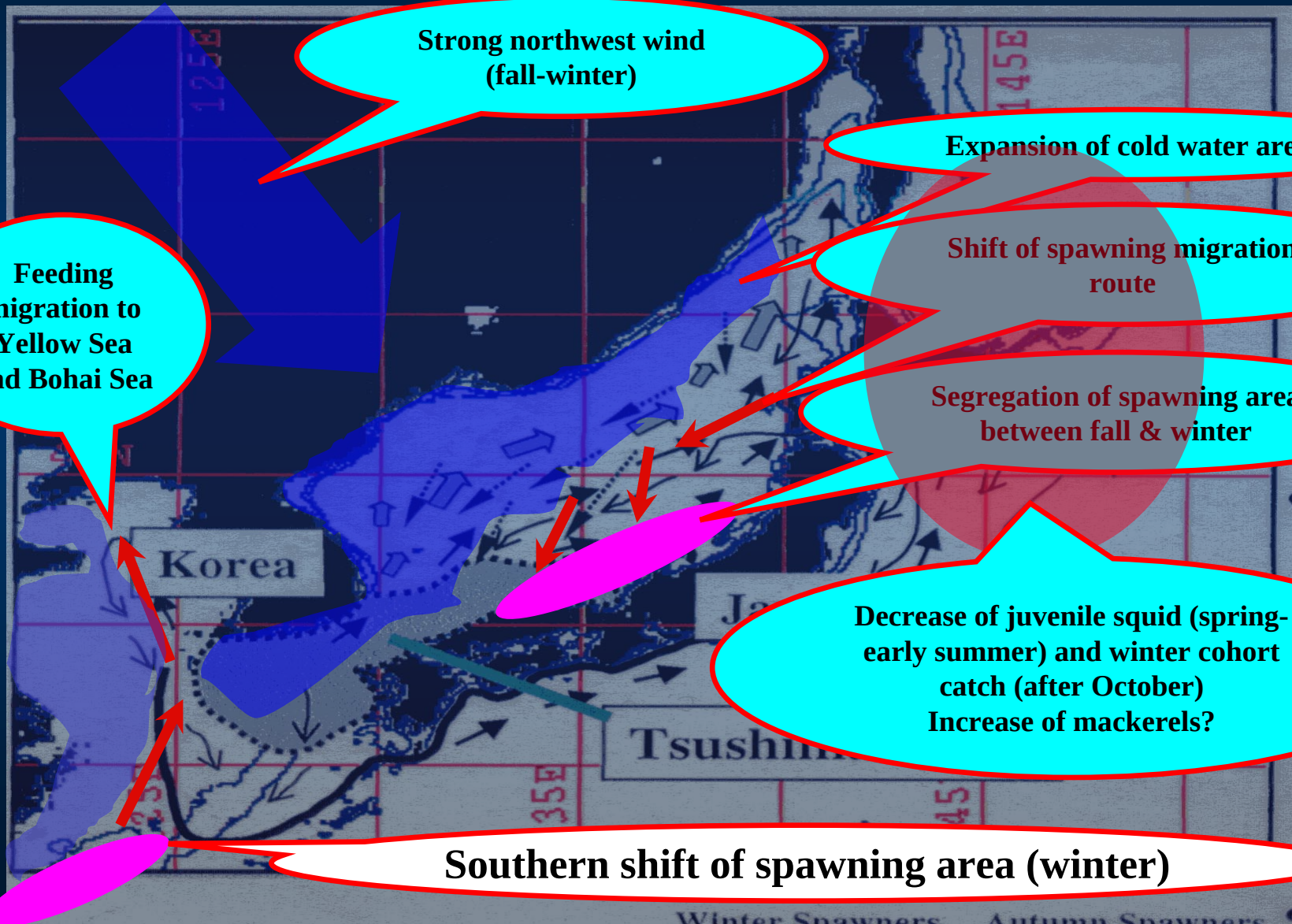

Mackerel


Jack mackerel

Similarities and differences in spawning temperature patterns represent those in the long-term population dynamics patterns. (Takasuka, 2006)

Summary

How to predict stock fluctuations of common squid ?
(Especially, decline of winter stock during a cool year and regime)



Thanks from the squid!