Why do ommastrephid squids increase in abundance during warm regime?

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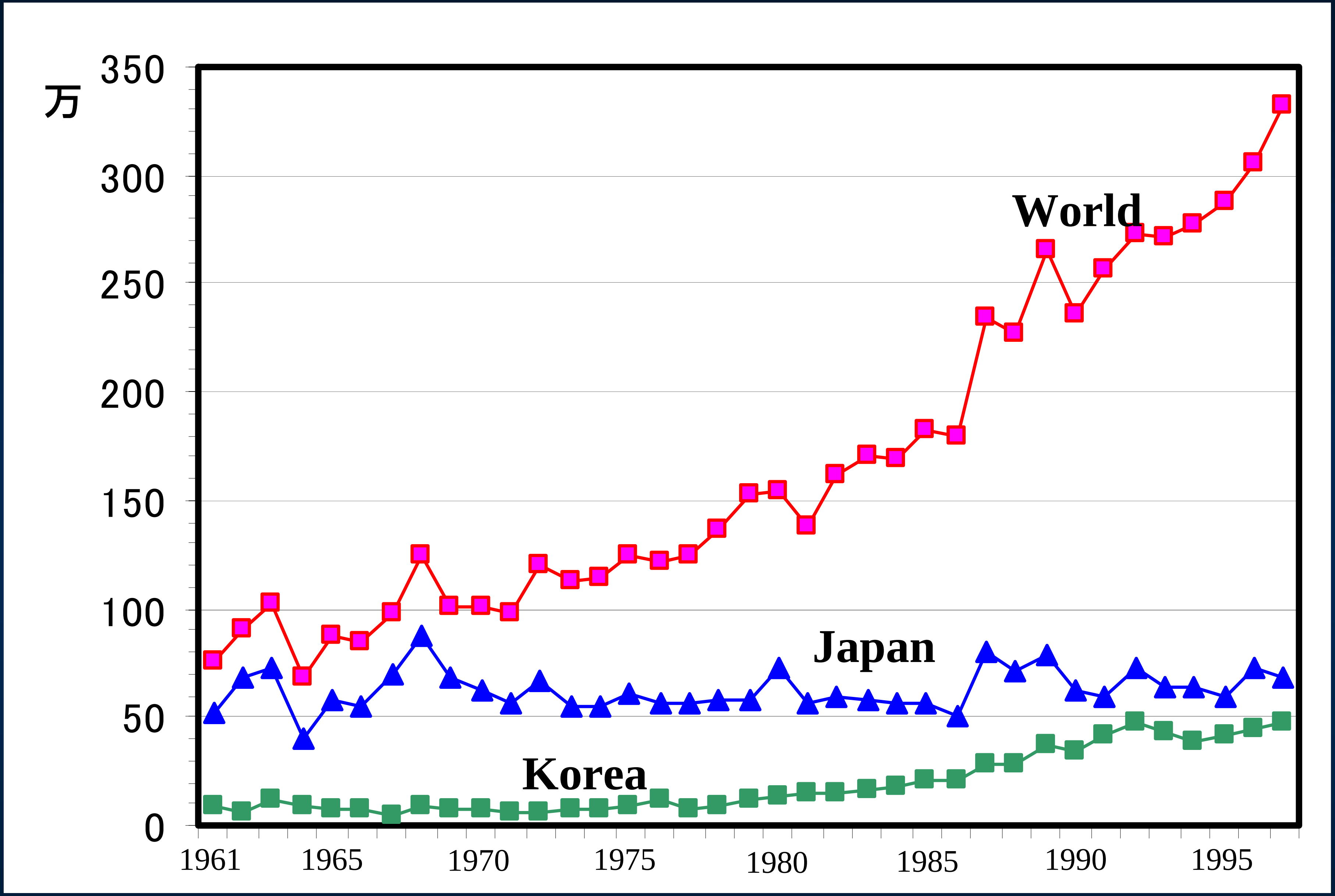

Annual catches of cephalopod including squid and octopus in the world, Korea and Japan（FAO,2001）

What is ommastrephid squid?

Distribution

Life cycle

Reproductive characteristics

Stock fluctuation

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Sthenoteuthis oualaniensis
M. Iwagou

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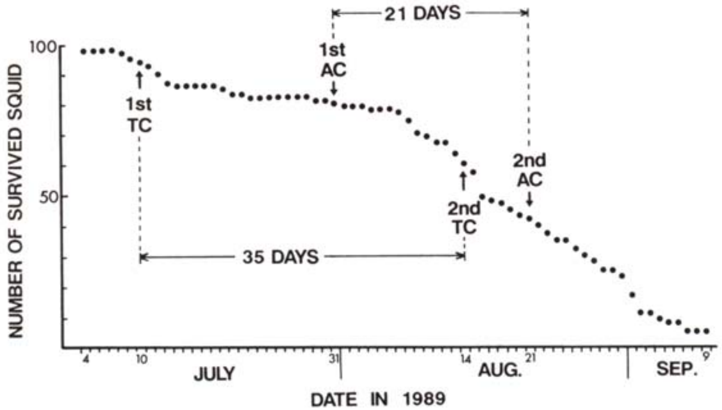
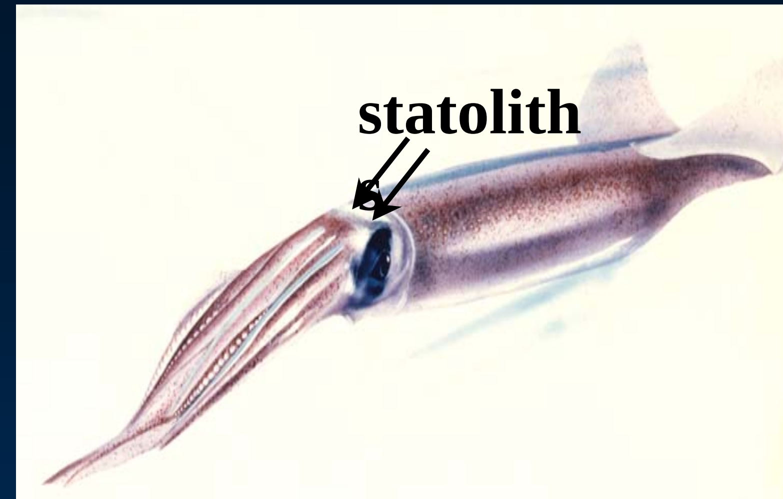
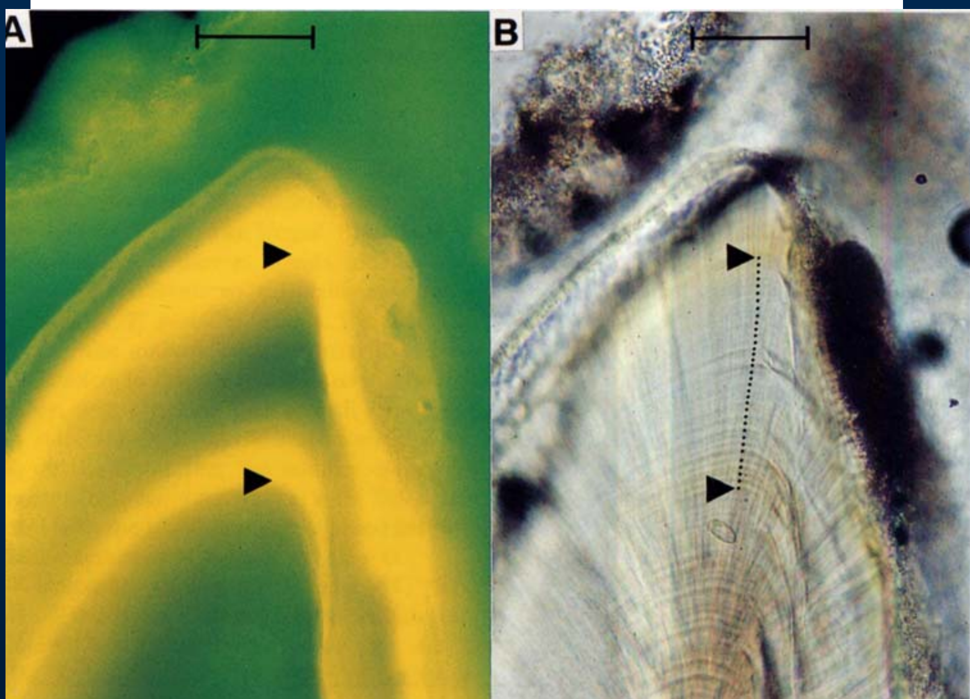


Fig. 1. Daily change in the number of surviving squid *Todarodes pacificus* during the rearing period and dates and intervals of the first and second oral administrations of tetracycline HCl(TC) or alizarin complexone (AC).





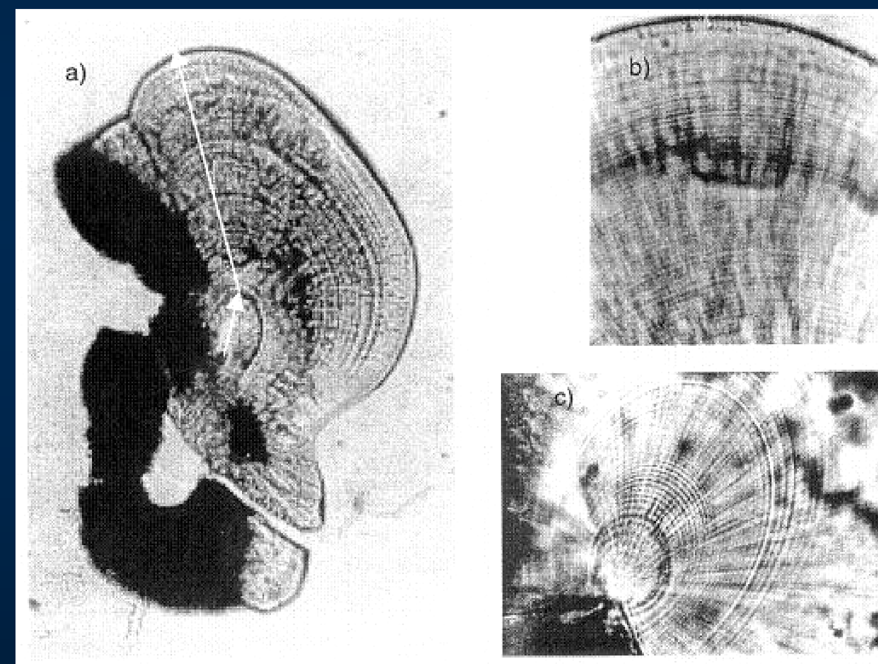
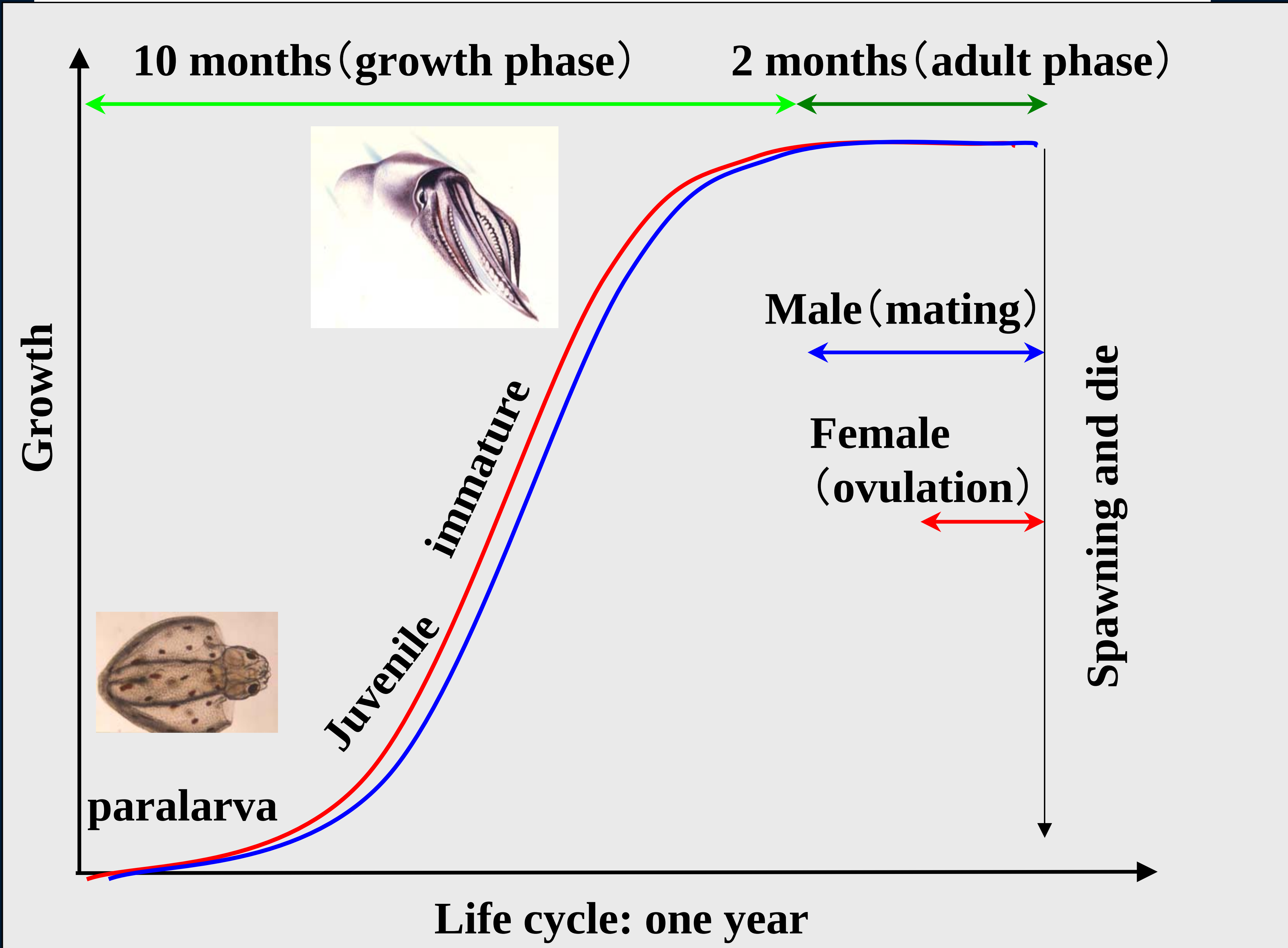


Fig. 6: (a) Posterior view of a polished statolith of an *Illex argentinus* adult (female, *ML* = 248 mm, statolith total length = 1.01 mm). Arrows indicate the counting axis. (b) View of the dark zone. (c) View of the nucleus and postnuclear zone

Daily growth rings in the statoliths (*T. pacifucs*)
Nakamura and Sakurai (1991)

Daily growth rings in the statoliths (*I. arzentinus*) Arkhipkin(1993)

Life cycle of Ommastrephid squids (*e.g. T. pacificus*)



What is ommastrephid squid?

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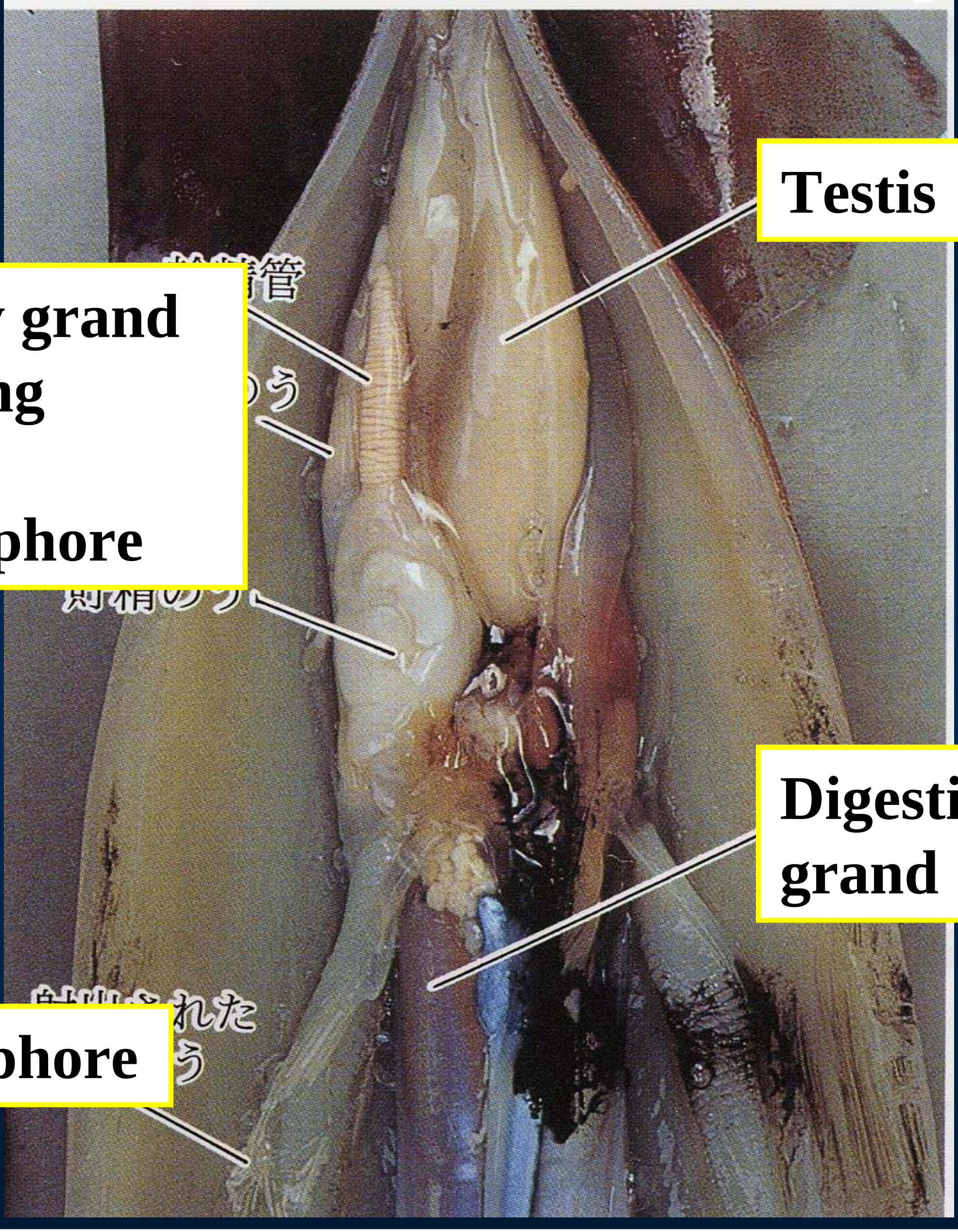
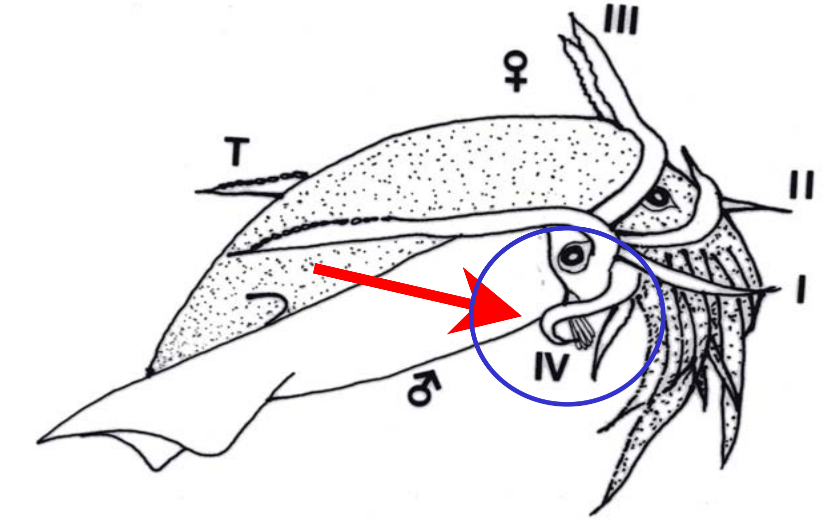
Reproductive characteristics of Omastrephid squids

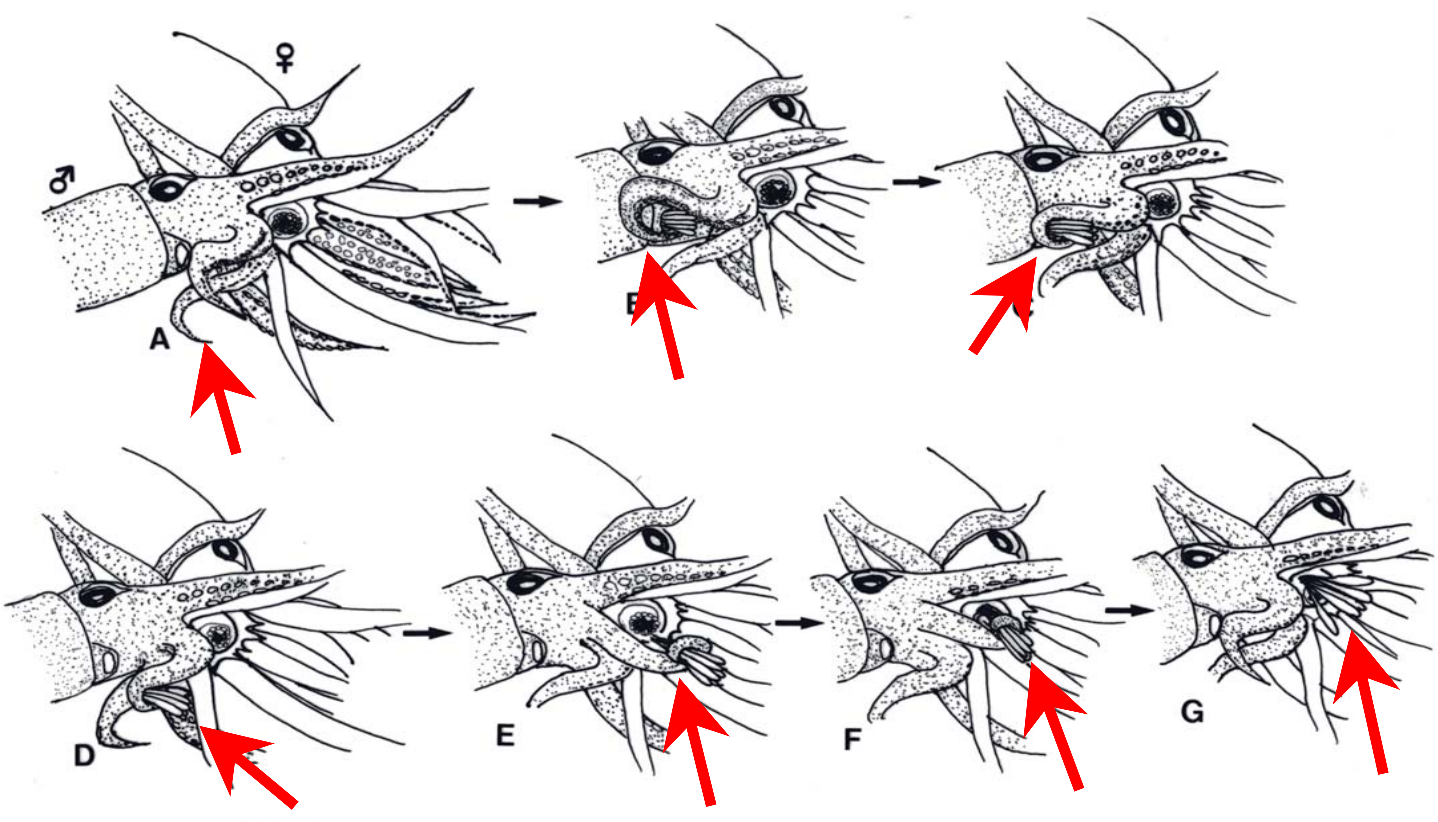


Reproductive organs of male squid (*T. pacificus*)

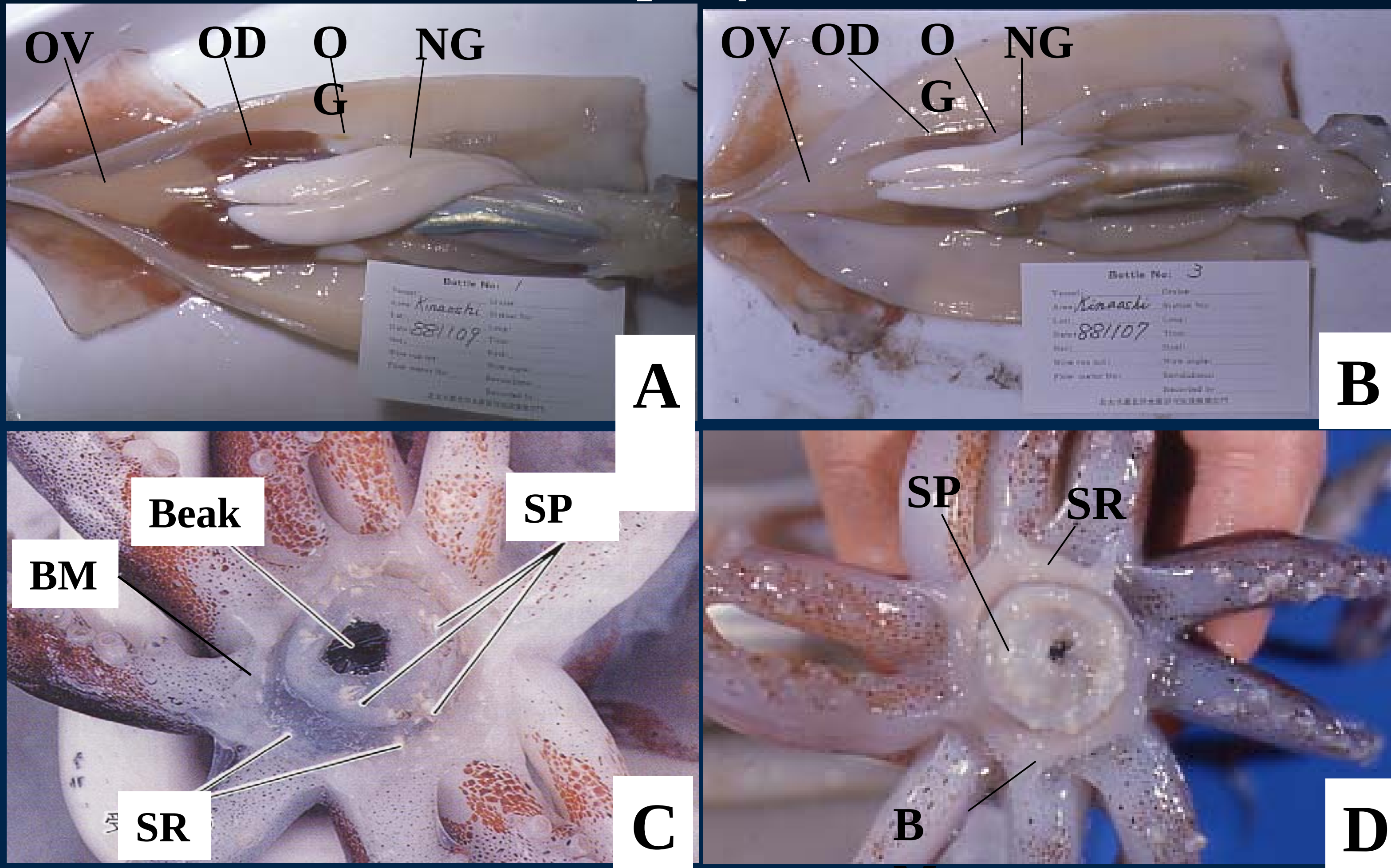
Mating behavior of *T. pacificus*

Male grasps female around head and mantle with his arms and tentacles. Male's hectocotylus sweeps past his funnel, picks up spermatophores, and transfers them to the female's buccal memblane.





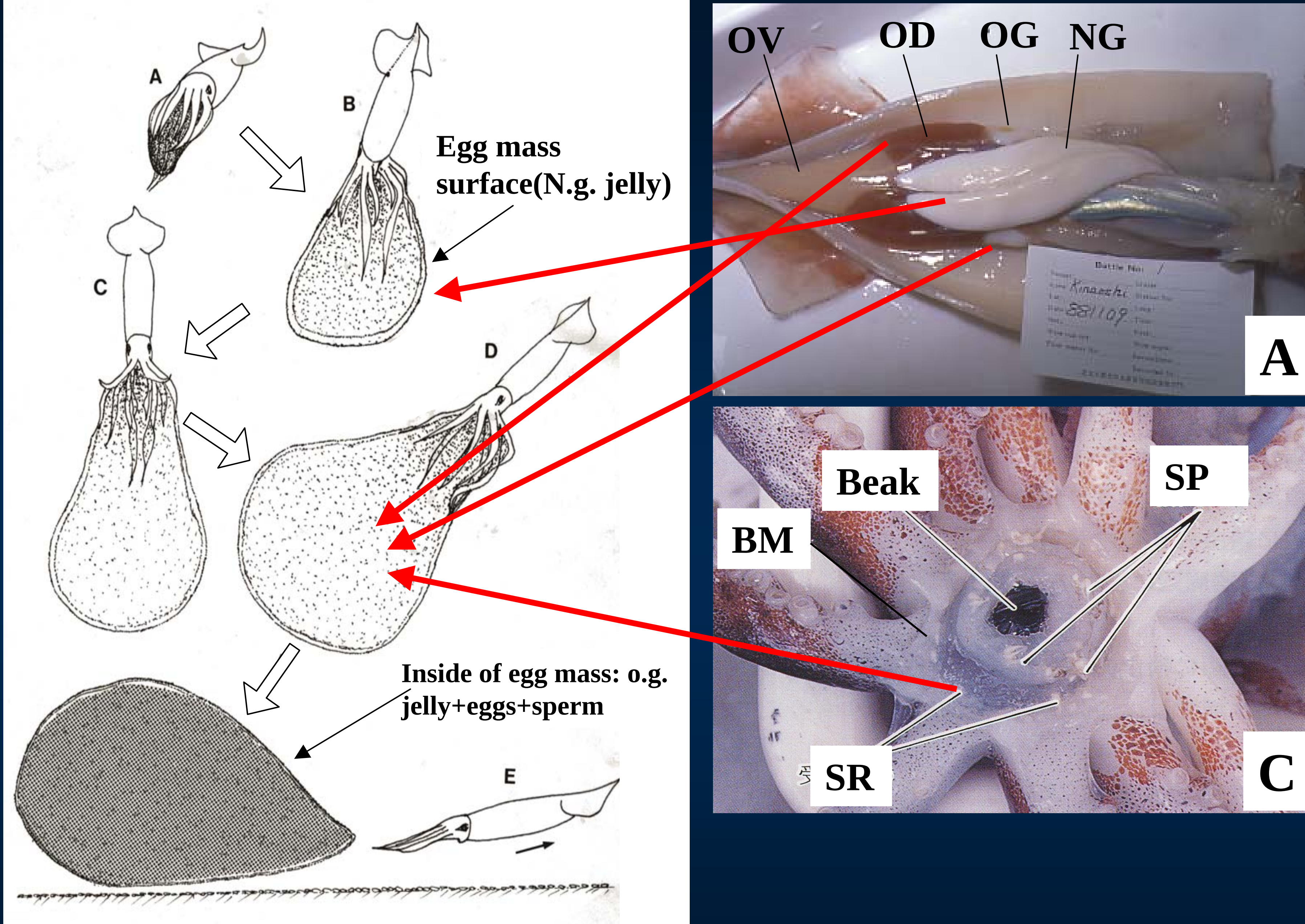
Todarodes pacificus



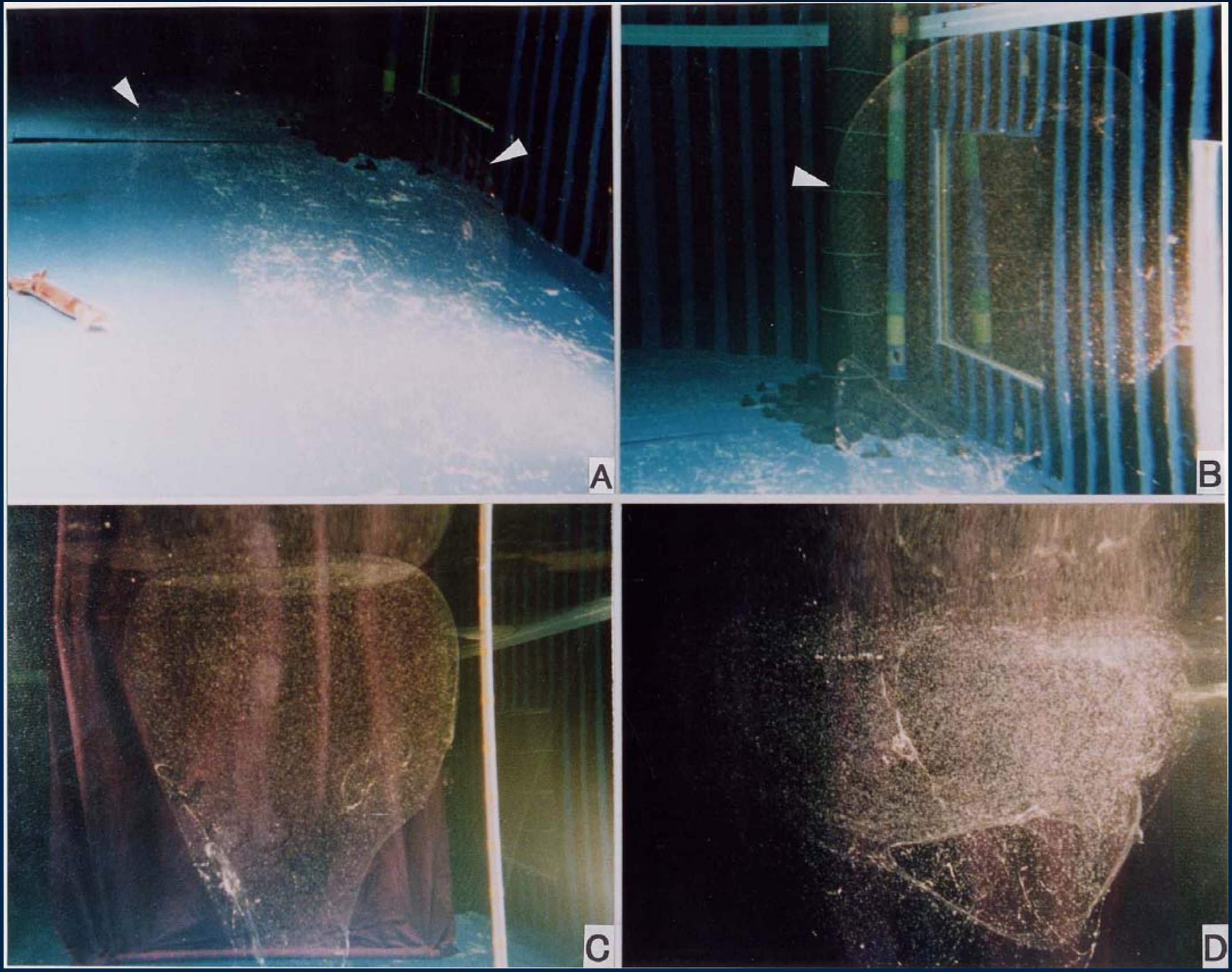
Before spawning **After spawning**

OV:ovary, OD: oviduct, OG: oviducal grand, NG: nidamental grand, BM: buccal membrane, SP: sperm ball, SR: seminal receptacle, B: beak.

How to transfer spermatophores to female: <u>To buccal membrane</u>: *T. pacificus*, *O. bartrami*. <u>To inner mantle cavity near mouth of oviduct</u>: *Illex sp*.



Spawning behavior of *T. pacificus* was similar to that of *I. Illecebrosus* (O'Dor *et al.* 1982). Egg-mass formation resembled the swelling of a balloon.

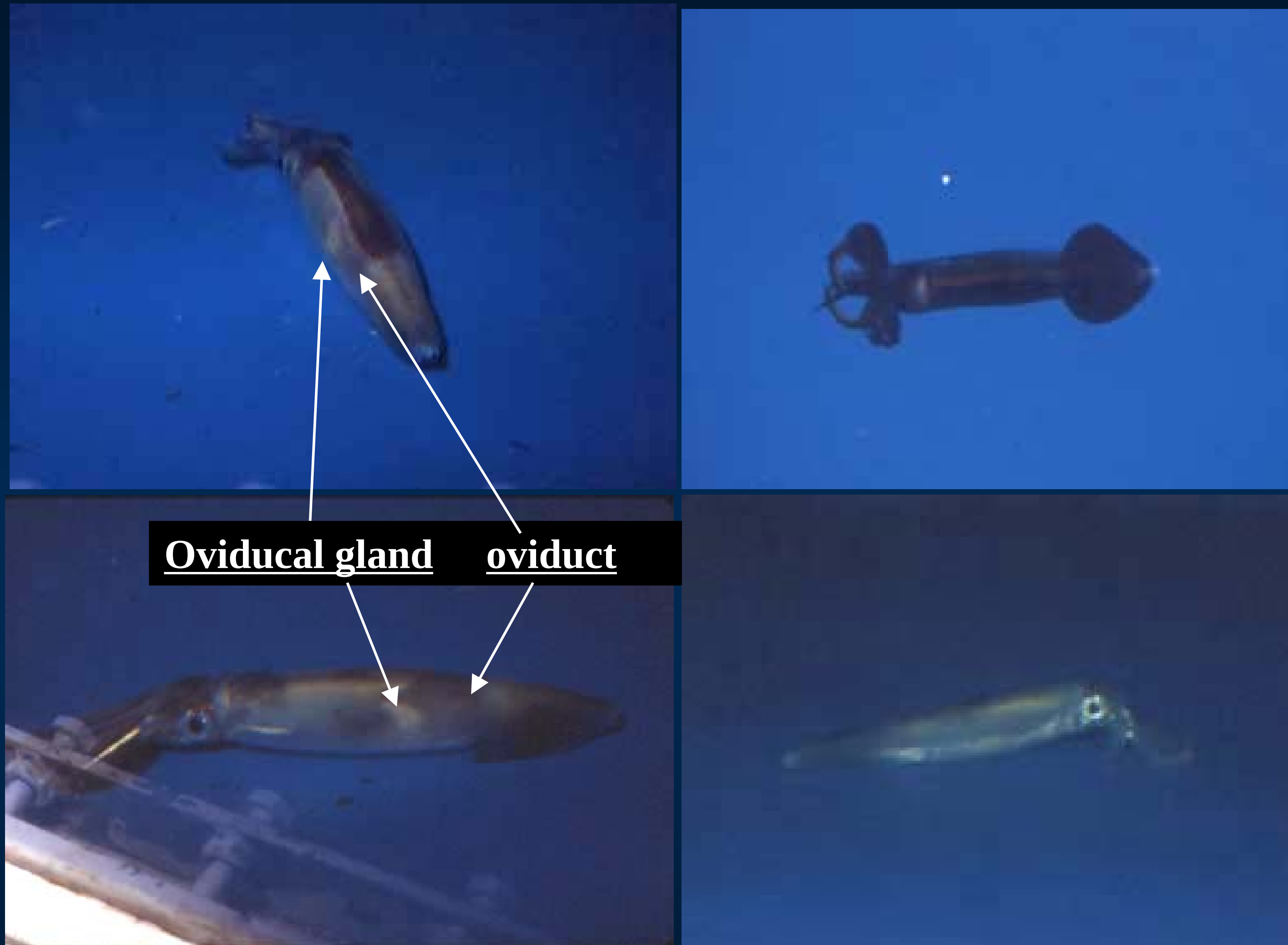


Egg mass of
T. pacificus
in captivity

A: after spawning
B: 4 hrs after sp.
C: 2 days
D：5 days

All of ommastrephid squids may produce gelatinous, spherical, nearly neutrally buoyant egg masses. However, egg masses were not observed in the sea.

Possible spawning type: single spawning: *T. pacificus*, multiple spawning: *S. oualaniensis, O. bartrami, Illex sp*, unknown: *D. gigas, Nototodarus sp.*



T. pacificus **female sits down the bottom just before spawning and may need the sea bottom (continental self and slope).**

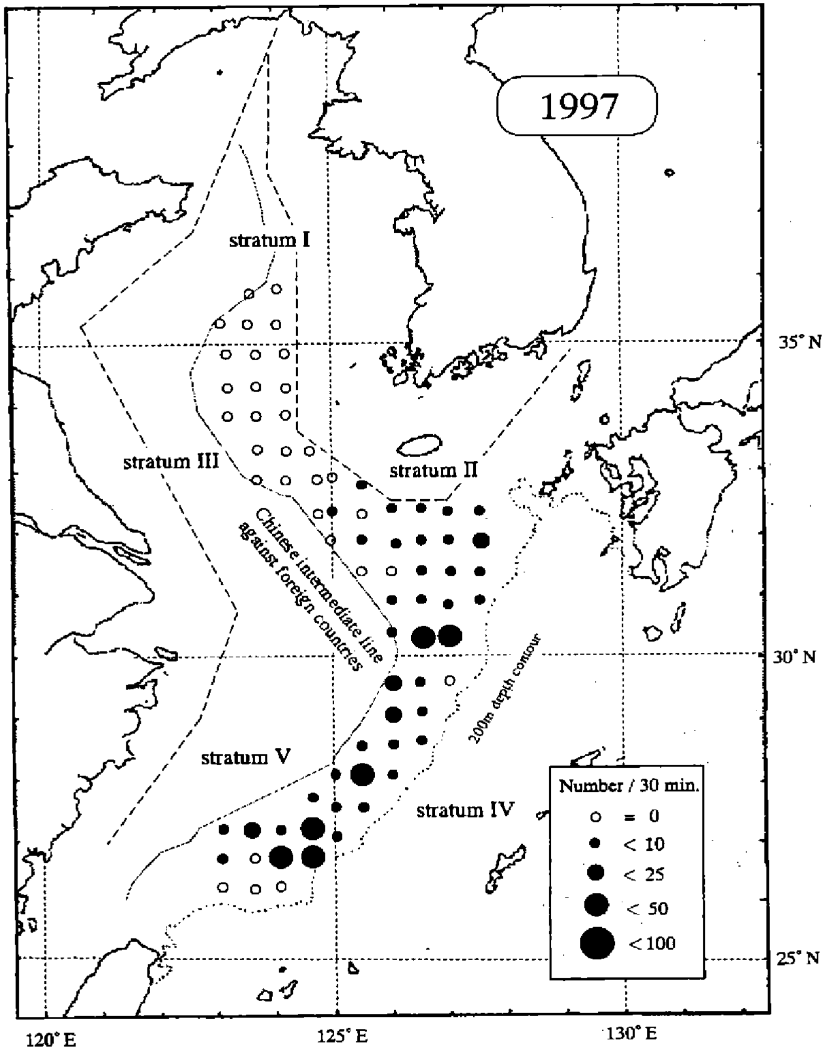
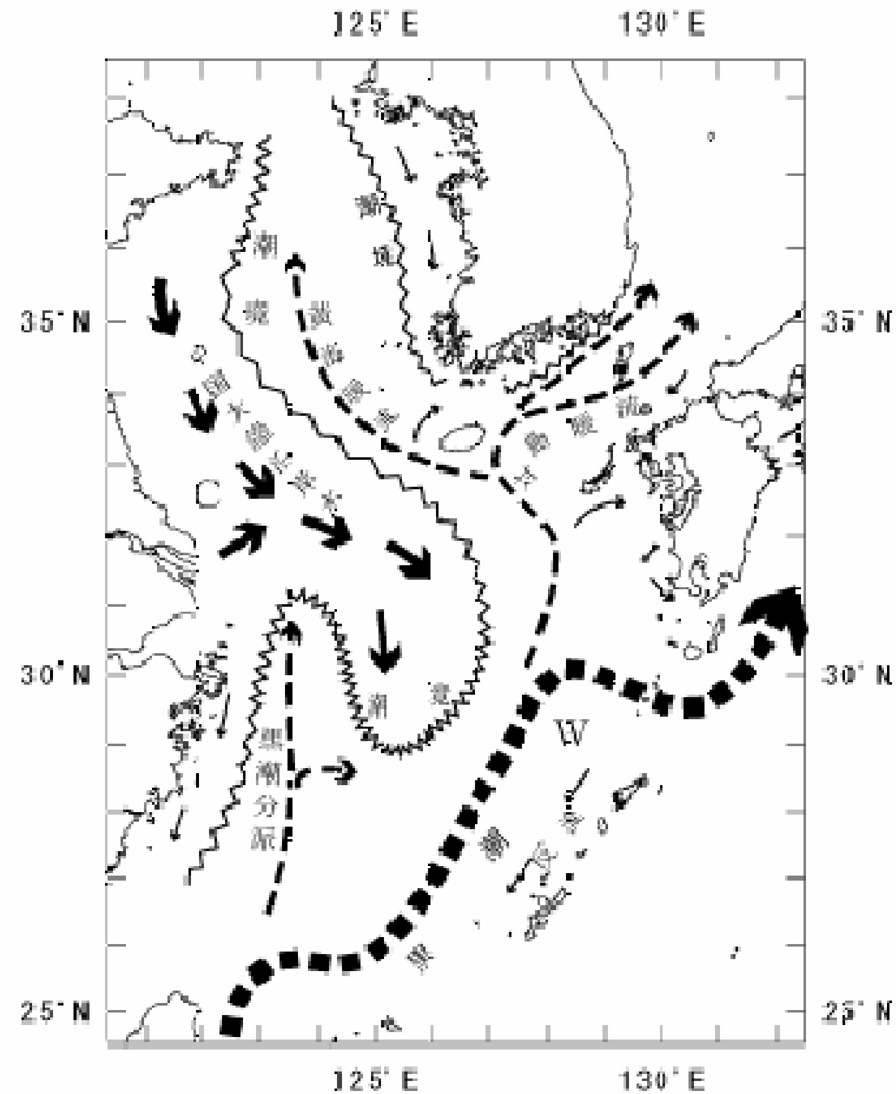
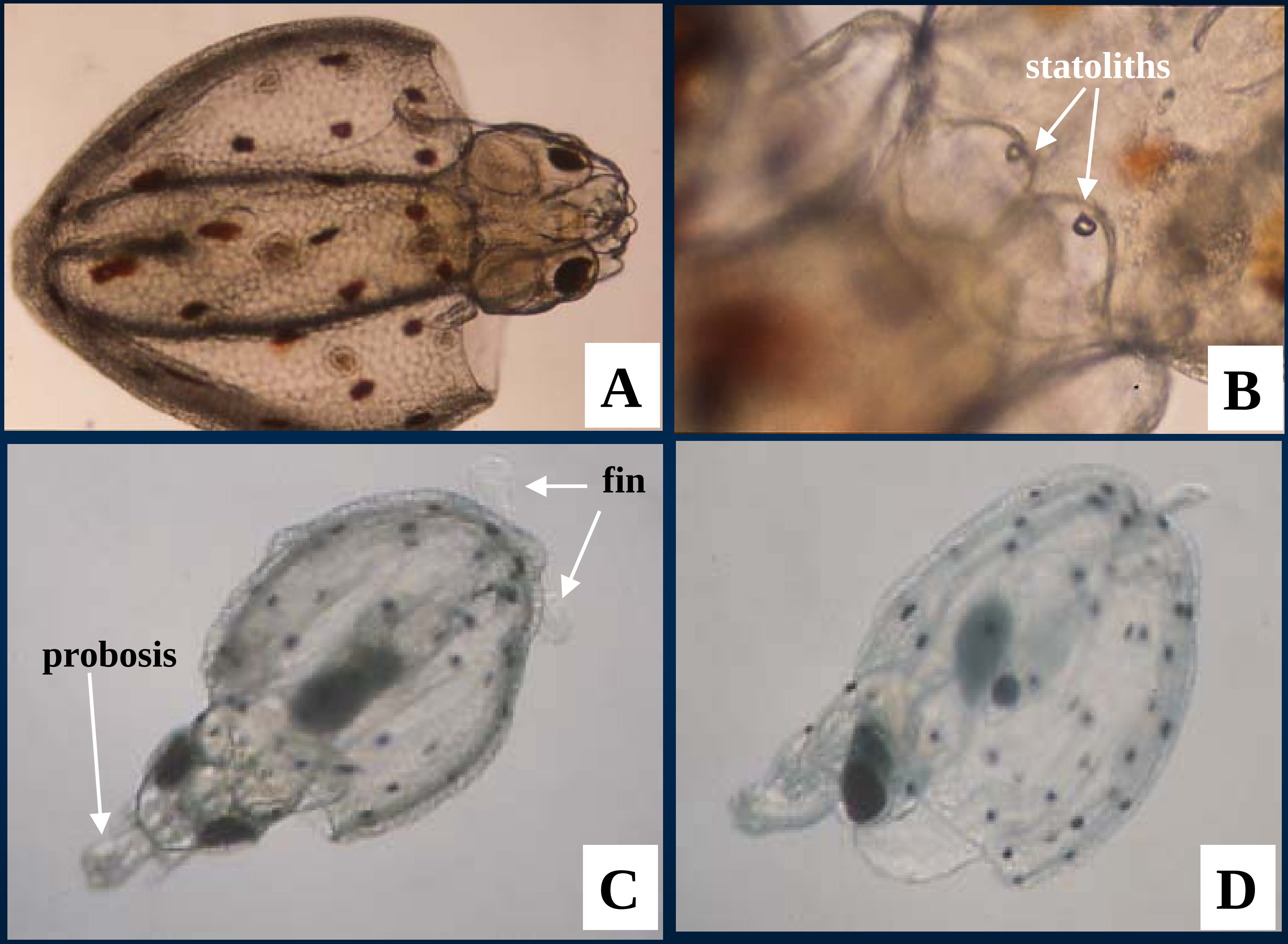


Fig. 2. Distributions of the Japanese common squid number caught by bottom trawl survey in winter of 1997. (Yamada,1998)

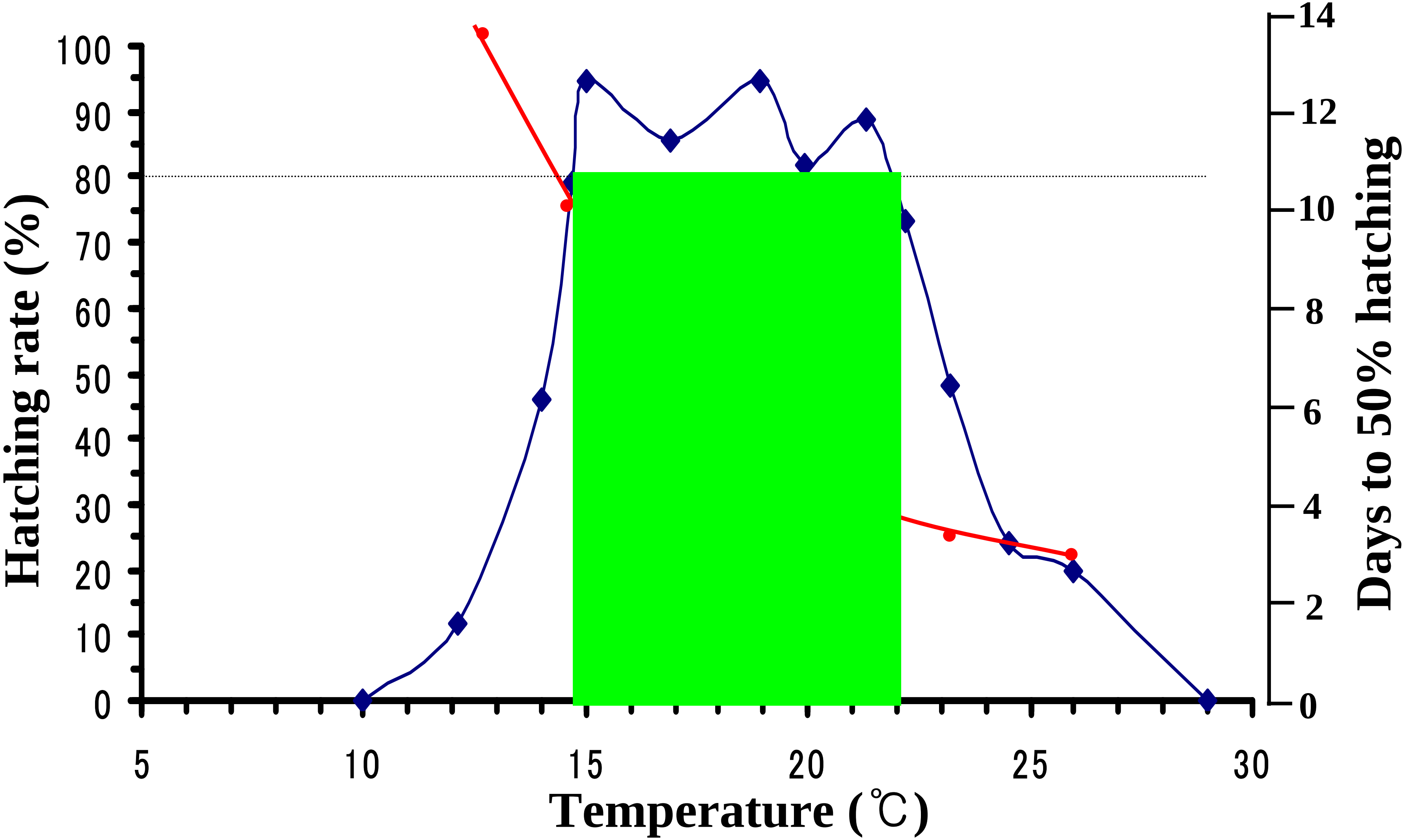


Schematic diagram of water masses during winter (Kondoh, 1985)

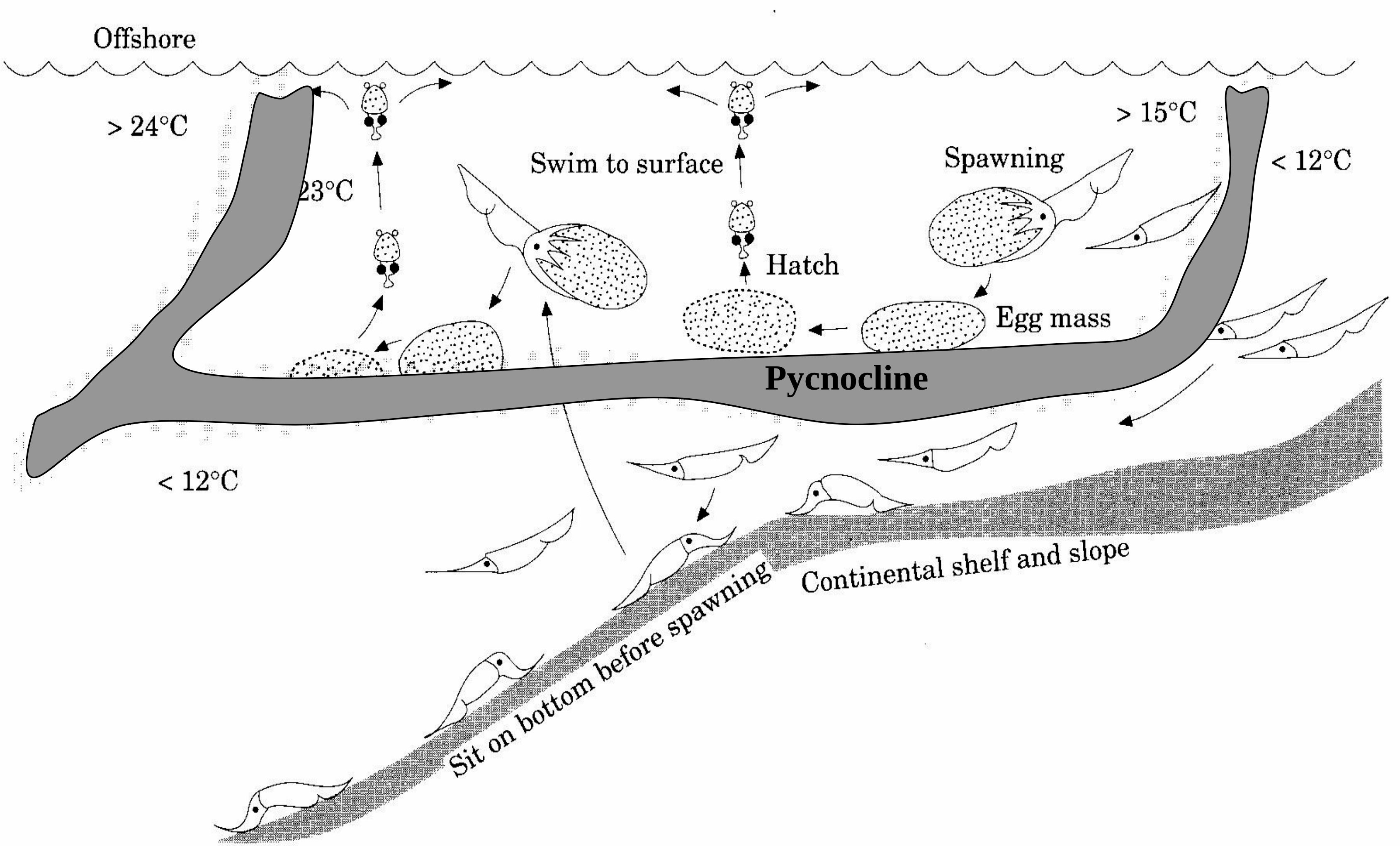
Bottom trawls collect exhausted, spent (post-spawning) *T. pacificus* females on the shelf and slope at 100-500 m depth.



A: hatchling, B: statoliths of 4 days paralarva，C,D: 5 days after hatching



The temperature range for normal embryonic development is 15-23 ℃, which was examined by artificial fertilization methods and egg masses maintain their structure for 4-10 days at temperature between 15-23℃ (Sakurai *et al*., 1996) .



Schematic view of reproductive processes of *Todarodes pacificus* (working hypothesis based on results of experimental studies). (Sakurai *et. al*., 2000)

Schematic diagram in early life stage of *Illex illecebrosus* from egg masses to hatchling

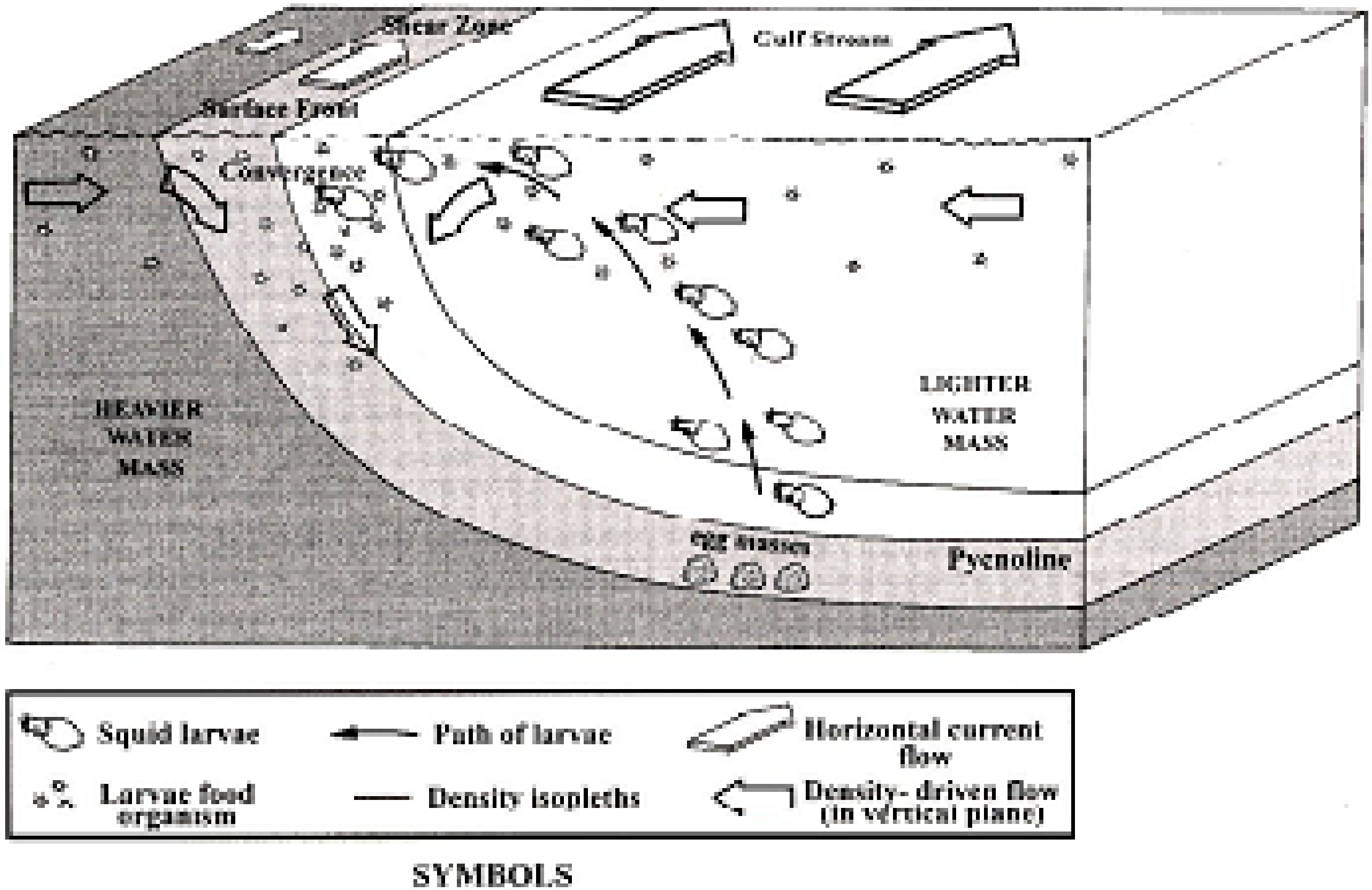


Figure 6.2. Schematic diagram: Within the pycnocline, squid egg masses find a neutrally buoyant level, where they are suspended at mid-depth at suitable development temperatures and under conditions of reduced predation. Upon hatching, squid paralarvae may rise to the surface layer, where they would be carried into the convergent frontal zone by the density-driven flow.

(Bakun and Csirke1998)

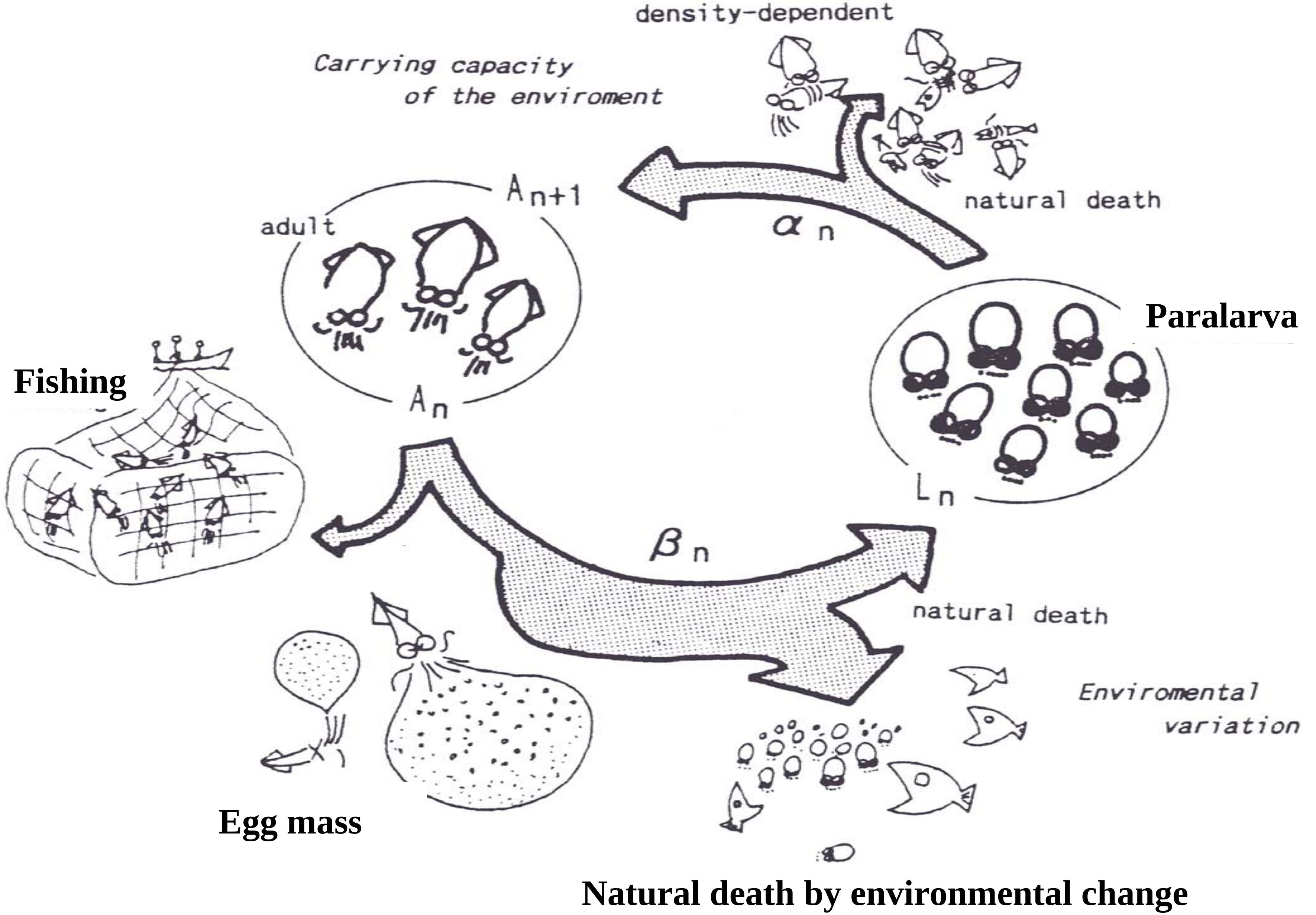
What is ommastrephid squid?

Distribution

Life cycle

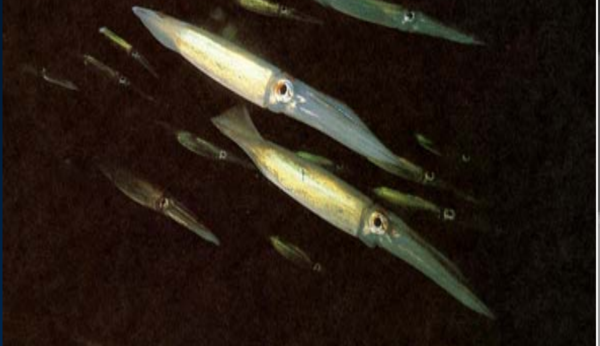
Reproductive characteristics

Stock fluctuation



Scheme of life cycle and stock fluctuation of ommastrephid squid
（Isoda & Azumaya，1998）

Short fined squid, *Illex illecebrosus*



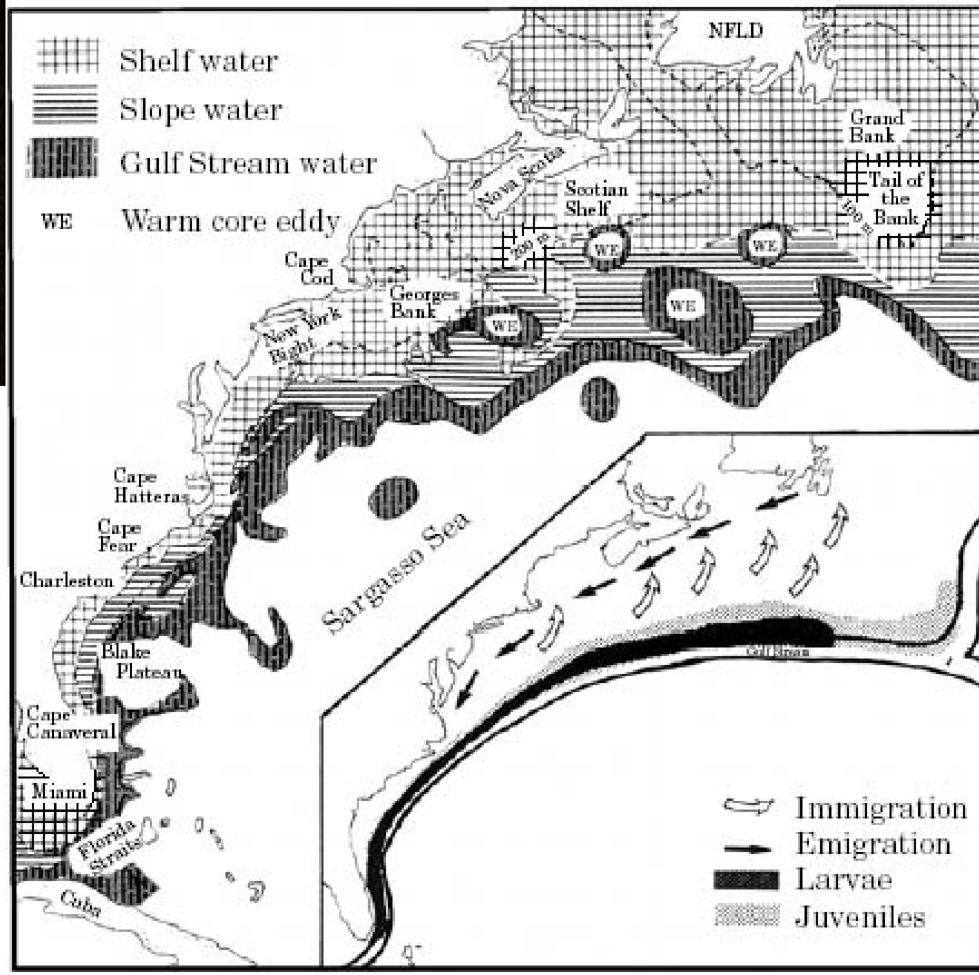
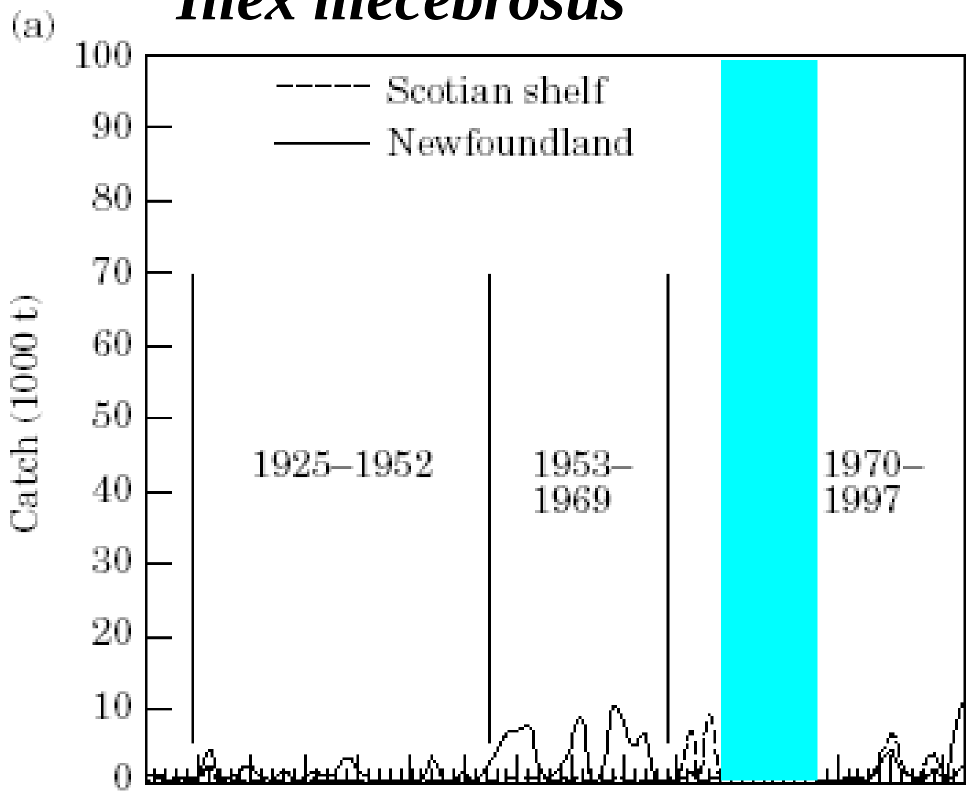


Figure 1. Schematic representation of the life history of short-finned squid in relation to features of the Gulf Stream System (from Rowell and Trites, 1985).

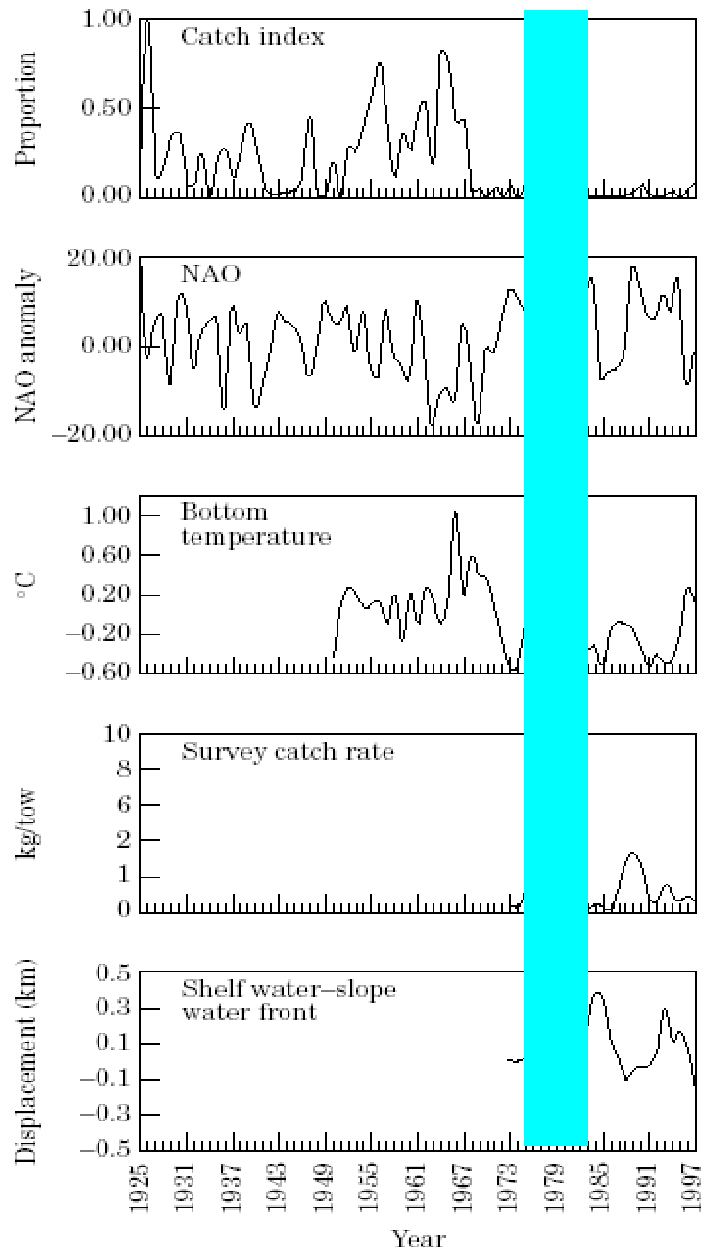
Schematic representation of the life histroy of *I. Illecebrosus*. (Dawe *et al*., 2000)

Illex illecebrosus



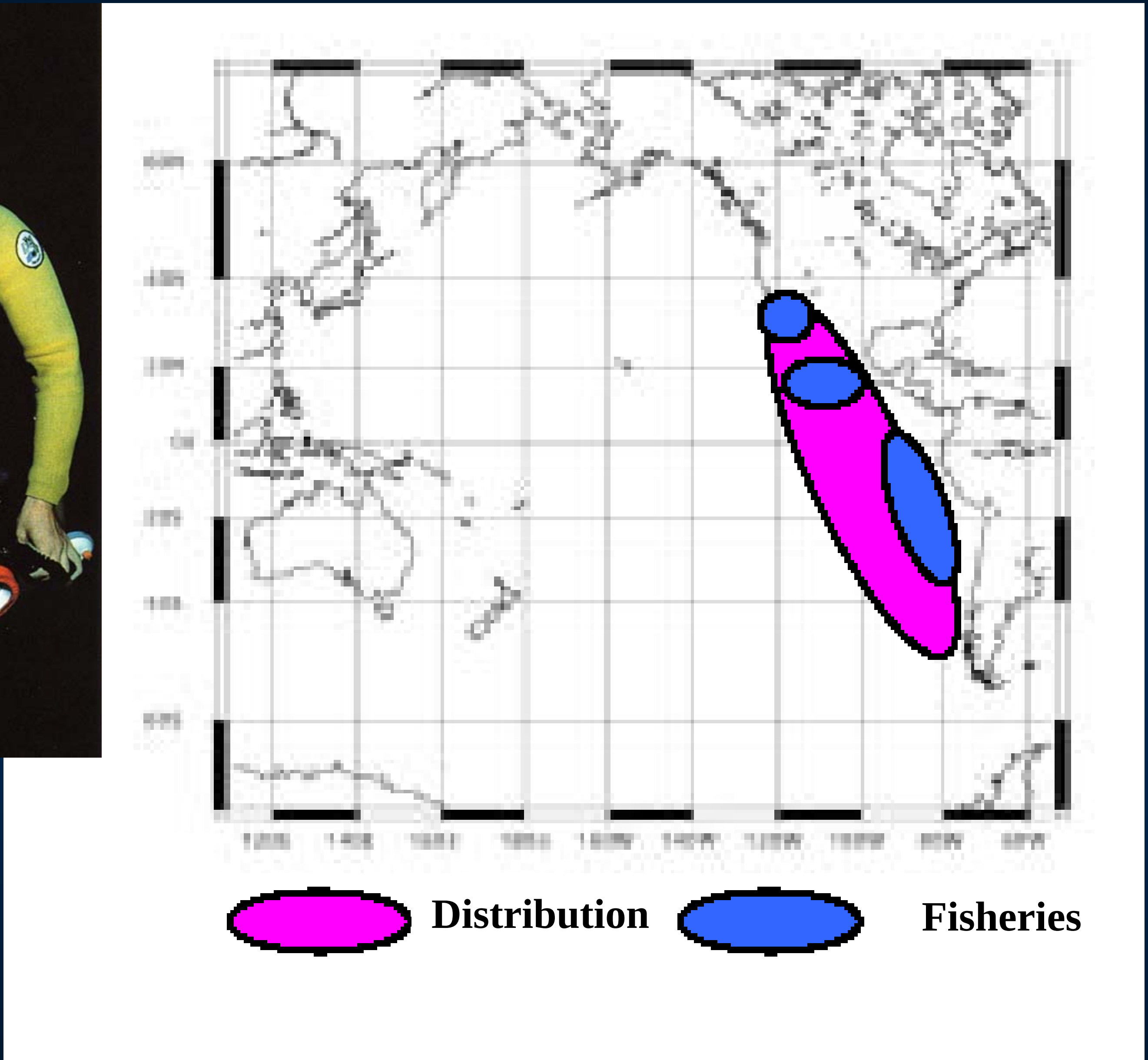
Annual trend in catch by fisheries area.
(Dawe *et al*., 2000)

Squid abundance was positively related to a favorable oceanographic regime associated with a negative NAO (weak NE winter winds), high water temperatures off Newfoundland, increased meandering of Gulf Stream, and so on.

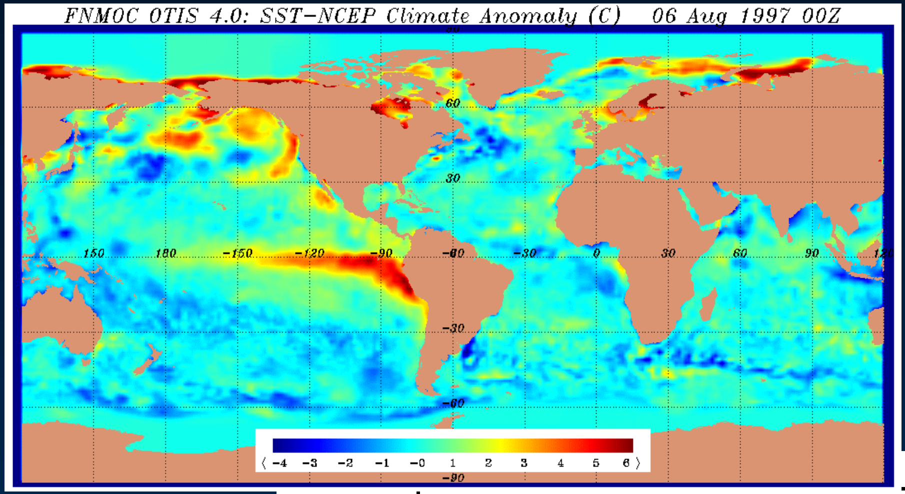


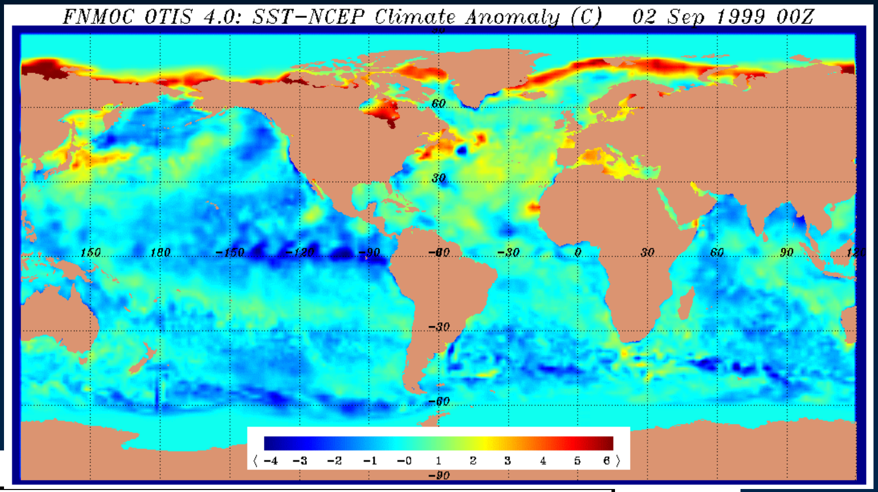
Annual trend in squid abundance indices and in the environmental indices.

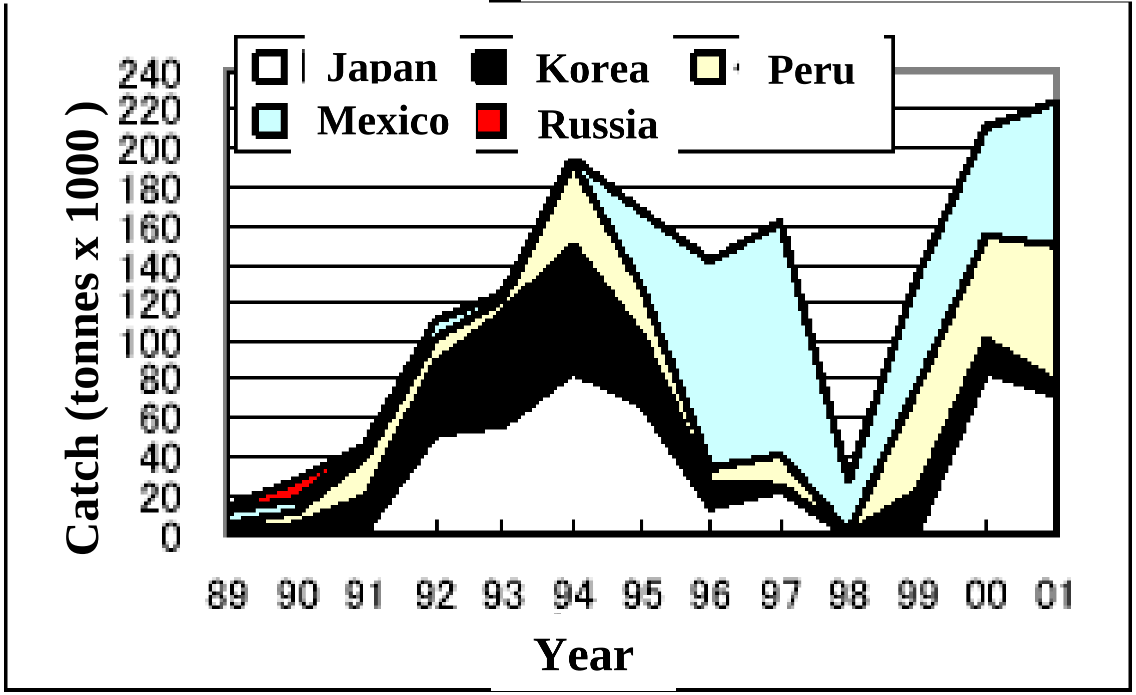
Jumbo squid, *Dosidicus gigas*



(T. Ichii, 2004)

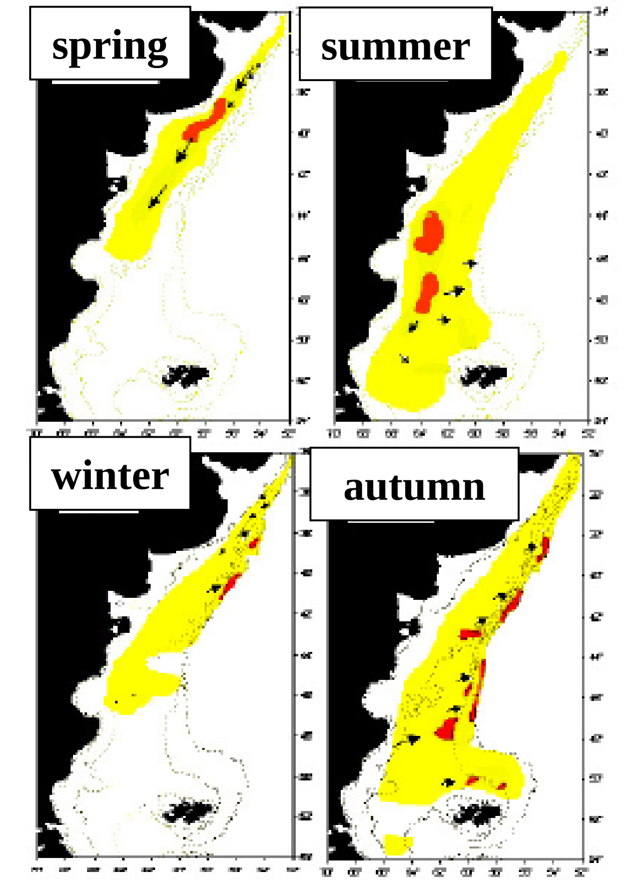




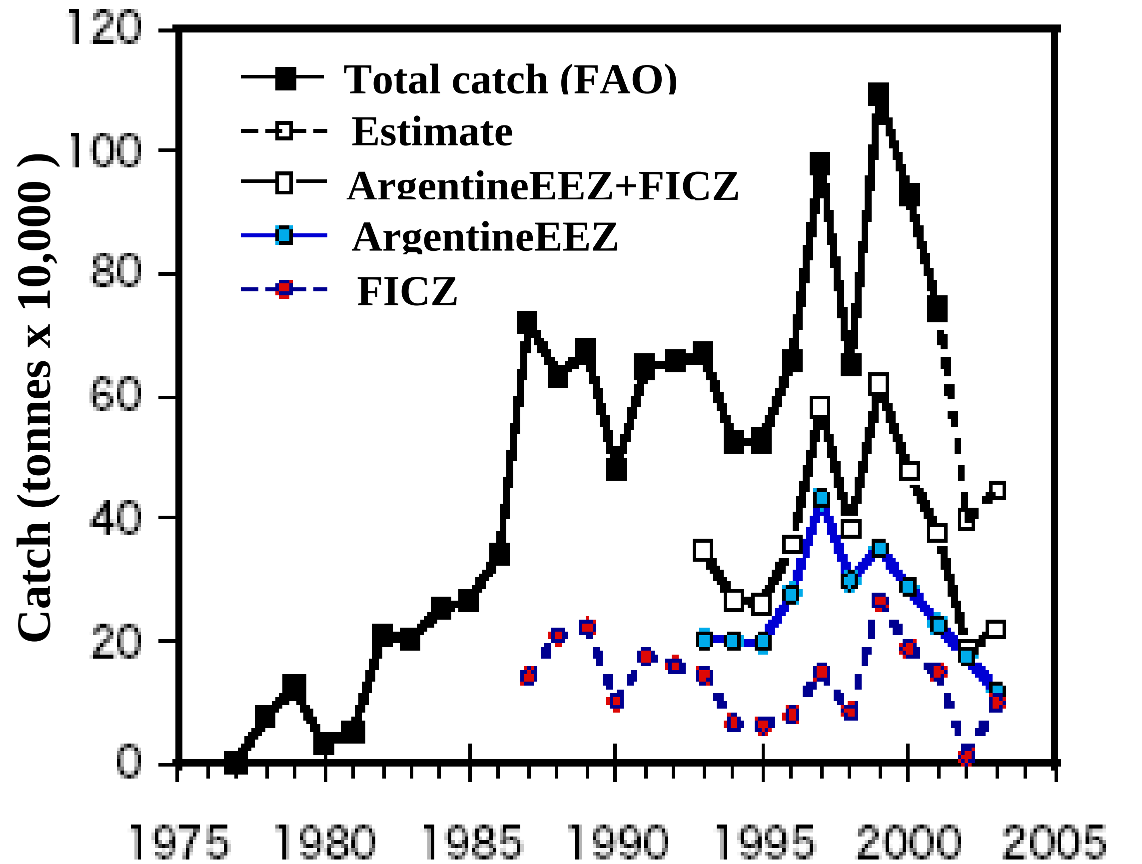


The relationship between *D. gigas* catch and the SOI was found to be strongest (Waluda et al., 2004). El Nino effects to northward of the distribution and La Nina effects to the reproductive success (Ichii, 2004).

Argentine shotfin squid, *I. argentinus*



Seasonal changes of fishing areas



Annual trend in catch by fisheries area (Sakai, 2004)

Flying squid (Red squid), *O. bartrami*

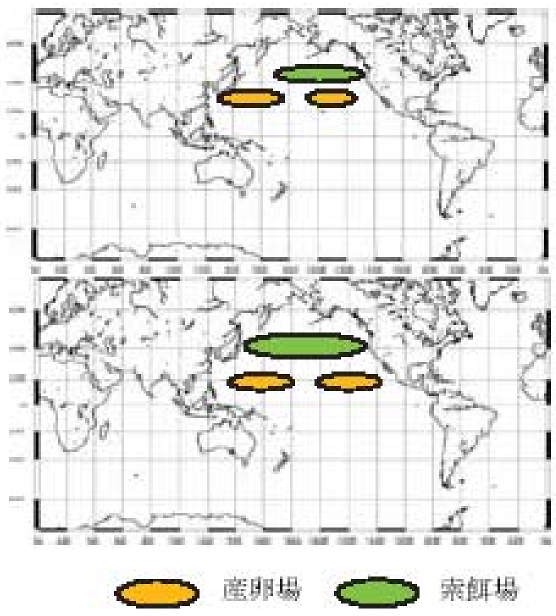
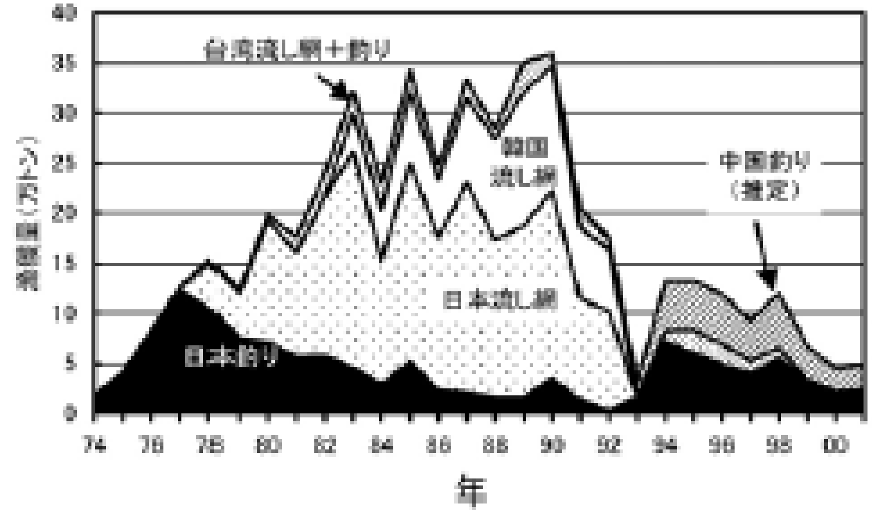
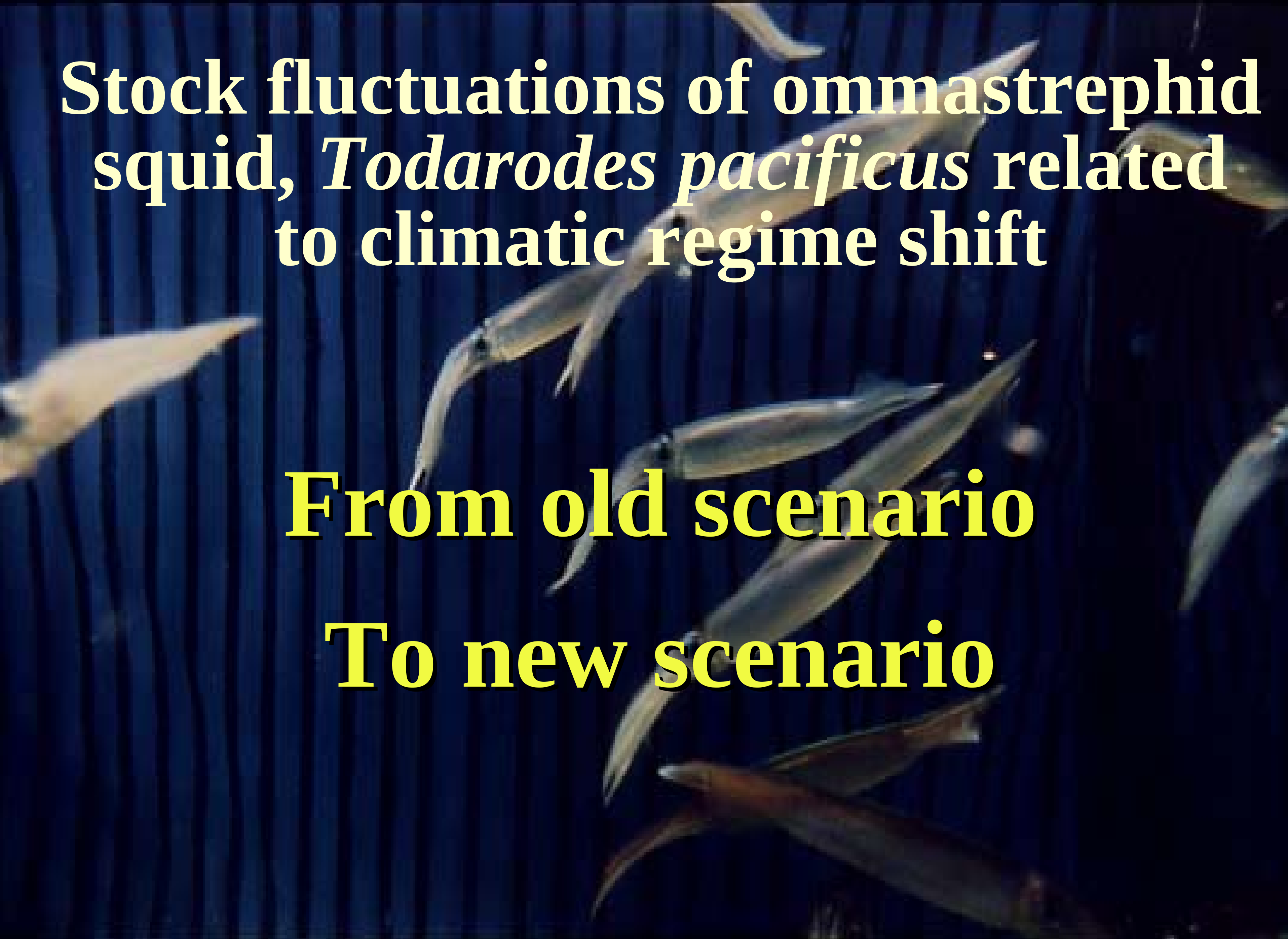


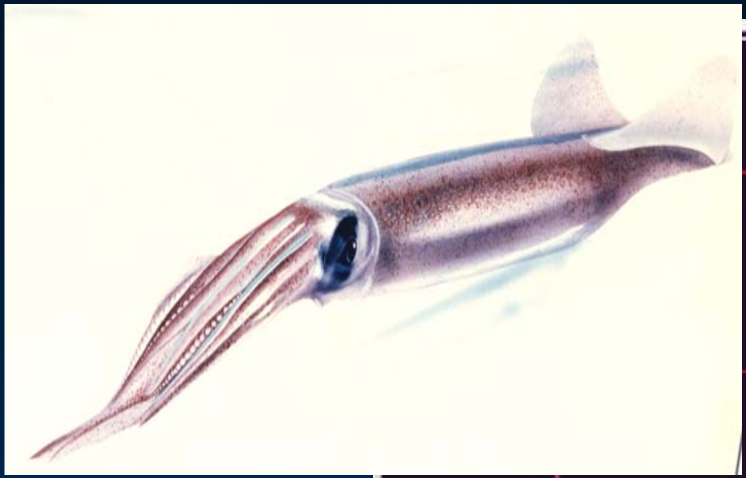
図 2. アカイカ秋生まれ群（上）と冬春生まれ群（下）の回遊
漁場は索餌場に形成される。

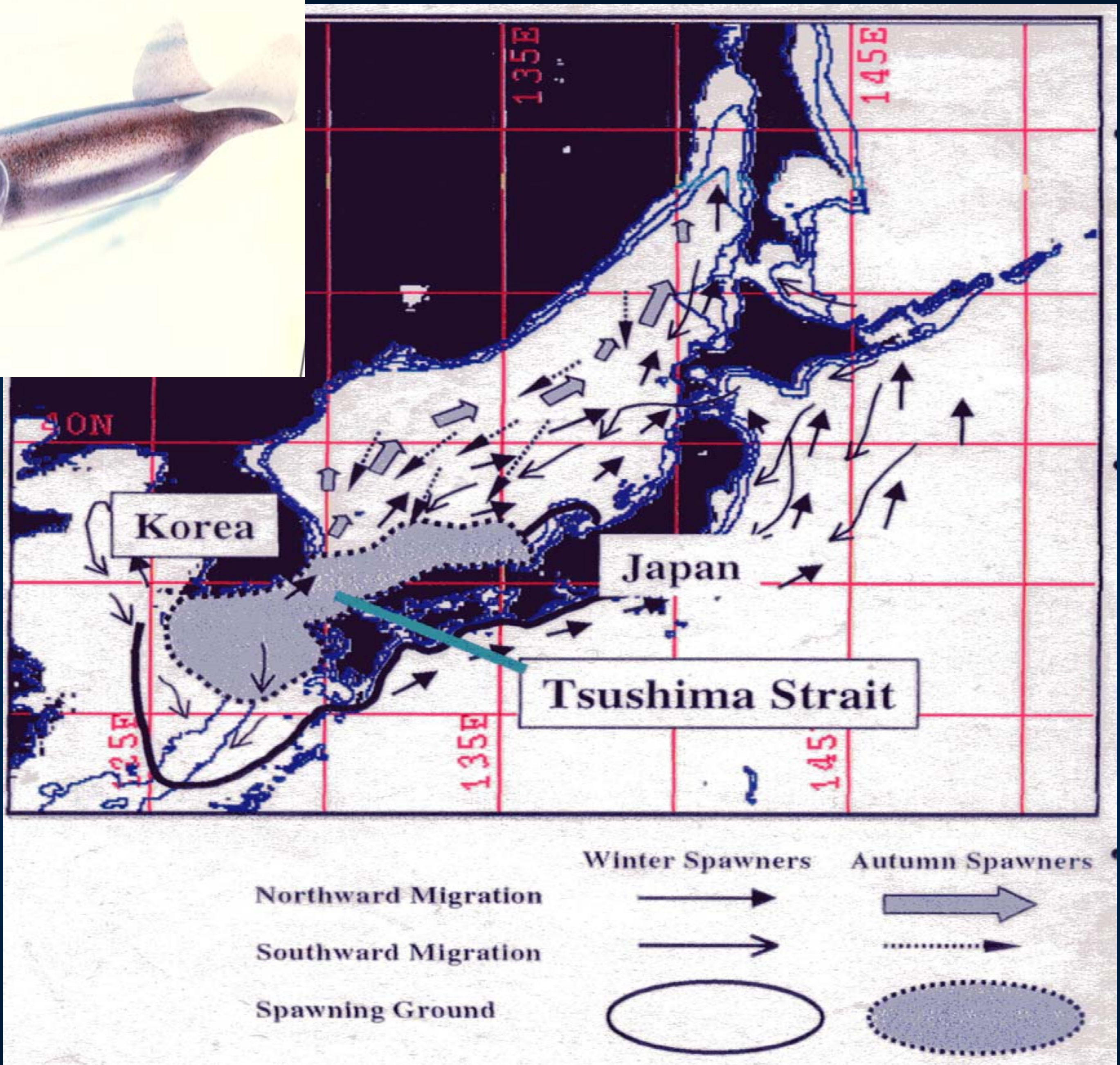


Annual trend in catch by fisheries area(Ichii, 2004)

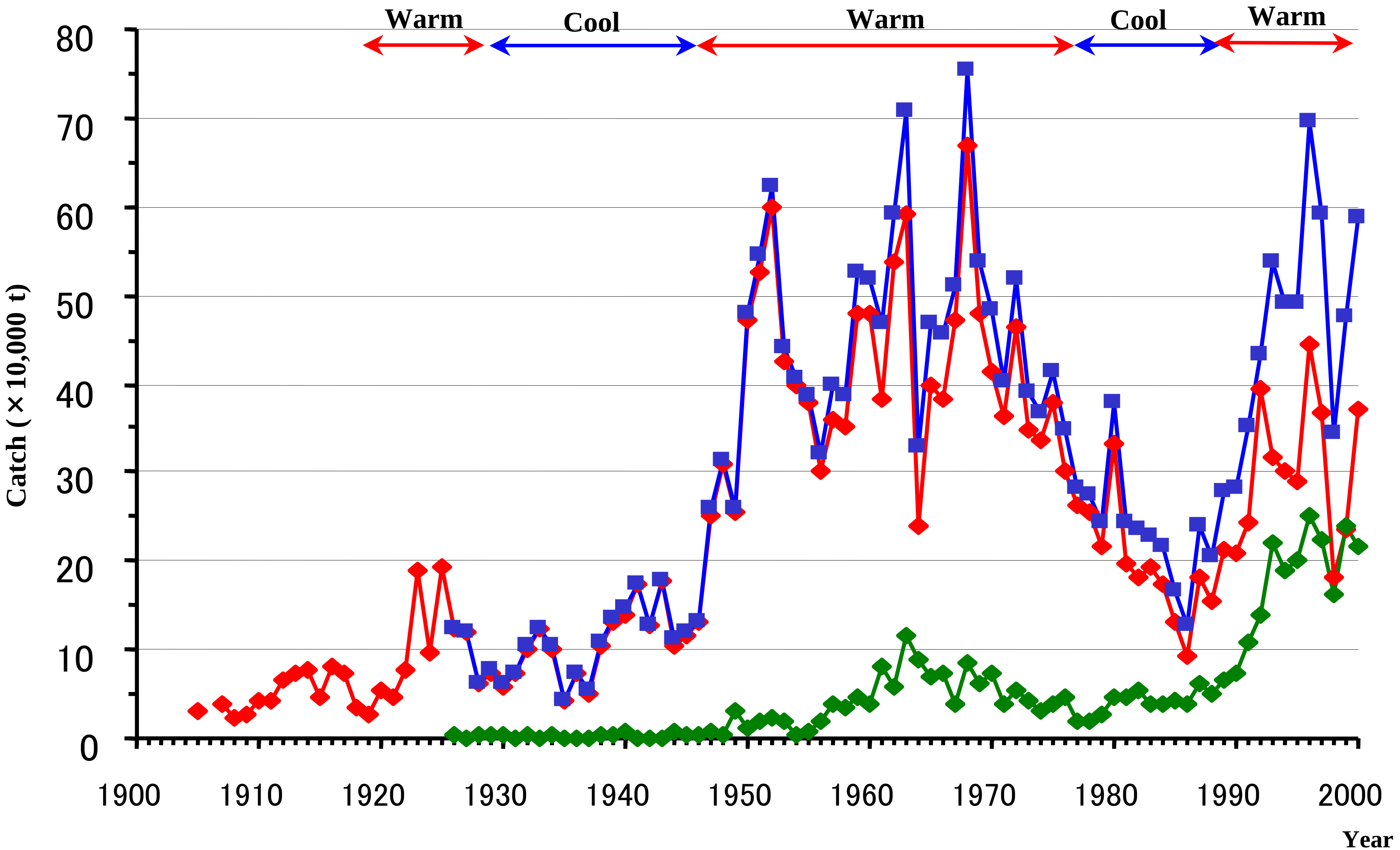
Please see Dr. John Bower’s poster presentation!


Stock fluctuations of ommastrephid squid, *Todarodes pacificus* related to climatic regime shift
From old scenario
To new scenario

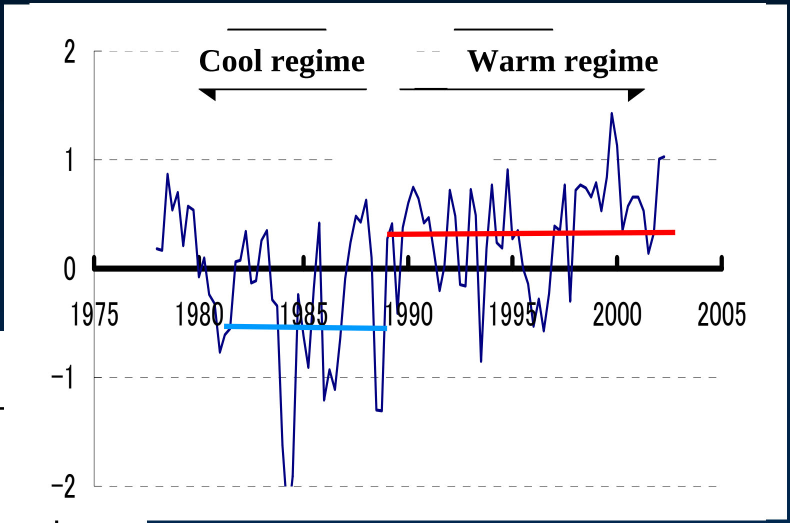




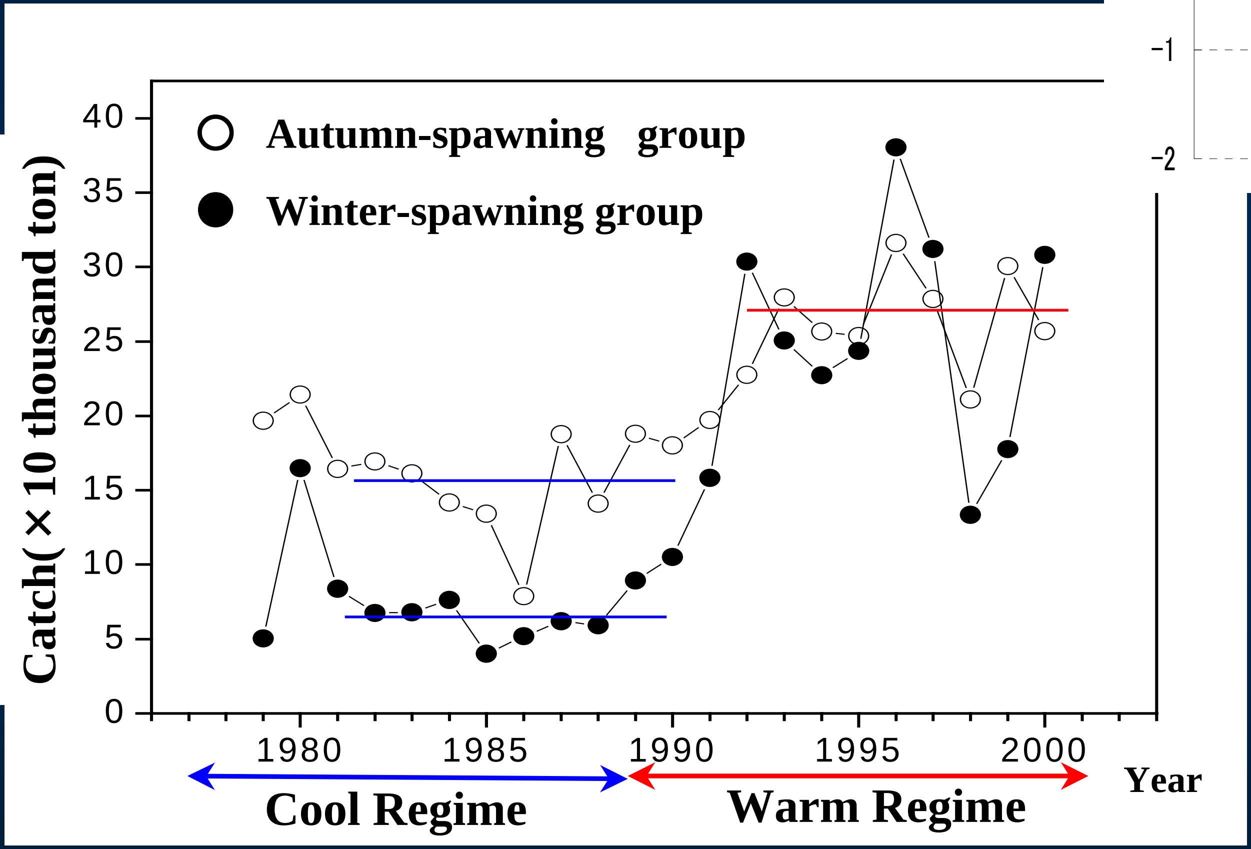
Spawning grounds and migration routes of *Todarodes pacificus*



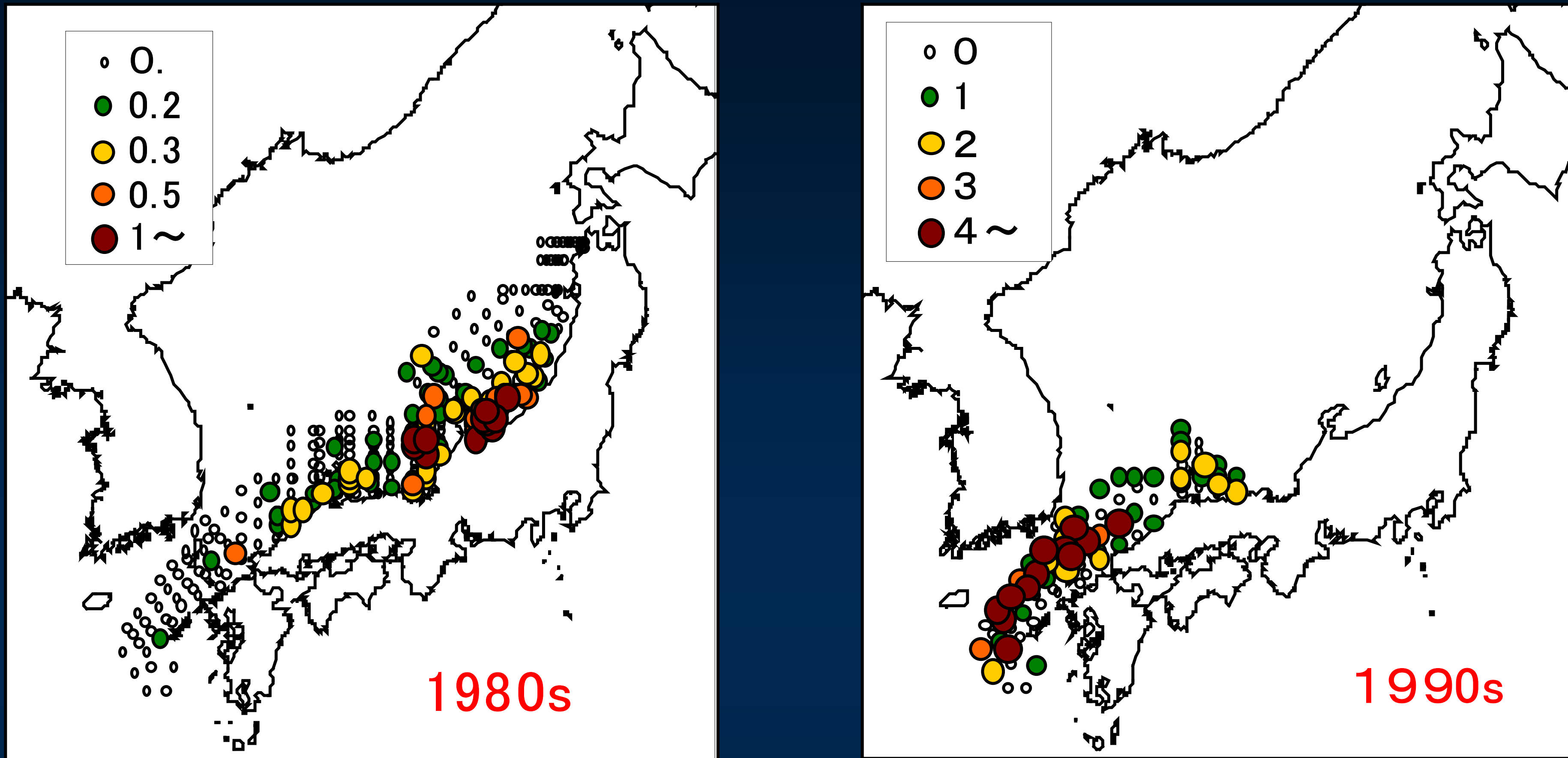
Annual fluctuation in common squid, *Todarodes pacificus* catches of Korea and Japan during the 20th Century. (Data derived from the Japan Sea Research Institute, Japan and the National Fisheries Research and Development Institute, Korea). Horizontal lines indicate interdecadal regime shifts in water temperature in the western North Pacific (Minobe,1997). (Sakurai *et al*., 2001)



Annual changes of water temperature anomary at 50 m depth in water of the Tsushima Warm Current during 1978 and 2001. (Japan Sea National Fisheries Research Institute)



Annual fluctuation of autumn- and winter-spawning common squid catches. (Kidokoro, 2003)



Changes of distribution patterns of *T. pacificus* paralarvae in 1980's (cool regime) and 1990's (warm regime). (No. of paralarvae/tow). (T. Goto, in press)

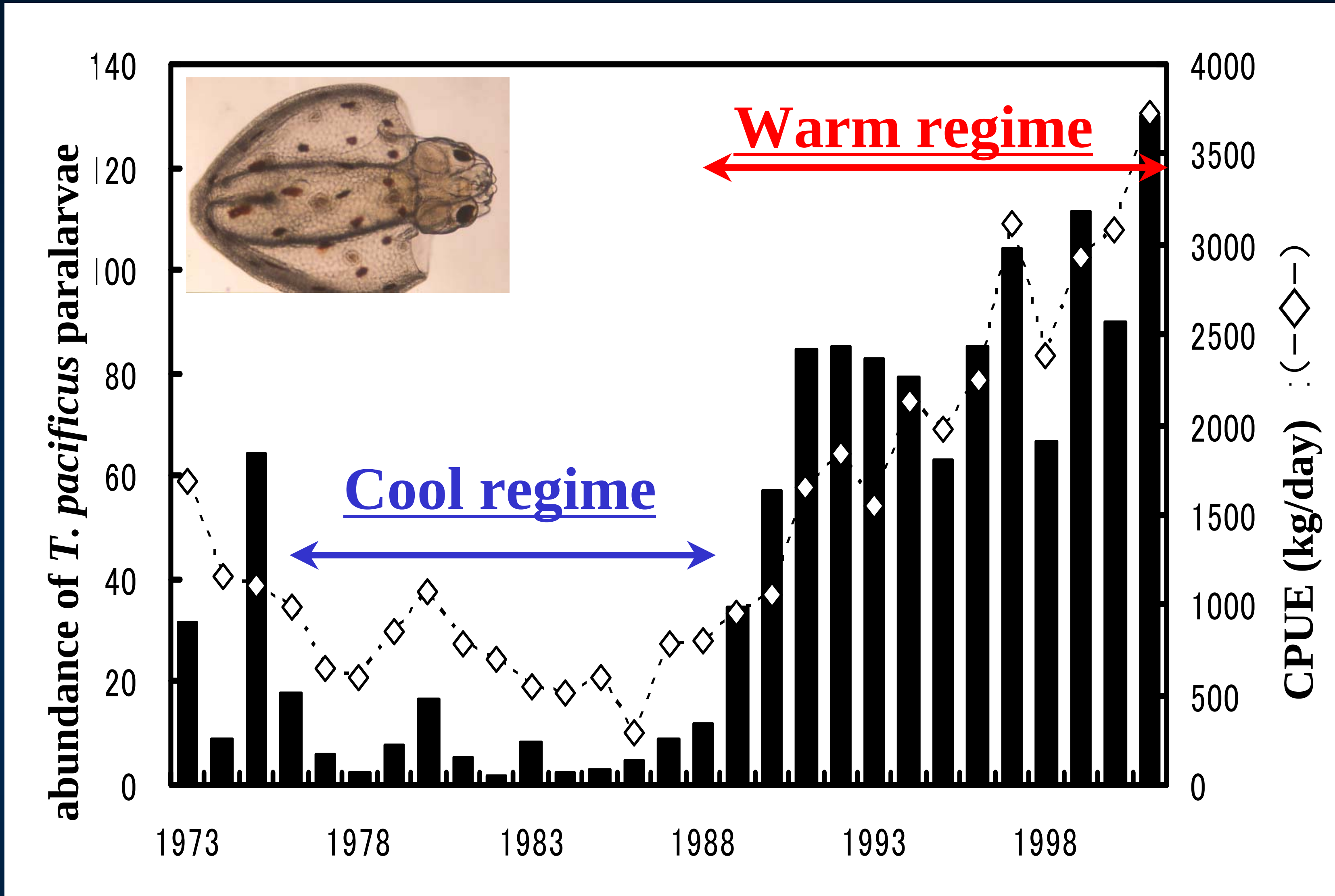


Fig. Annual changes of abundance of T. pacificus paralarvae / 1000m^3 (Oct-Nov) and CPUE (kg/day , May-Oct, Japan Sea) (Goto *et al*, 2002)

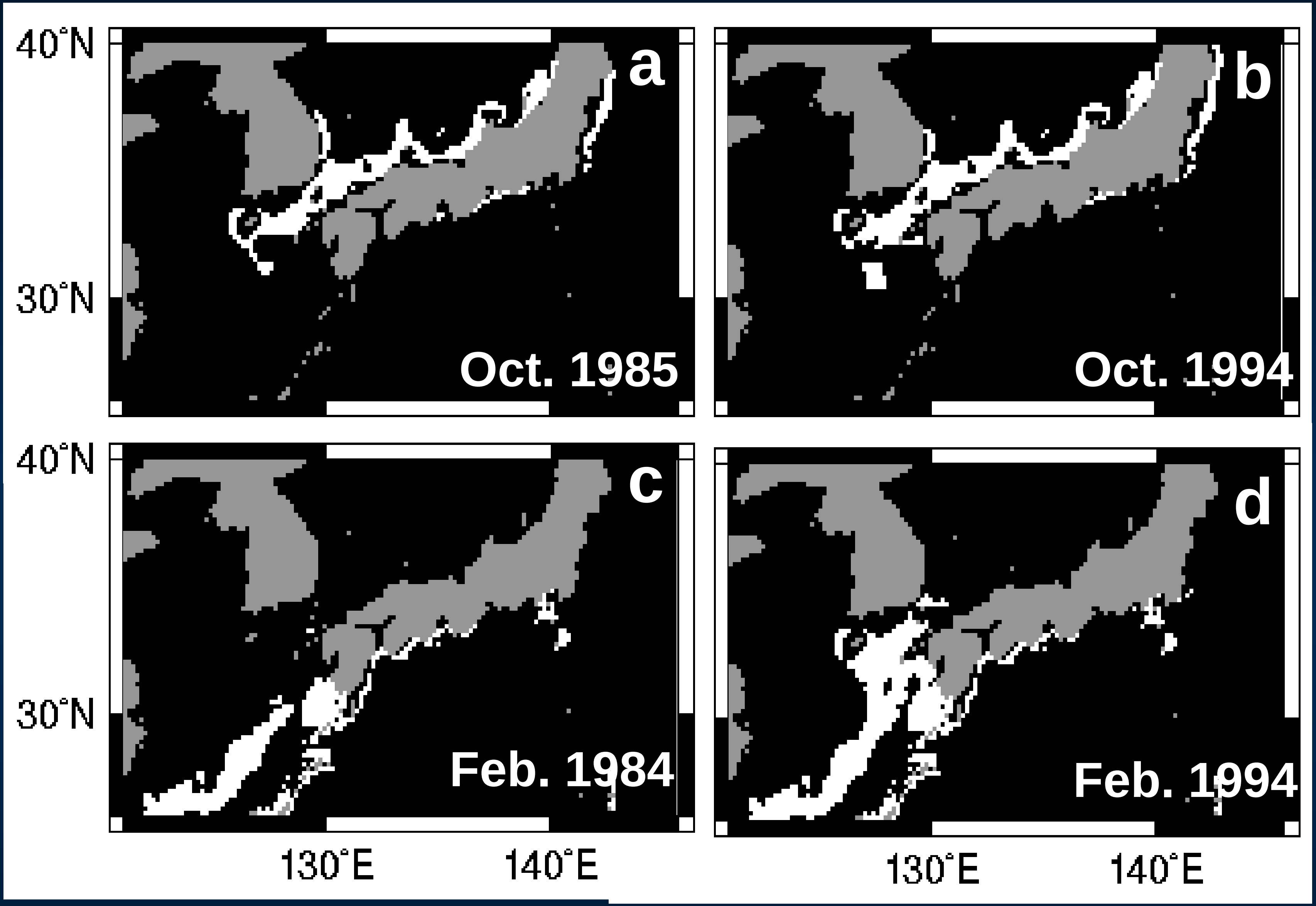
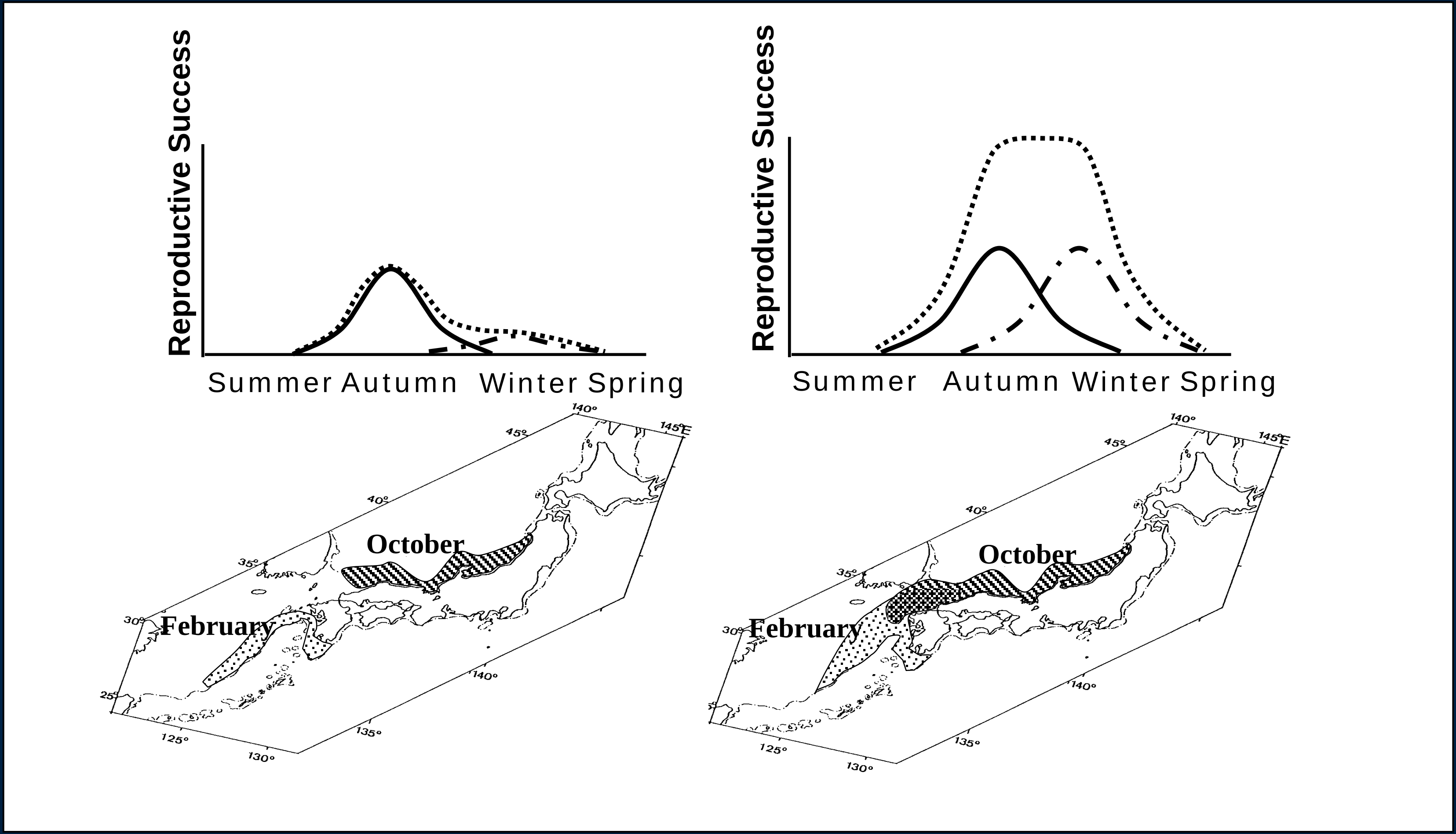


Fig. Comparison of seasonal shifts in inferred spawning areas (white) between October and February in 1985/1986 (cold year) and 1994 (warm year), based on GIS data. (after Sakurai *et al.*, 2000)

Possible scenario of stock fluctuations of *Todarodes pacificus* with changes of inferred spawning areas during autumn and winter related to climatic regime shifts. **(Sakurai *et al.*, 2002)**



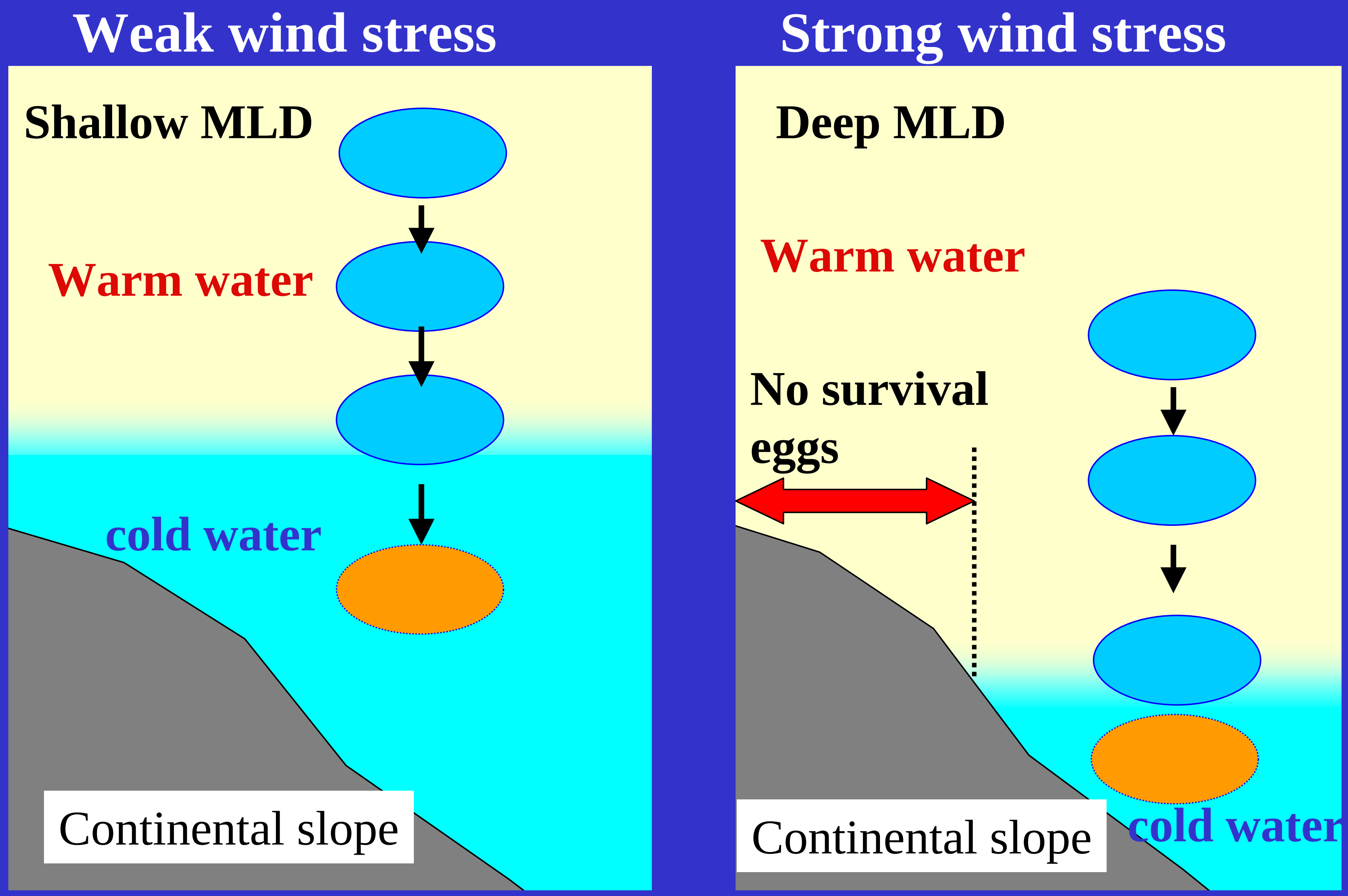
The autumn and winter spawning areas extended and overlapped in the Japan/East Sea and East China Sea when adult stocks increased during a warm regime after 1989.

Stock fluctuations of Japanese common squid (*Todarodes pacificus*) related to the winter monsoon

Objectives:

*How dose 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
Strong wind stress
Shallow MLD
Warm water
cold water
Continental slope
Deep MLD
Warm water
No survival eggs
cold water
Continental slope

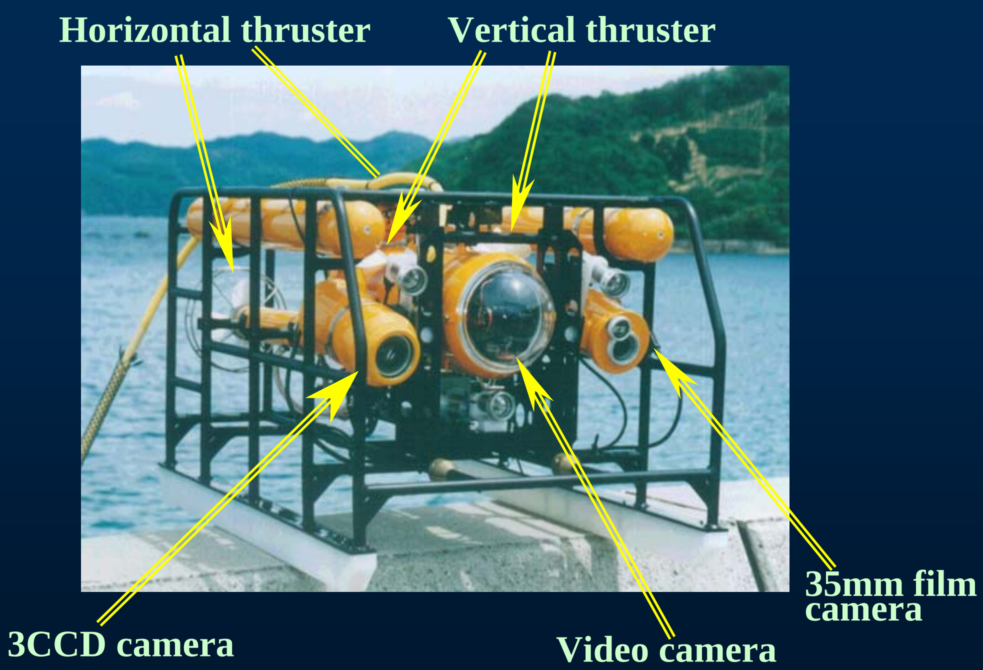
Natural egg mass survey using ROV

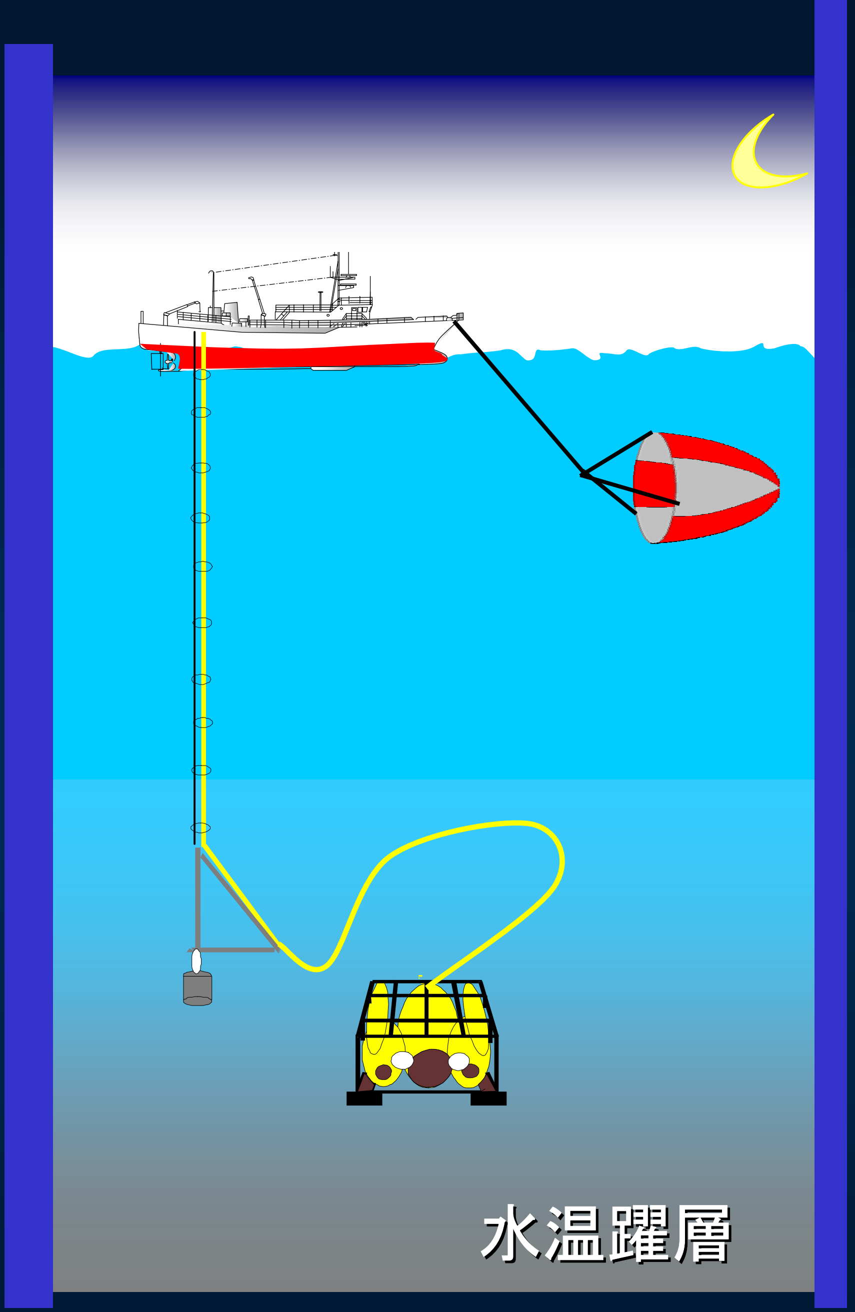
ROV (Expert Nova System , KOWA Co.Ltd.)

Equipments :

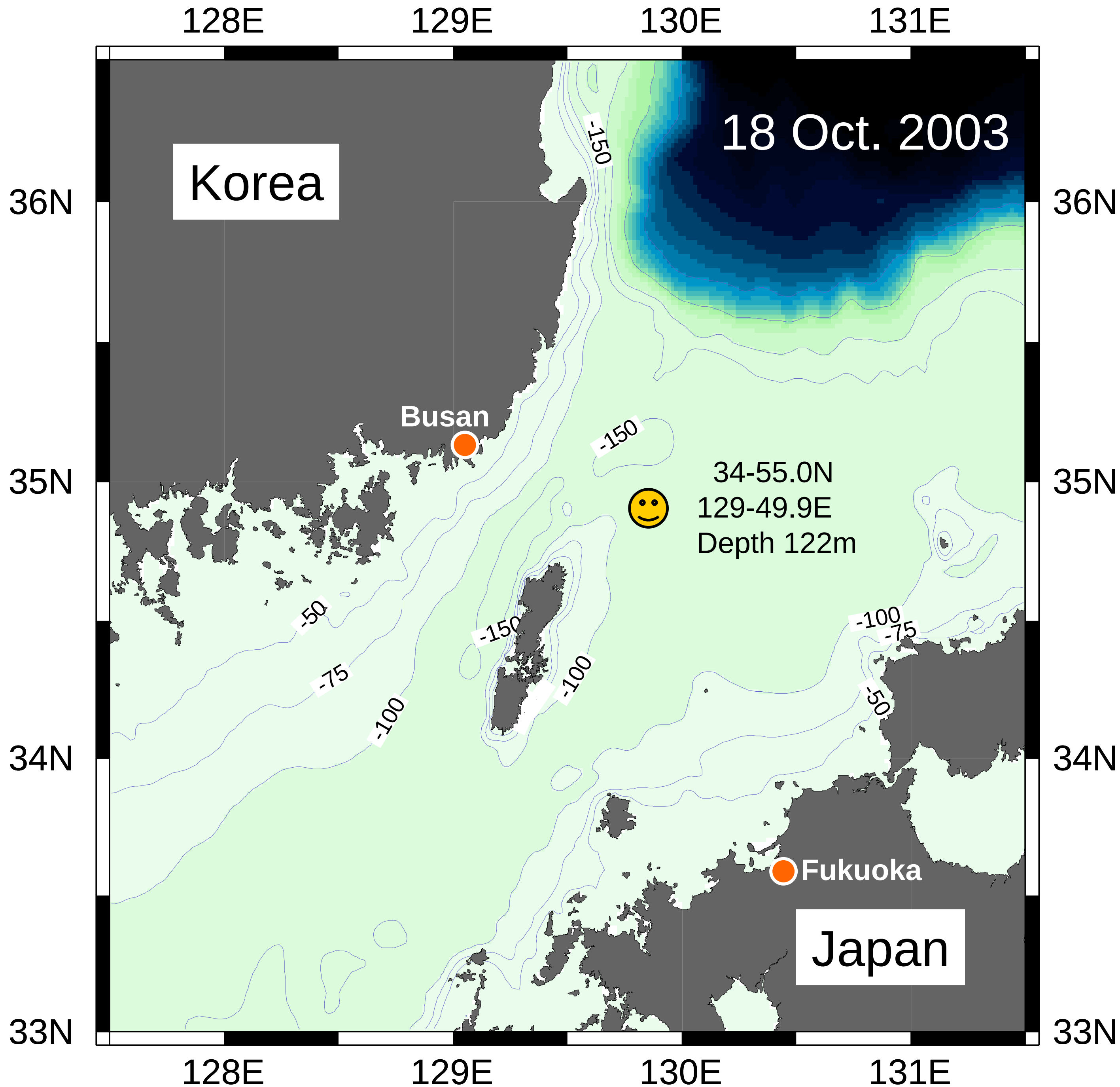
- Two pairs of thrusters
  - *Horizontal and Vertical*
- 3 Cameras
  - *3CCD, video and 35-mm*

Capacity to resist depth : 400m





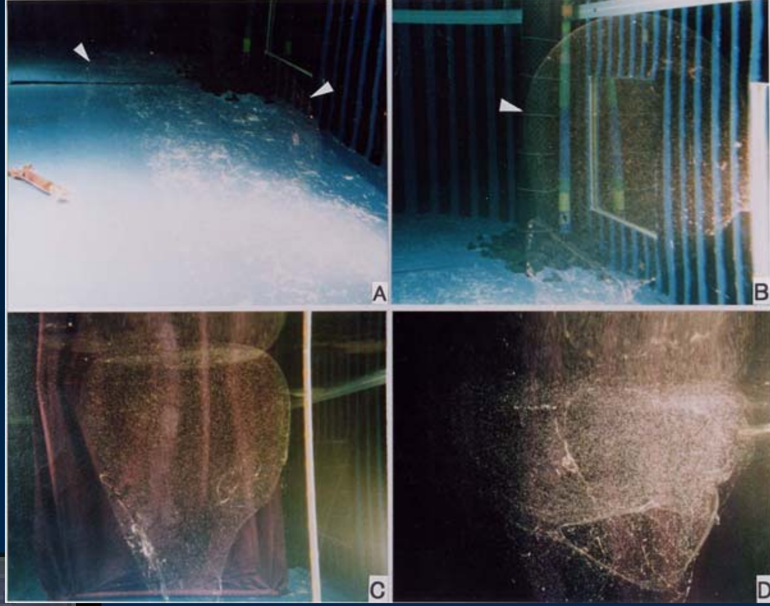
Schema of ROV observation



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

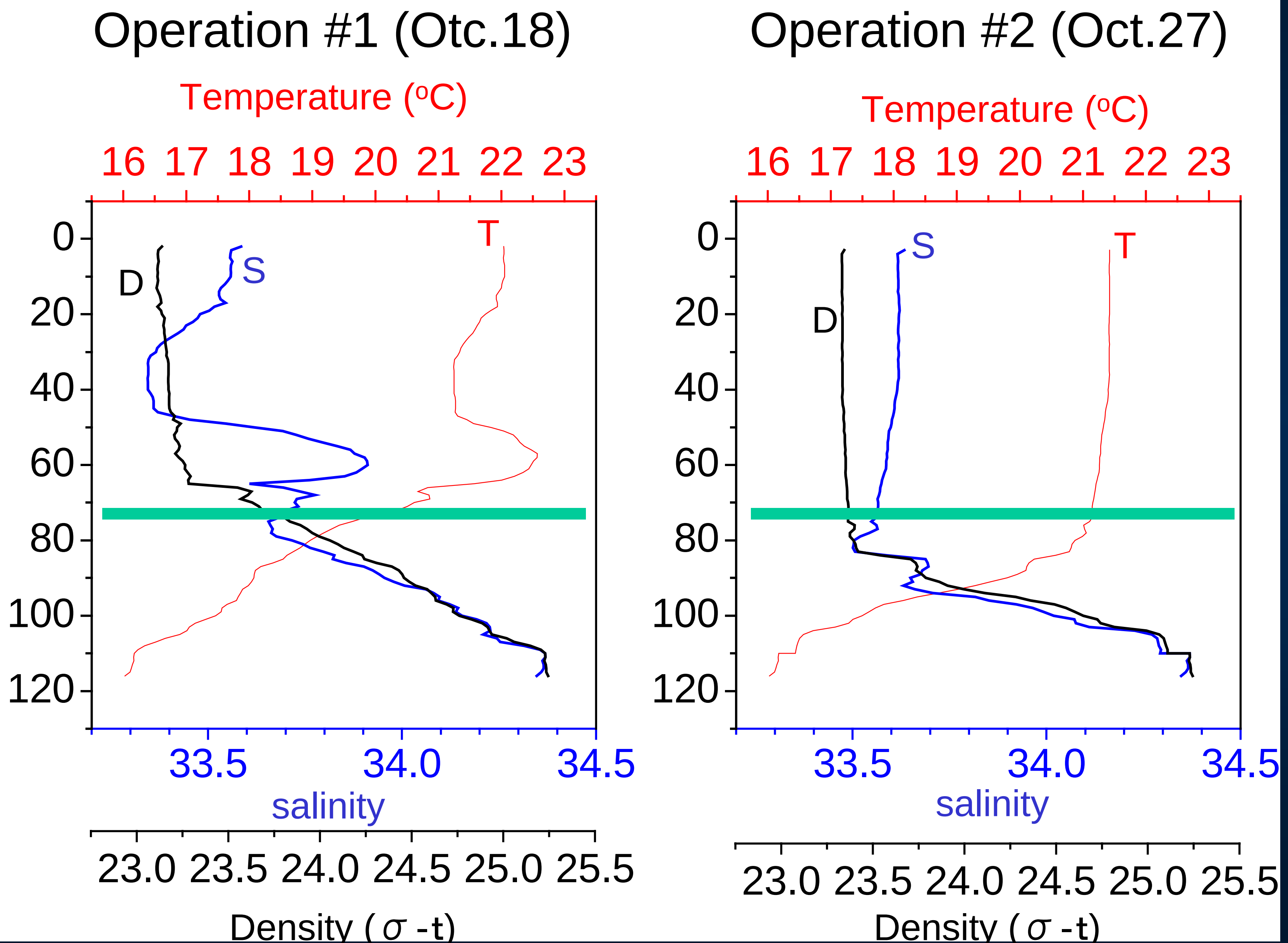
Coming Soon !!

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

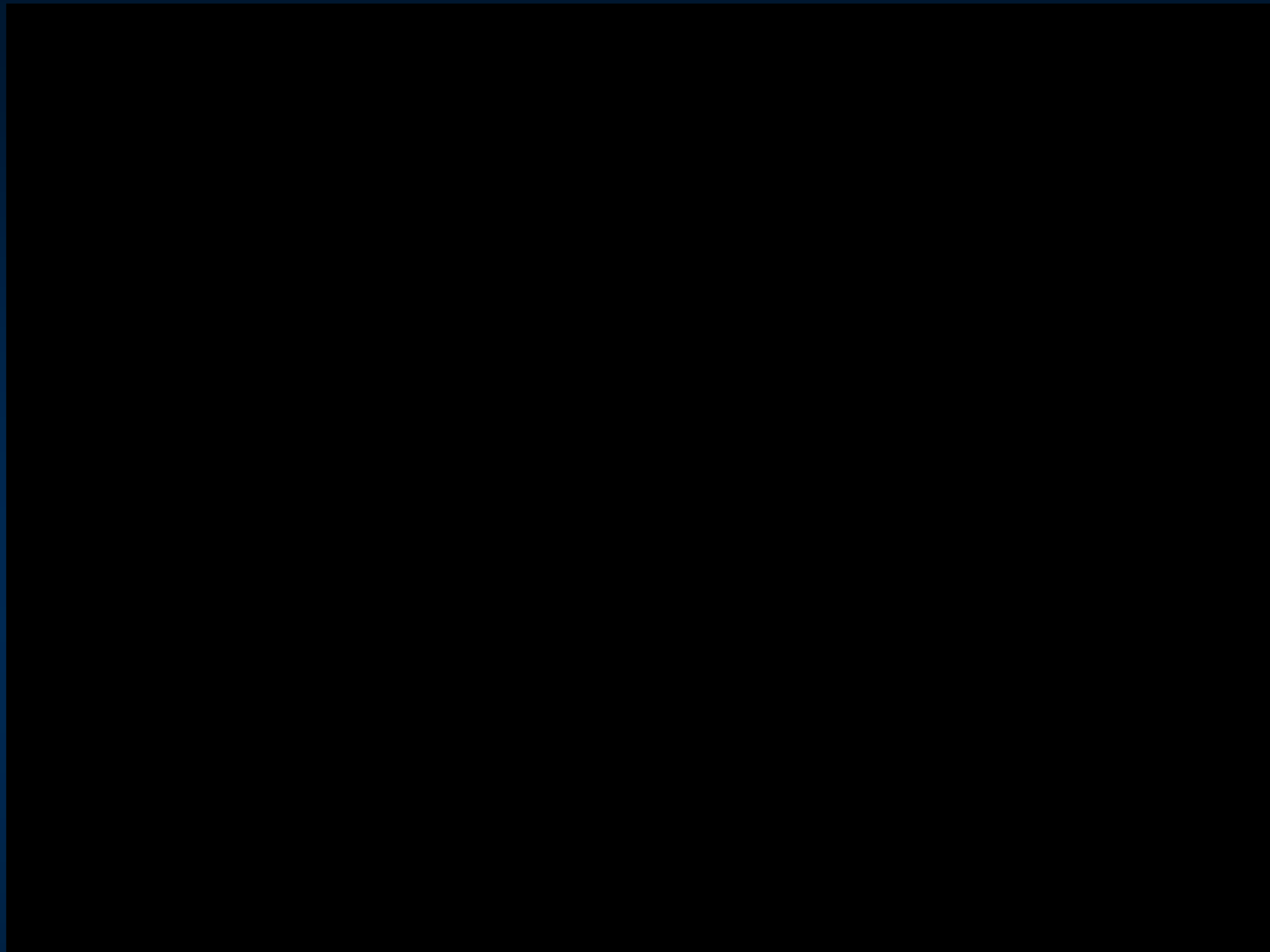


Egg mass of *T. pacificus* in captivity

Vertical hydrographic features at the ROV station



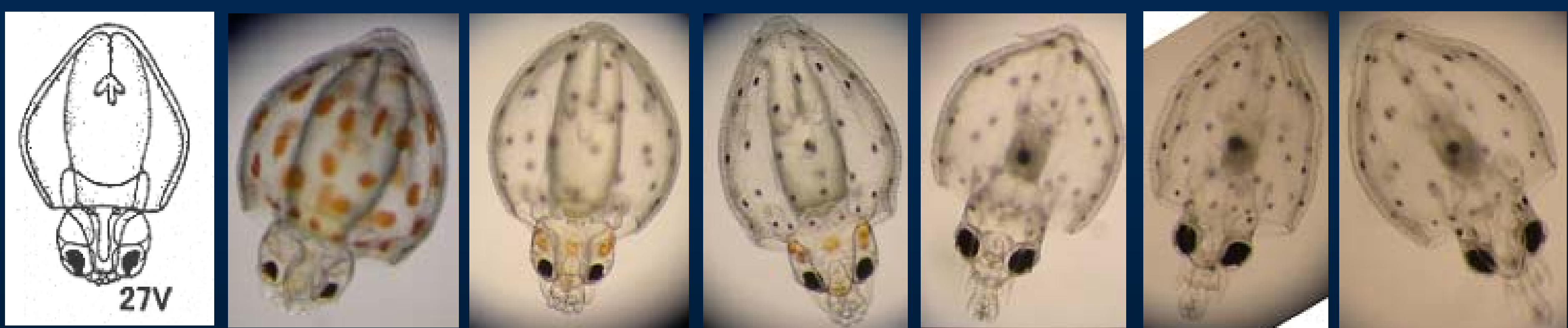
Can hatchlings swim up from near thermocline to surface in the same temperature range of 15-23℃ for normal embryonic development?



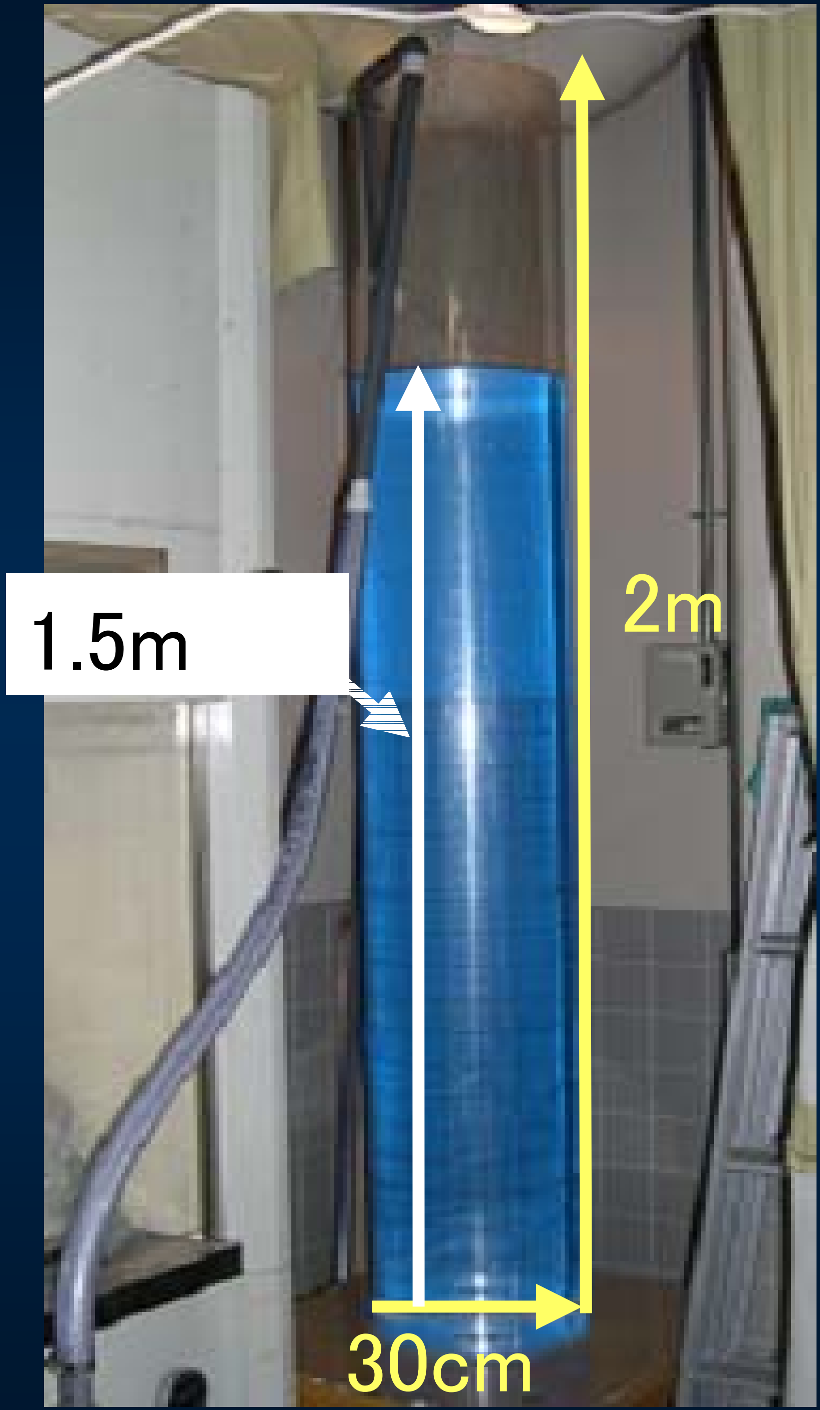
Can hatchlings swim up from near thermocline to surface in the same temperature range of 15-23℃ for normal embryonic development?

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

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

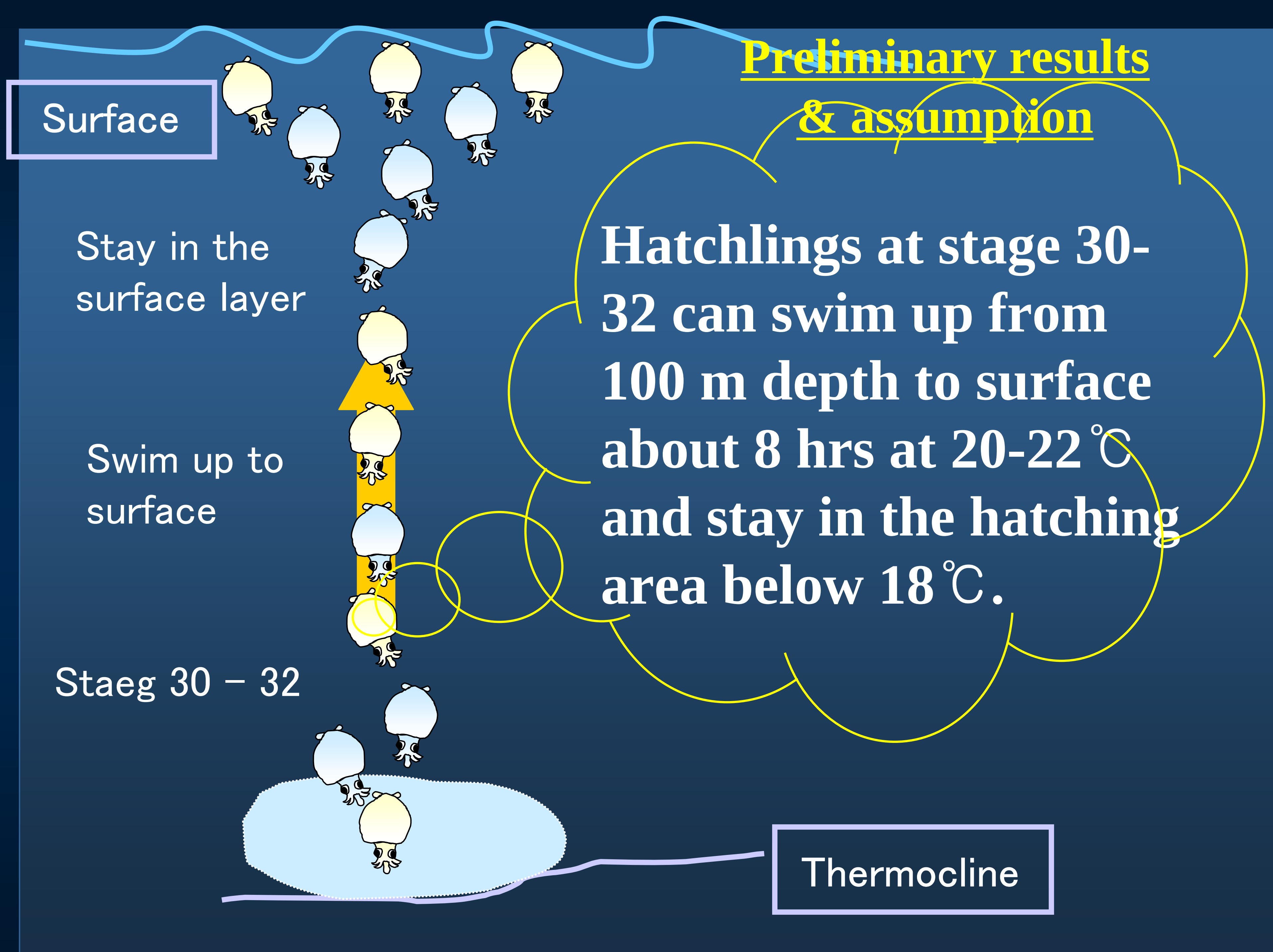


stage27 stage28 stage29 stage30 stage31 stage32 stage33



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

Ongoing experiment!


Preliminary results
& assumption
Surface
Stay in the
surface layer
Swim up to
surface
Staeg 30 – 32
Hatchlings at stage 30-32 can swim up from 100 m depth to surface about 8 hrs at 20-22℃ and stay in the hatching area below 18℃.
Thermocline

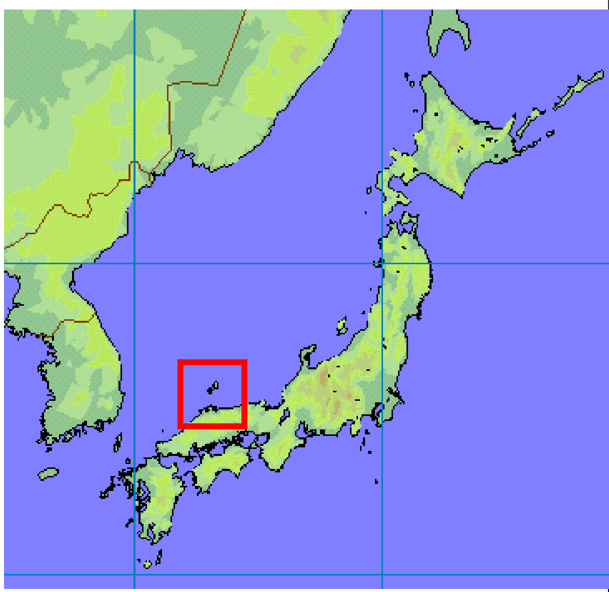
Survey:

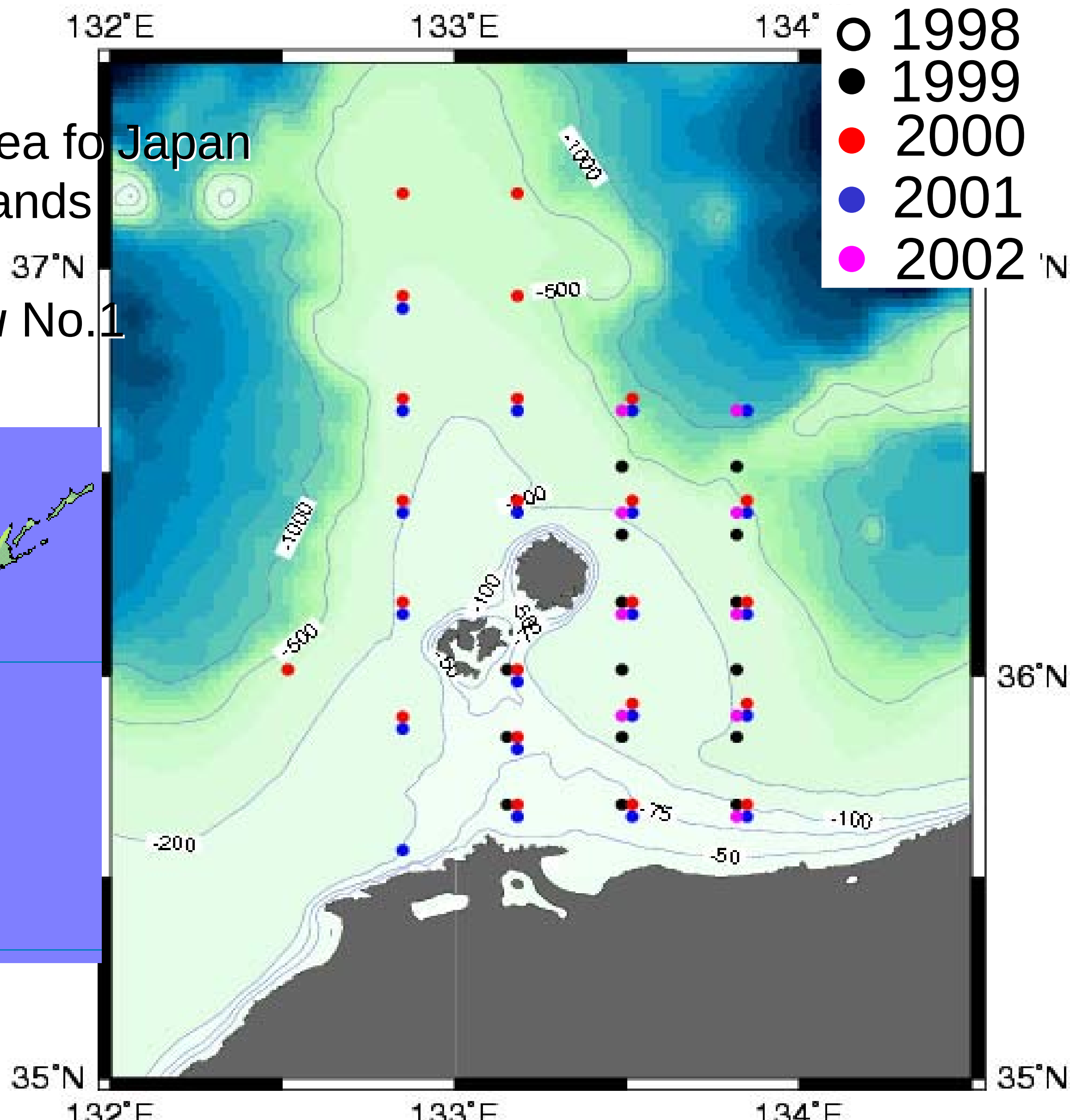
Please see Dr. J. Yamamoto's poster presentation!

Period : Nov. 1998-2002

Area : Southwestern Sea fo Japan
Near the Oki Islands

Ship : R/V *Tottori Maru* No.1

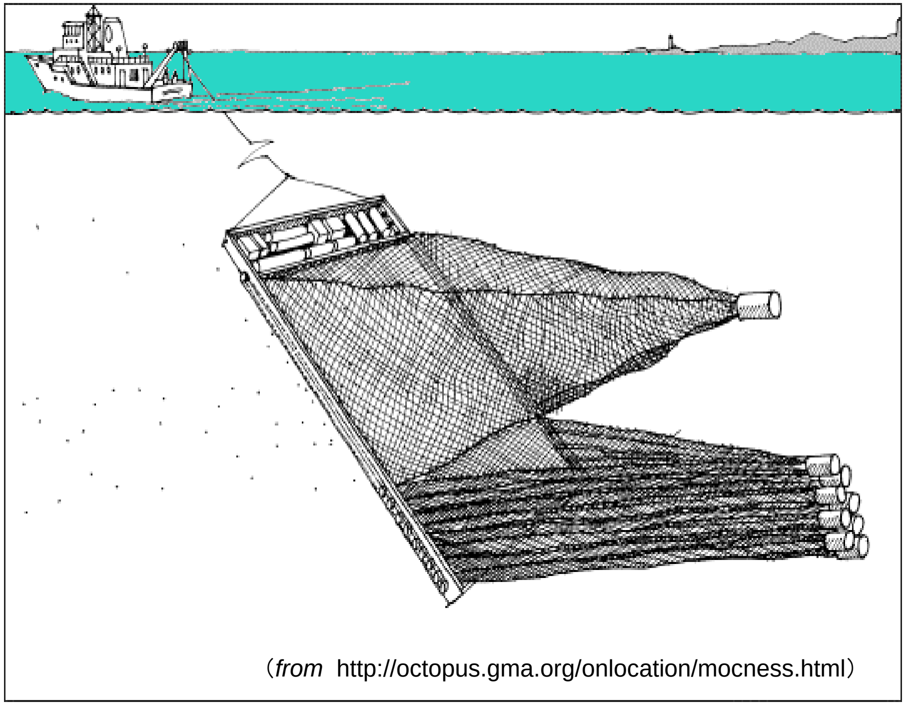




Paralarvae Sampling:

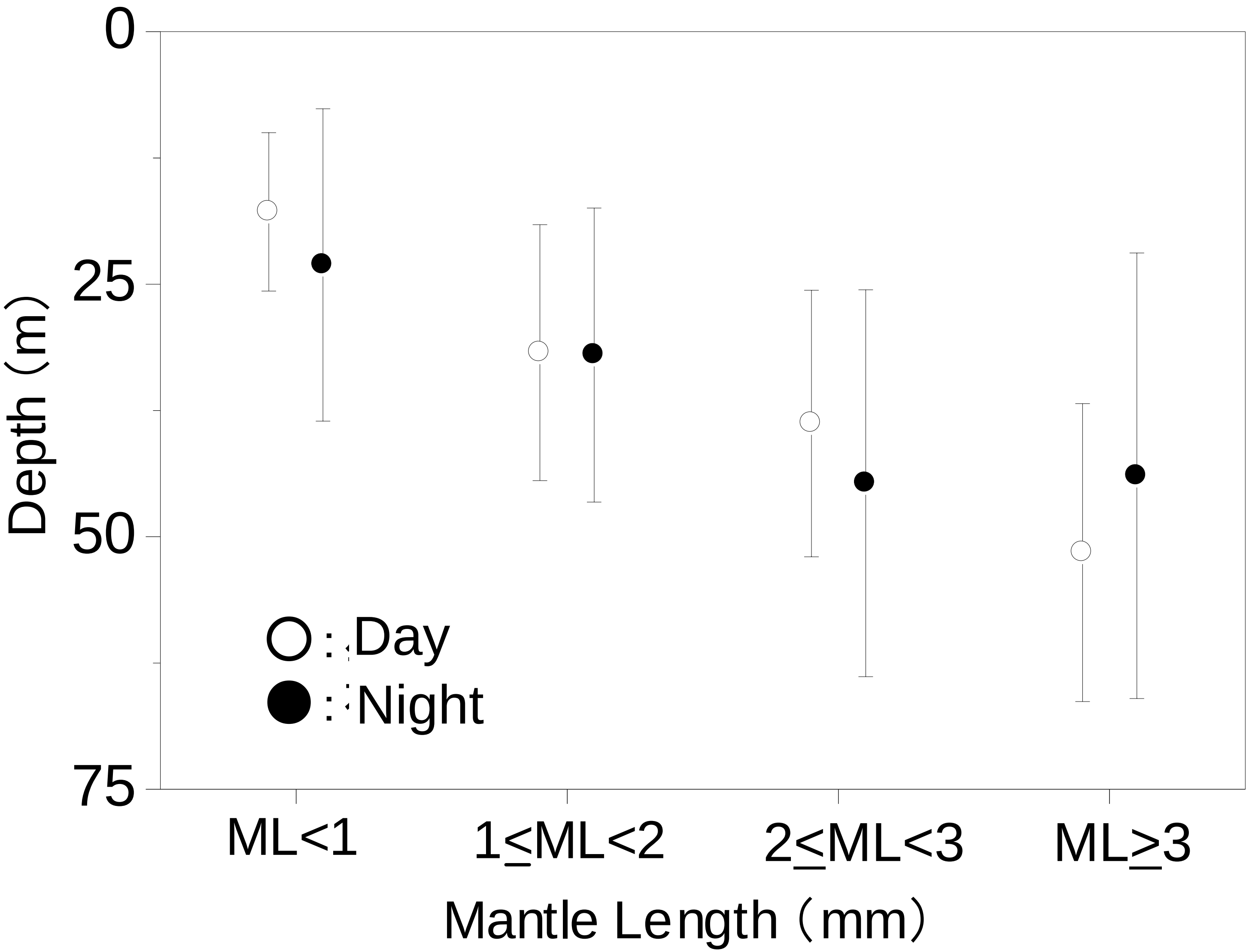
Net System : **MOCNESS (BESS-1)**
Mesh size : **0.333 mm**
Sampling depth intervals **: 0, 0-25, 25-50, 50-75 and 75-100m**

A snapshot of MOCNESS sampling on the R/V *Tottori Maru No.1*



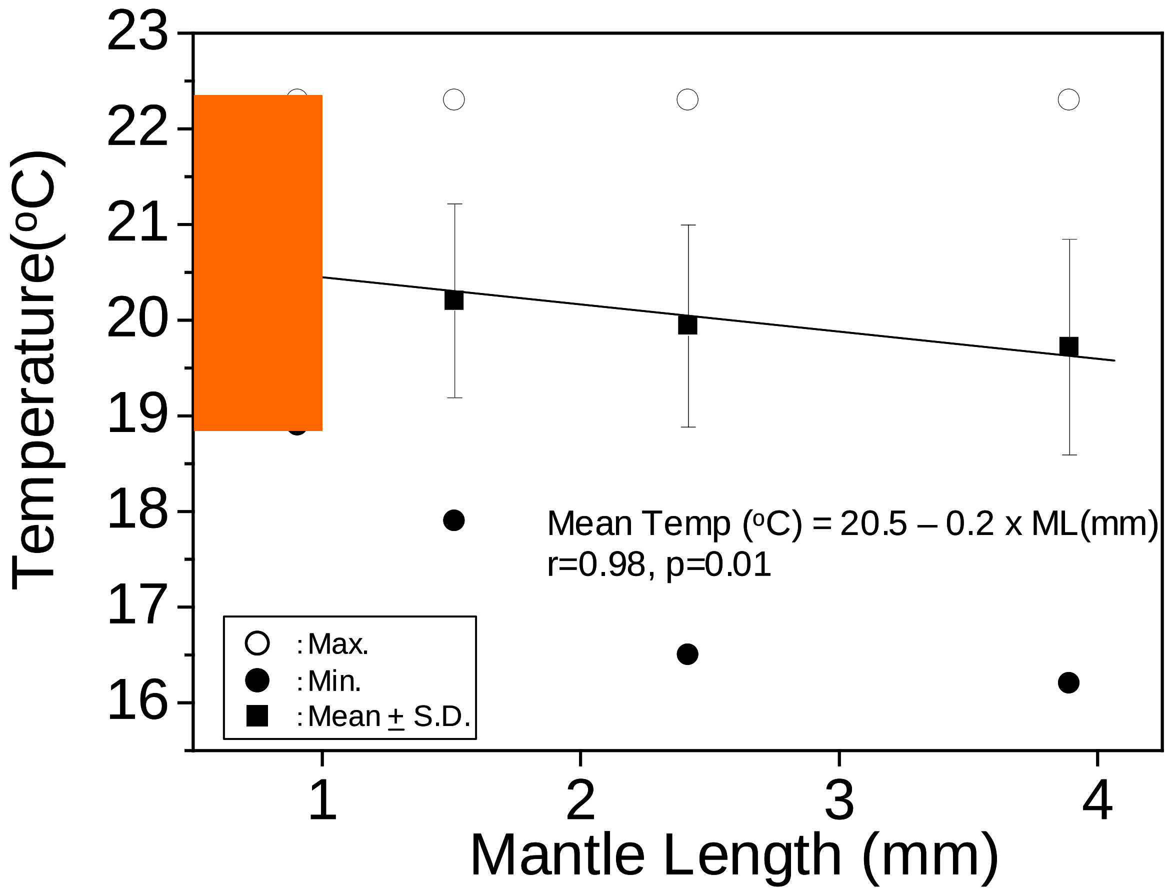
A sketch of a research vessel towing a MOCNESS

Weight Mean Depth (Σdens. x depth / dens.) **Day and Night**



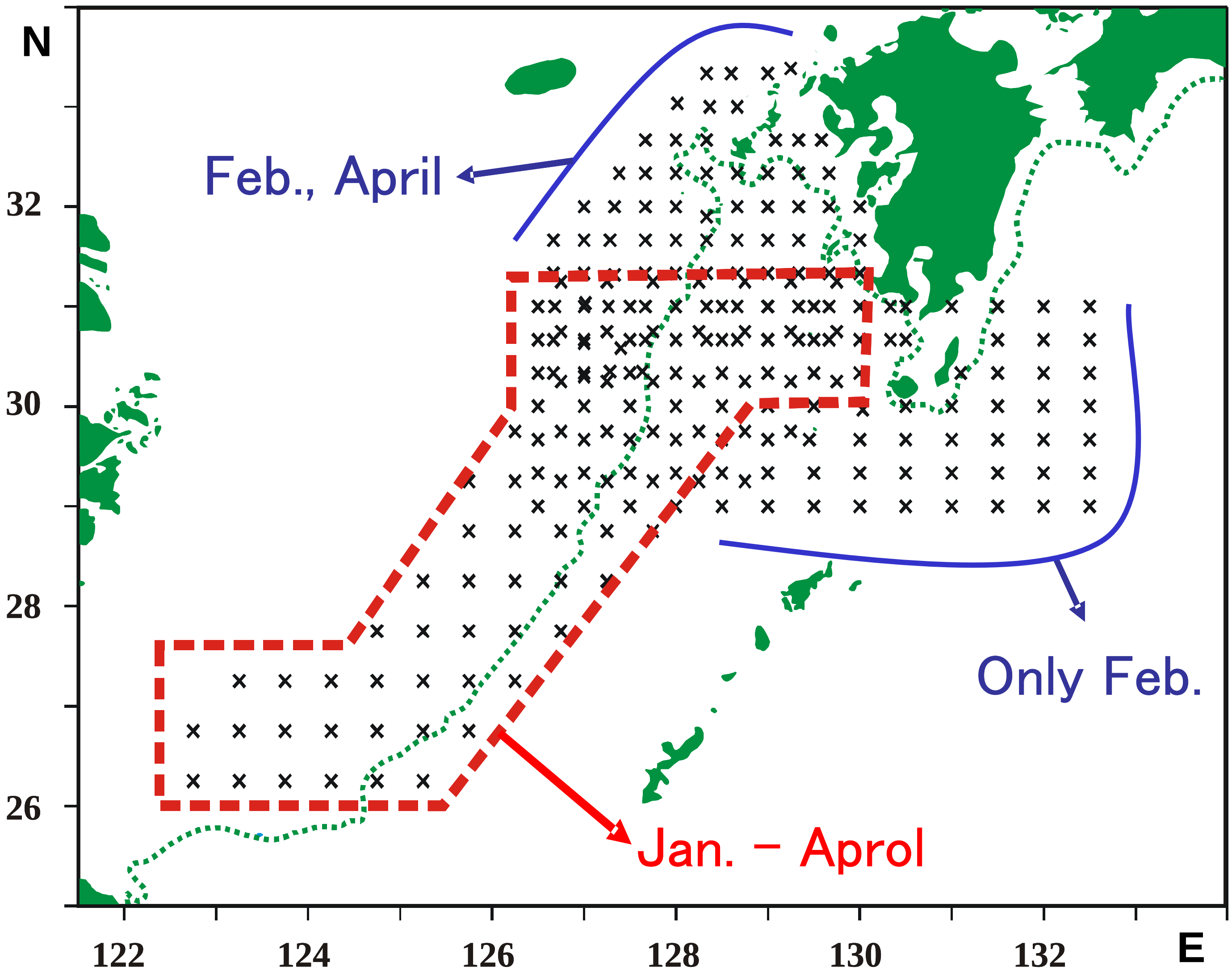
No significant difference between Day and Night (t-test)

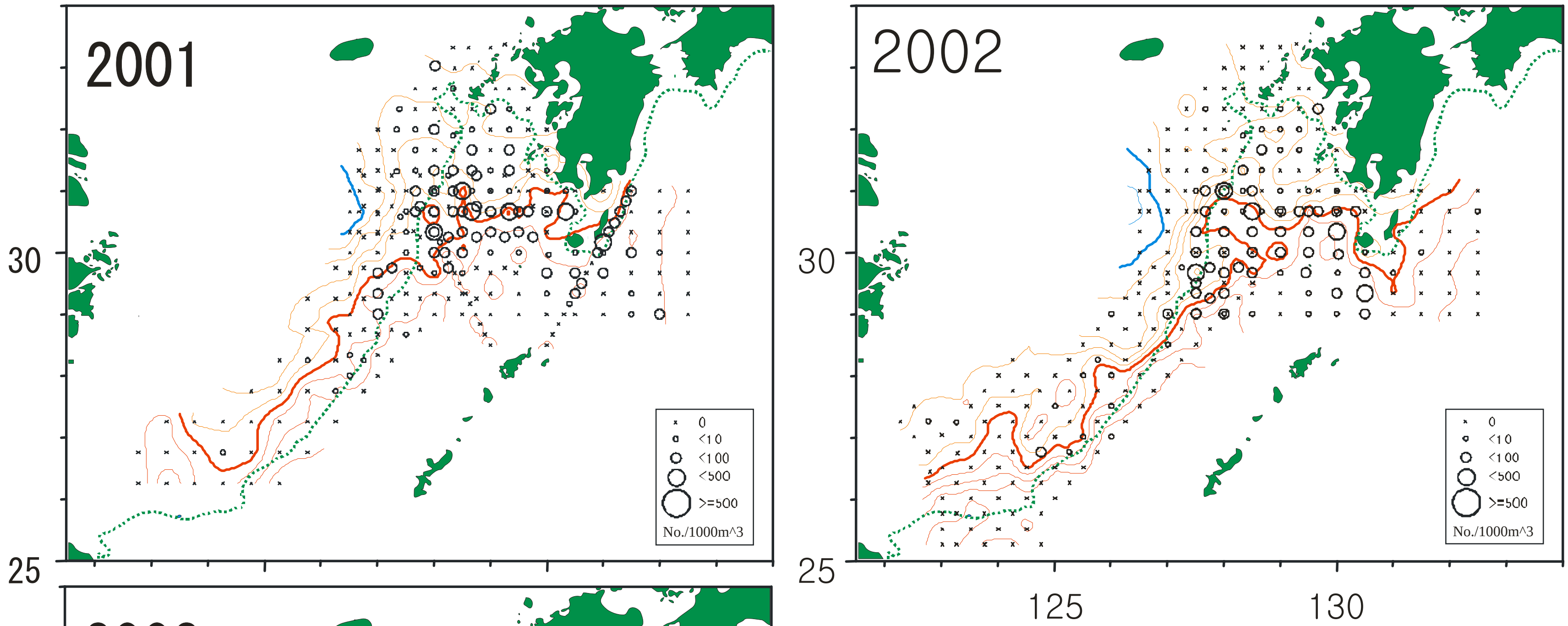
Changes in the Temperature for the Mantle size

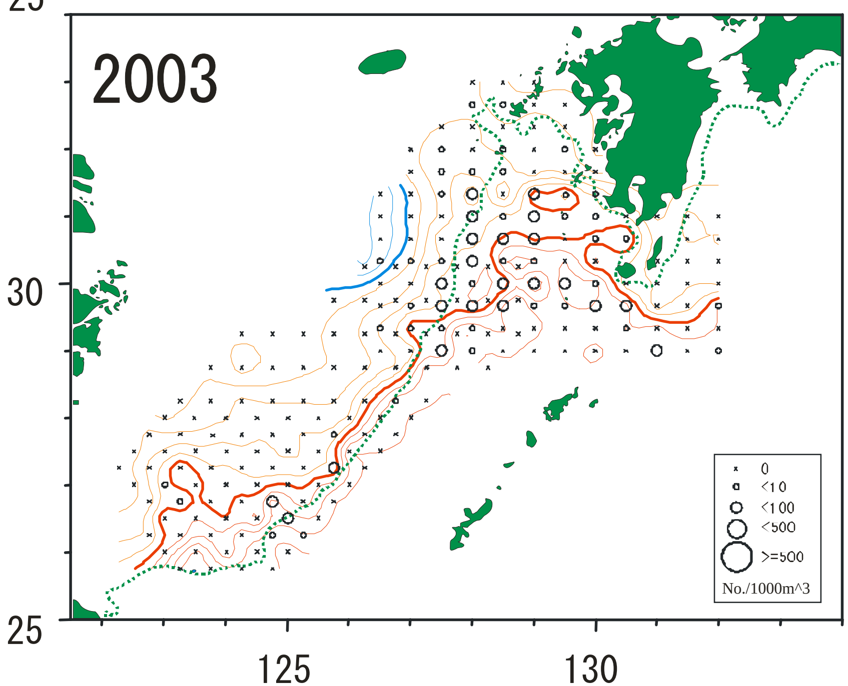


Changes in the temperature of paralarvae collected for the paralarval Mantle length. Squares are mean temperature and error bars are ± one standard deviation about the mean abundance plotted at the mean mantle length of the each ML size group. Open and solid circles show maximum and minimum temperature about the temperature that paralarvae occurred.

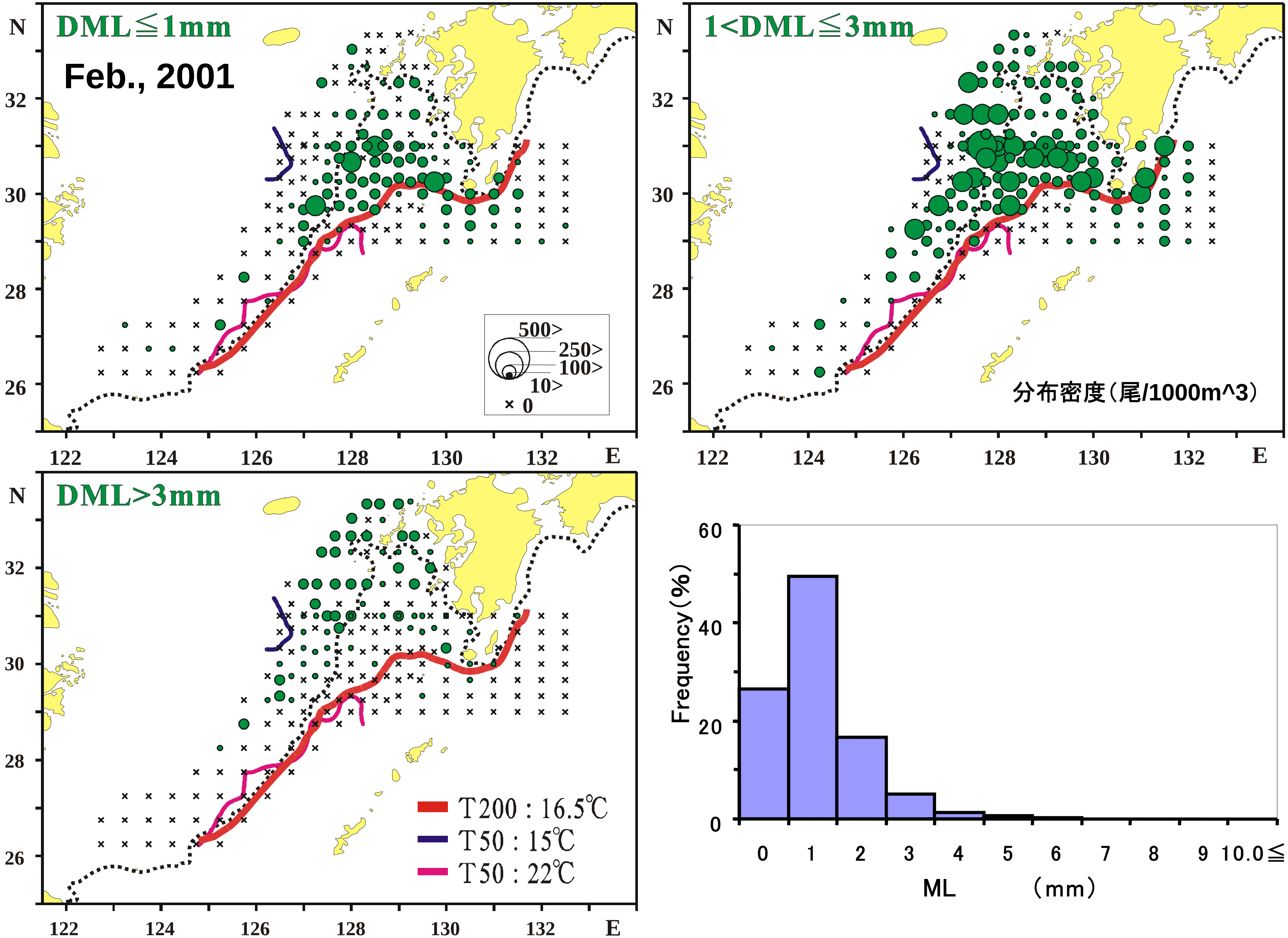
Pralaraval distribution surveys done by the Hokkaido National Fisheries Research Institute after 2001.





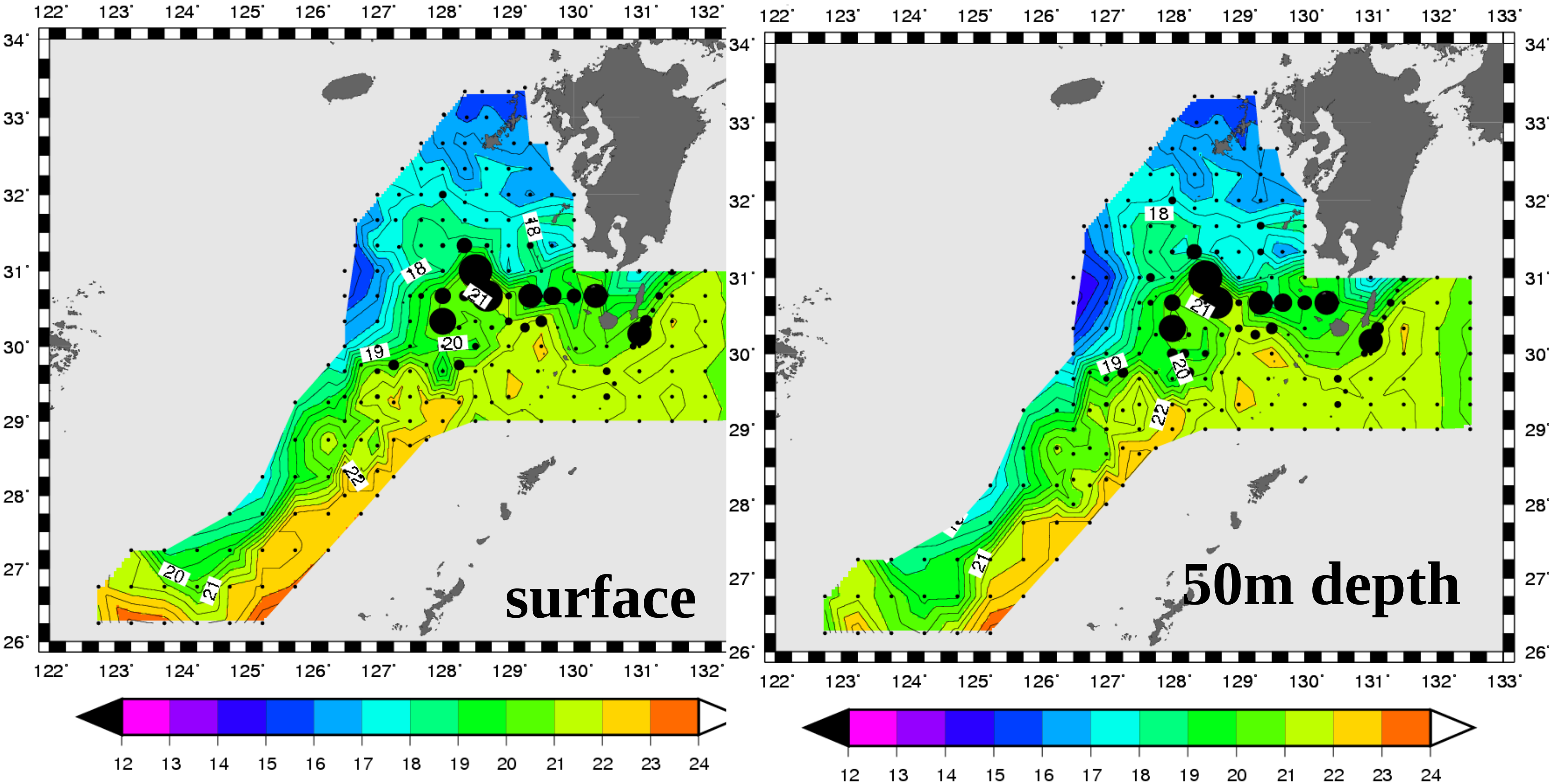


Distribution and abundance of *T. pacifcius* hatchlings below <1 mm ML to about 10 days after hatching, Febrary, 2001-2003. (No. / 1000 m^3)



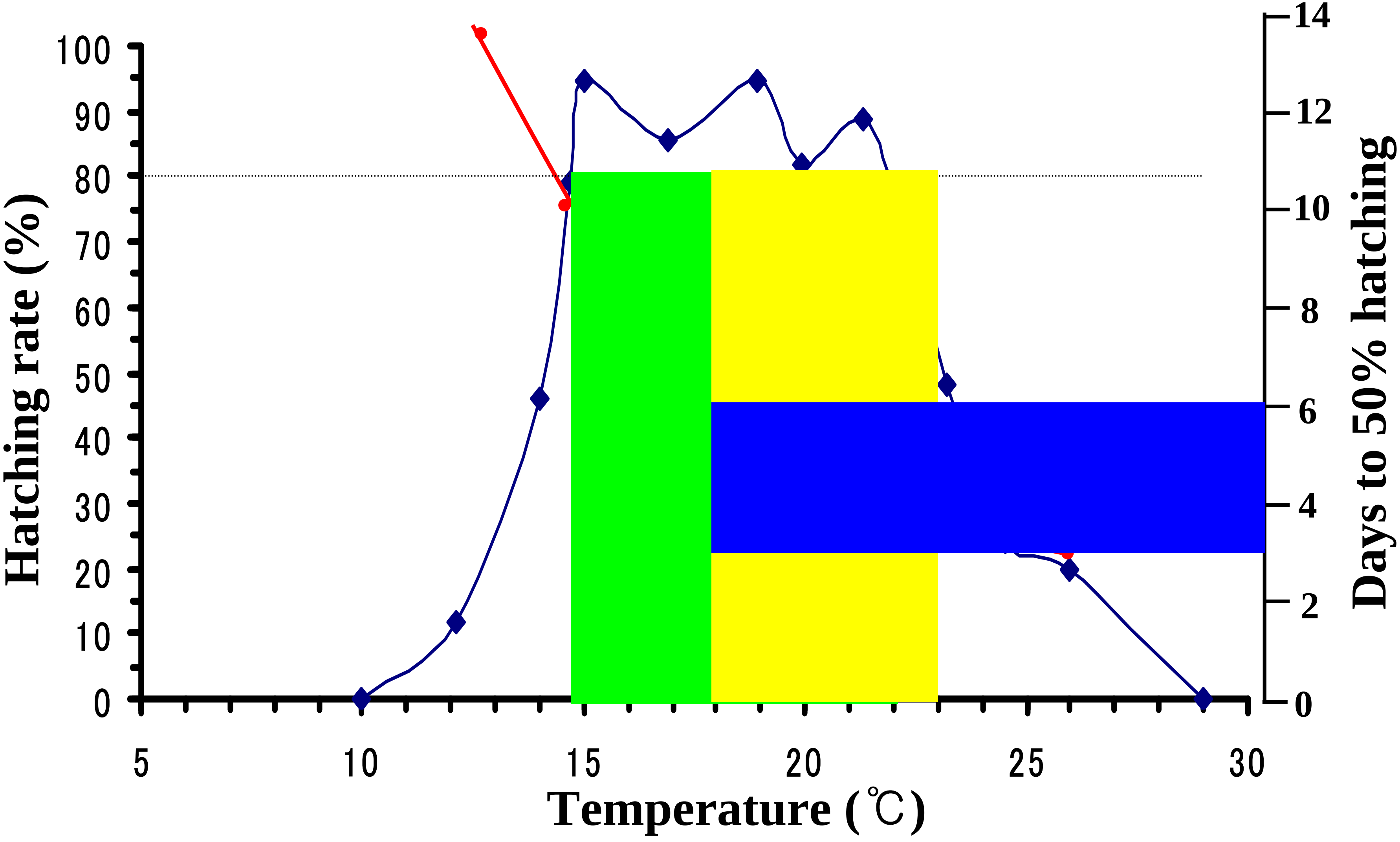
DML≦1mm
Feb., 2001
1<DML≦3mm
DML>3mm
N
E
122
124
126
128
130
132
26
28
30
32
500>
250>
100>
10>
× 0
分布密度（尾/1000m^3）
T200 : 16.5℃
T50 : 15℃
T50 : 22℃
Frequency（%）
0
20
40
60
0
1
2
3
4
5
6
7
8
9
10.0≦
ML
（mm）

Relationships between distribution and abundance of hatchlings(<1 mm ML), and SST and temperature at 50 m depth in February, 2001.



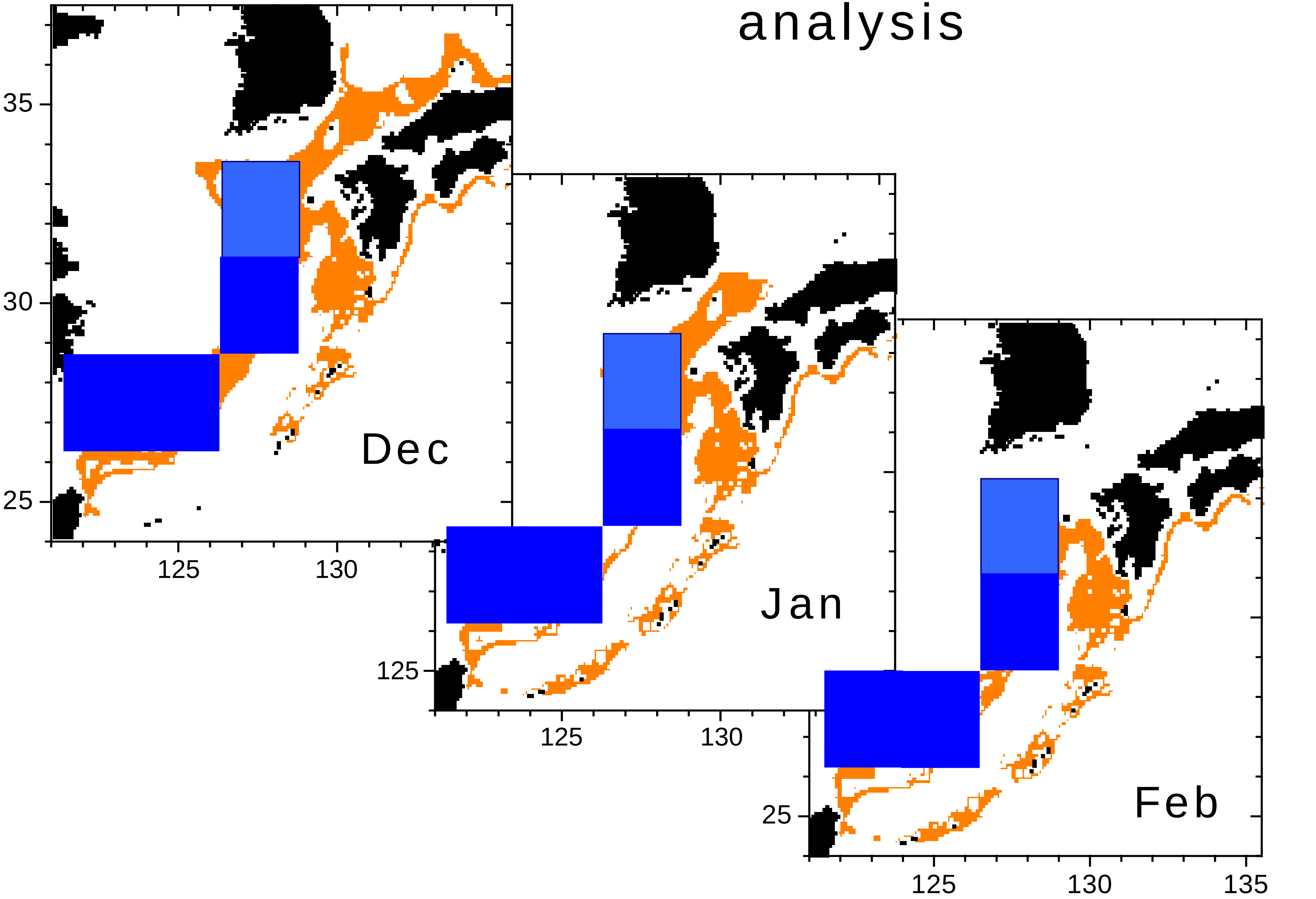
●;100ind./1000m^3
(1mm> palalarva)

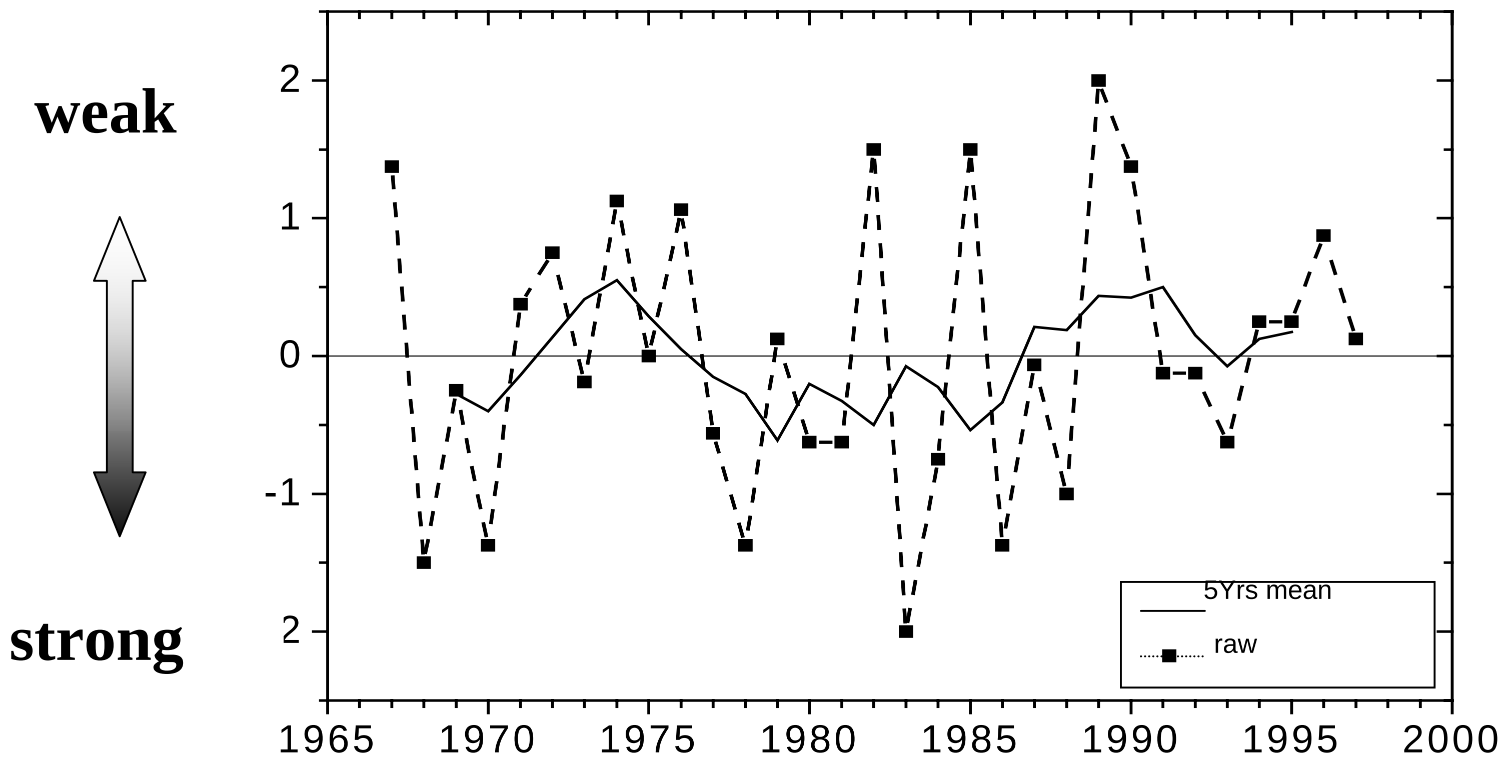
(Sakai, pers.com.)



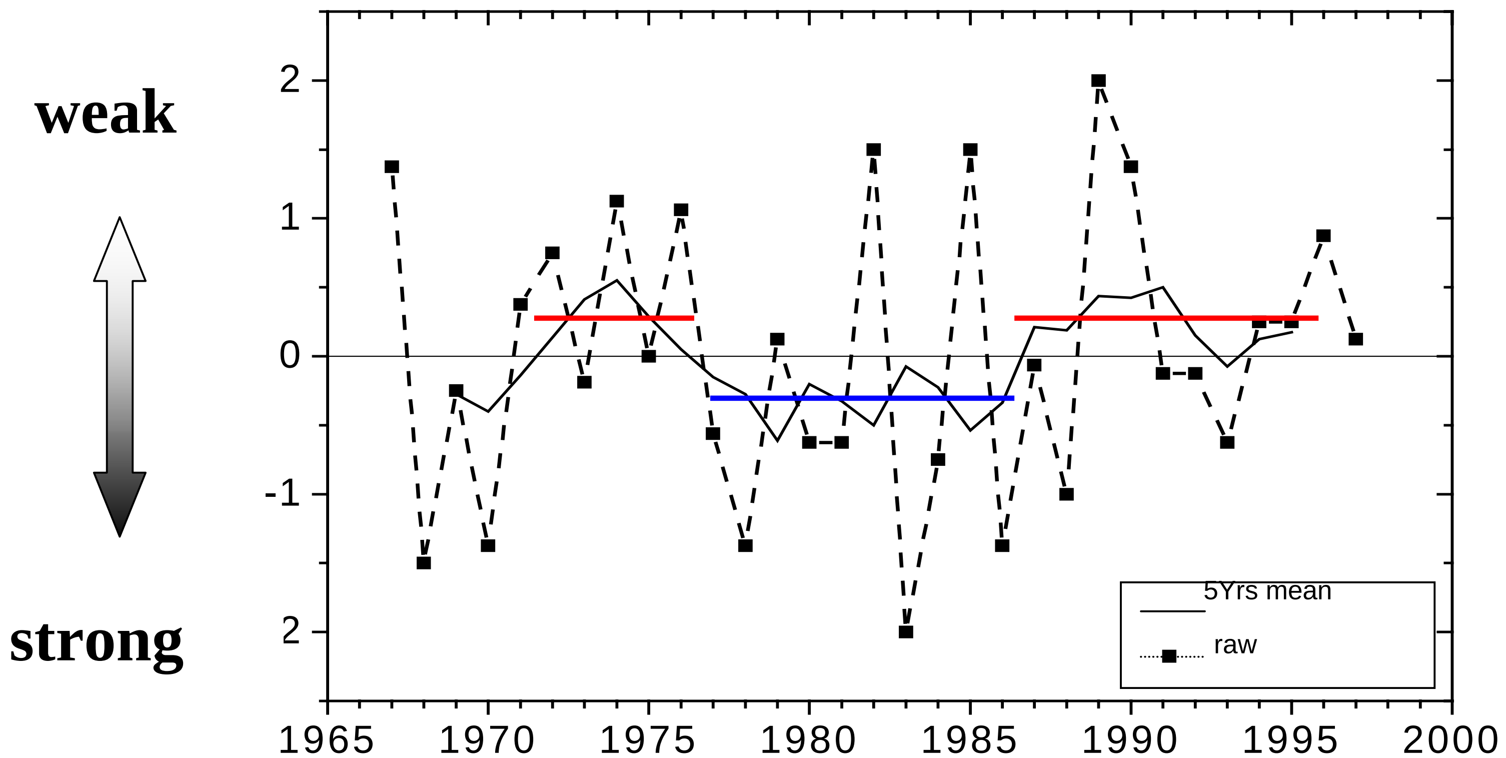
Hatchlings can survive more limited warm temperature than that of embryonic development.

Survey areas for metrological and MLD analysis



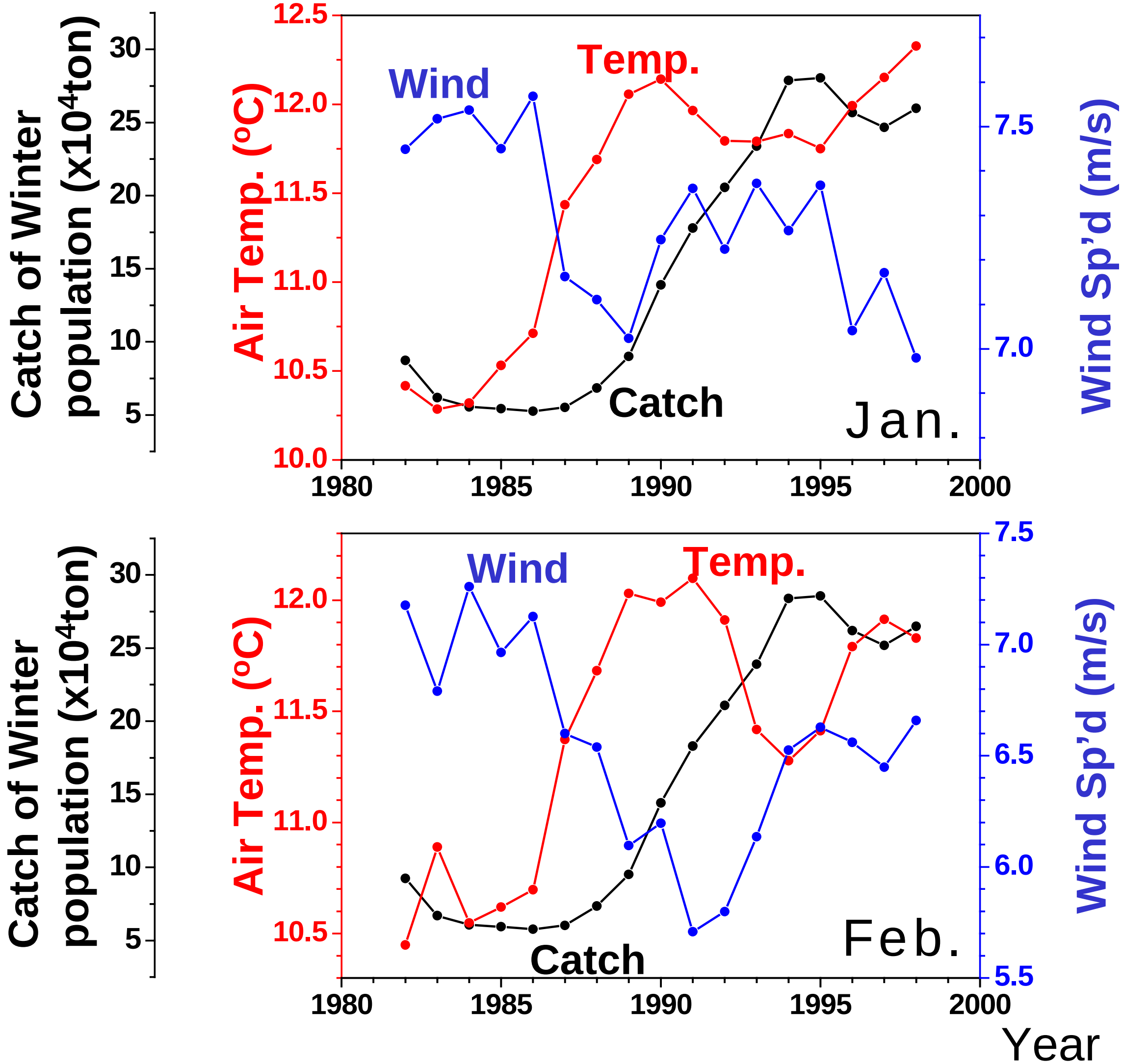


Annual change of Aleutian low pressure index. **(Nakamura and Honda, 2002)**

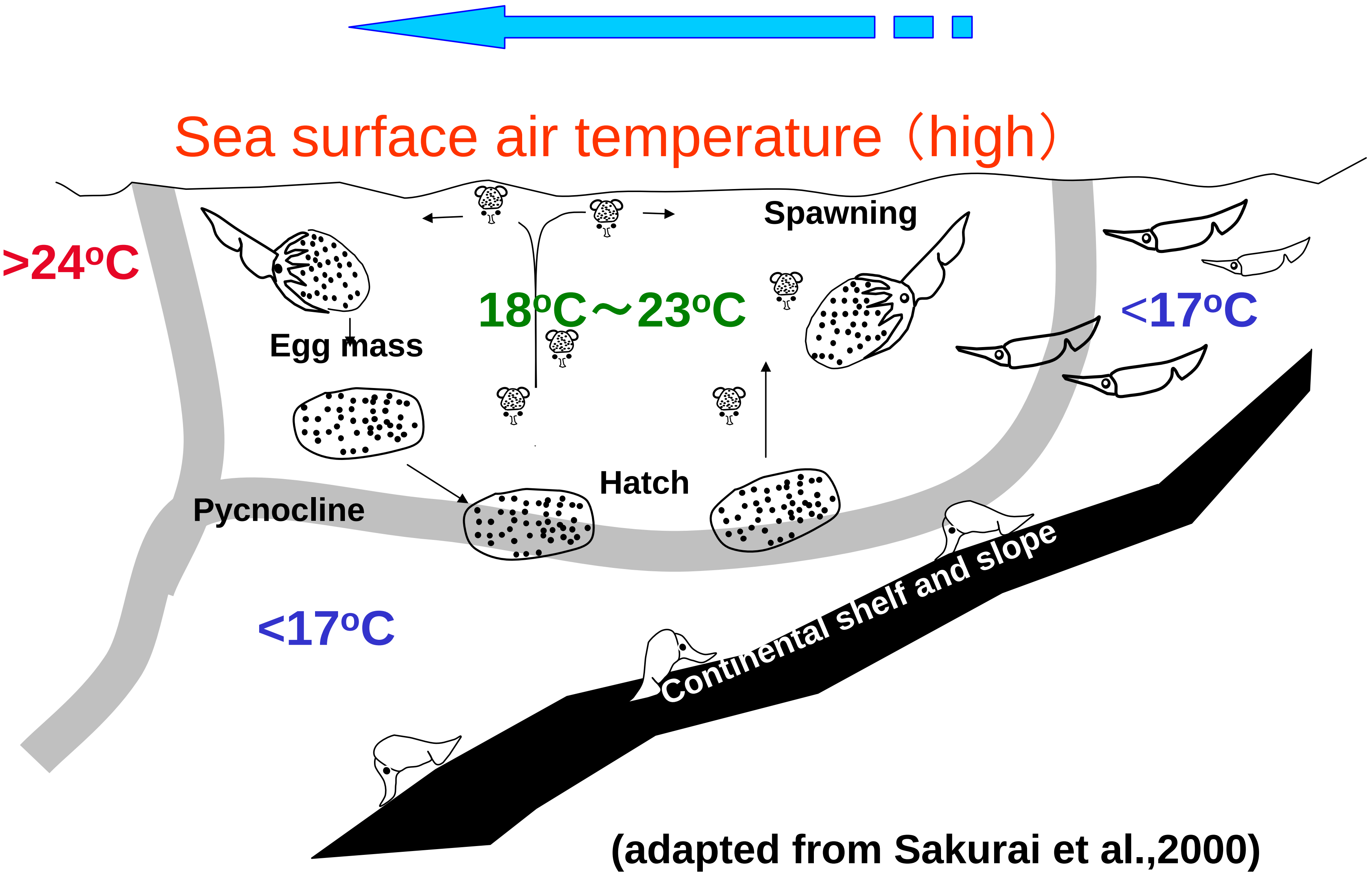


Annual change of Aleutian low pressure index. **(Nakamura and Honda, 2002)**

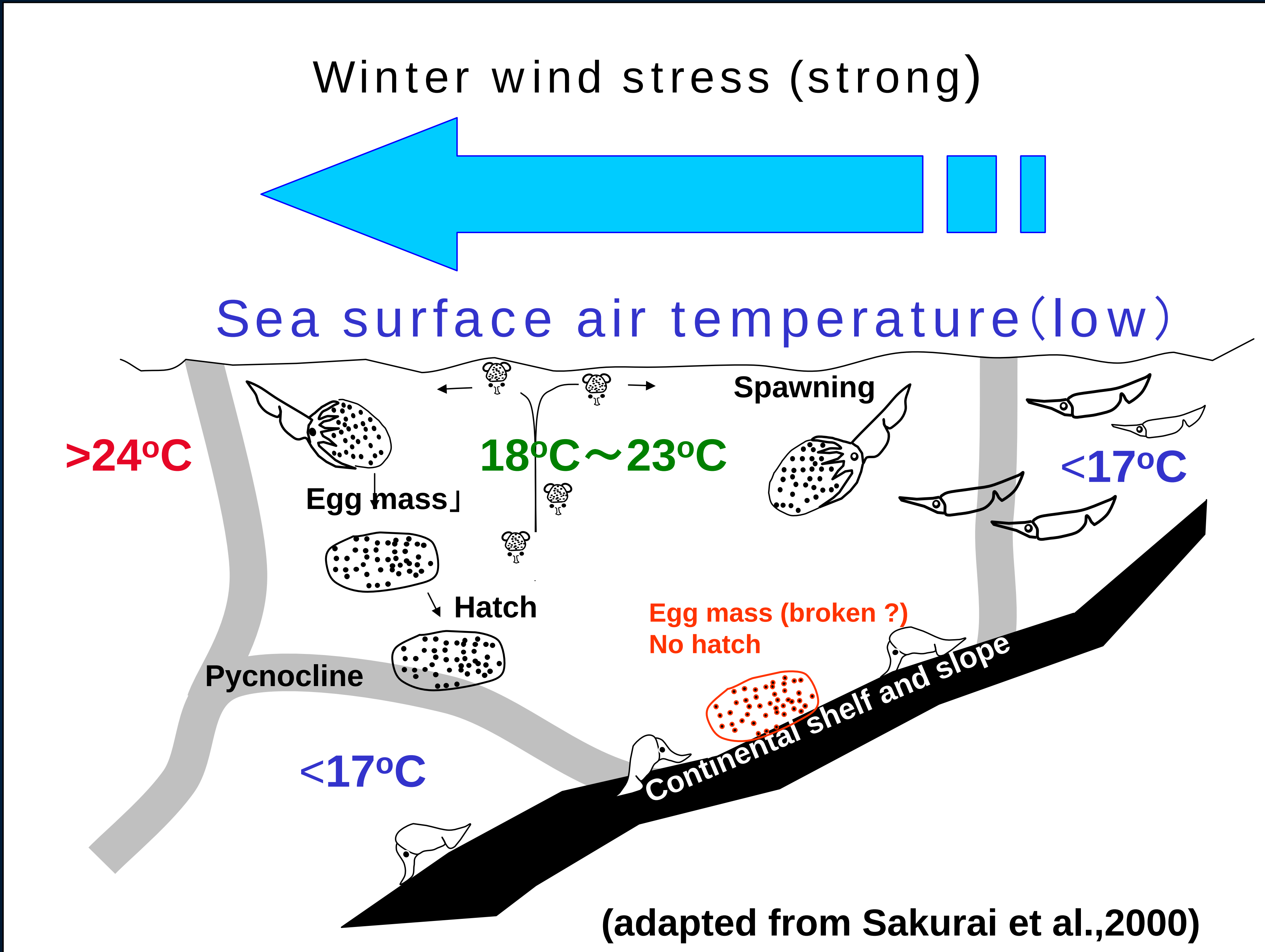
Changes in the 5-year means of surface air temperature, wind speed and the winter population catch in the coldest months



Winter wind stress (weak)



(adapted from Sakurai et al.,2000)


Winter wind stress (strong)
Sea surface air temperature(low)
Spawning
>24°C
18°C～23°C
<17°C
Egg mass
Hatch
Egg mass (broken ?)
No hatch
Pycnocline
<17°C
Continental shelf and slope
(adapted from Sakurai et al.,2000)

Thanks from the squid!