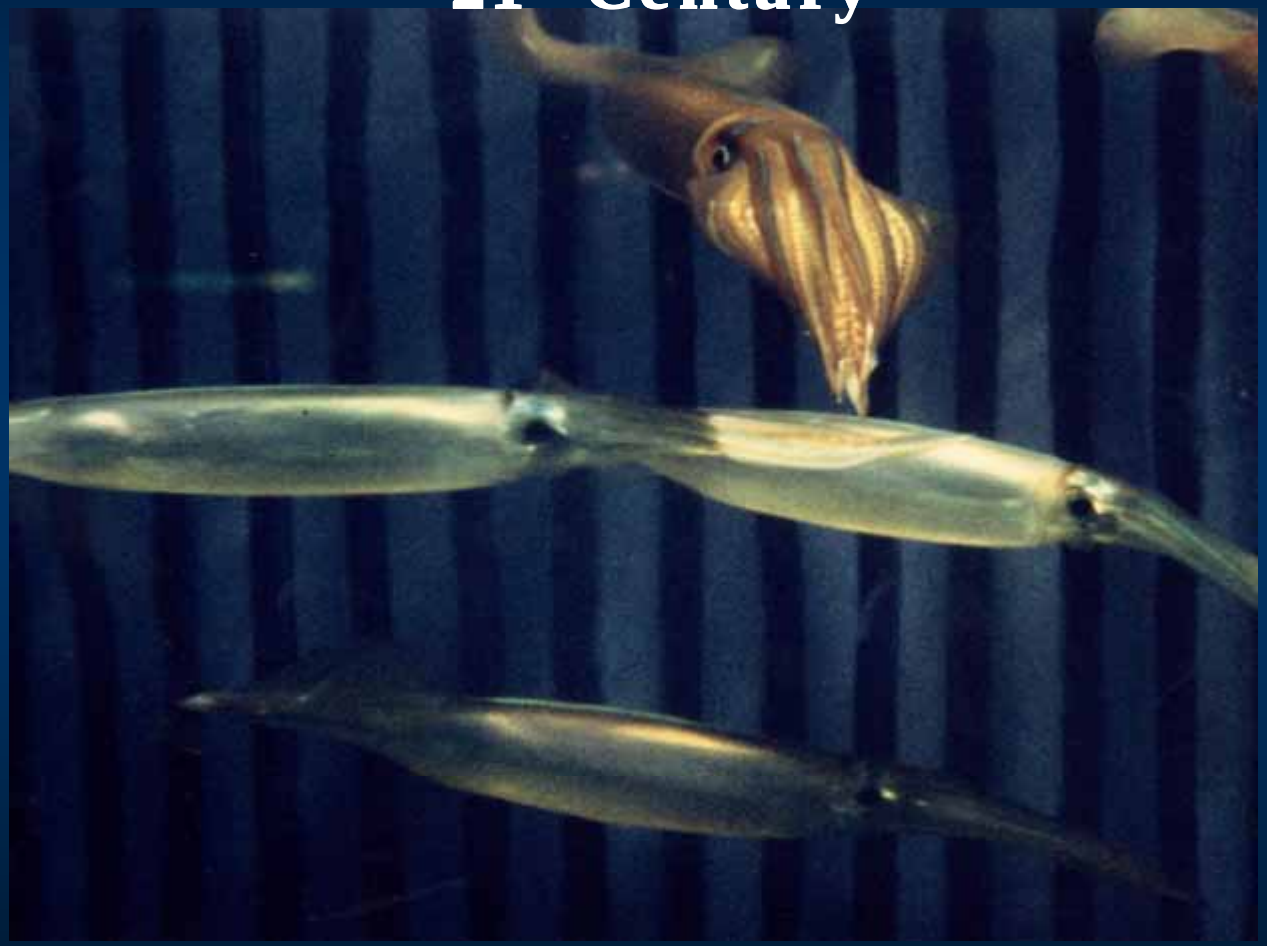
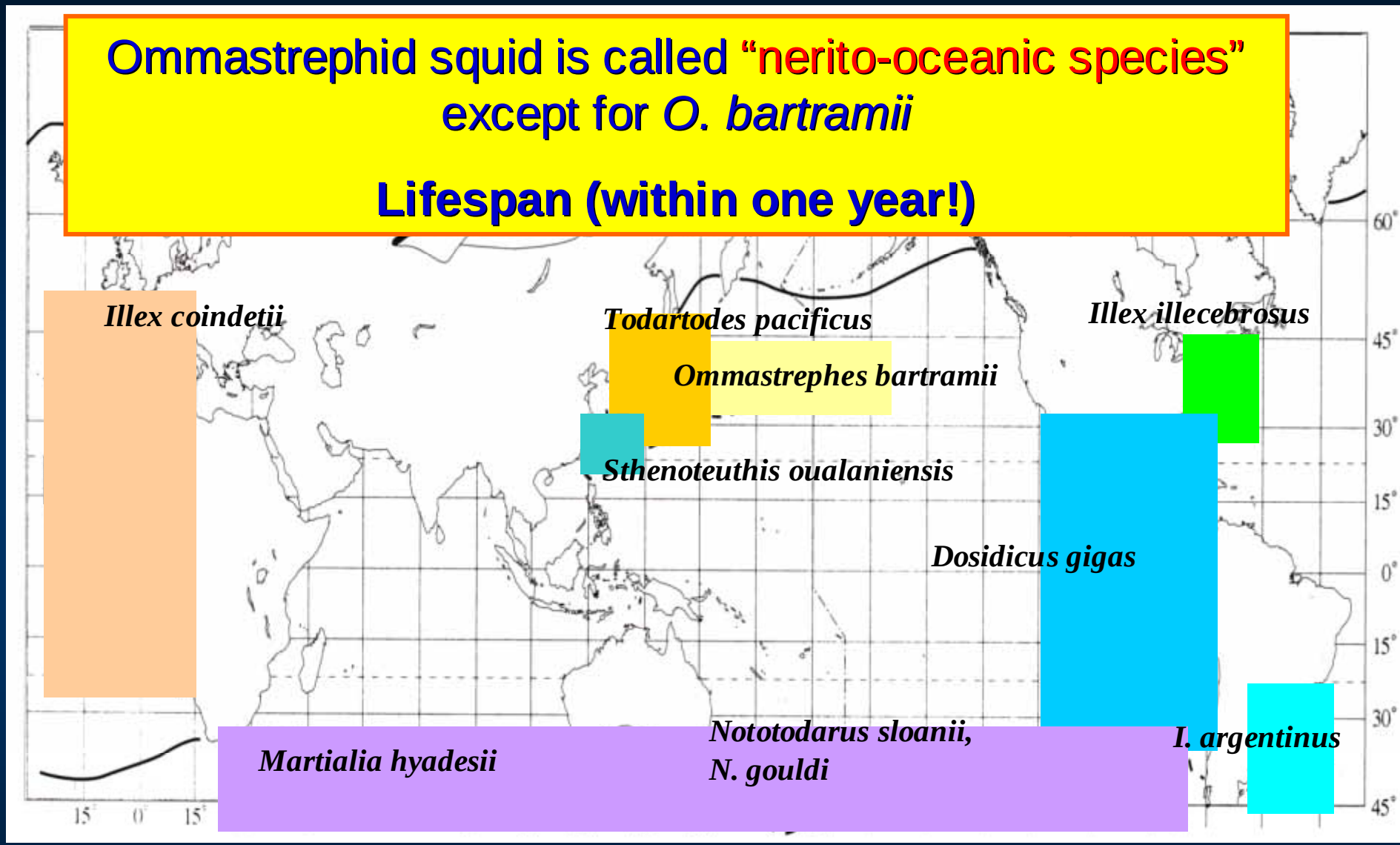
Prediction of life strategy and stock fluctuation of the Japanese common squid, *Todarodes pacificus*, related to climate change during the 21st Century



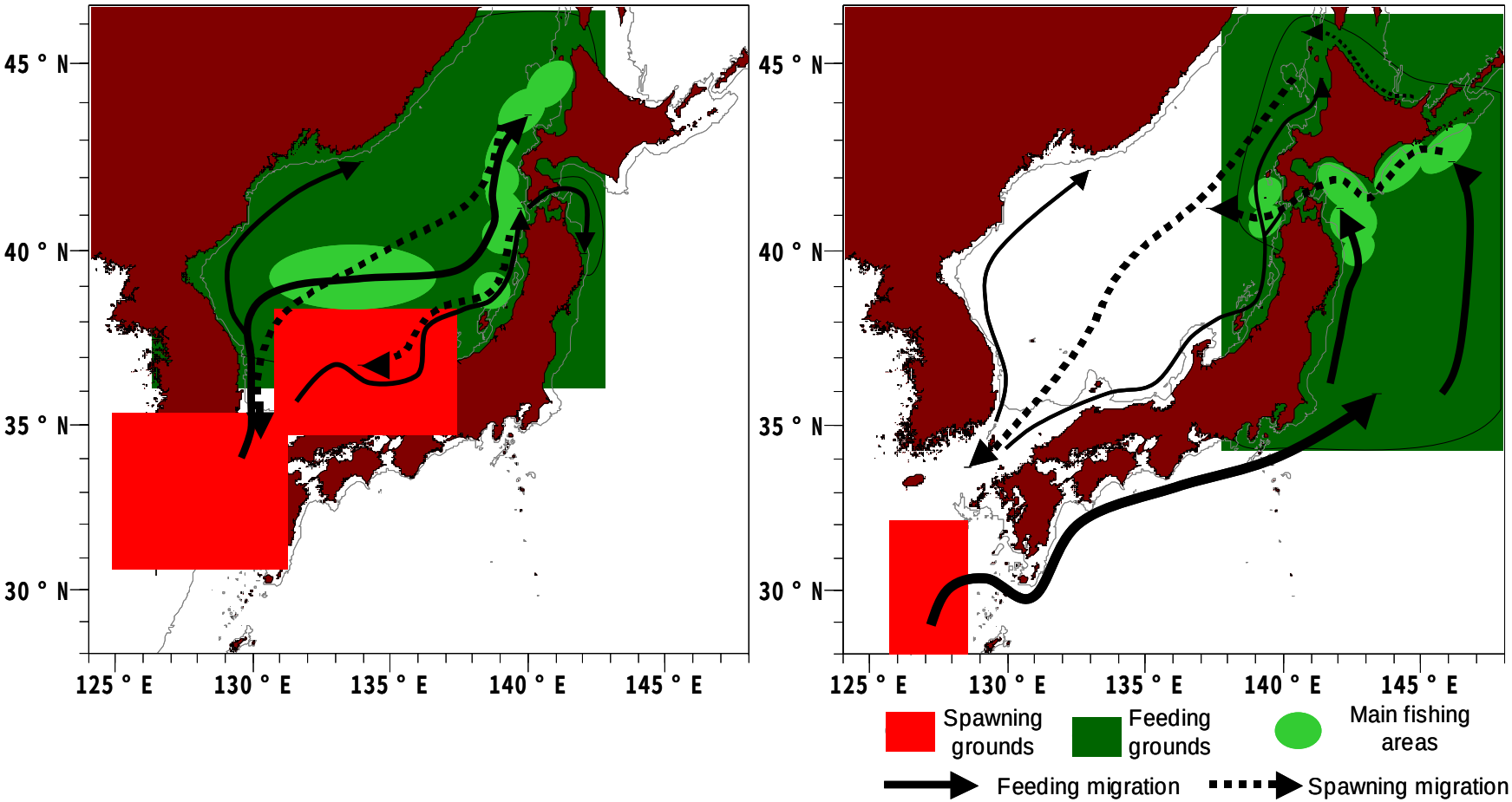
Y. Sakurai and M. J. Kishi, Hokkaido University

Ommastrephid squid is called “nerito-oceanic species” except for *O. bartramii*

Lifespan (within one year!)



Main fishing grounds of ommastrephid squids (Okutani, 1995)



Spawning grounds and migration routes of *T. pacificus*

Background

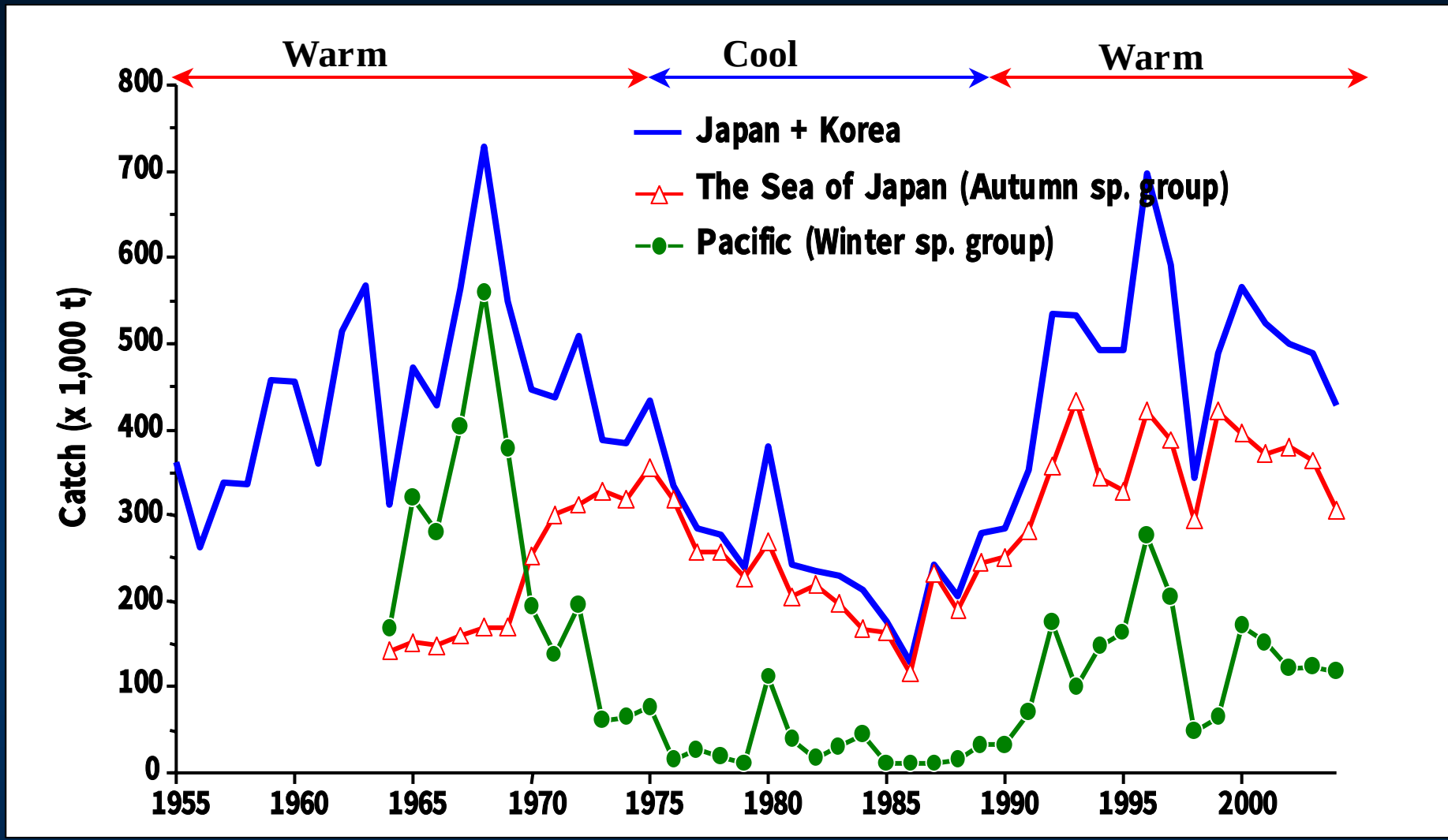
• Recruitment success in *T. pacificus* depends largely on environmental conditions (e.g. SST, wind stress, MLD) at the spawning and nursery grounds

• Annual catches of *T. pacificus* decreased during the cool regime during the late-1970s and late-1980s, and increased after the late 1980s warm regime period.

(Sakurai et al., 2000, 2002)

Objective

・ To present a new scenario for how life strategy and stock size of *T. pacificus* might change due to climatic forcing such as annual climate change, cool and warm regime shifts and global warming during the 21st Century.

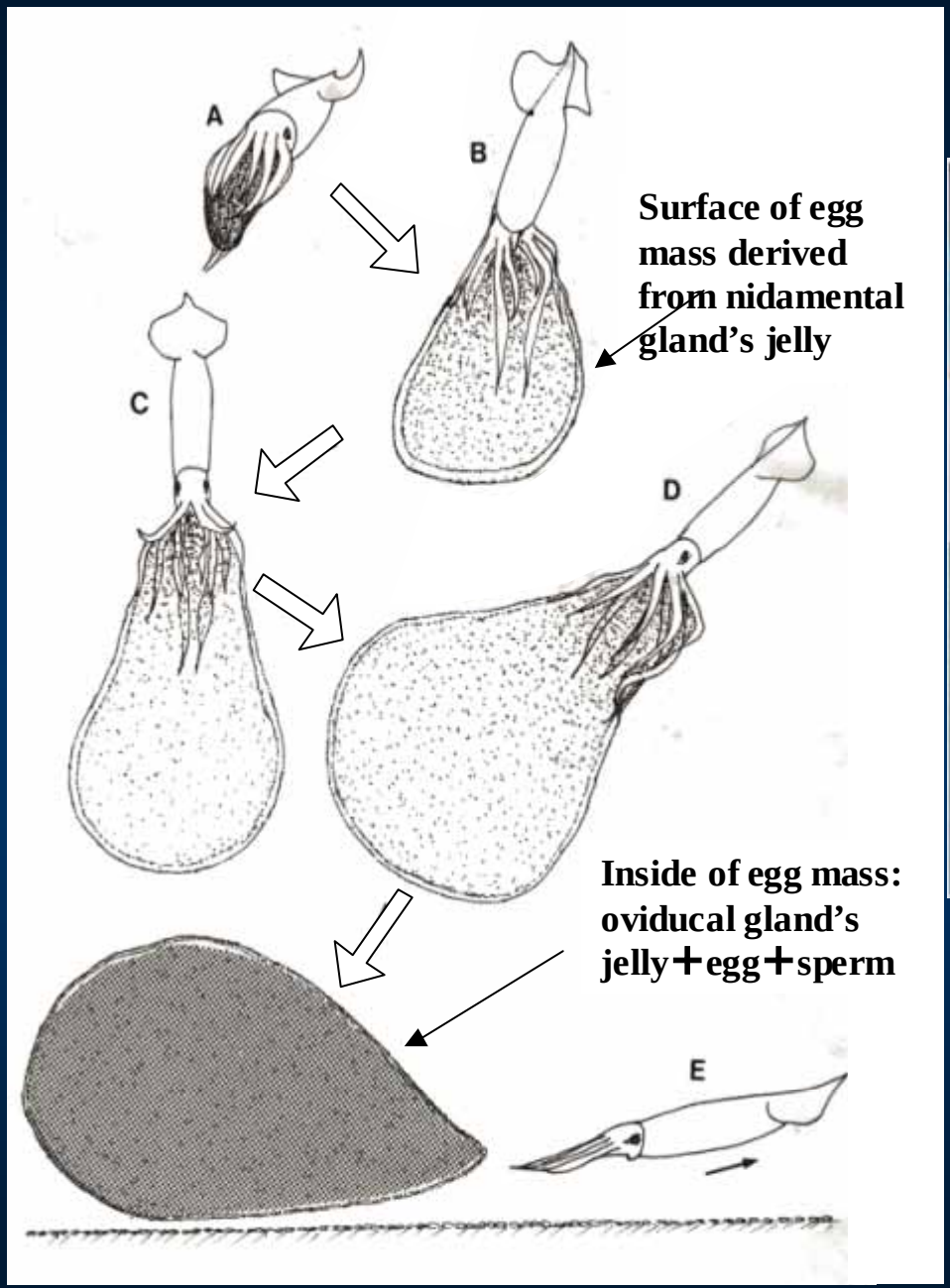


Annual fluctuation in common squid, *T. pacificus* catches of Korea and Japan during 1955 - 2004.

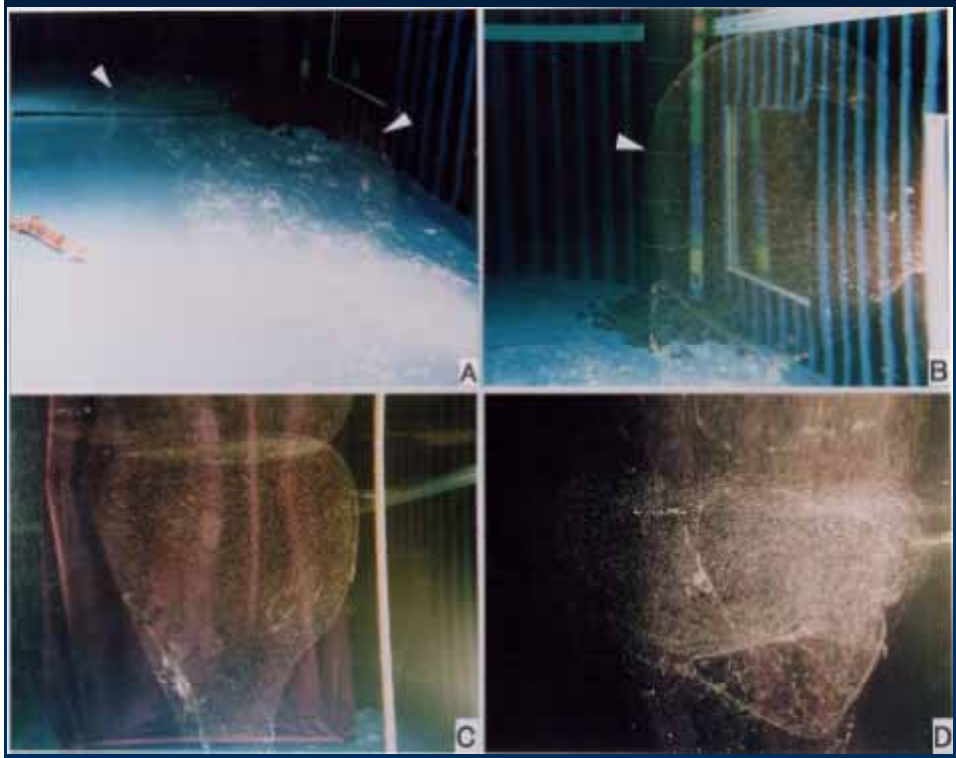
(Data derived from the Japan Sea Research Institute, Japan and the National Fisheries Research and Development Institute, Korea).

The new reproductive hypothesis of Japanese common squid, *T. pacificus* based on captive experiments and field surveys;

"The reproductive areas for spawning and occurrence of active hatchlings were formed the SST areas between 18-24℃ (especially 19.5-23℃) and within a specific range of bottom topography ranged from 100 m to 500 m, where the pycnocline (or thermocline) was well developed in themid-water"



Spawning behavior of *T. pacificus*



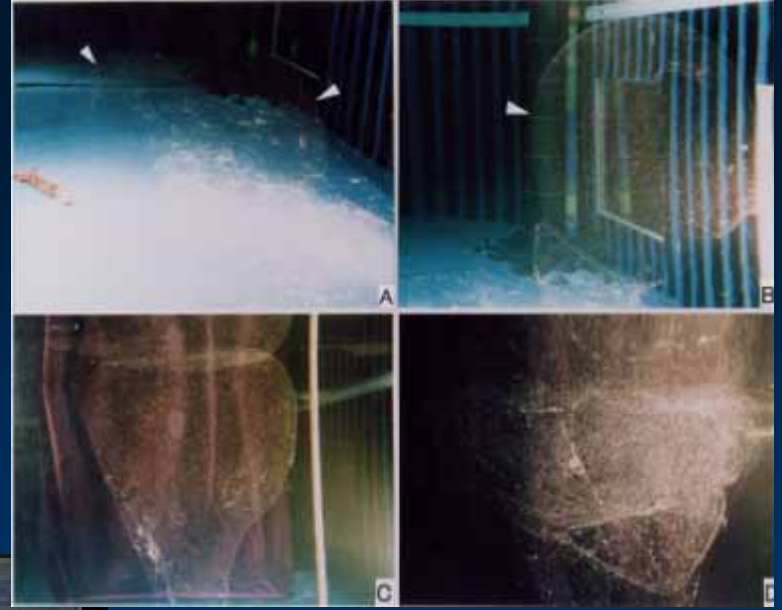
Egg mass of *T. pacificus* in captivity

A: just after spawning, B: after 4 hrs, C: 2 days, D: 5days at 20℃

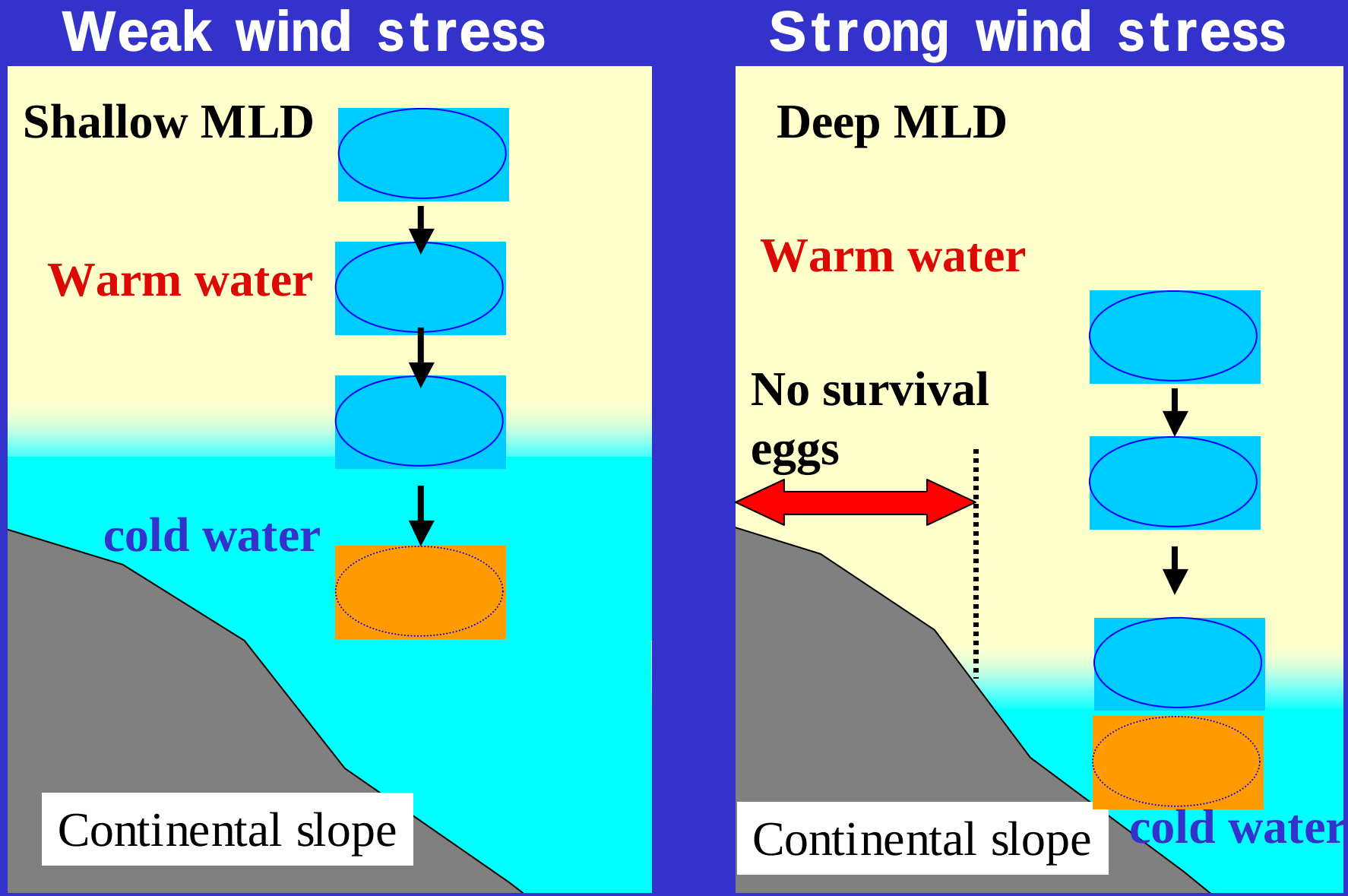
Ripe female before spawning sitting on the bottom of captive

tank

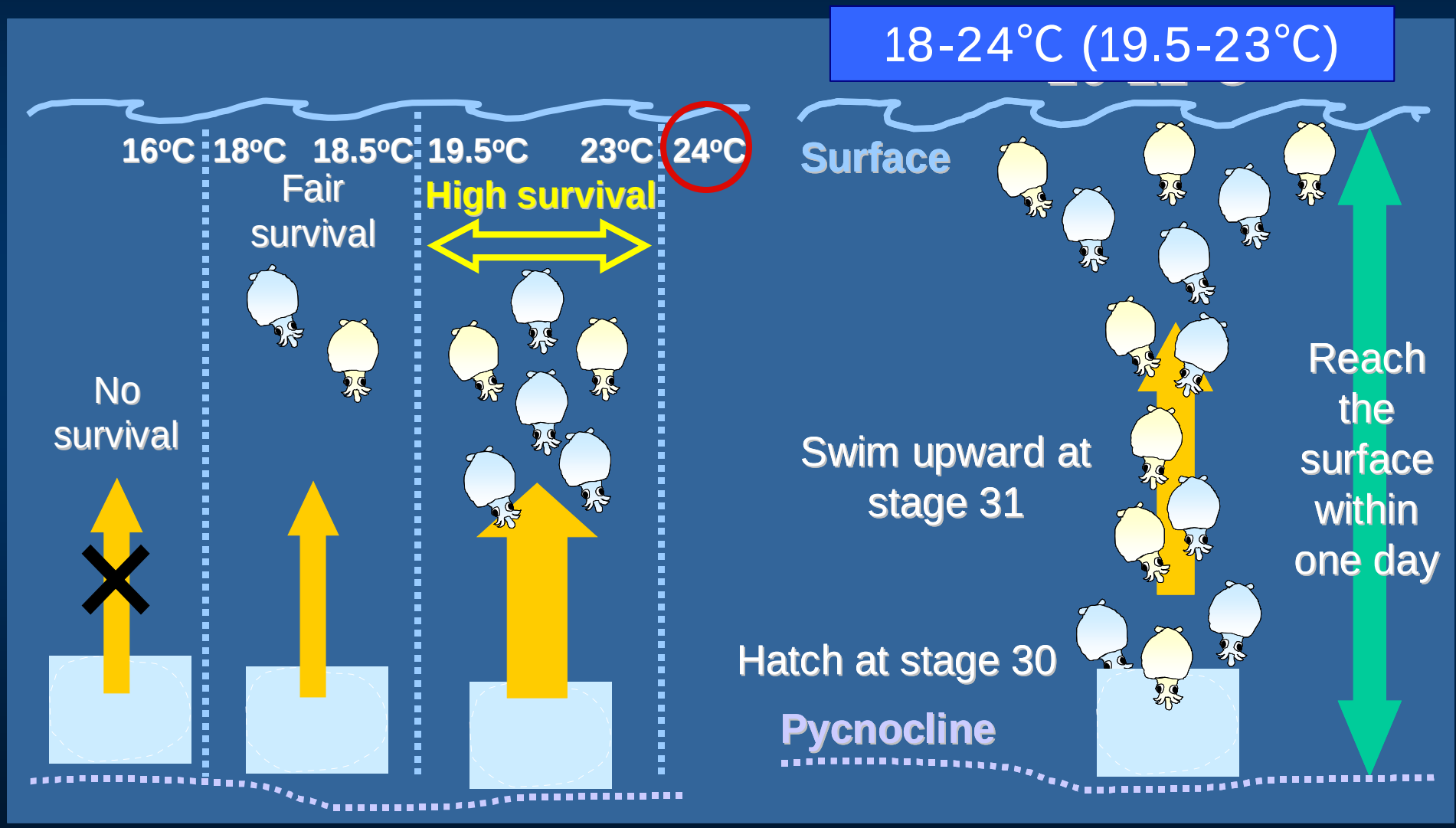
Gelatinous sphere mass resembling *T. pacificus* egg mass (Depth:80m, Temp:21℃, Oct. 18, 2003)

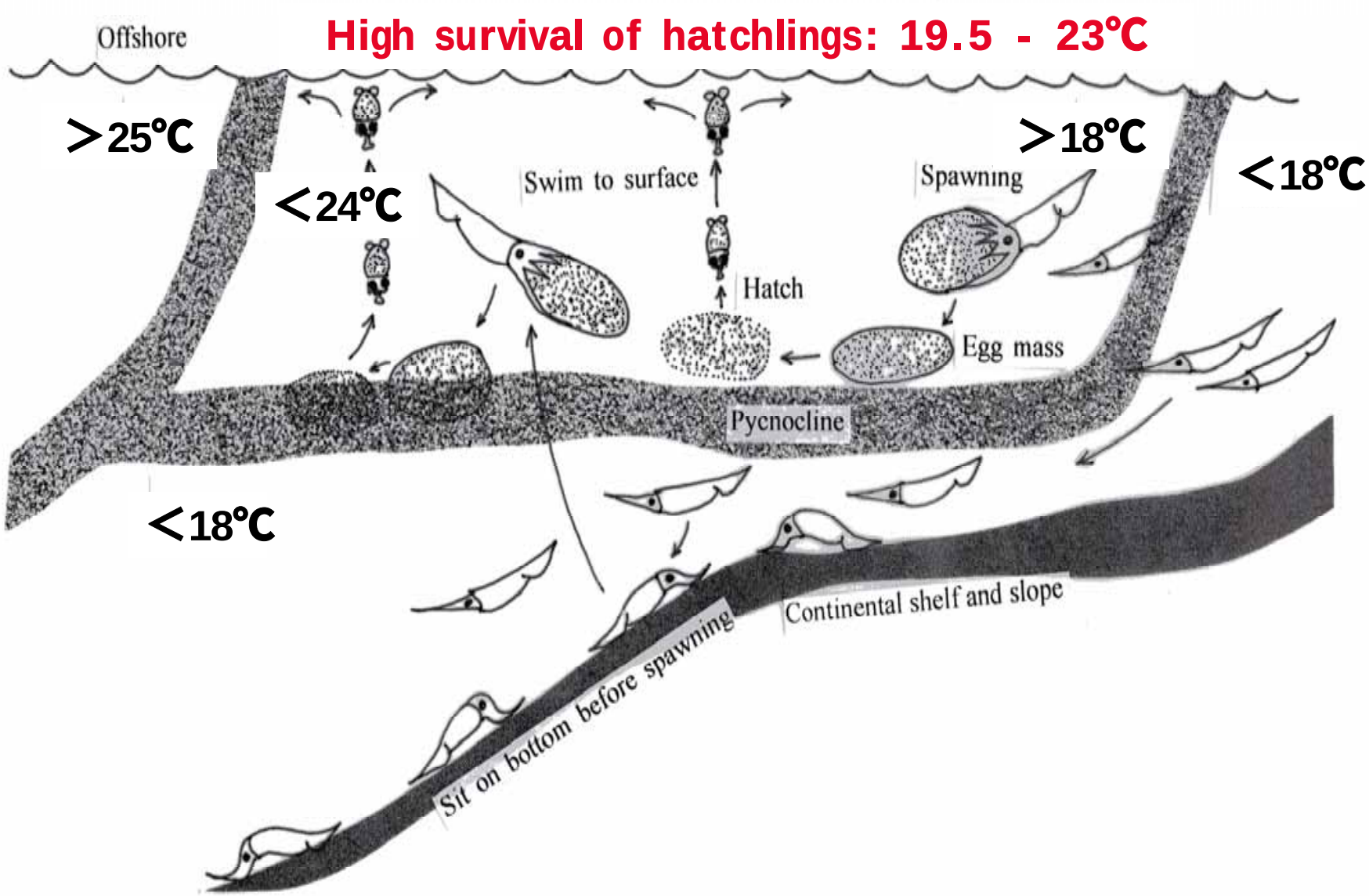


Egg mass of *T. pacificus* in captivity


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

High survival of eggs and active hatchlings occur at 18-23°C, and especially ranged between 19.5-23°C, and can survive at the surface layer of 24°C.



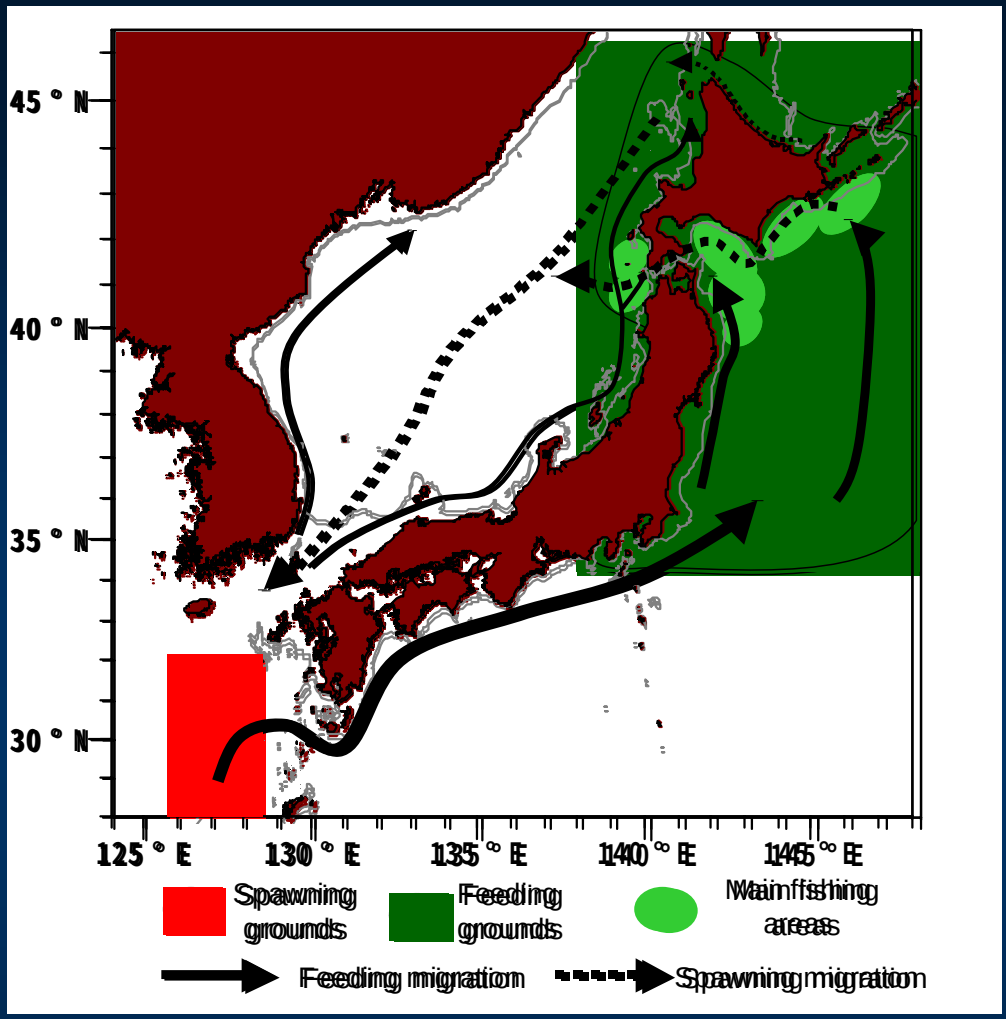


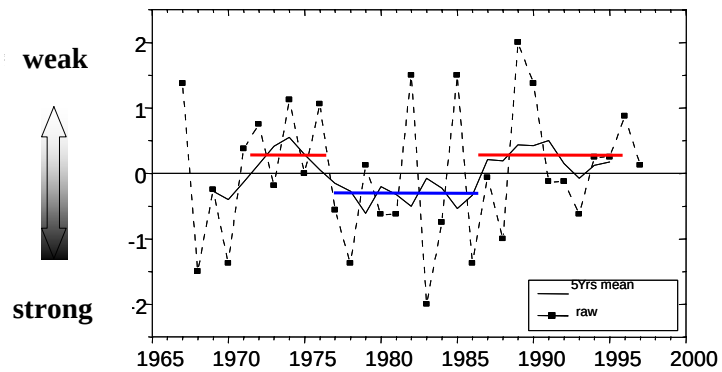
New Schematic view of reproductive processes of *T. pacificus*

Stock fluctuations of Japanese common squid (*Todarodes pacificus*) related to climatic regime shifts

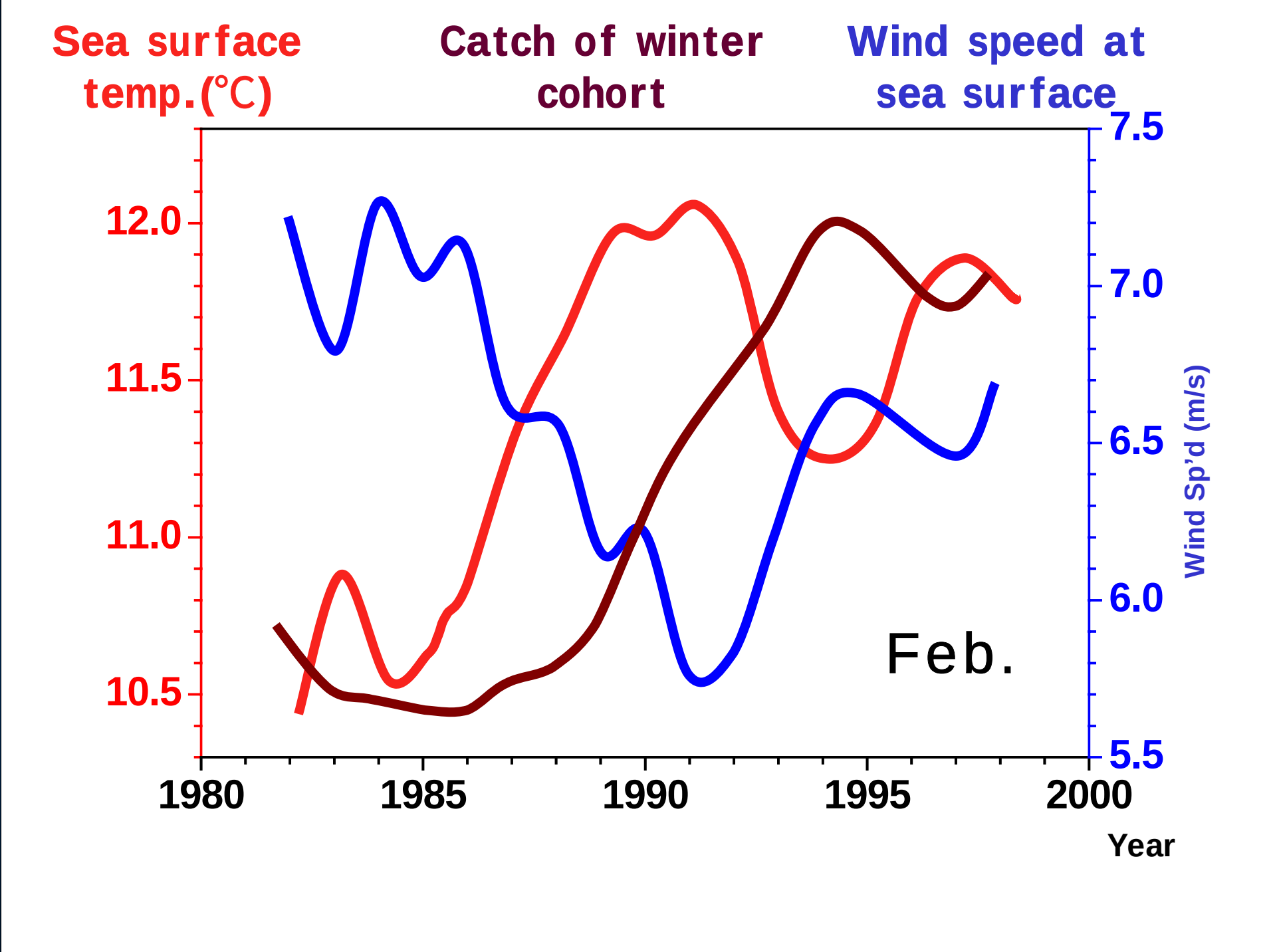
Can we explain the following question?

- "Annual catches of *T. pacificus* decreased during the cool regime during the late-1970s and late-1980s, and increased during warm regime period after the late 1980s".
- How do changes of wind stress, sea and air temperature or MLD affect the success of reproduction?



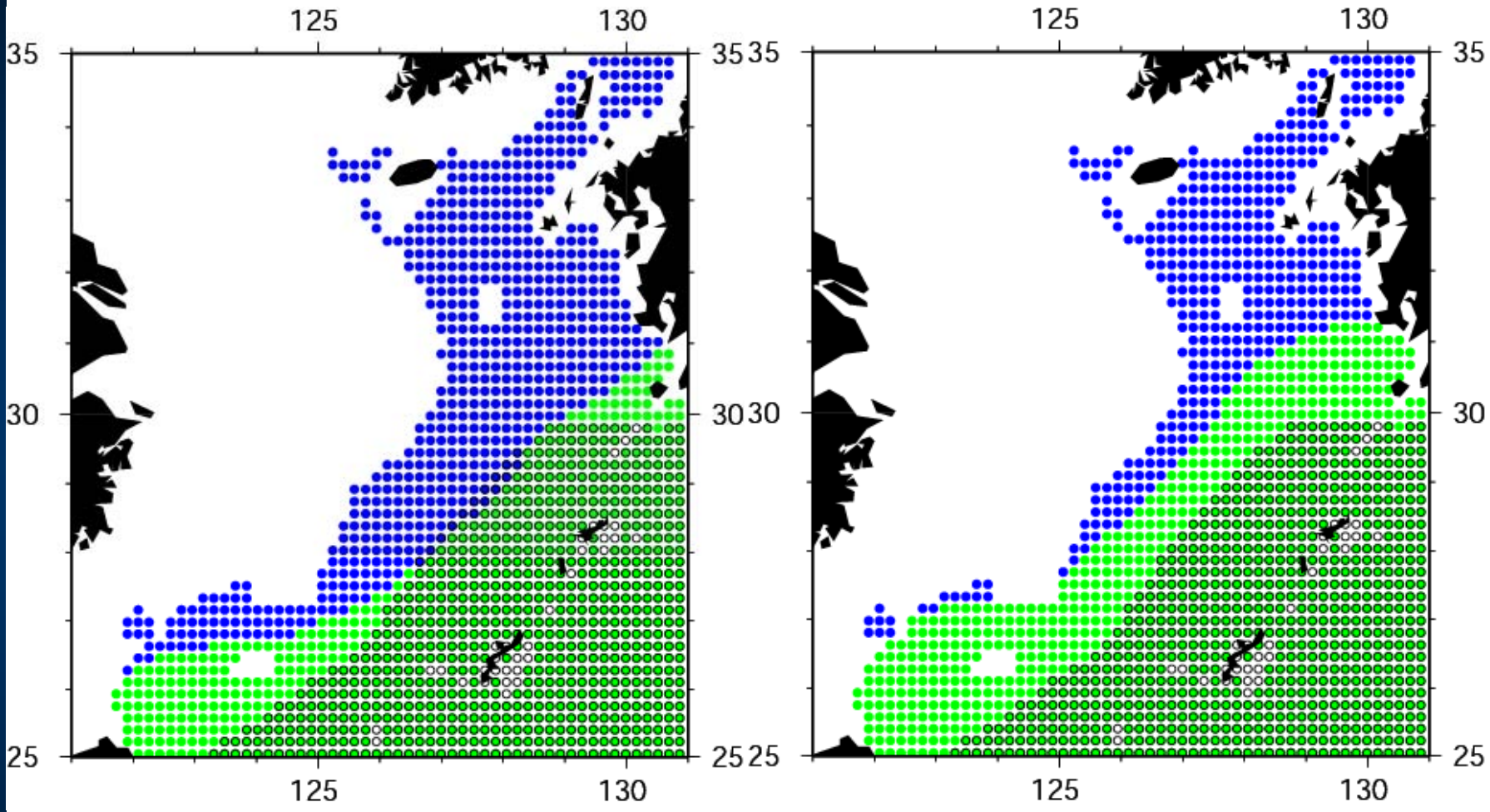


Annual change of Aleutian low pressure index. **(Nakamura and Honda, 2002)**


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)
Feb.
1980
1985
1990
1995
2000
Year

Feb. Cool (1983-1989)

Feb. Warm (1990-2000)



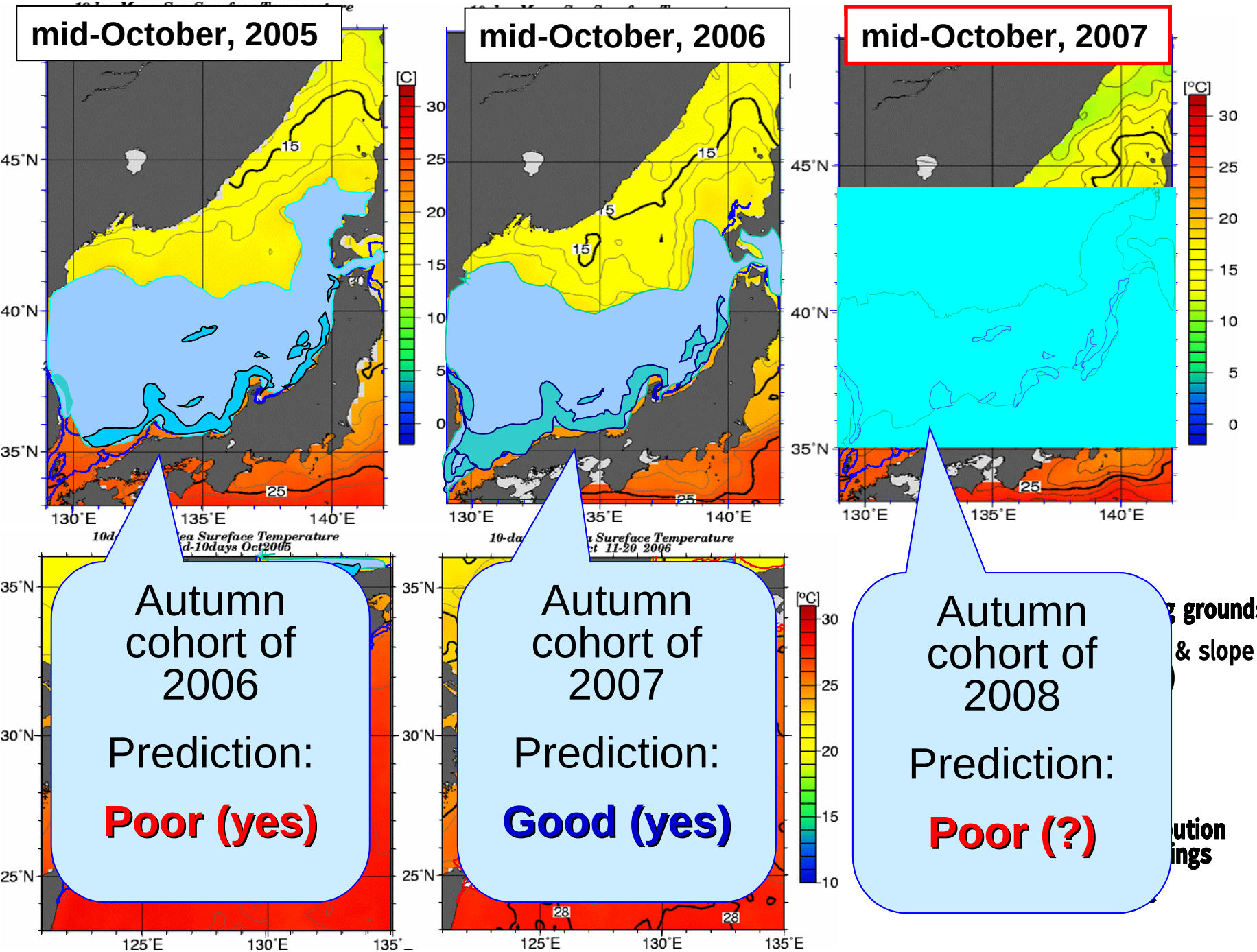
< 18.0-23.0 ≥

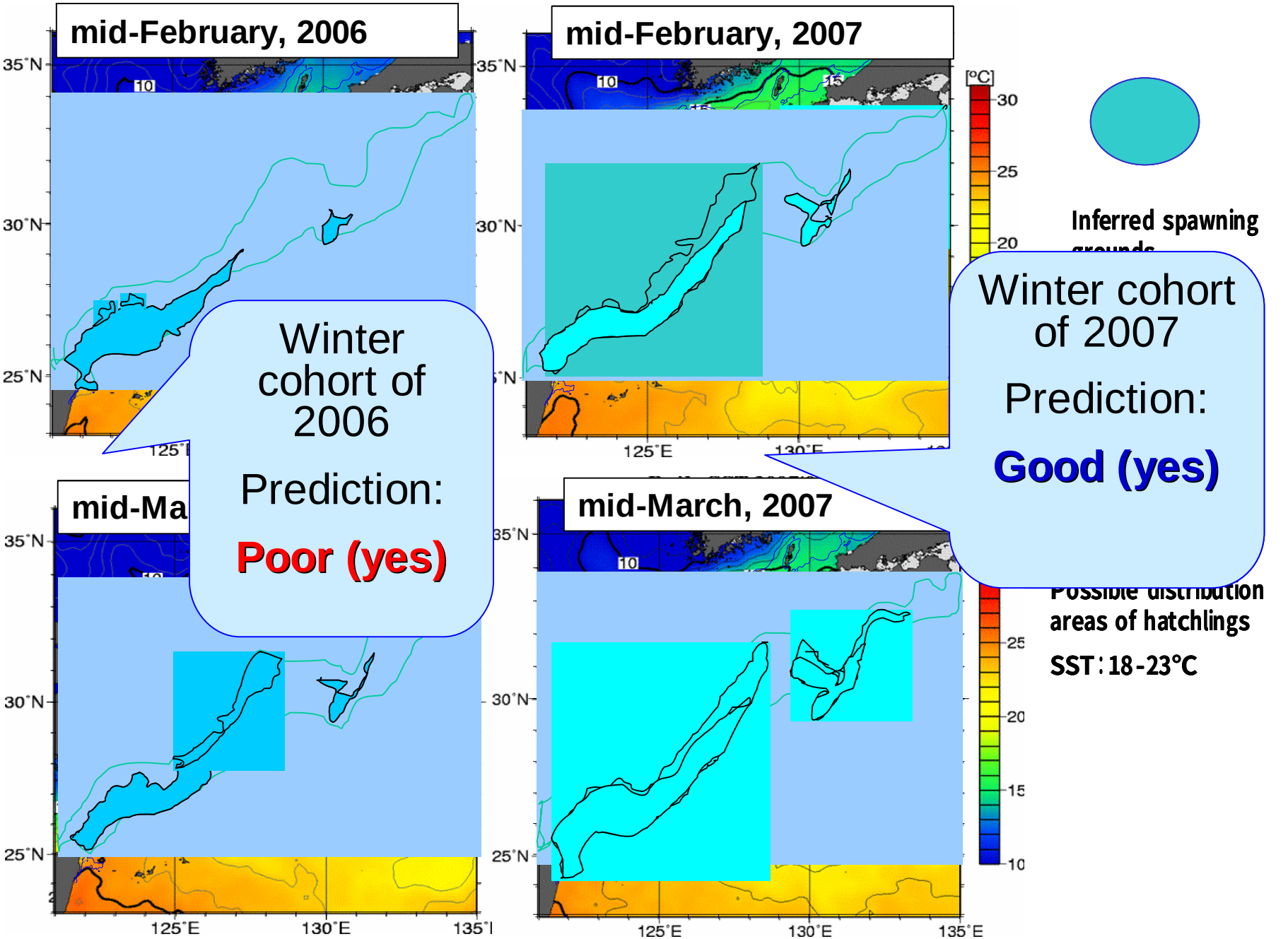
cooler optimal warmer

O off the Kuroshio

Stock fluctuations of Japanese common squid (*T. pacificus*) related to annual climate change

Can we predict the next year's stock level (poor or good) based on the new reproduction hypothesis?


mid-October, 2005
mid-October, 2006
mid-October, 2007
[C]
[°C]
45°N
40°N
35°N
130°E
135°E
140°E
15
25
Autumn cohort of 2006
Prediction:
Poor (yes)
Autumn cohort of 2007
Prediction:
Good (yes)
Autumn cohort of 2008
Prediction:
Poor (?)
30°N
25°N
125°E
130°E
28
g grounds
& slope
ution
ings


mid-February, 2006
mid-February, 2007
mid-March, 2007
mid-Ma
35°N
30°N
25°N
125°E
130°E
135°E
10
15
[°C]
30
25
20
15
10
Winter cohort of 2006
Prediction:
Poor (yes)
Winter cohort of 2007
Prediction:
Good (yes)
Inferred spawning
Possible distribution areas of hatchlings
SST：18-23°C

Can we predict the life strategy and stock fluctuations of Japanese common squid (*T. pacificus*) related to the global warming scenario by IPCC during the 21th Century ?

○ Qualification of inferred spawning areas, *Todarodes pacifica*（Nakazima, 2007）

-Topography： each cell including water above 100～500m bottom depth along the coast (yellow cell in the figure)

-SST：18～24℃

-January to December：at each month

Figure in each cell indicates the maximum depth.

Green cell: land area, orange cell: inferred spawning area, red cell: disappeared spawning area with global warming

-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	170	-100	-100	-100	600	1900	1900	2150	2150	2650	2650	2650	2150	2900
-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	250	-100	250	100	1100	2650	2650	2650	2650	2650	2650	2650	3400	4150
-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	750	750	-100	1650	2650	2650	2900	2900	2900	2900	2900	3400	3400	4150	4900
-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	1050	900	-100	-100	-100	2650	2650	2900	2900	2900	2900	3400	4150	4150	4900	5400
-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	1650	1650	1200	-100	-100	1650	2650	2650	2900	2900	-100	3400	4150	4900	4900	5400	5400
-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	2650	2650	2650	1400	-100	-100	-100	2150	2150	-100	-100	4150	4150	4900	5400	5400	5400	5400
-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	2900	2900	2900	2650	-100	-100	-100	-100	-100	-100	3650	4150	5150	5150	5400	5400	5400	5400	5400
-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	2900	2900	3400	3400	3400	-100	-100	-100	-100	-100	-100	3500	4900	5150	5400	5400	5400	5400	5400	5400	5400
-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	2650	3400	3400	3400	3400	3400	3400	3400	3400	2900	-100	500	500	4900	5150	5150	5400	5400	5400	5400	5400	5400	5400	5400	5400
-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	2900	3400	3400	3400	3400	3400	3400	3400	3400	2650	-100	-100	1750	4900	5150	5150	5400	5400	5400	5400	5400	5400	5400	5400	5400
55	-100	-100	-100	-100	-100	-100	-100	2500	2650	2650	2650	2650	2650	2650	2650	2650	2650	2650	-100	-100	-100	1750	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400
55	-100	55	55	55	-100	-100	-100	-100	2150	2150	2650	2650	2650	2150	2150	2150	2150	2150	-100	-100	-100	1750	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400
-100	-100	-100	55	65	-100	-100	-100	-100	-100	1900	1900	1900	1900	1900	1900	-100	1650	-100	-100	-100	30	1100	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400
-100	-100	65	65	65	65	-100	-100	-100	-100	1400	1650	1650	1650	1650	1650	-100	-100	-100	-100	-100	4900	4900	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400
55	55	65	65	65	65	-100	-100	-100	-100	900	900	-100	-100	-100	-100	-100	-100	-100	-100	-100	4900	4900	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400
55	55	65	65	75	75	-100	-100	-100	250	400	-100	-100	-100	-100	-100	-100	-100	-100	600	5150	5150	5150	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400
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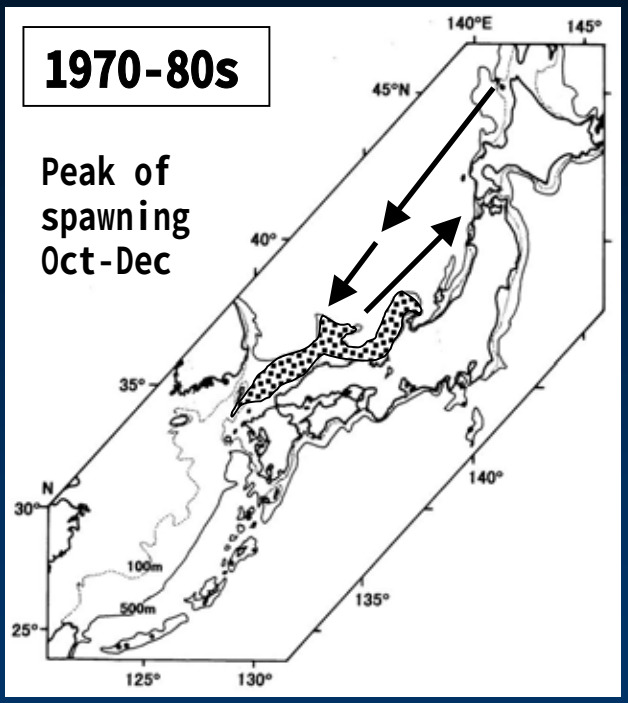
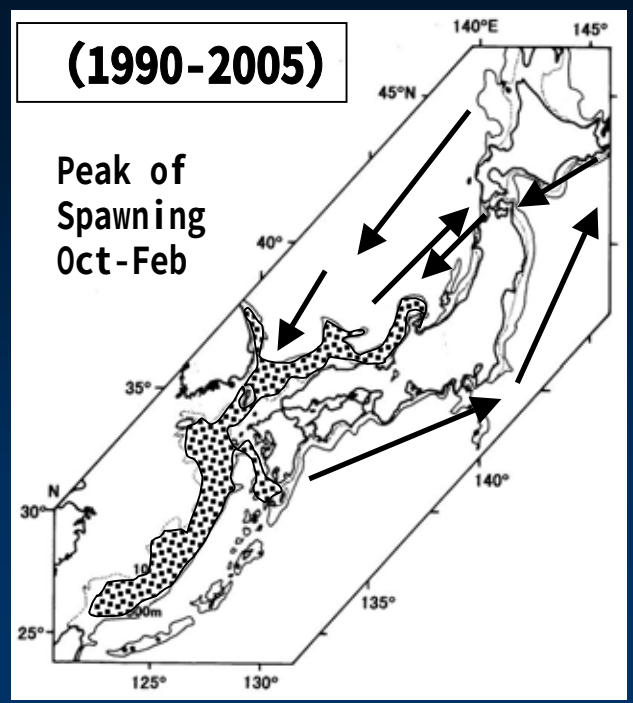
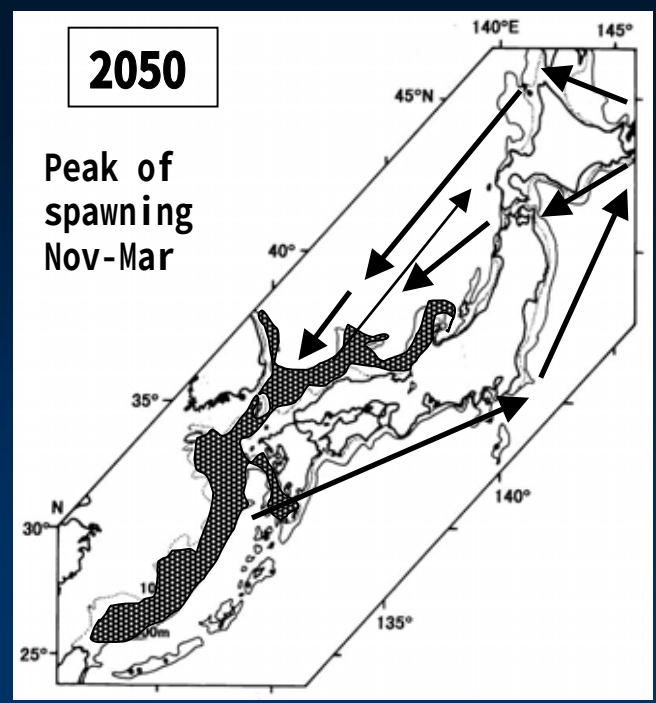
-100	-100	30	75	100	100	170	170	170	250	-100	-100	-100	2900	3650	3650	3650	3650	3650	3400	3900	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400
-100	-100	50	75	100	100	250	325	325	600	-100	-100	2900	3900	4900	4900	4900	4150	4150	3400	3900	5150	5150	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400
-100	-100	20	75	170	170	400	600	600	1200	2650	3650	3650	4900	4900	4900	4900	4150	4150	3400	3900	5150	5150	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400
-100	-100	75	120	250	250	500	900	900	1900	2900	4150	4150	4900	4900	4900	4900	4900	4900	3650	3900	4900	4900	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400
-100	-100	75	200	500	500	750	1400	1400	2650	3650	4900	4900	4900	4900	4900	4900	4900	4900	3900	3900	4900	4900	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400
-100	100	170	400	750	750	1050	1900	1900	3400	4150	4900	4900	4900	4900	4900	4900	4900	4900	4900	3900	4900	4900	5150	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400	5400
500	500	750	1200	1650	1650	2650	3900	3900	4150	4900	4900	4900	4900	4900	4900	4900	4900	4900	4900	3900	3650	3650	4150	4900	4900	5150	5400	5400	5400	5400	5400	5400	5400	5400
750	-100	1650	2150	2900	2900	3900	4900	4900	4900	4900	4900	4900	4900	4900	4900	4900	4900	4900	4900	3900	3650	3650	4900	5150	5150	5400	5400	5400	5400	5400	5400	5400	5400	5400

Inferred spawning areas of *Todarodes pacifica* is limited by the bottom depth of continental self and slope (100-500 m)







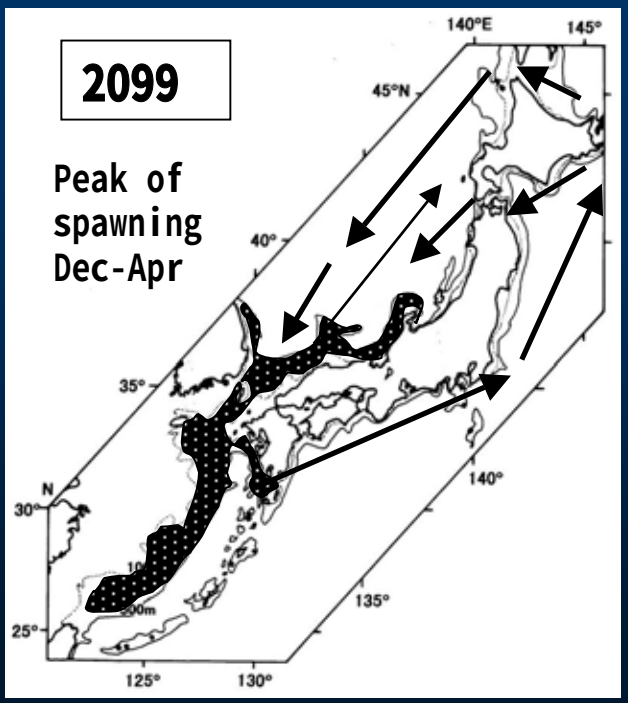


Fig. Predicted spawning periods,areas, and migration routes of *T. pacificus* during 1970-80s(cool regime),1990-2005(warm regime),2050(SST: 2℃ increase), 2099(SST: 4℃ increase). Estimated environmental changes in waters around Japan based on the IPCC global warming scenario (Kawamiya et al., 2007)

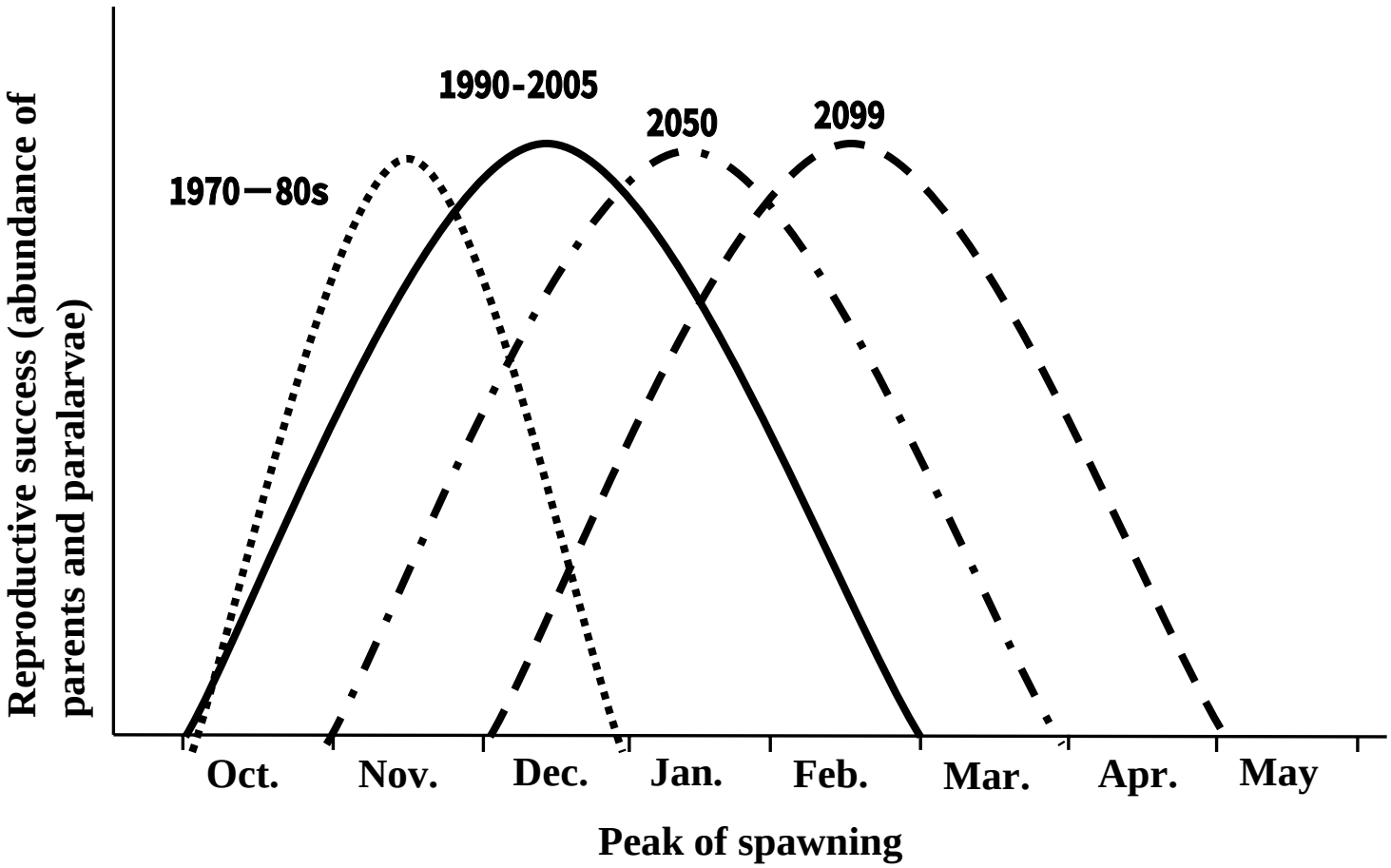


Fig. Predicted spawning periods of *T. pacificus* during 1970-80s (cool regime),1990-2005 (warm regime),2050 (SST: 2℃ increase), 2099 (SST: 4℃ increase). Estimated environmental changes in waters around Japan based on the IPCC global warming scenario (Kawamiya et al., 2007)