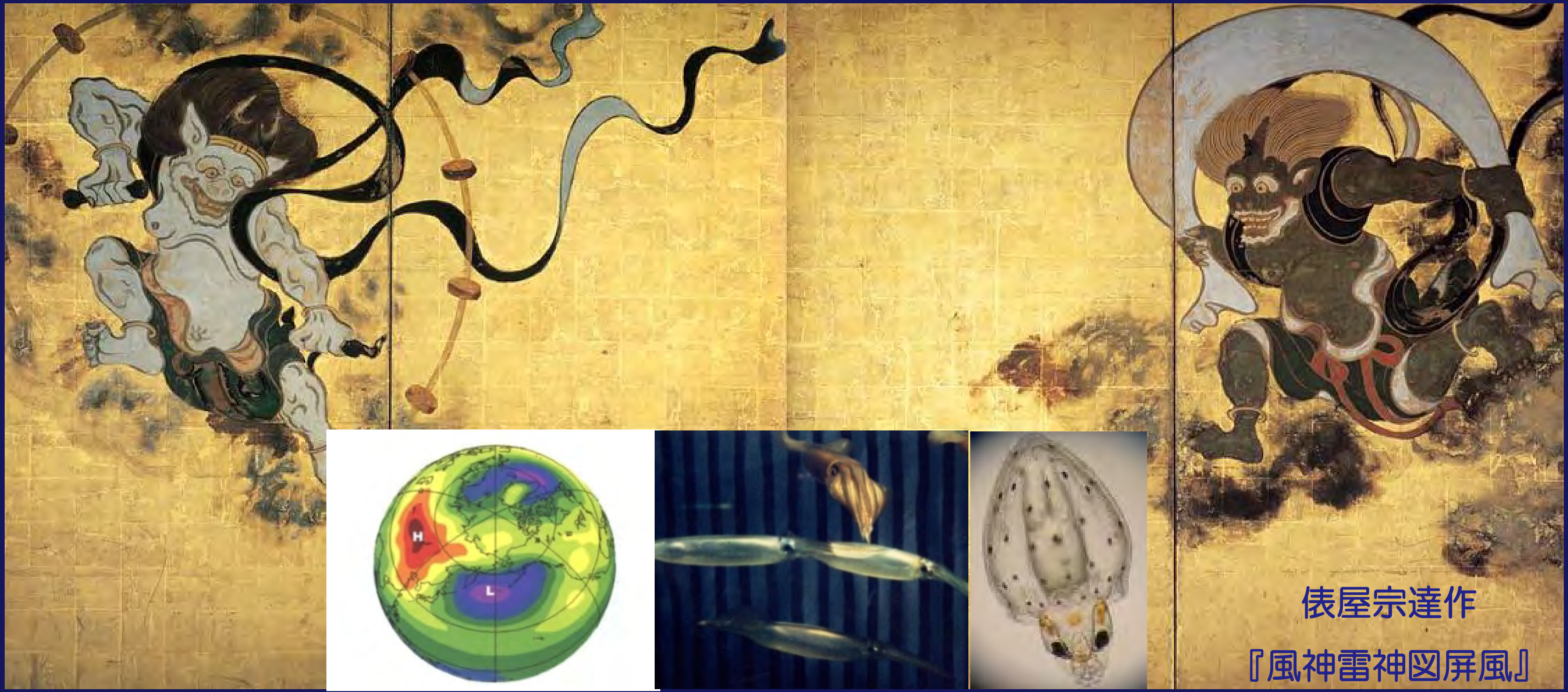
Recent decline in winter stock of Japanese flying squid, *Todarodes pacificus* related to climate change during winter-spring



Yasunori **SAKURAI**

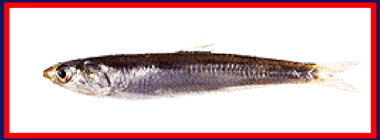
Professor Emeritus, Hokkaido University
Hakodate Cephalopod Research Center, Fisheries and Oceans Hakodate

Hakodate, Hokkaido, 041-8611, Japan
E-mail: sakurai@fish.hokudai.ac.jp

Sardine

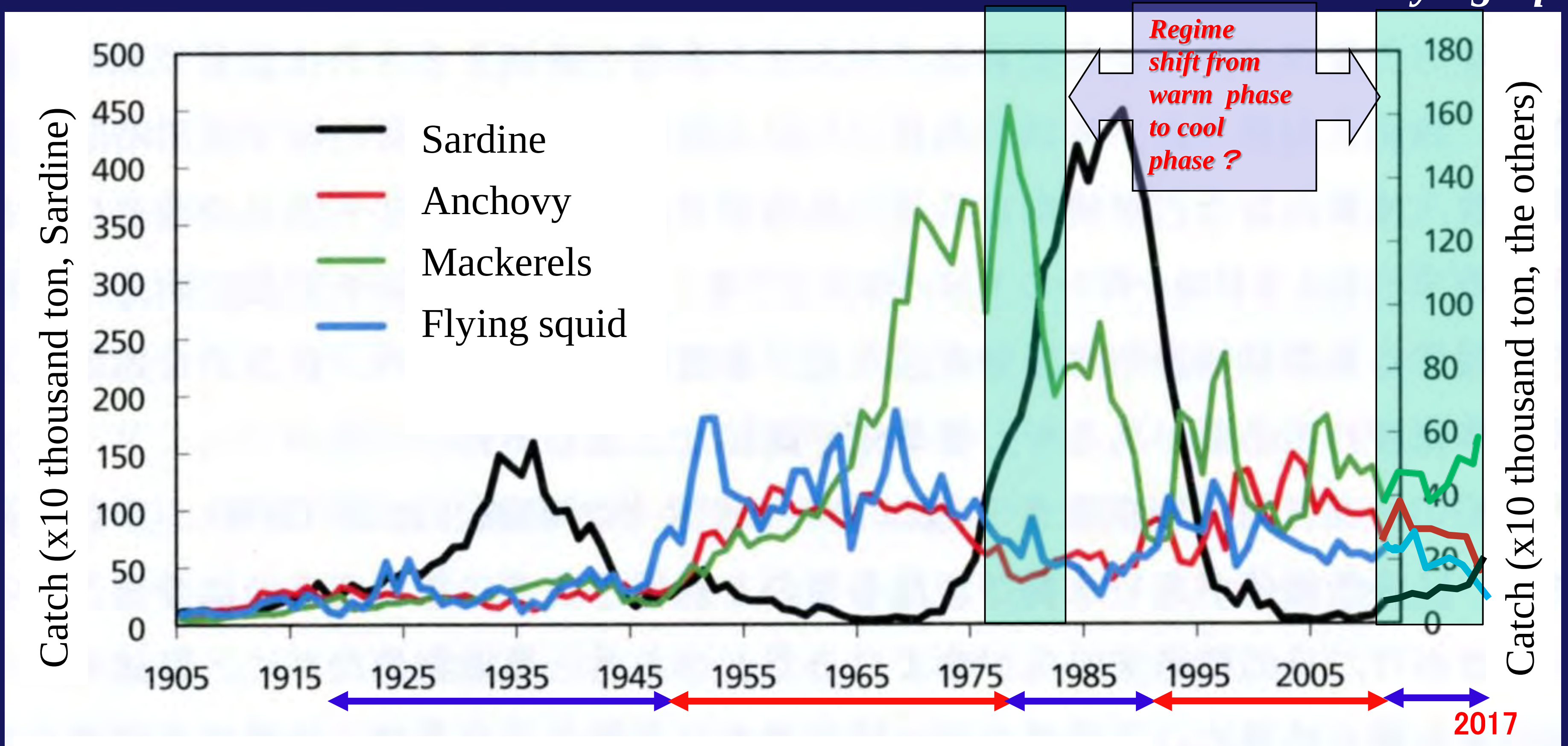
Mackerels

Jack mackerel



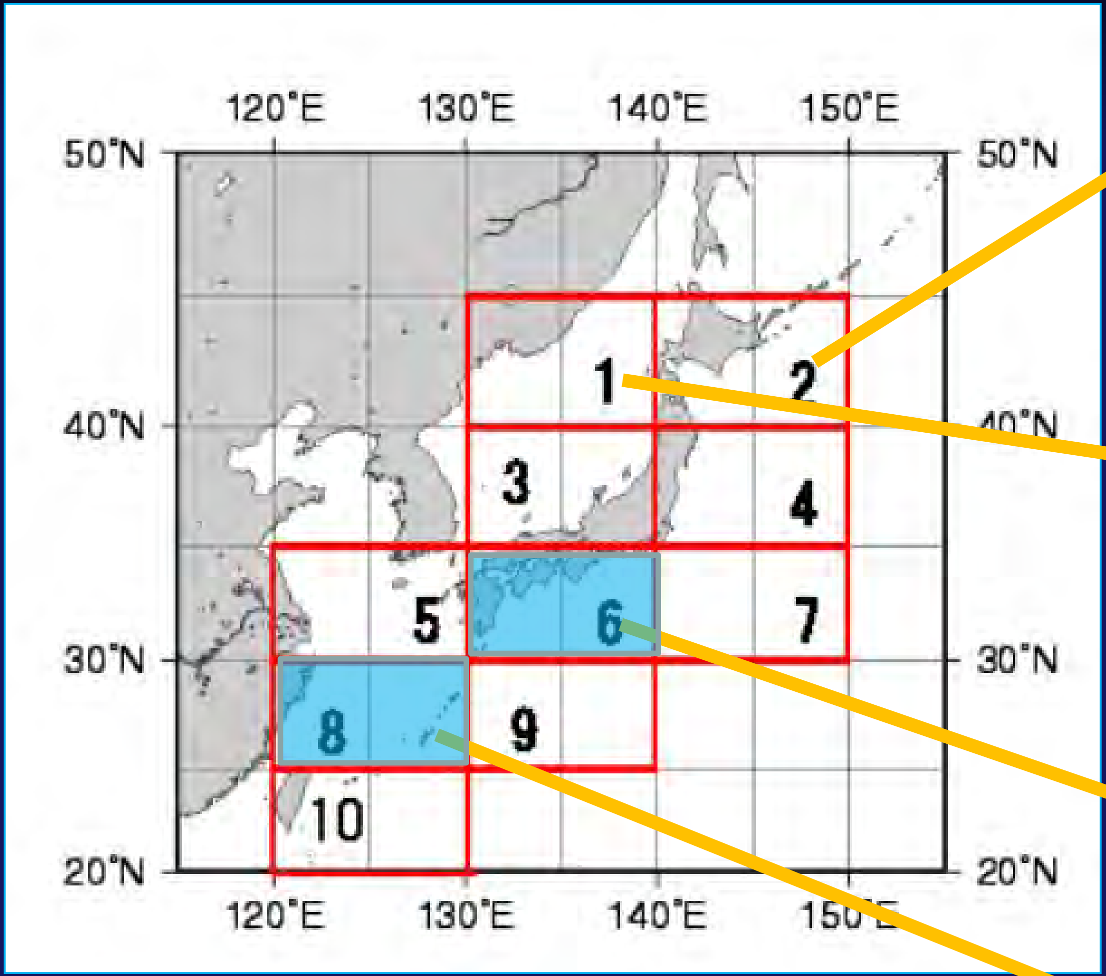
Anchovy

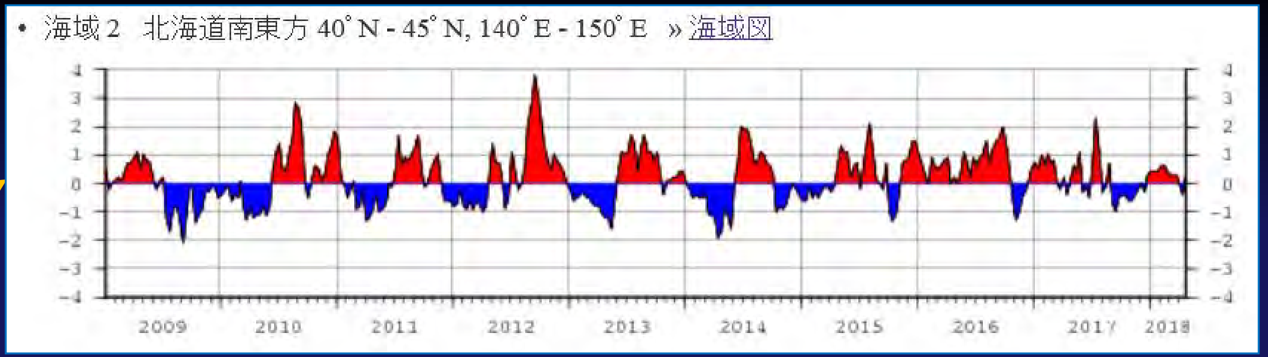
Japanese Flying squid

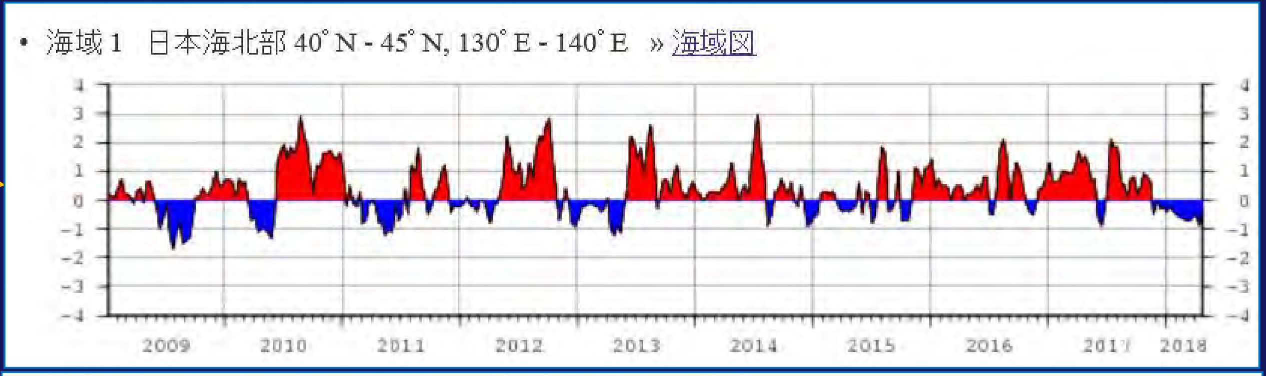


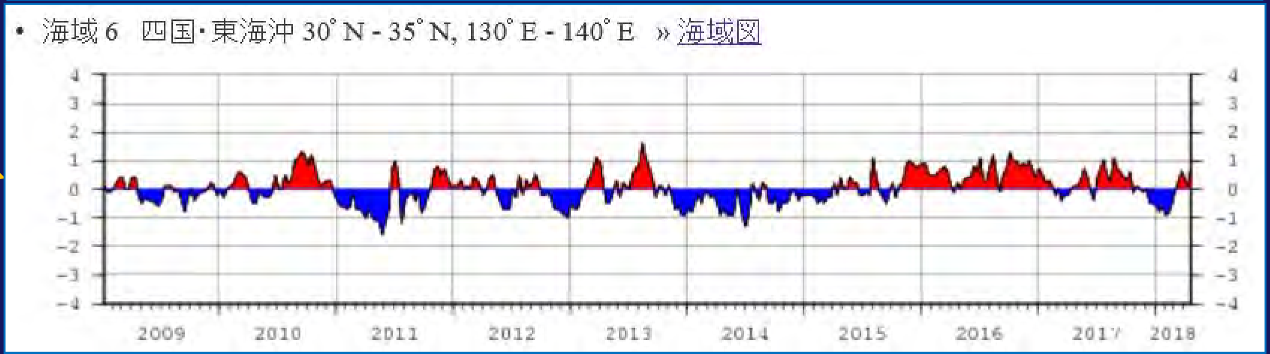
Catch trends of main pelagic species in Japan (1905～2016)

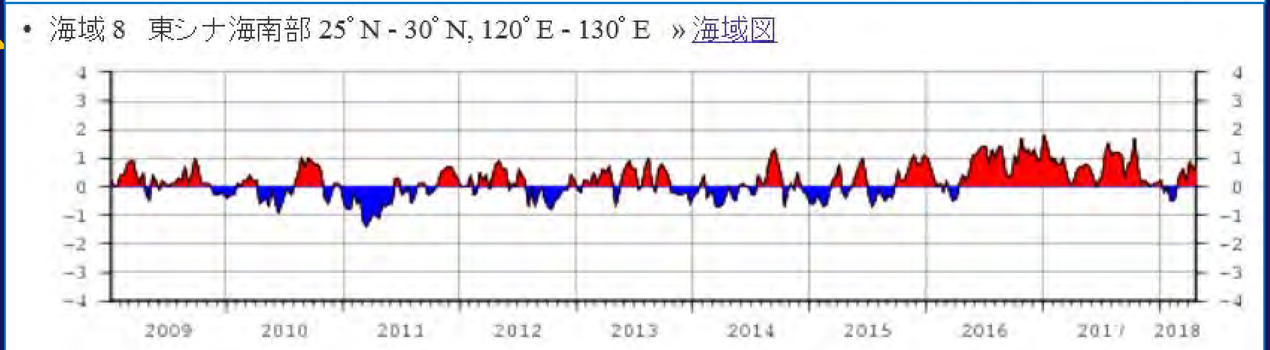
（After Yatsu，2014)





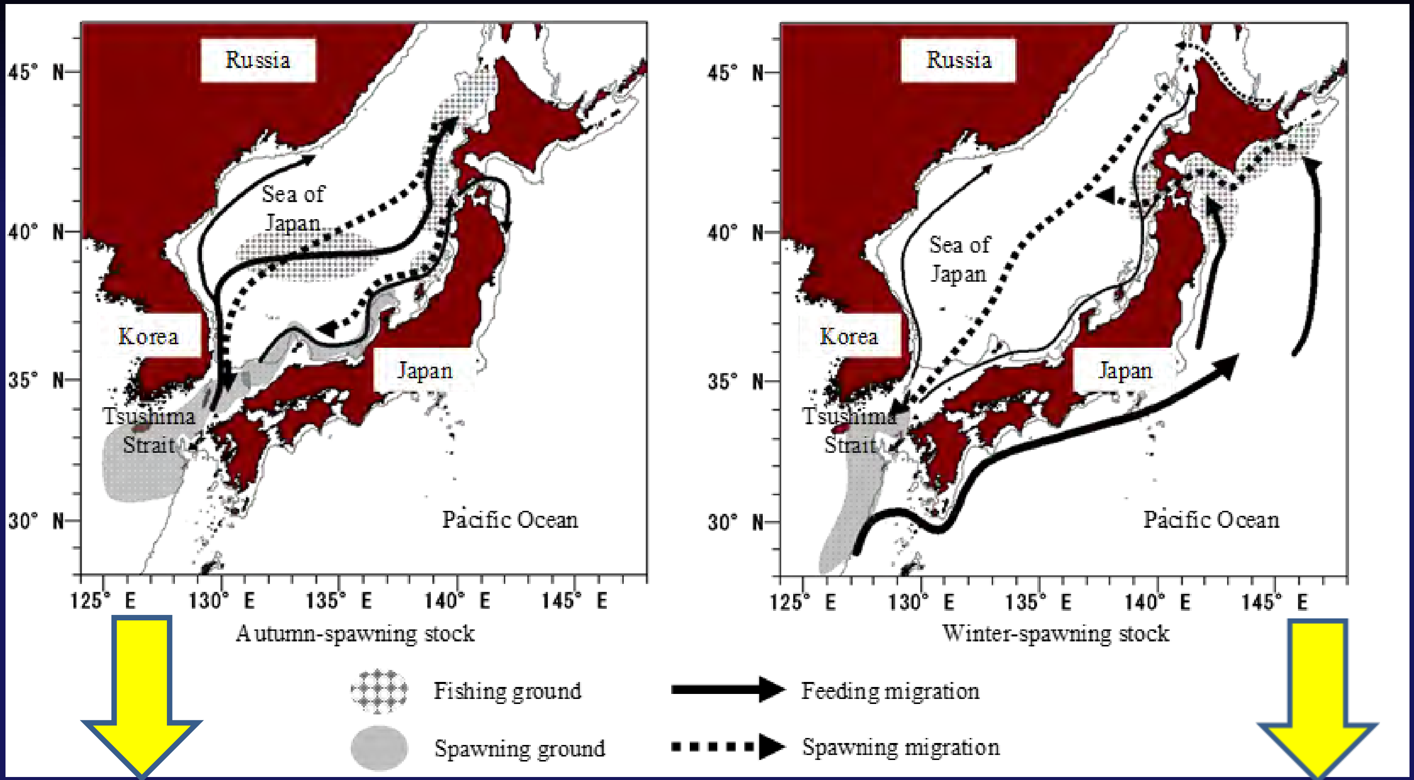






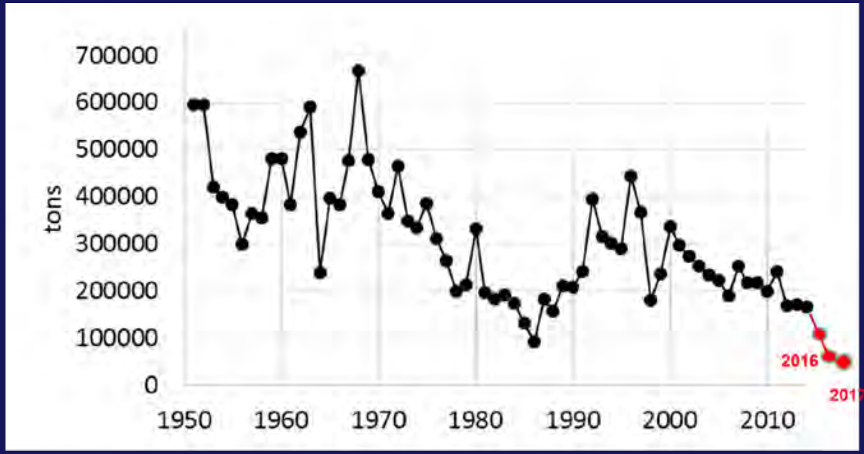
・Off Shikoku：Cool phase of spring after 2010 (good recruit of Pacific sardine)

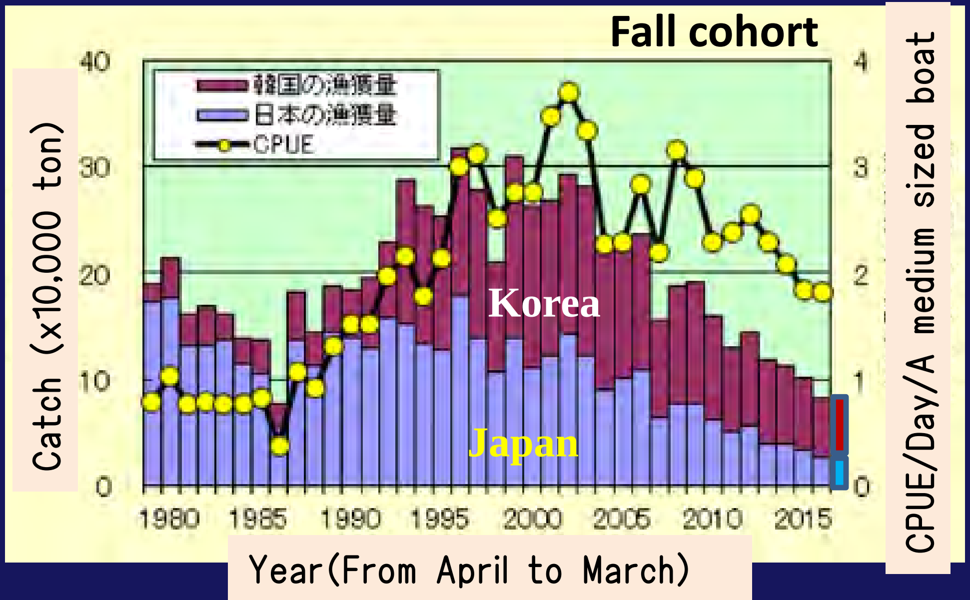
・East China Sea: Temporal cooling during winter in 2015, 2016 & 2018 (Abrupt decline of *T. pacificus* winter cohort)

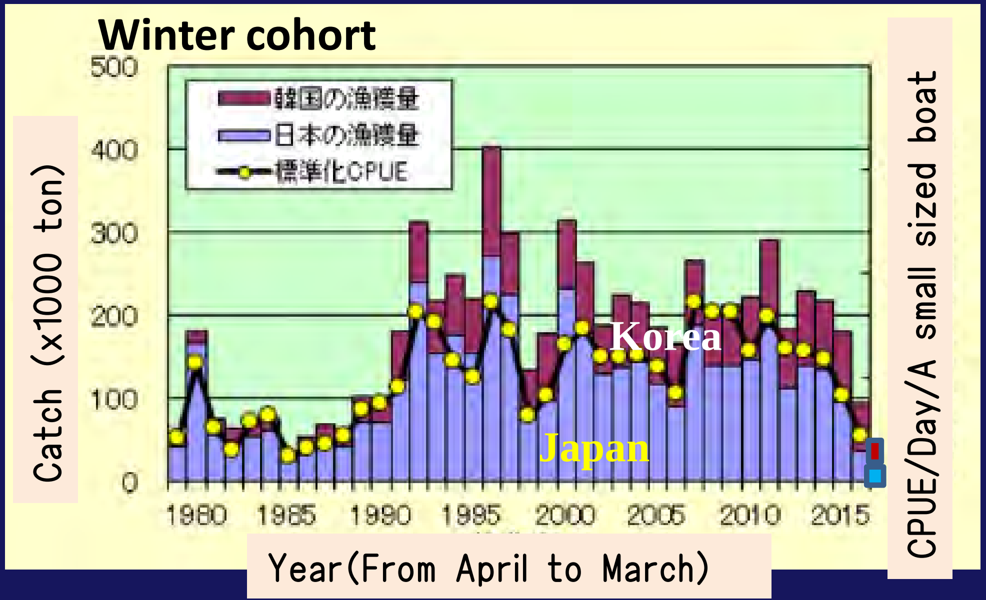


Estimated catches of winter cohort in Japan and Korea, 2017

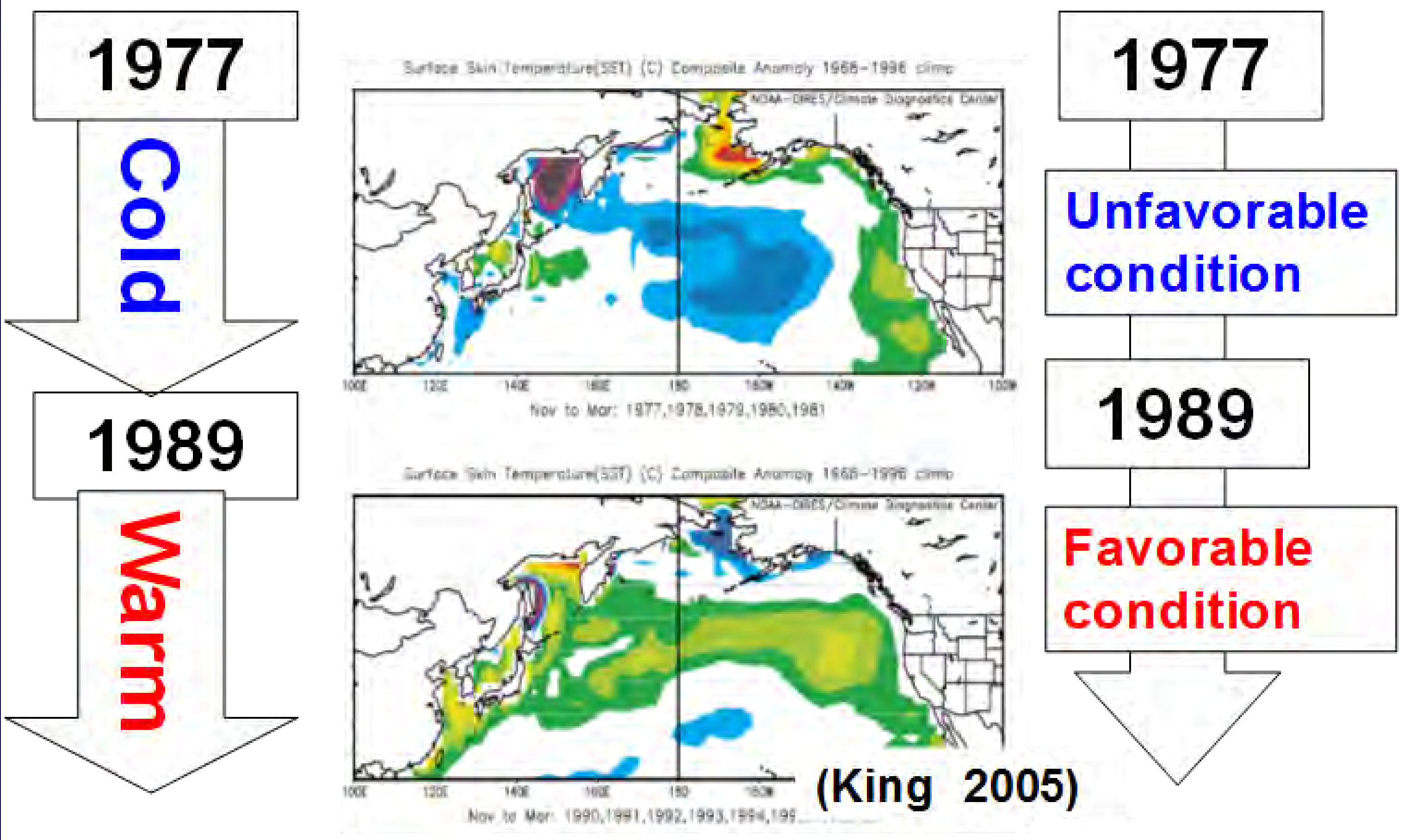
Japan: 29,000 ton
Korea: 24,000 ton
Total: 53,000 ton



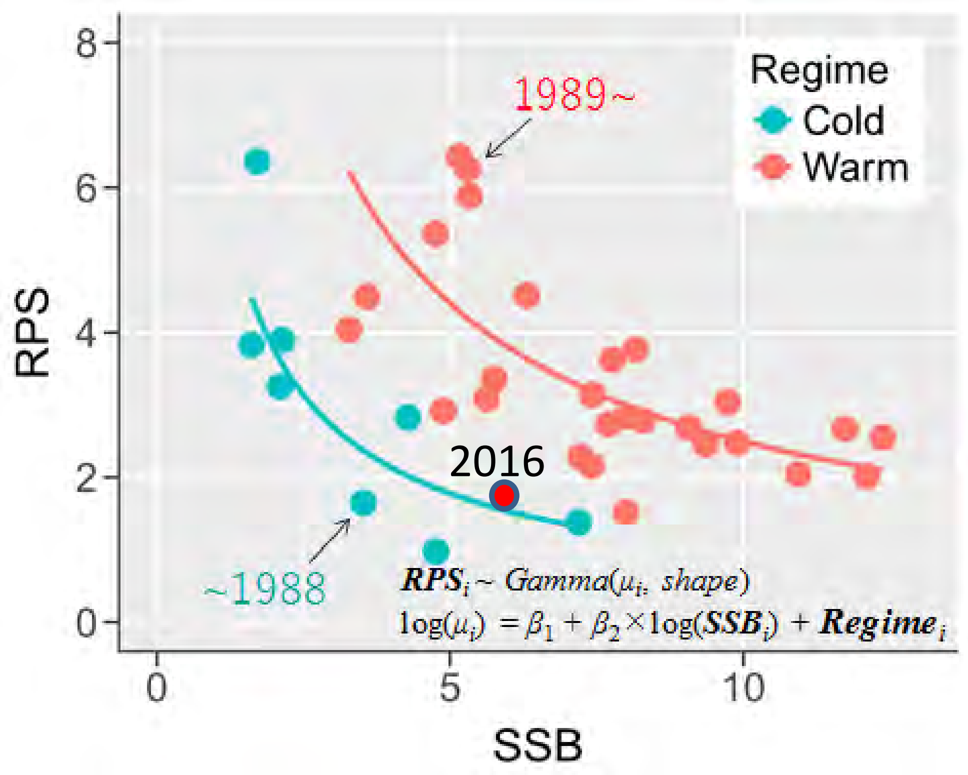




(from Fisheries research agency Japan, http://abchan.fra.go.jp/digests2017/html/2017_18.html)



Schematic diagram of climate regime shift in the north Pacific and change in stock size of Japanese flying squid (Kidokoro et al., in press. Modified from King ed. 2005)



Relationship between spawning biomass and RPS (Recruit per spawner) of *T. pacificus* by regime (in the case of winter spawning stock)
(Kidokoro et al., in press)

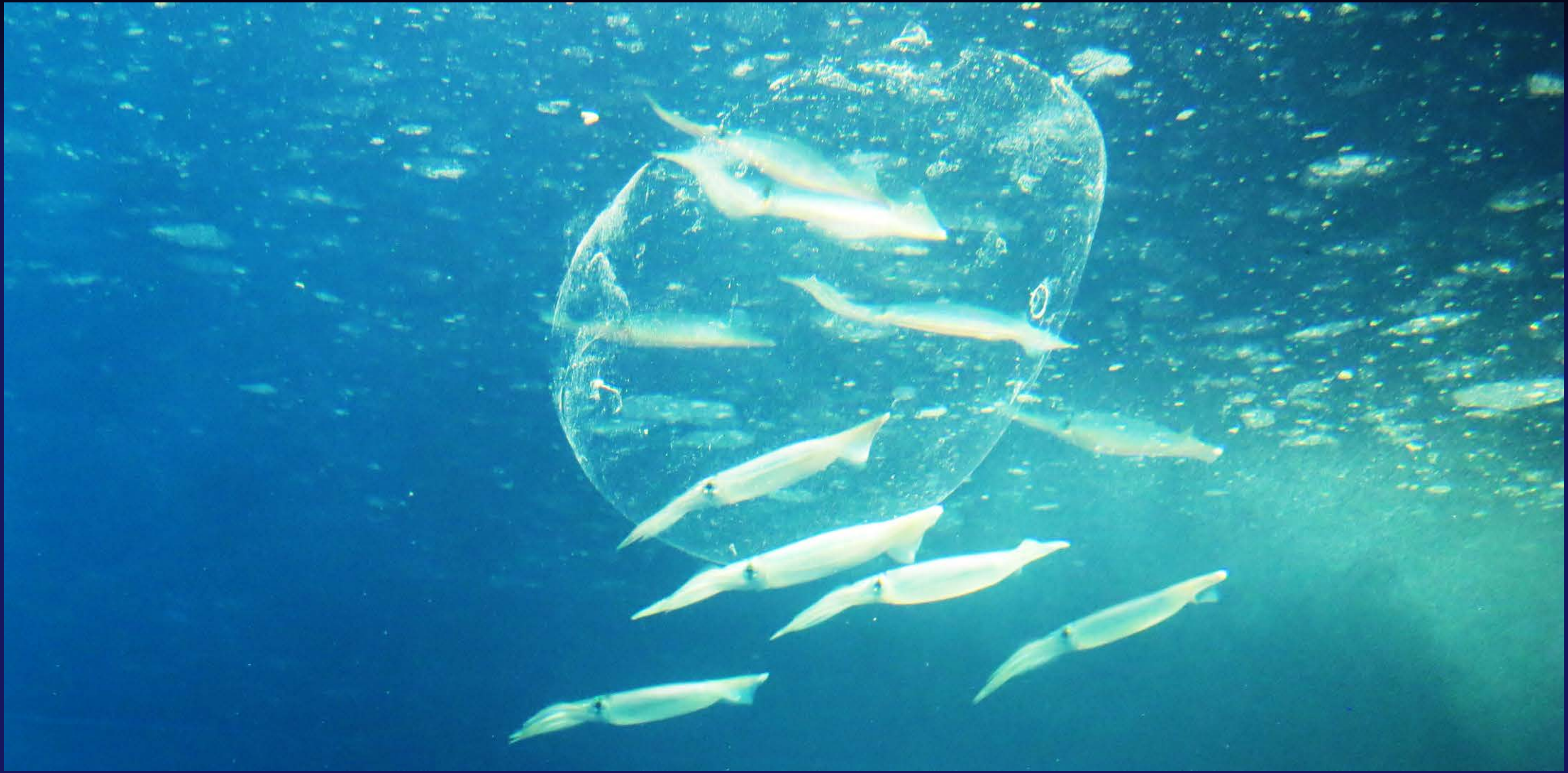
- Annual catches of *T. pacificus*, especially of the winter spawning population decreased during the cool regime period from the late-1970s to late-1980s, while Japanese sardine, *Sardinopsis japonicus* increased exponentially.
- After the late-1980s warm regime period, squid catch had increased and sustained the Japanese squid markets. Catch fluctuations of *T. pacificus* are similar with those of Jack mackerel, *Trachurus japonicus* and the Japanese anchovy, *Engraulis japonicus*.
- This phenomenon is called "**species replacement with climate regime shifts between warm and cool period**".

Stock fluctuations of Japanese flying 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". ➡ Published

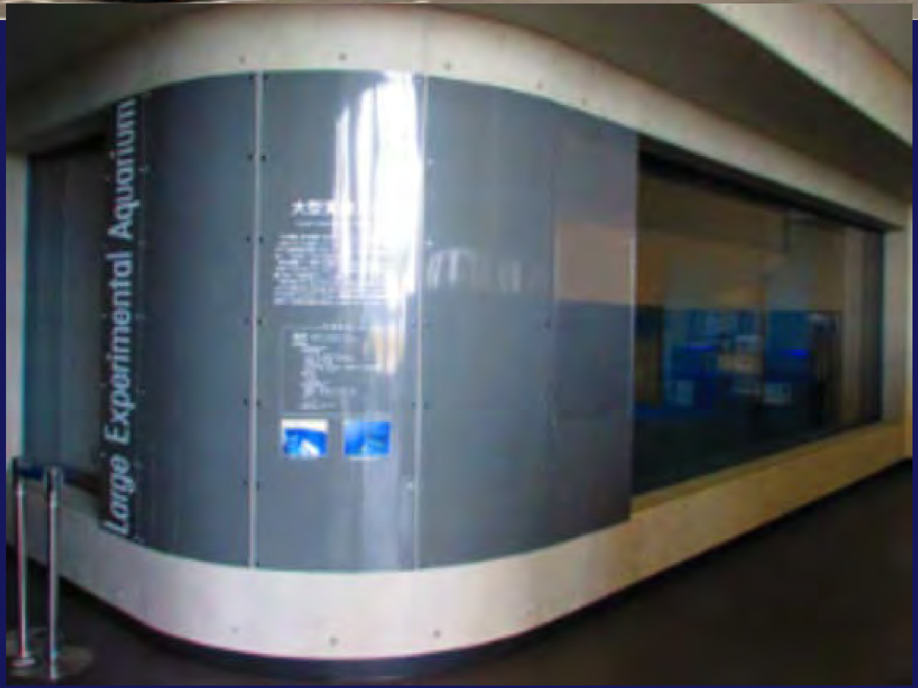
- Recent decline in winter stock of Japanese flying squid related to climate change during winter-spring. ➡ This presentation

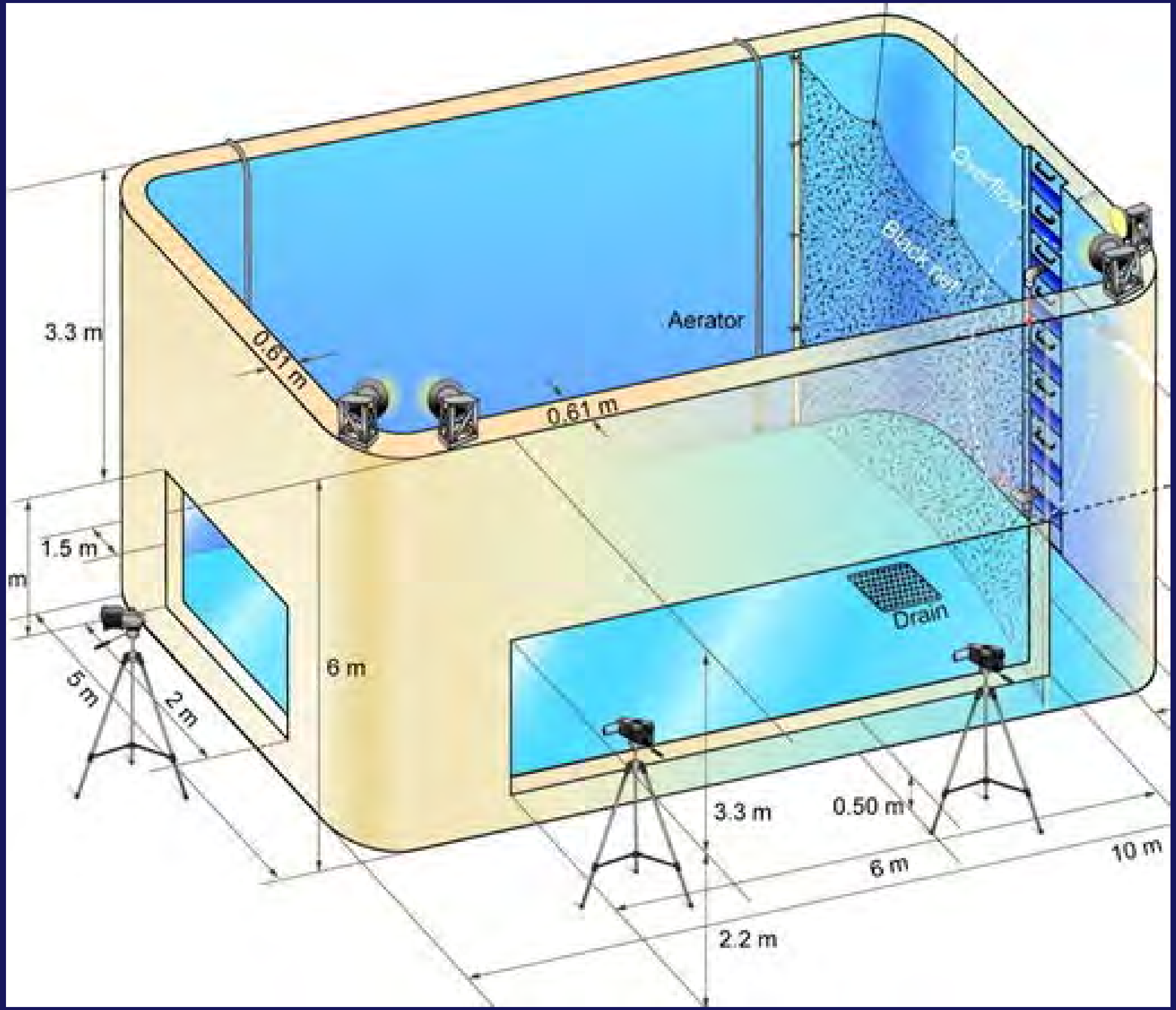


New findings of spawning and, structure and function of egg mass of *Todarodes pacificus* in captive experiments

Large experimental tank

Hakodate Research Center for Fisheries and Oceans

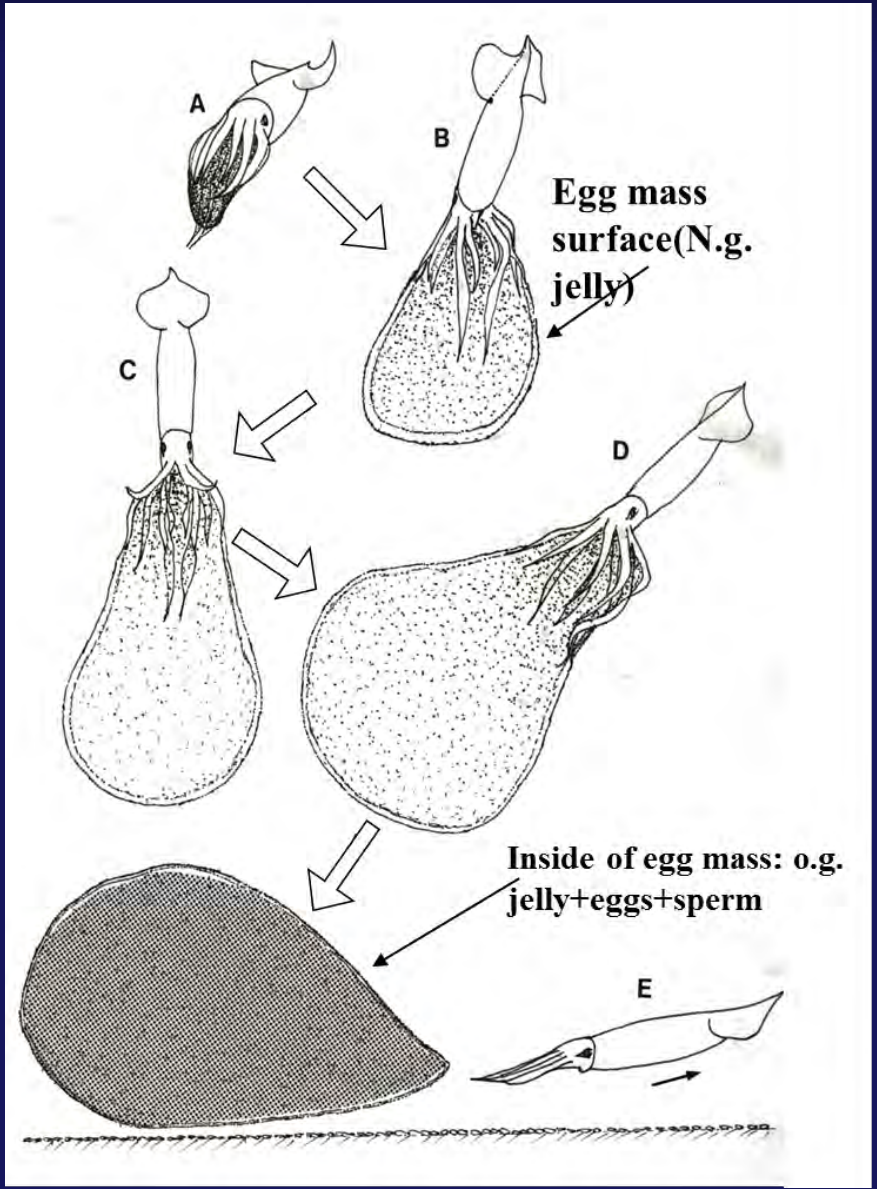




Experimental tank drawn to scale and highlighting its parameters

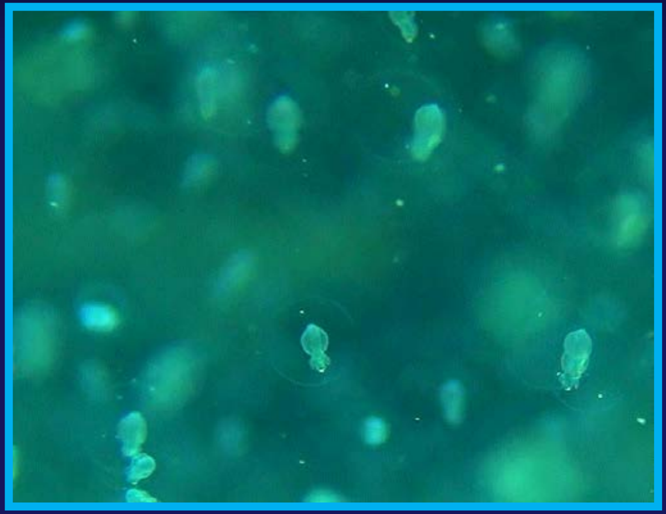
Puneeta et al., 2015

Spawning behavior

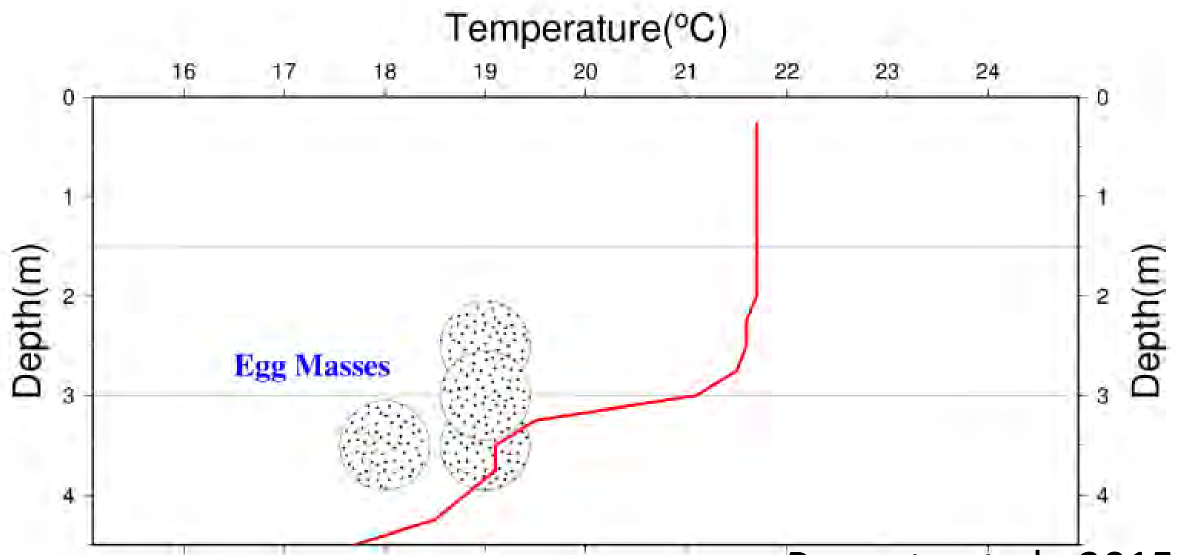


Sakurai et al., 2003

Egg mass in the thermocline

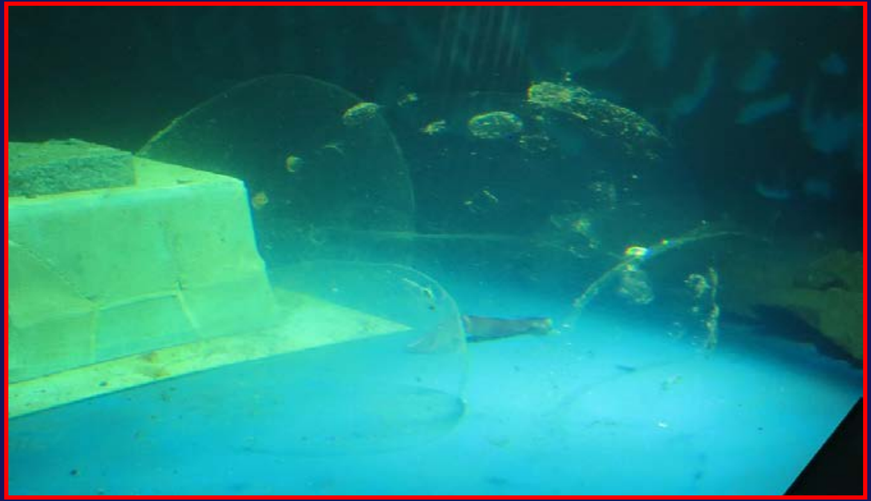


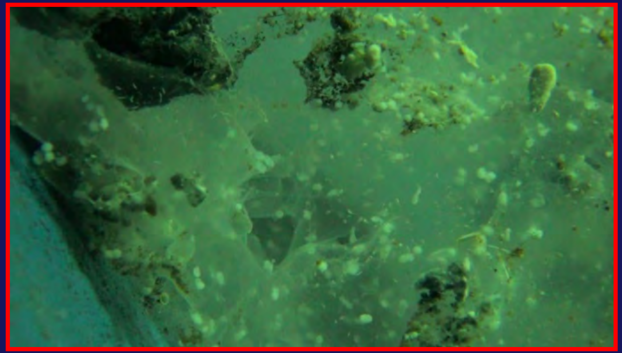
- All the egg masses were floating in the temperature range 21.6 ^{0}C to 18.8 ^{0}C.



Puneeta et al., 2015

Egg mass in the absence of thermocline



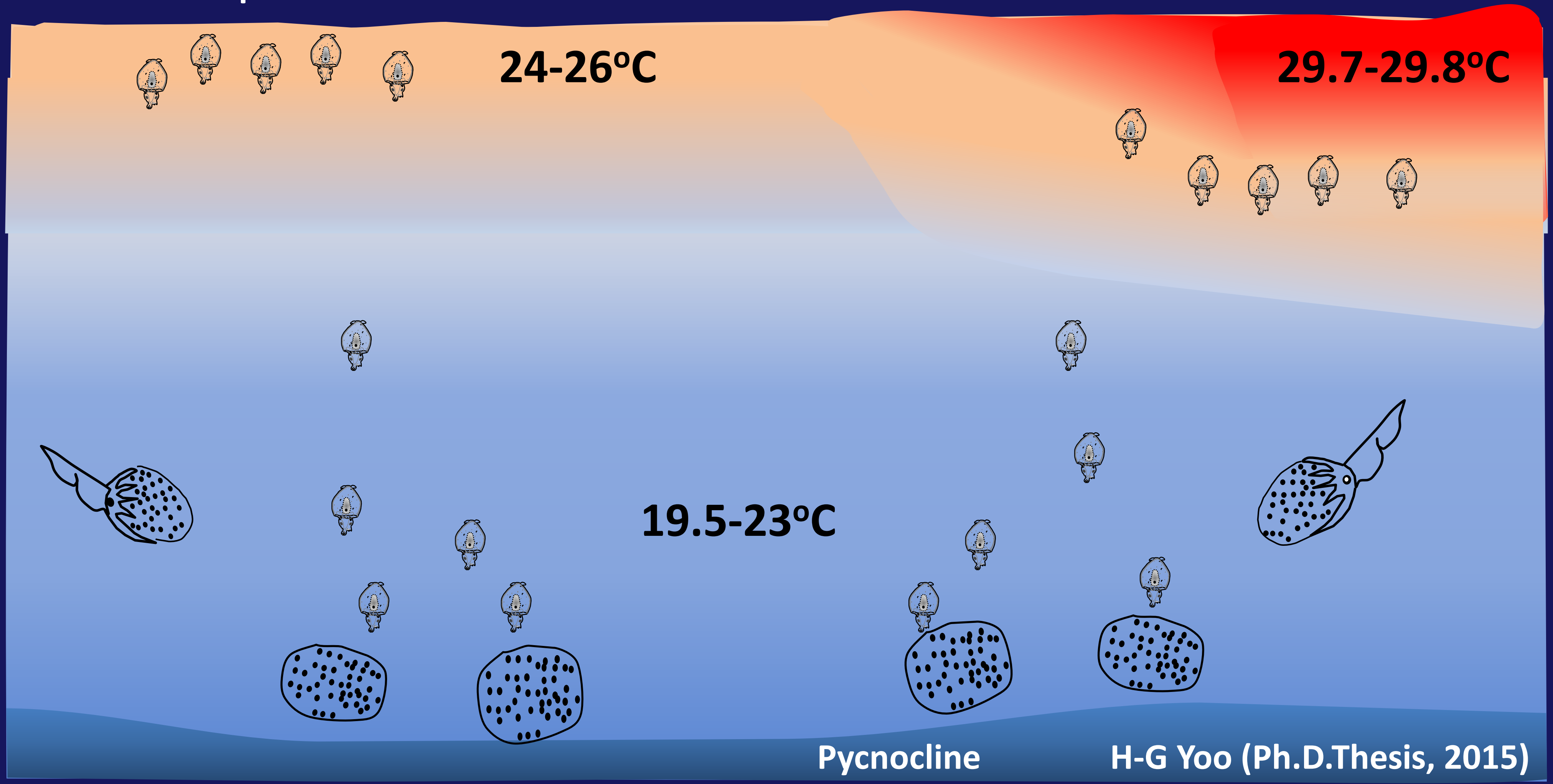


After the thermocline was broken egg masses were found on the floor of the aquarium and gradually collapsed in three to four days. The egg masses were infected by protozoan, other zooplankton and microorganisms.

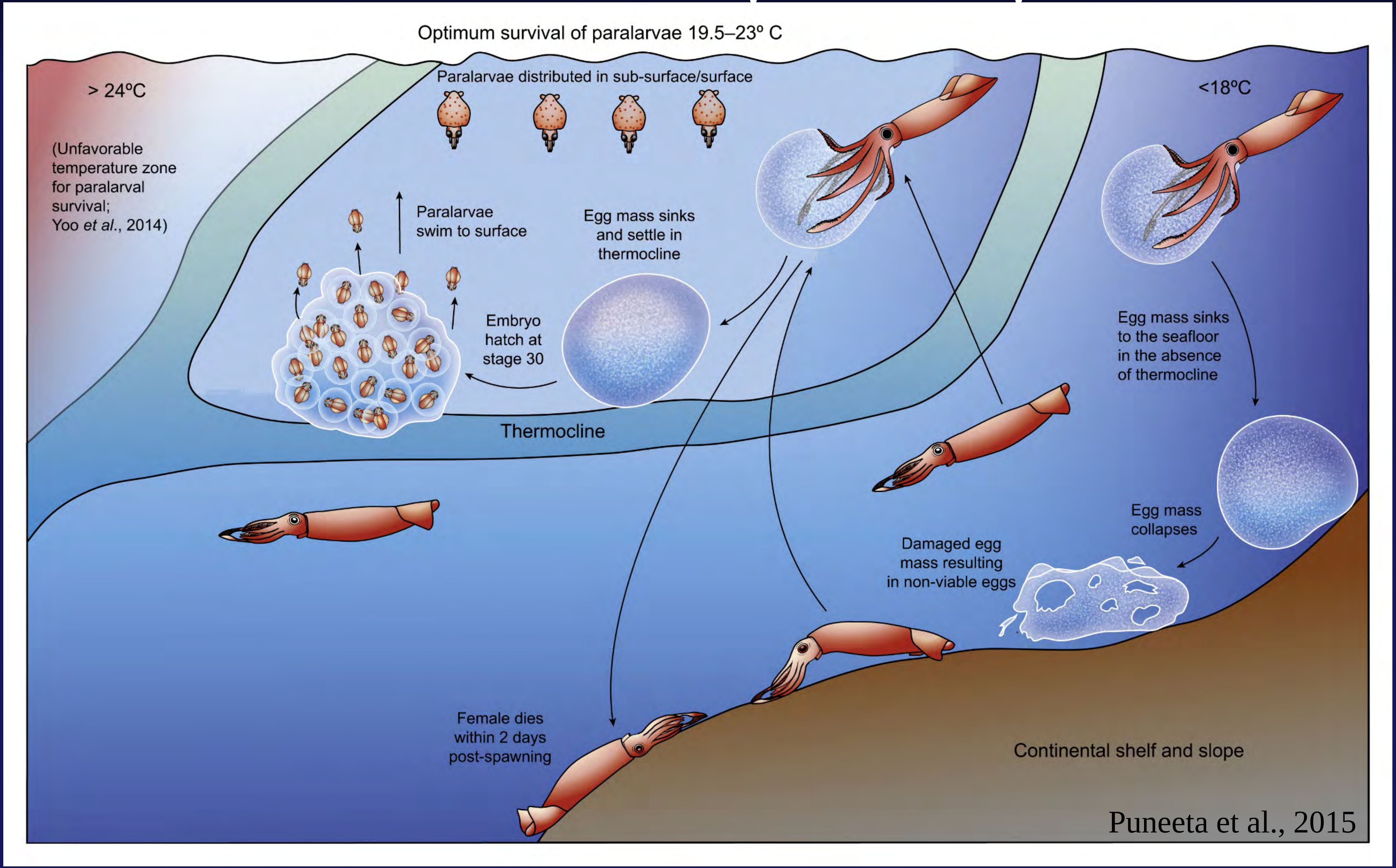
All the embryos within the egg mass were abnormal and dead.

Survival of *T. pacificus* paralarvae

Hatchling survival is probably heavily affected by unfavorably warm (>24°C) sea surface temperature



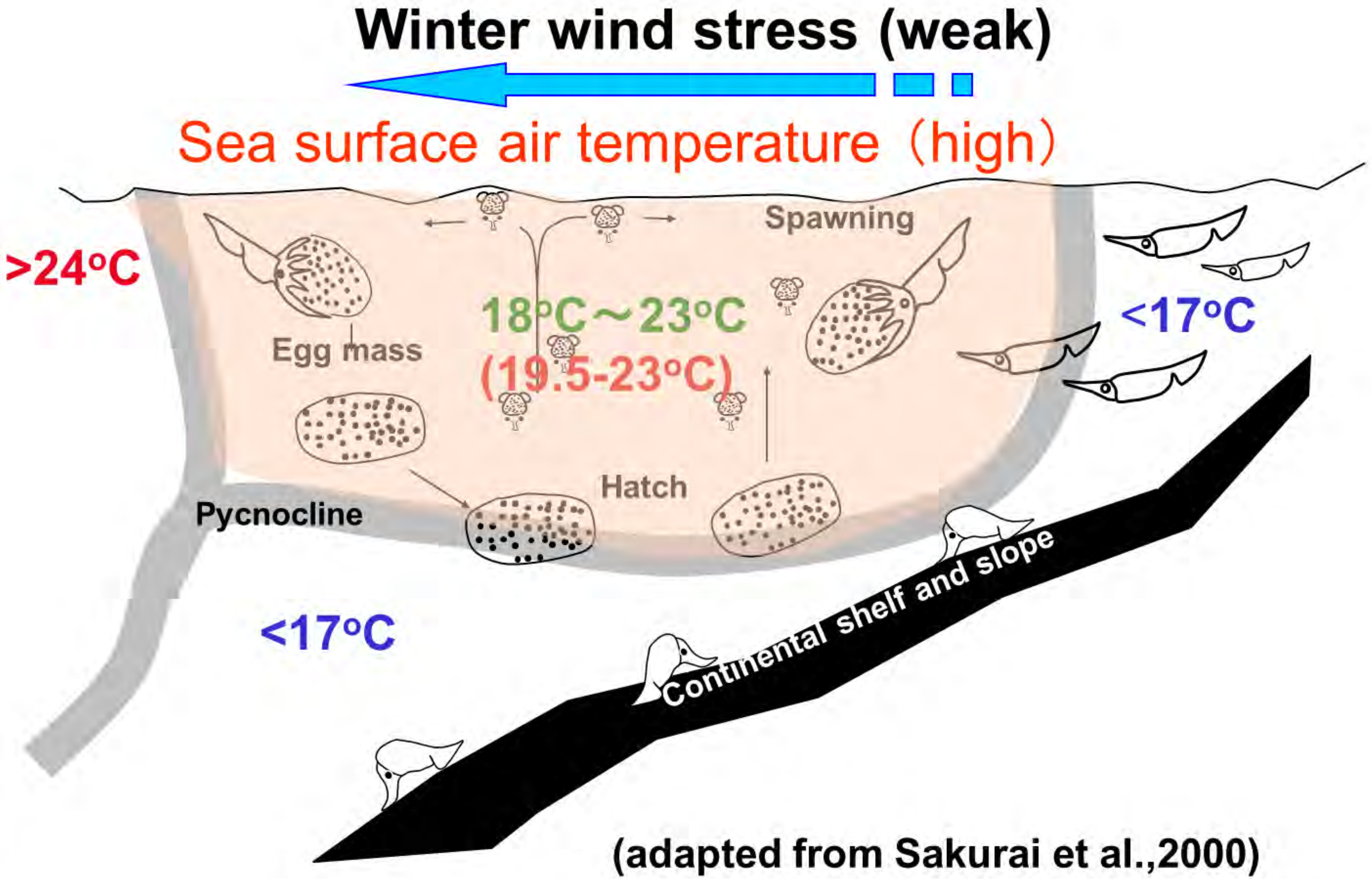
New Schematic view of reproductive processes



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

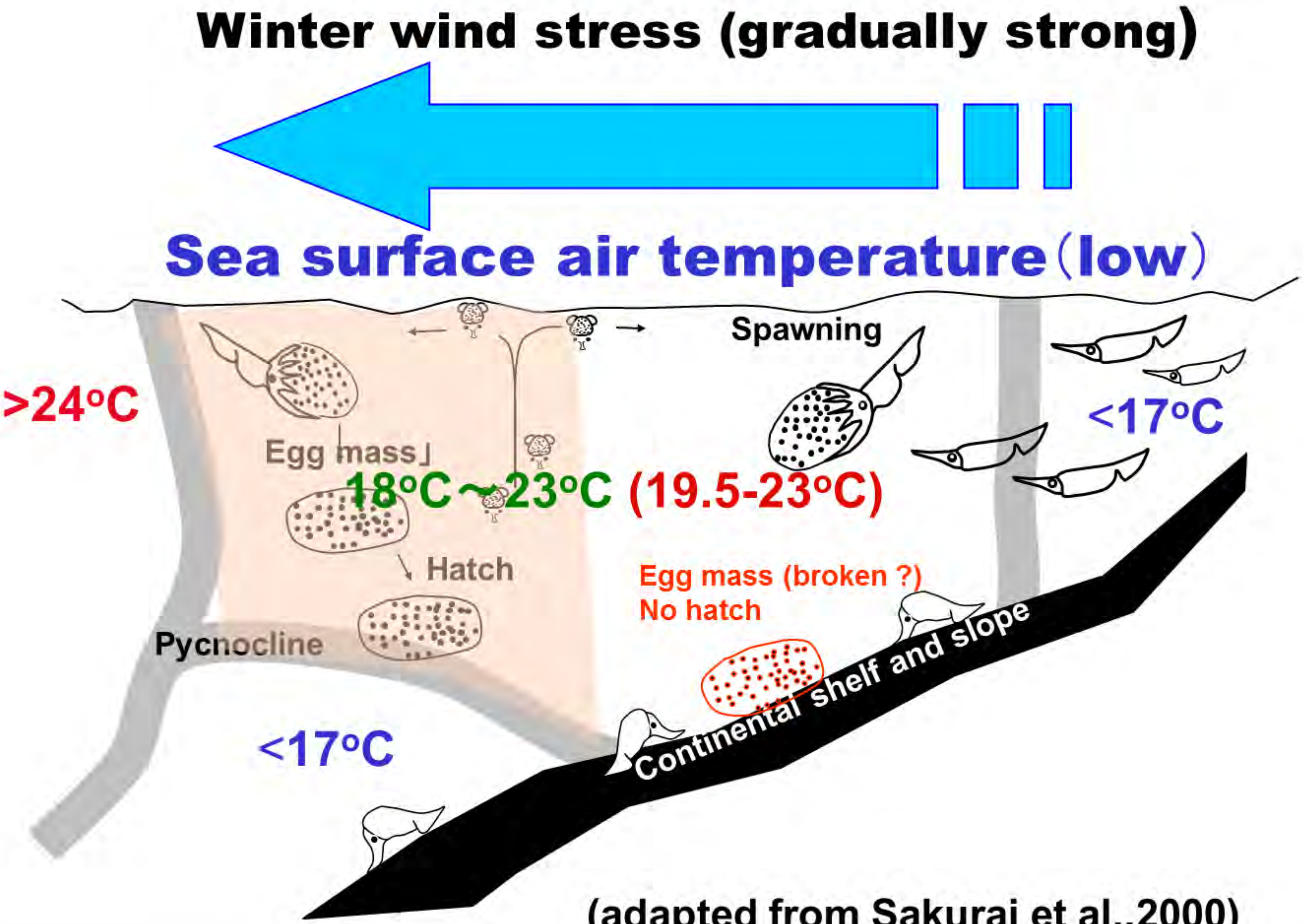
"The reproductive areas for spawning and occurrence of active hatchlings were formed the SST areas between 18-24°C (especially 19.5-23°C) and within a specific range of bottom topography ranged from 100 m to 500 m, where the pycnocline (or thermocline) was well developed in the mid-water"

During warm regime



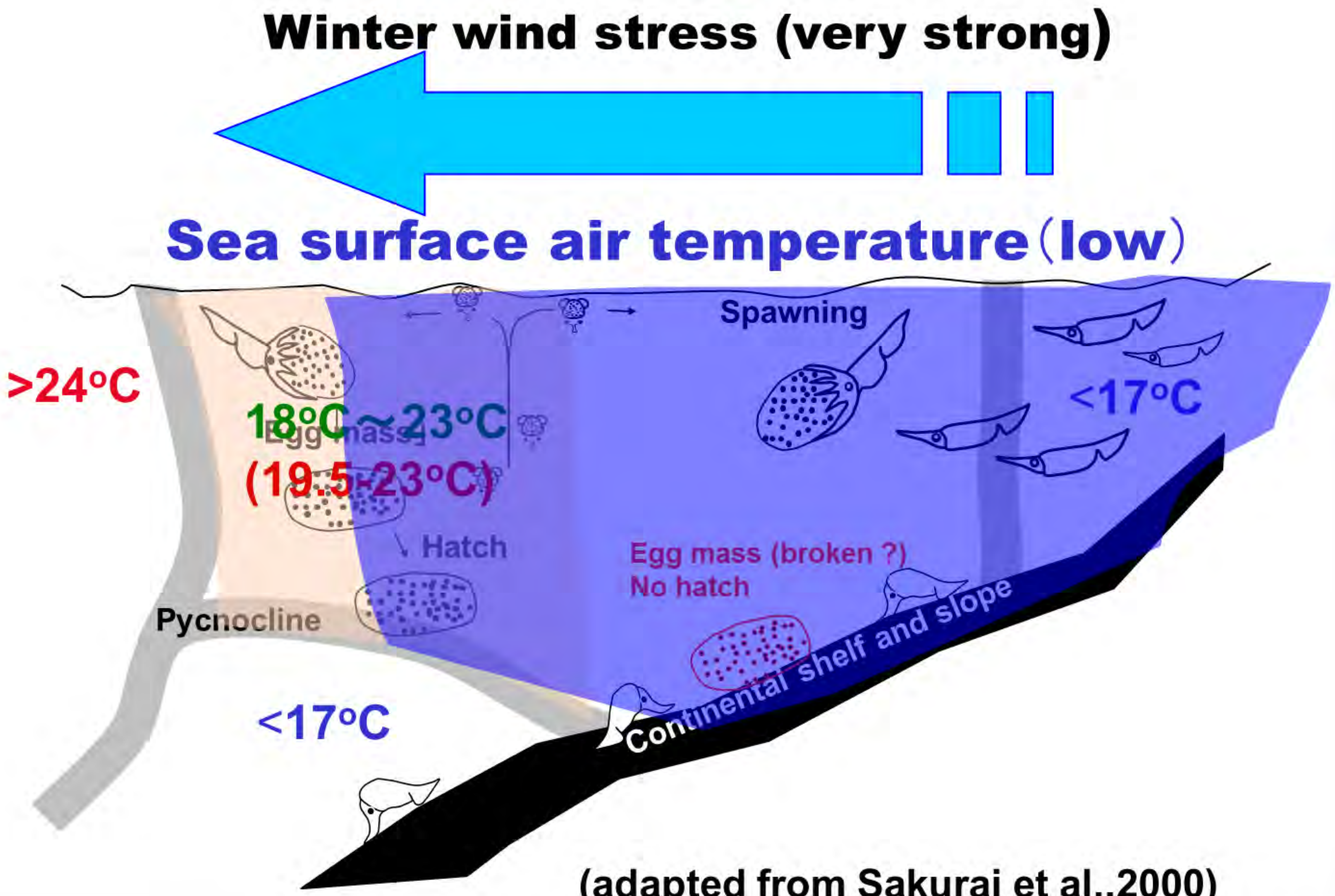
(adapted from Sakurai et al.,2000)

Start of cool regime



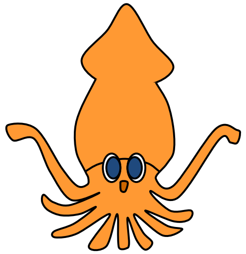
(adapted from Sakurai et al.,2000)

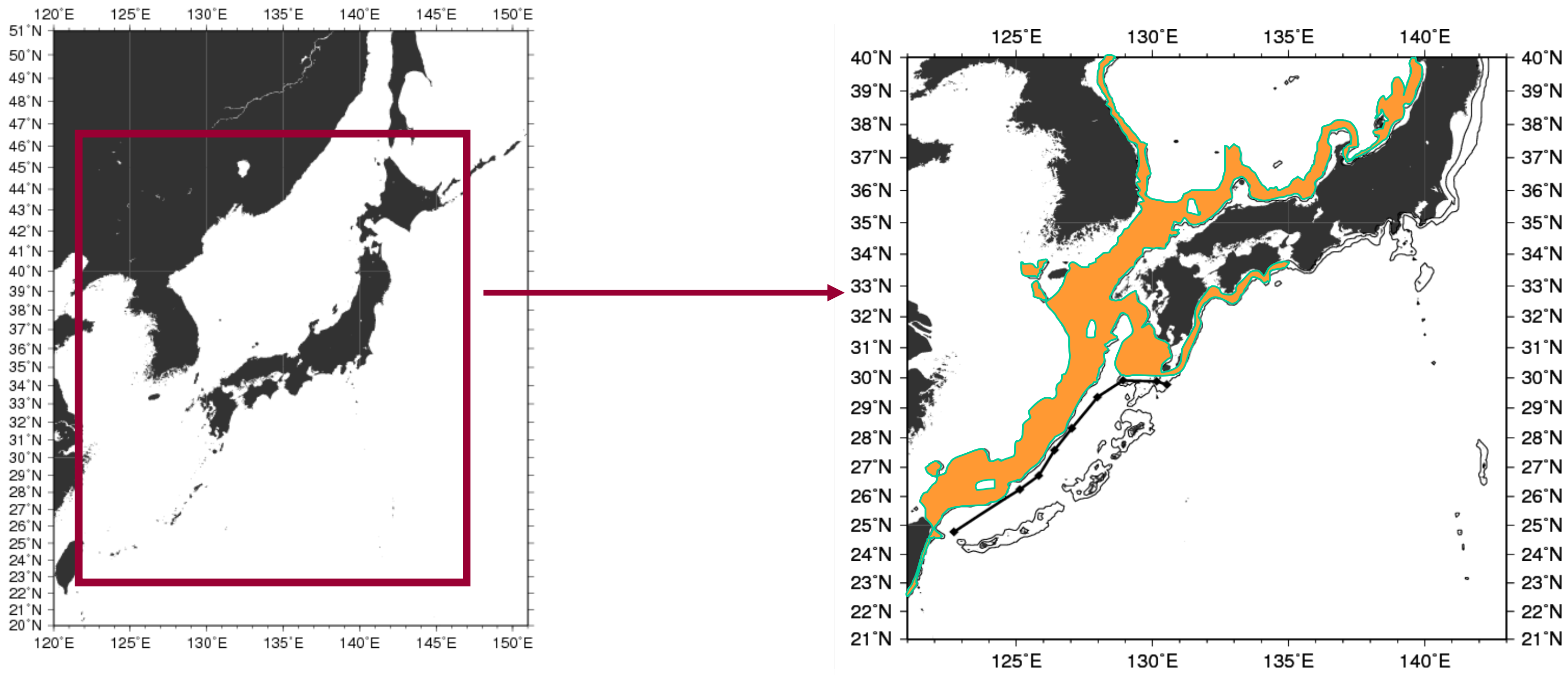
During cool regime



(adapted from Sakurai et al.,2000)

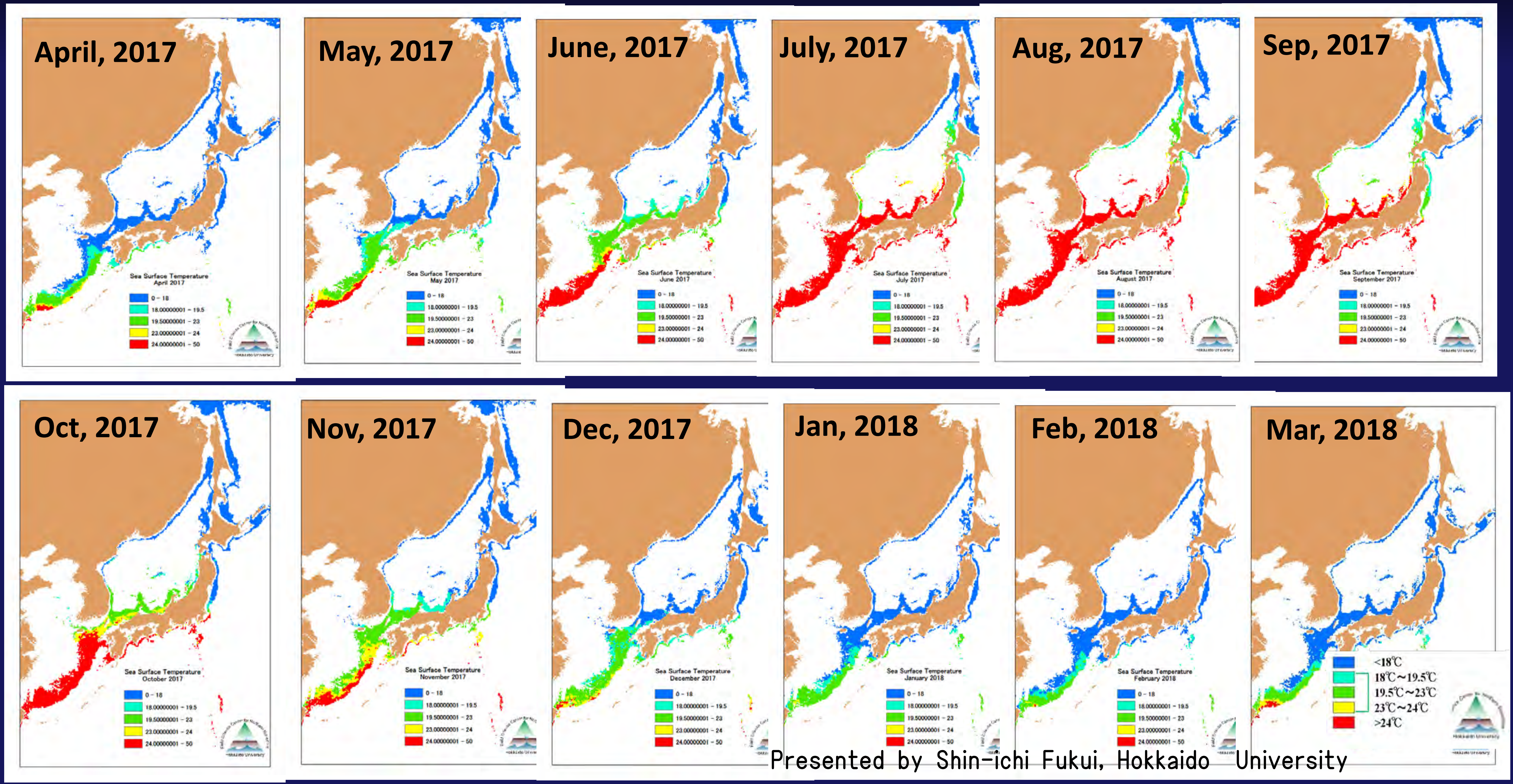
GIS mapping methods of inferred spawning areas



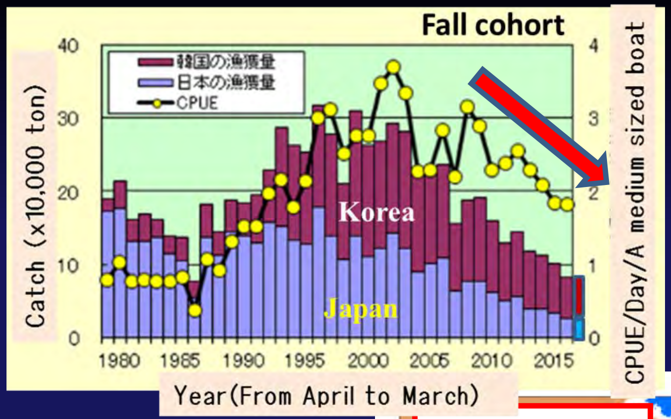


- Ripe female needs the sea bottom: 100-500m depth range NOAA/ETOPO1
- Optimum temperature for survival of hatchlings: 18.0 < SST < 24 ^{o}C
  (JMA; 1x1^{o}-1970~84; 0.25x0.25^{o}-1985~2012 and so on)
- Kuroshio axis (mean position as defined by Yamashiro *et al.*,1993)
- SST Data: NODC/AVHRR pathfinder version 5 (resolution 4km, nighttime data)
- Data analysis & pdf imput: ArcGIS, model builder & python script

Inferred spawning area through April to March, 2017-2018.

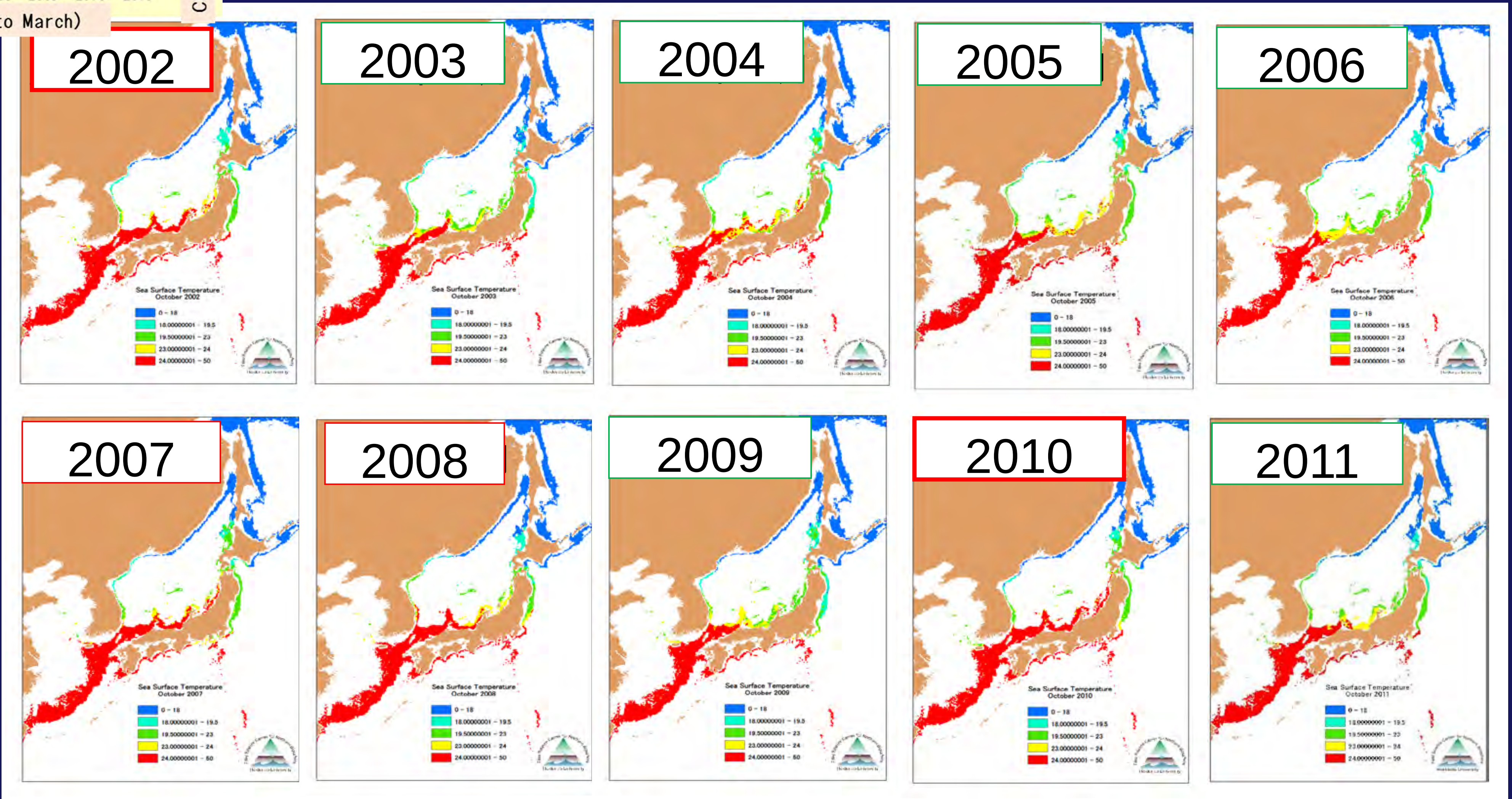


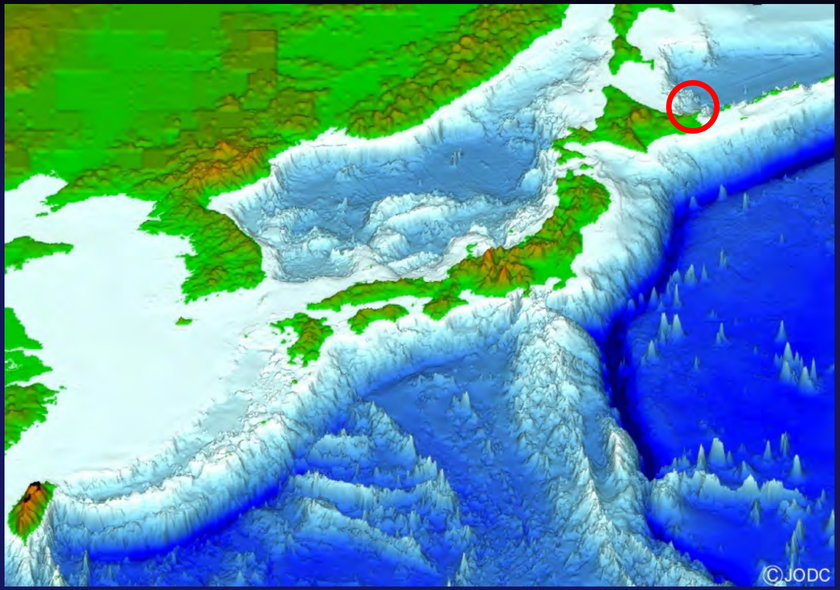
Presented by Shin-ichi Fukui, Hokkaido University



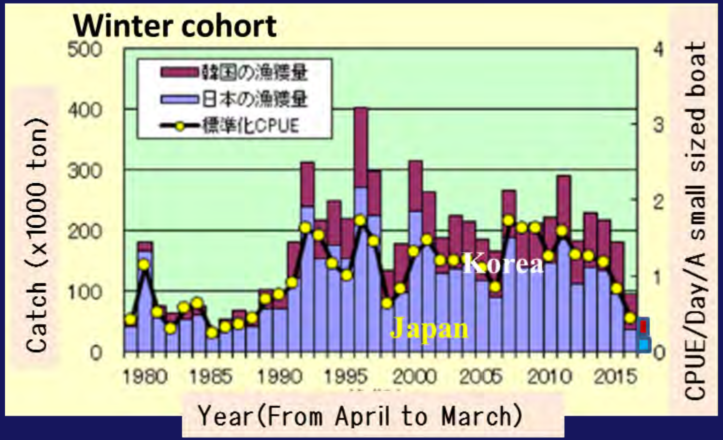
Inferred spawning area in October during 2002-2011

Hatchling survival is probably heavily affected by unfavorably warm (>24^{o}C) sea surface temperature in October after 2000s

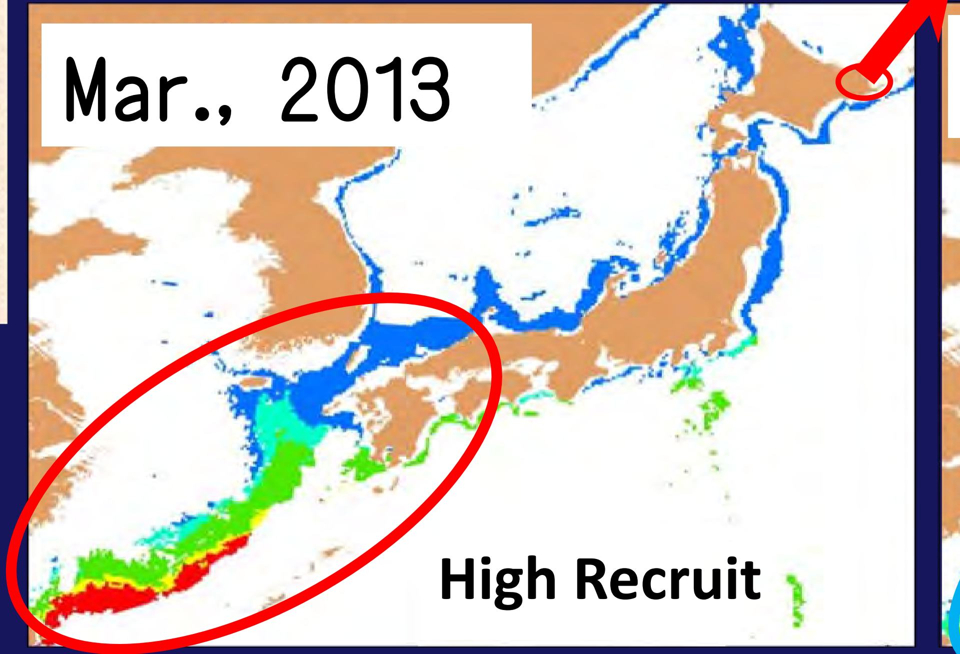


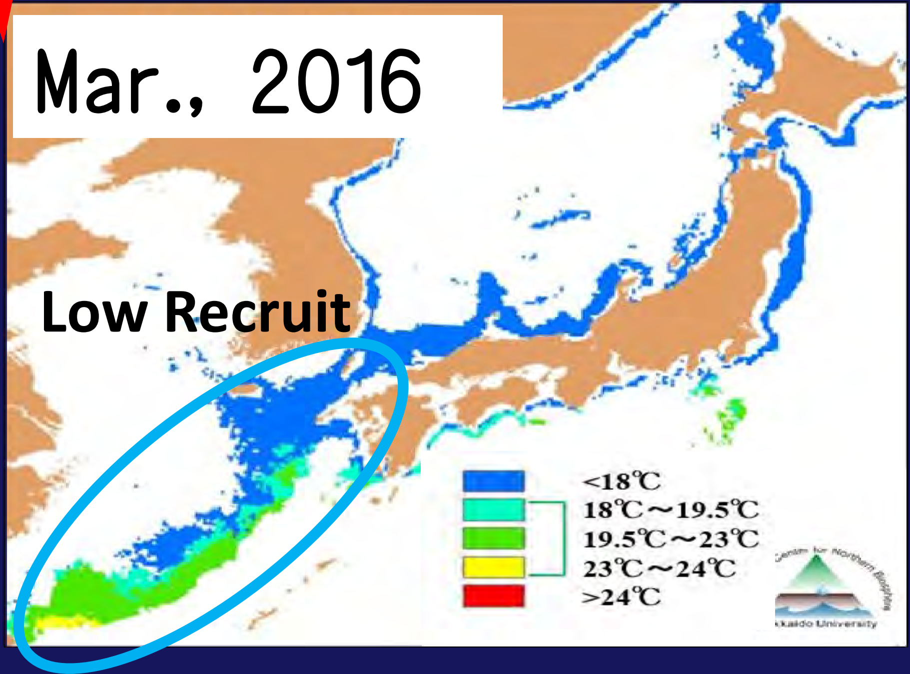


Rausu (Nemuro strait)
Landing of squid
2013: 25,000 ton
2016: 400 ton
2017: 100 ton

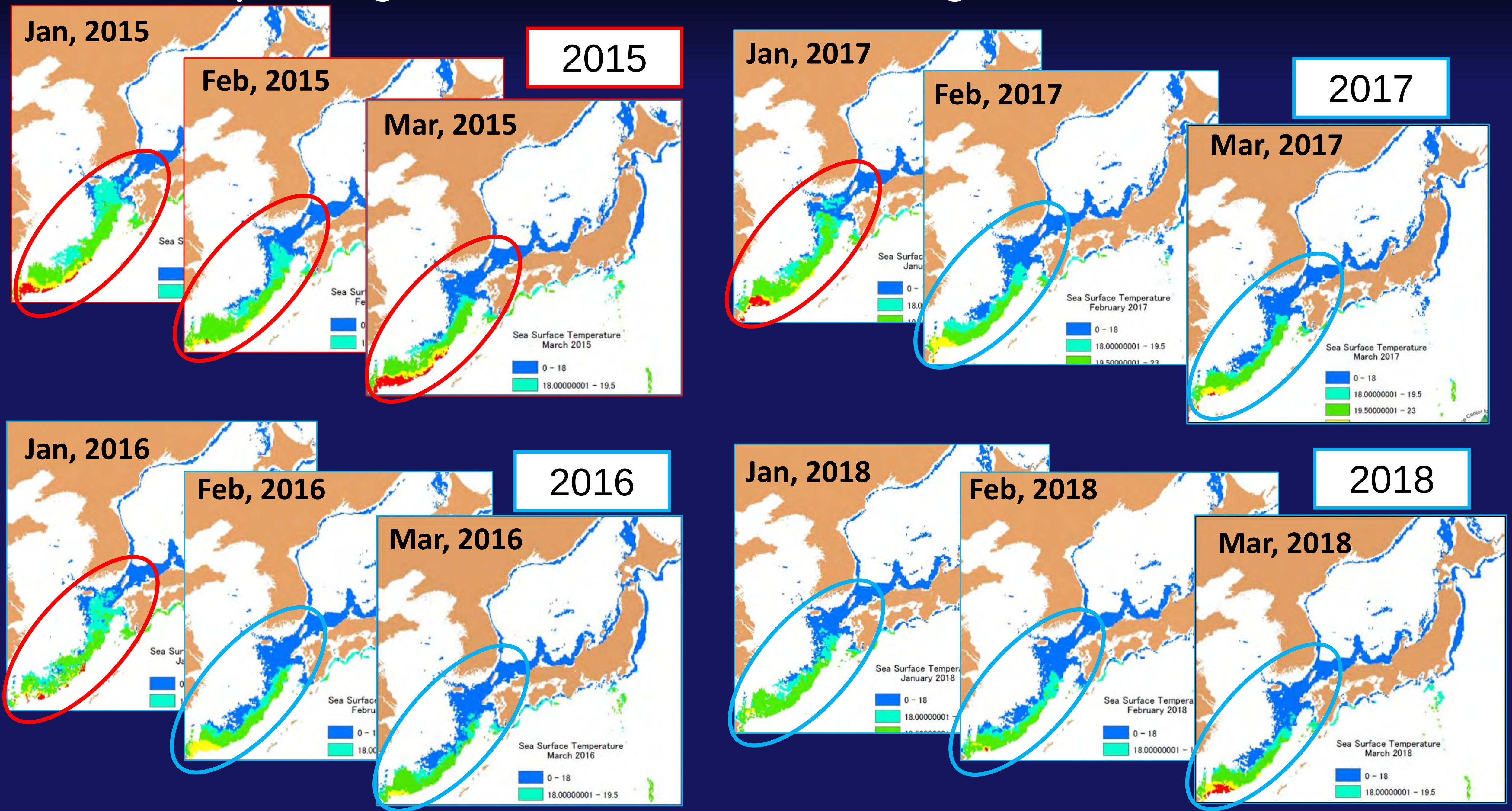


(from Fisheries research agency Japan, http://abchan.fra.go.jp/digests2017/html/2017_18.html)



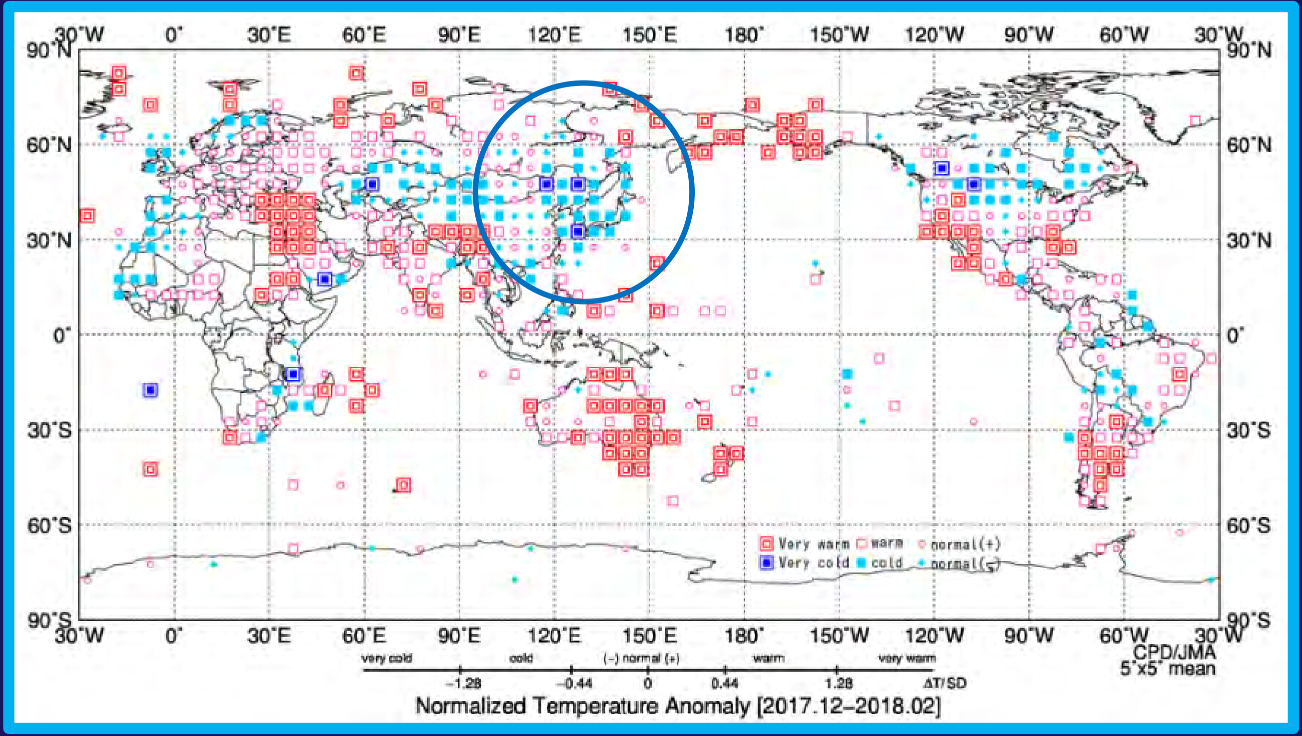


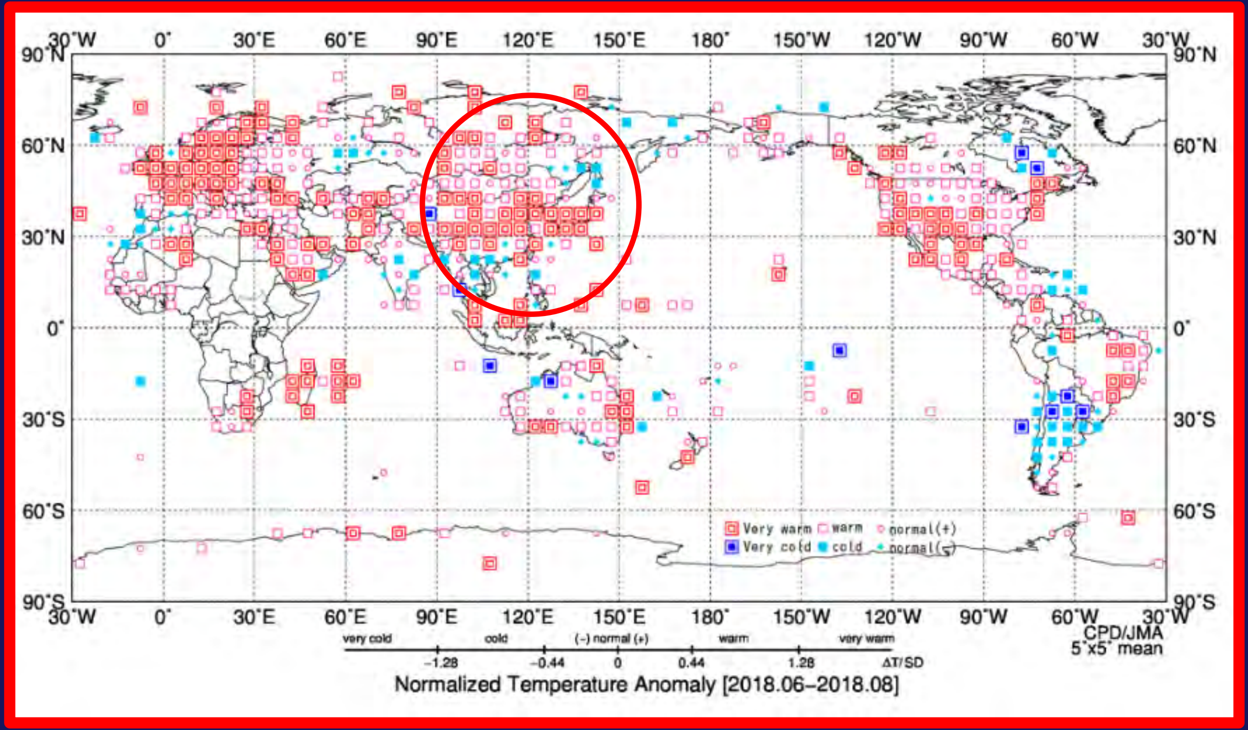
Inferred spawning areas were not recover during winter of 2016～2018



Severe winter

Intense heat summer





Normalized temperature anomaly of winter (Dec, 2017-Feb, 2018) and summer (Jun-Aug, 2018)

(From Japan metrological agency, http://www.data.jma.go.jp/gmd/cpd/monitor/climfig/?tm=seasonal&el=gtmp)

Summary

- After 2016, the catch of winter cohort has extremely declined while after 2010 the catch of Japanese sardine has increased, which is very similar to “species replacement phenomenon”.
- After the winter of 2016, the inferred spawning areas of the winter cohort in the East China Sea shrank and reduced to the continental edge off the Kyushu Island and the Nansei Islands.
- Hence the recent winter stock decline is thought to have occurred because the inferred spawning areas in winter were covered by cold sea surface water below 18ºC, which severely affects the survival of hatchlings.
- Is this “the temporal and local cooling events related to the decrease of Arctic sea ice” or Enso-event?
- We must focus on the fate of short-life squid as a indicator species of climate change including Global Warming

Thanks from the squid!

Photo by Kota Muramatsu, off Sanriku