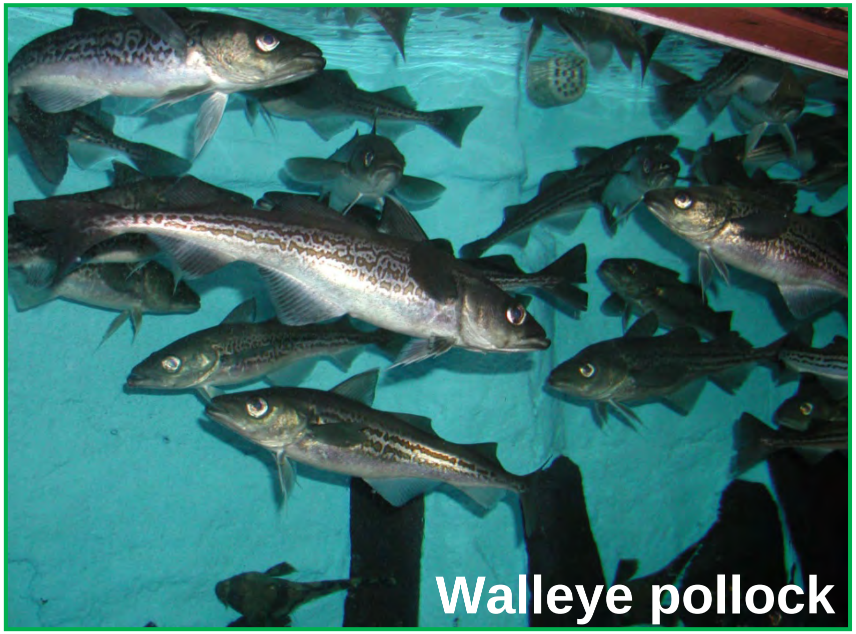
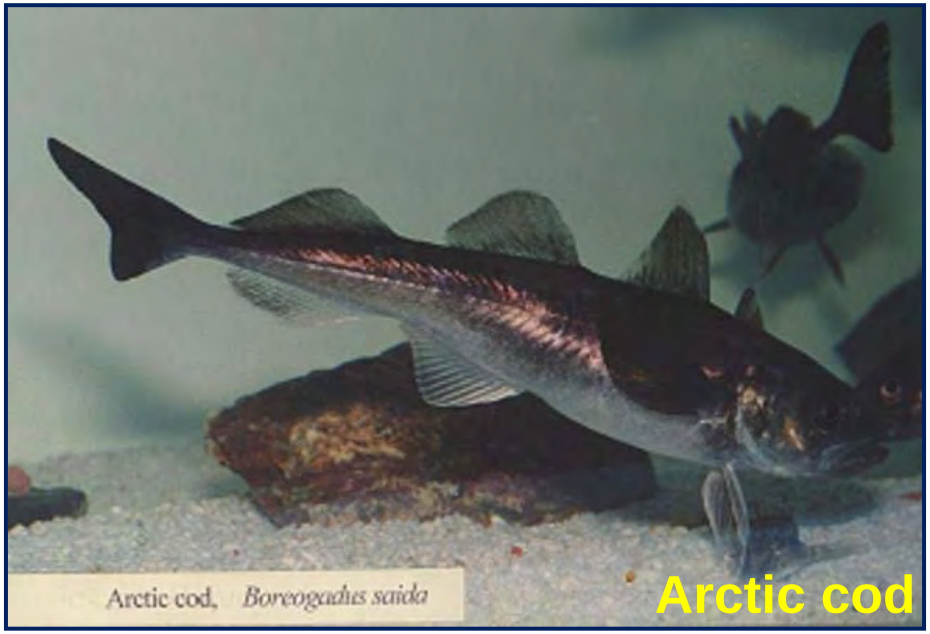
PICES 2012 (Hiroshima) October 12, 11:20 (W4-8743)

A comparison of reproductive characteristics and strategies between walleye Pollock (*Theragra* (*Gadus*) *chalcogramma*) and Arctic cod (*Boreogadus saida)*





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Outline of our presentation

1.Why will the walleye pollock be called "*Gadus chalcogramma*", not "*Theragra*"?

2.Comparison of reproductive characteristics among gadid fish

3. Reproductive characteristics of Pacific gadid fish related to physical condition of spawning grounds

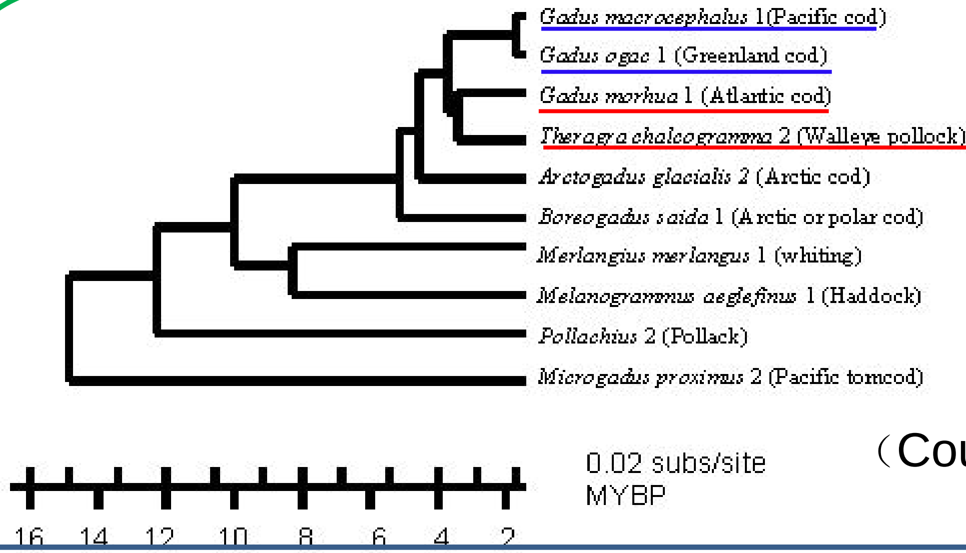
4.Brief summary of Arctic cod studies in the northern Bering Sea and Chukchi Sea by T/S Oshoro-Maru, Hokkaido University in the summer of 1991, 1992, 1994, 2007, 2008, and 2009

5.Laboratory studies on the response of walleye pollock eggs and larvae to temperature change

Why will the walleye pollock be called "*Gadus chalcogramma*", not "*Theragra*"?

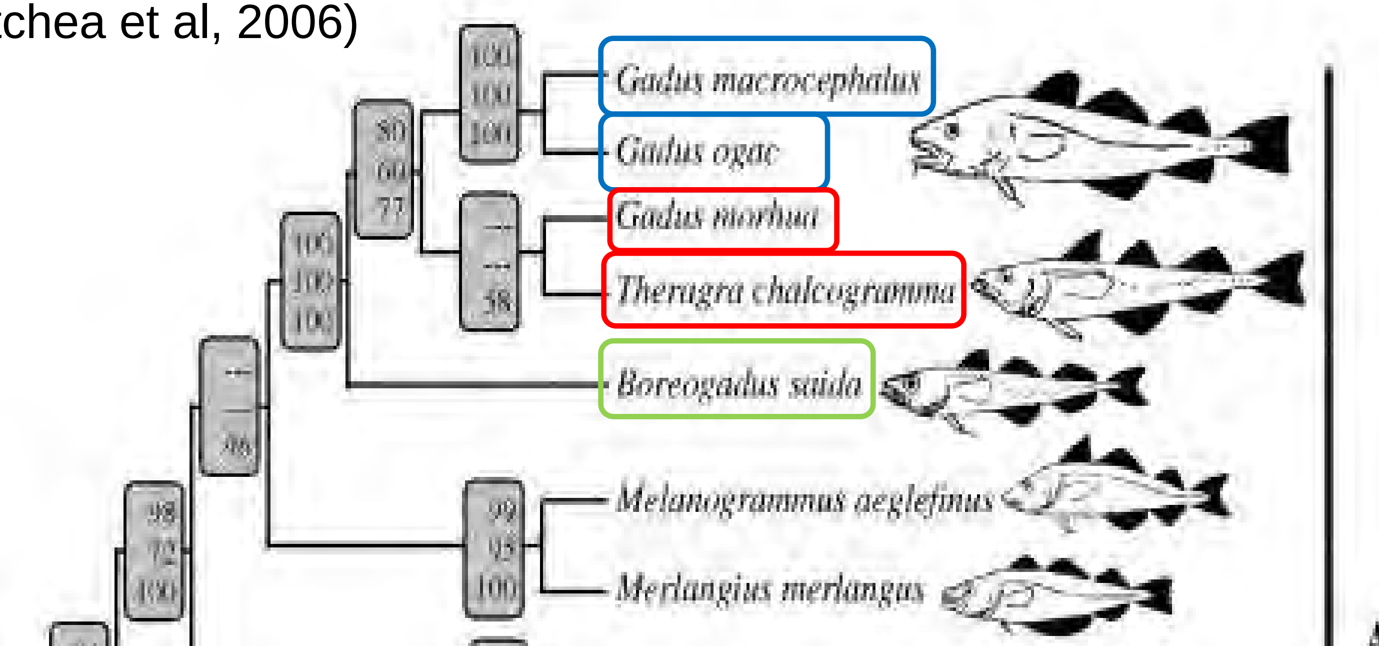
（Grant et al, 2010）

New classification of the Gadidae based on their morphology and phylogenetic analysis

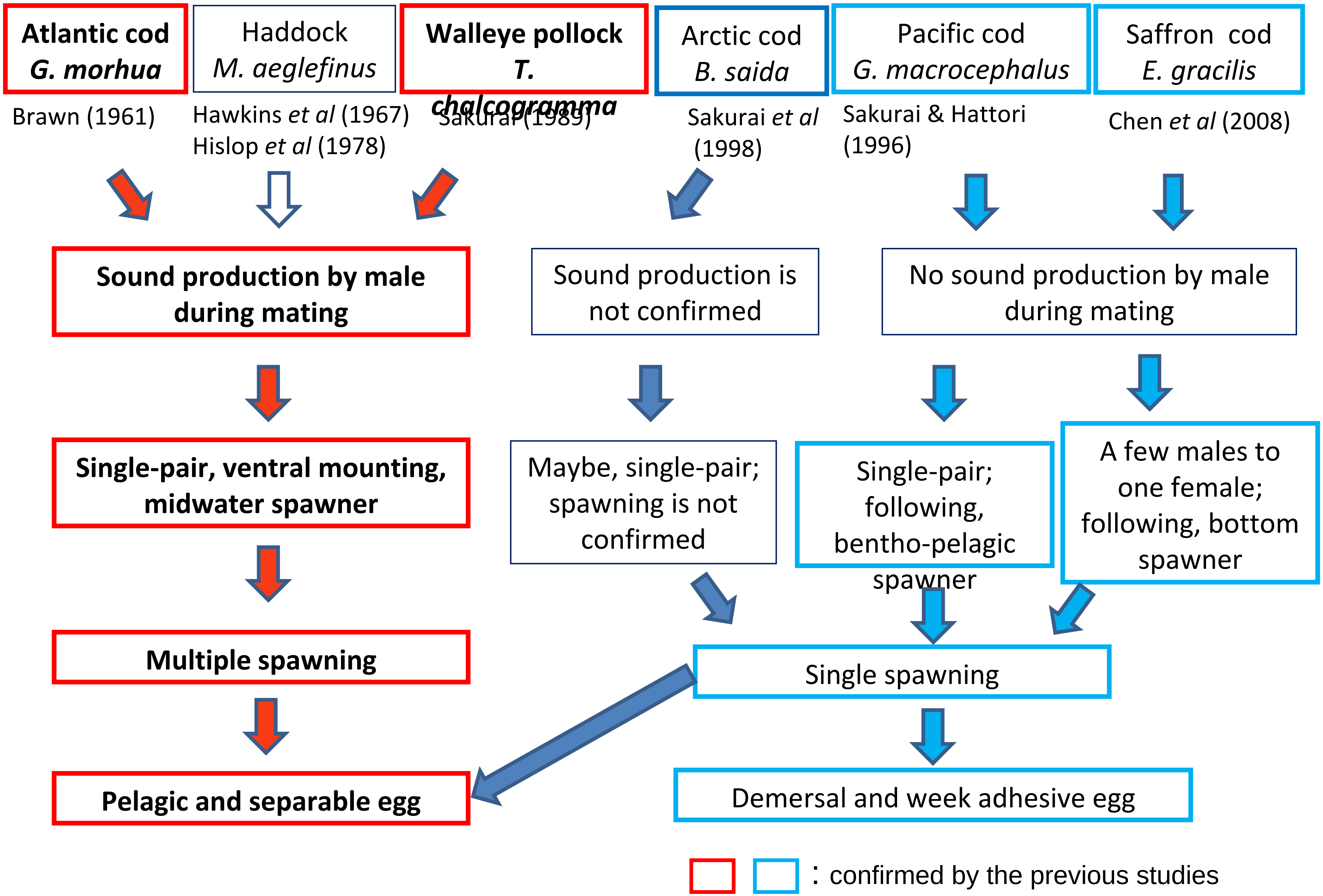


（Coulson, 2006）

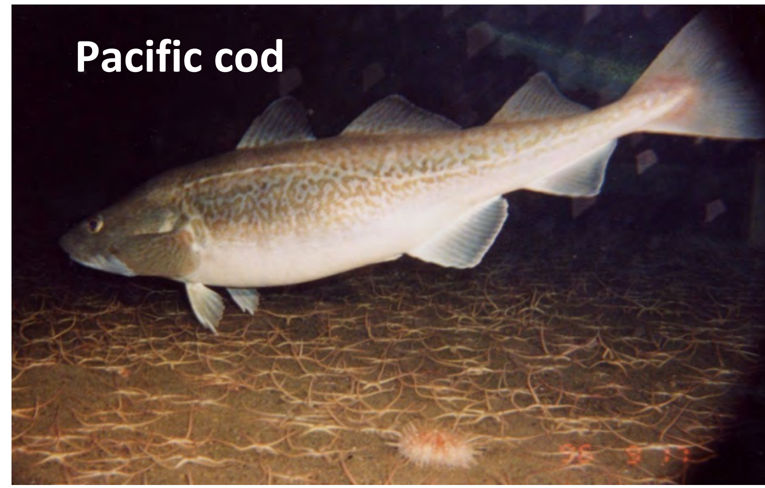
(Teletchea et al, 2006)

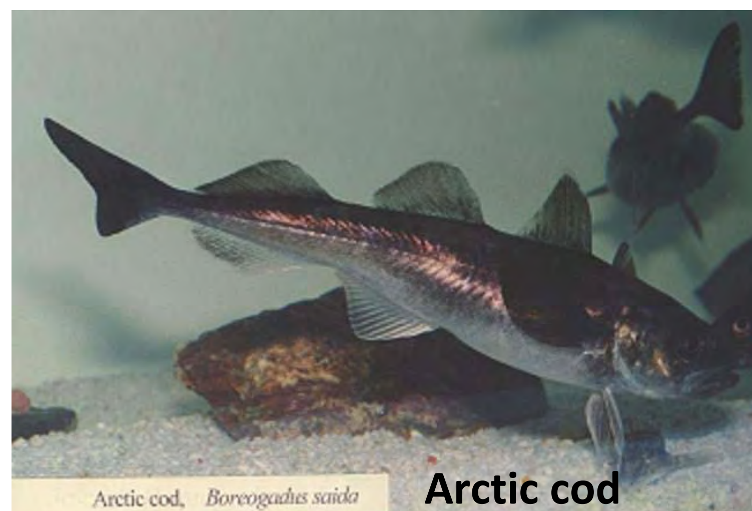


Comparison of reproductive characteristics among gadid fish

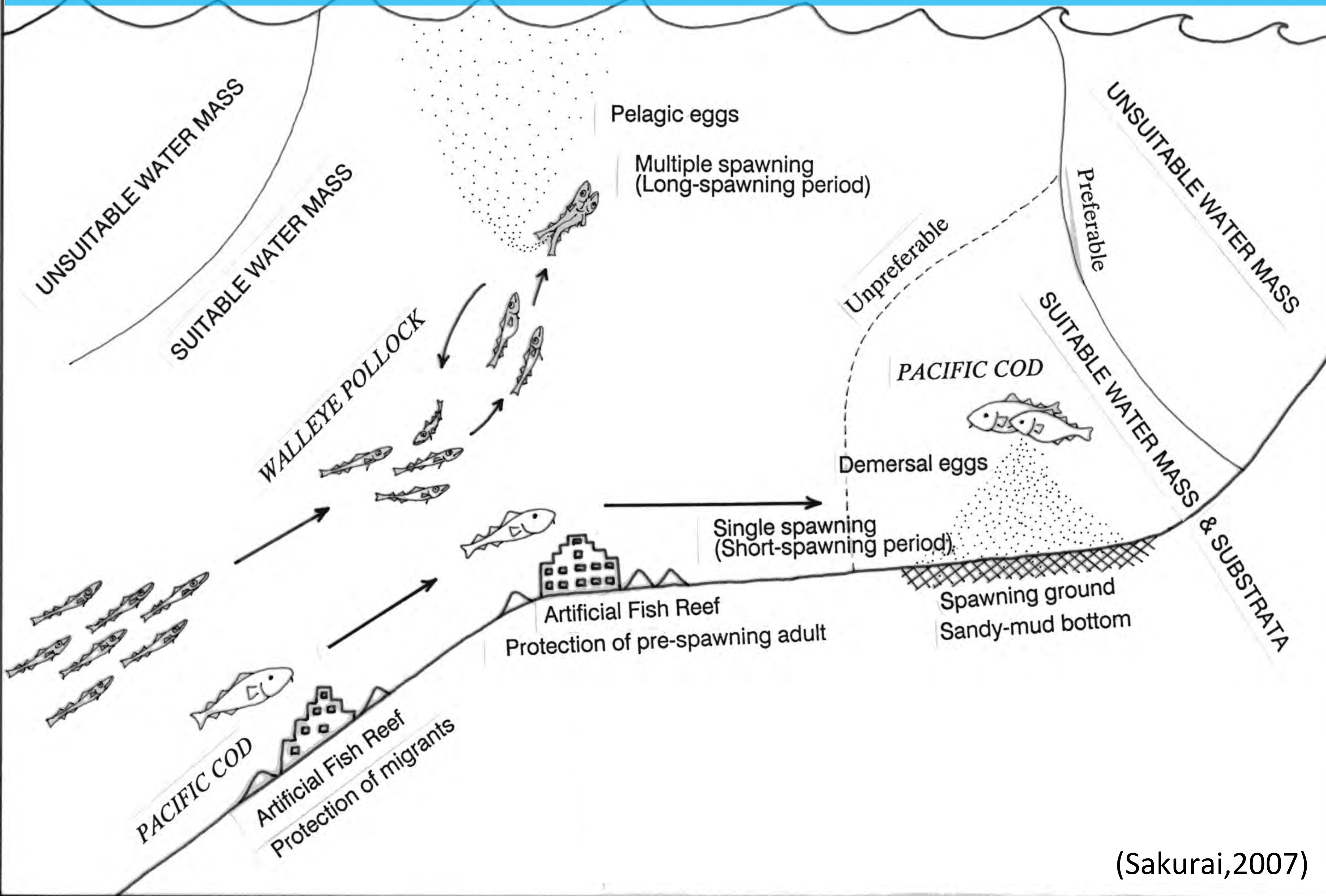


Reproductive characteristics of Pacific gadid fish related to physical condition of spawning grounds



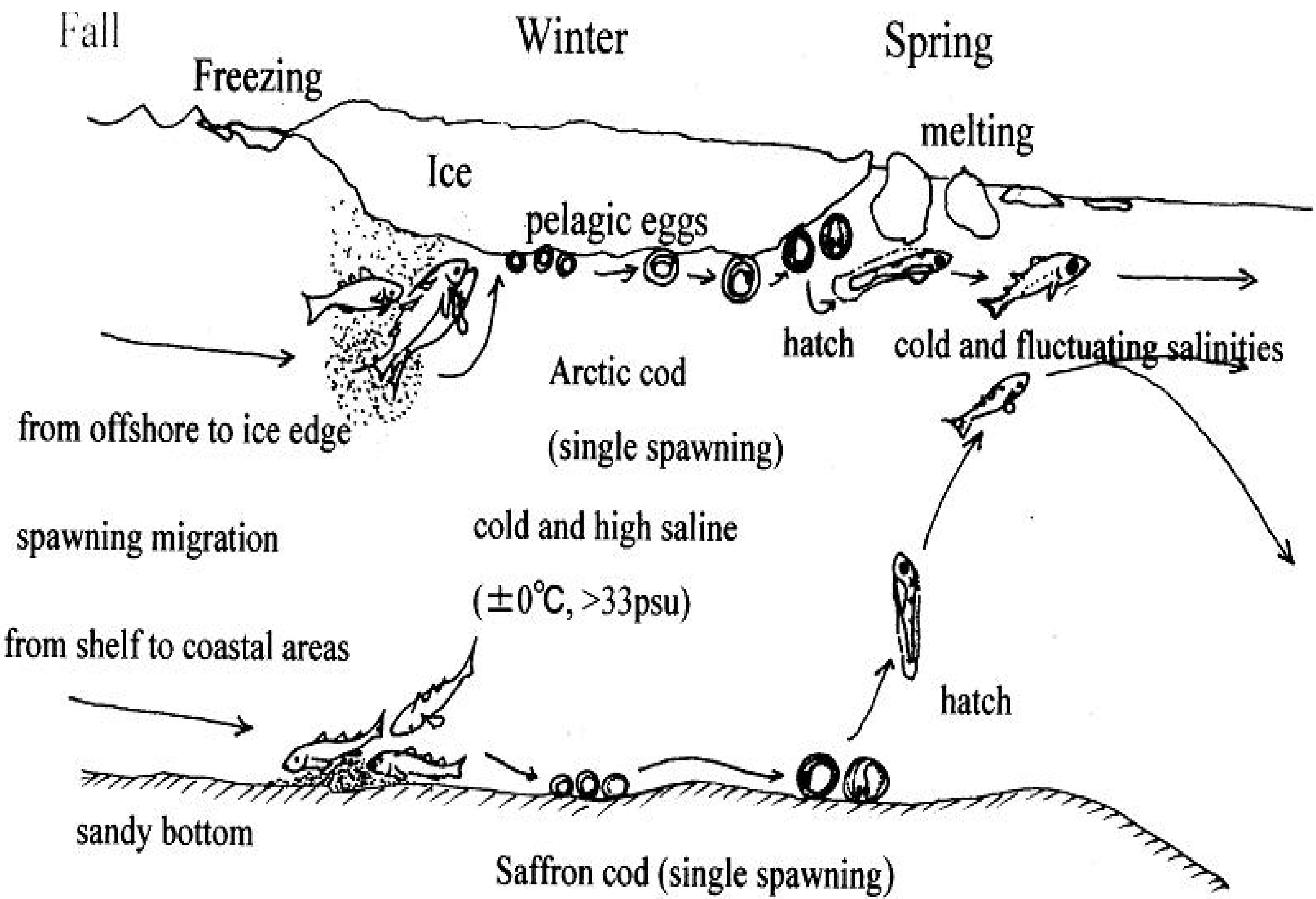


Schematic illustration of spawning strategy and reproductive characteristics of Pacific cod and walleye pollock. (Sakurai, 1989; Sakurai & Hattori, 1996)

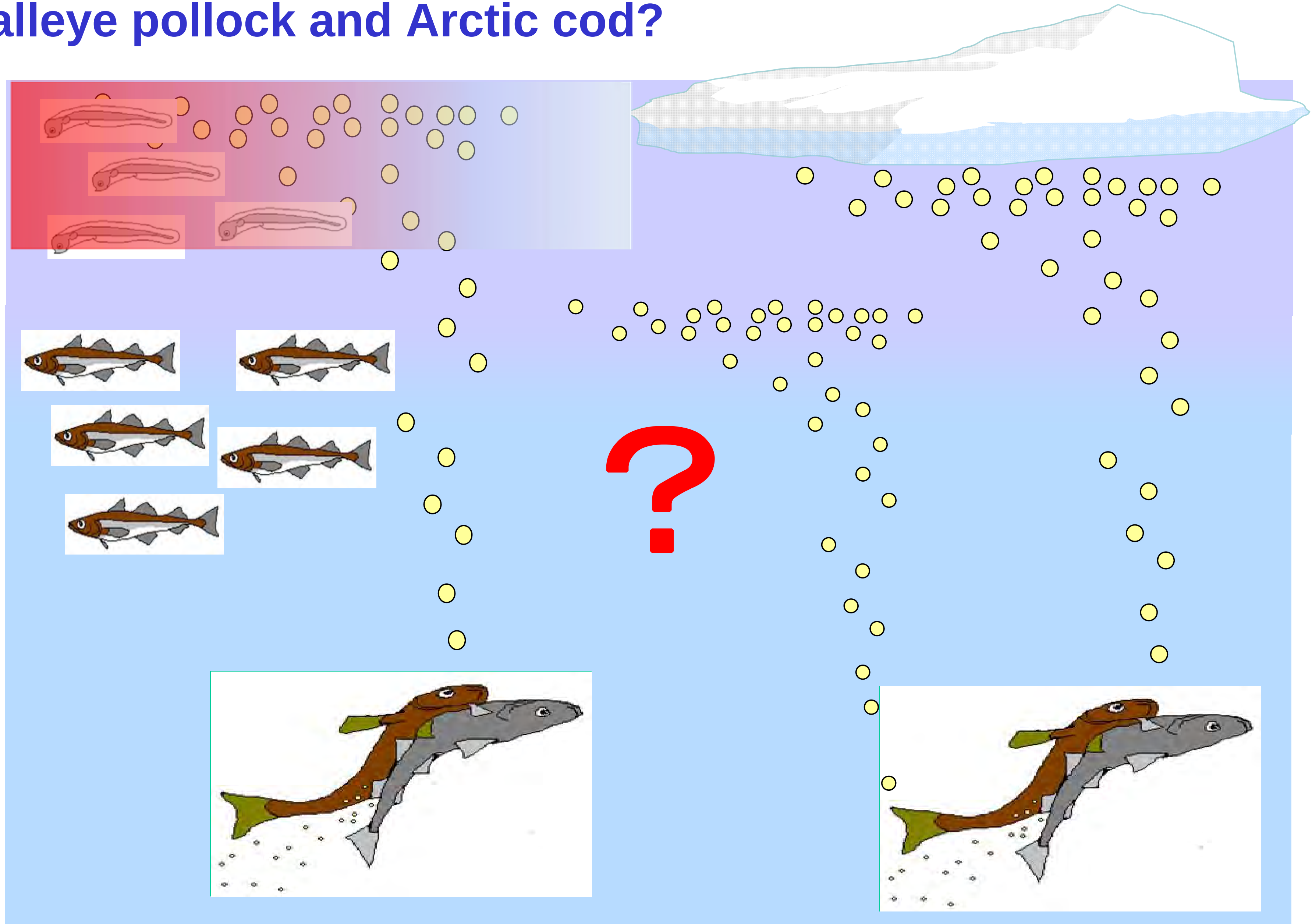


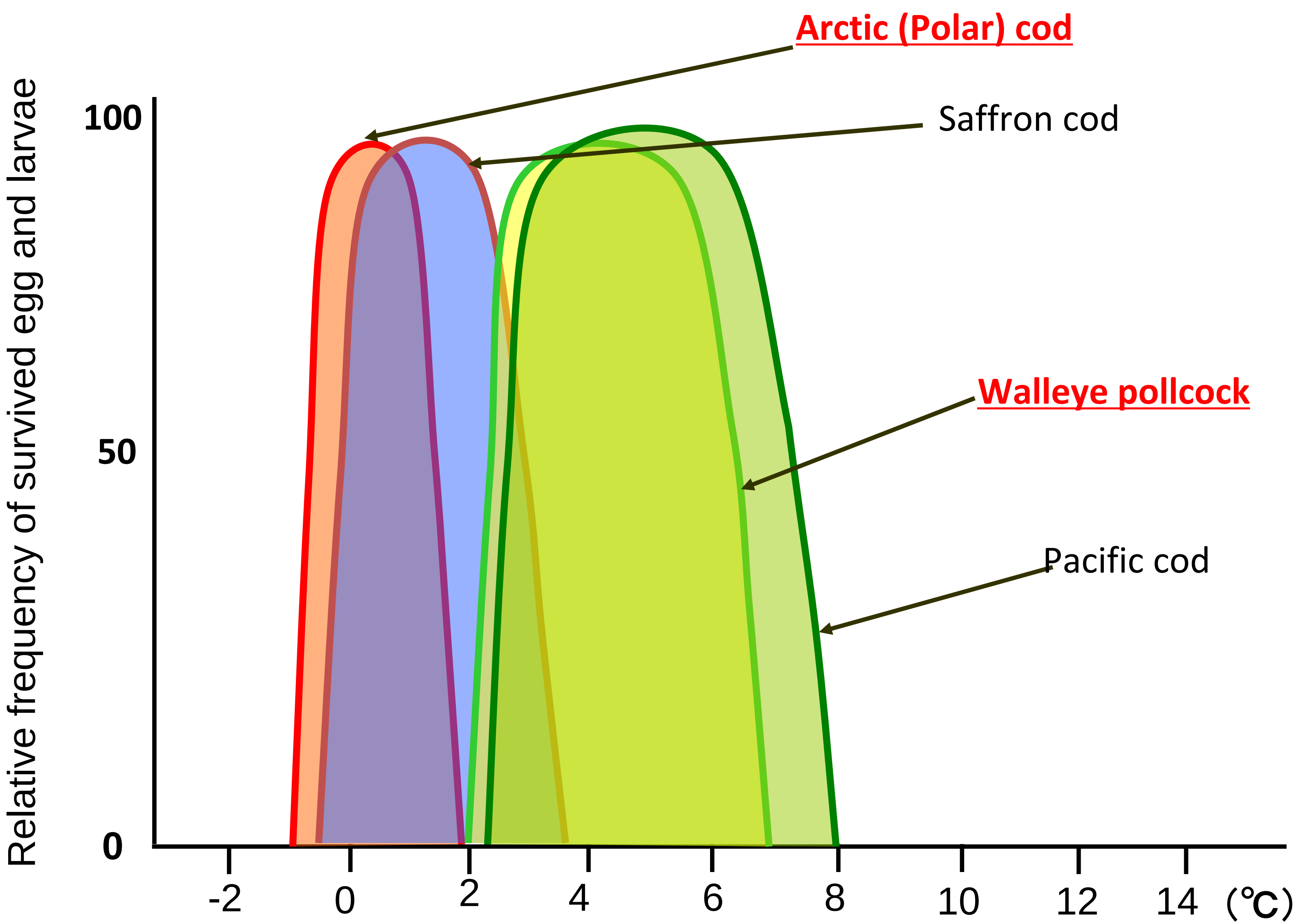
(Sakurai,2007)

Schematic illustration of spawning strategy of Arctic cod and saffron cod
(after Sakurai et al, 1996; Chen et al, 2008)



Do temperature and salinity of sea surface layer have a threshold values to survivals during the early life stages of walleye pollock and Arctic cod?



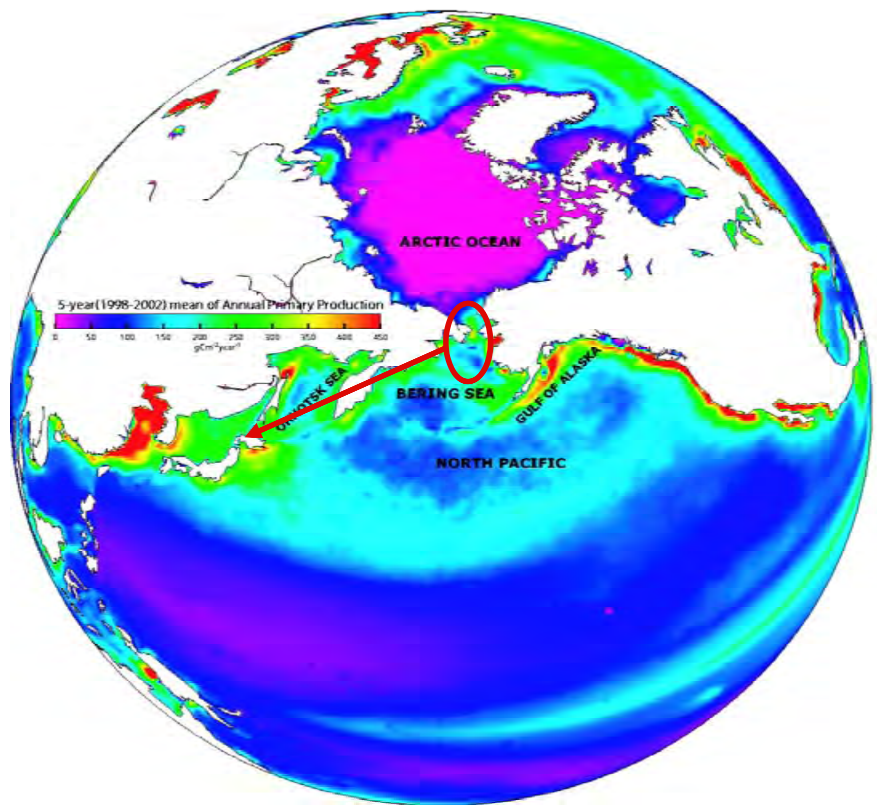


Range of estimated optimum temperature for survival of egg and larvae of Pacific gadid fish

Brief summary of Arctic cod studies in the northern Bering Sea and Chukchi Sea by T/S Oshoro-Maru, Hokkaido University in the summer of 1991, 1992, 1994, 2007, 2008, and 2009.

(Based on Sakurai et al.(1998); K. Okazi (2009), Y. Kurihara(2010), and C. Watanabe(2010), Master theses, Graduate School of Fisheries Sciences, Hokkaido University)

http://www2.fish.hokudai.ac.jp/fac/ship/oshoro/oshoro00.htm



Reproduction and early life stage of Arctic cod

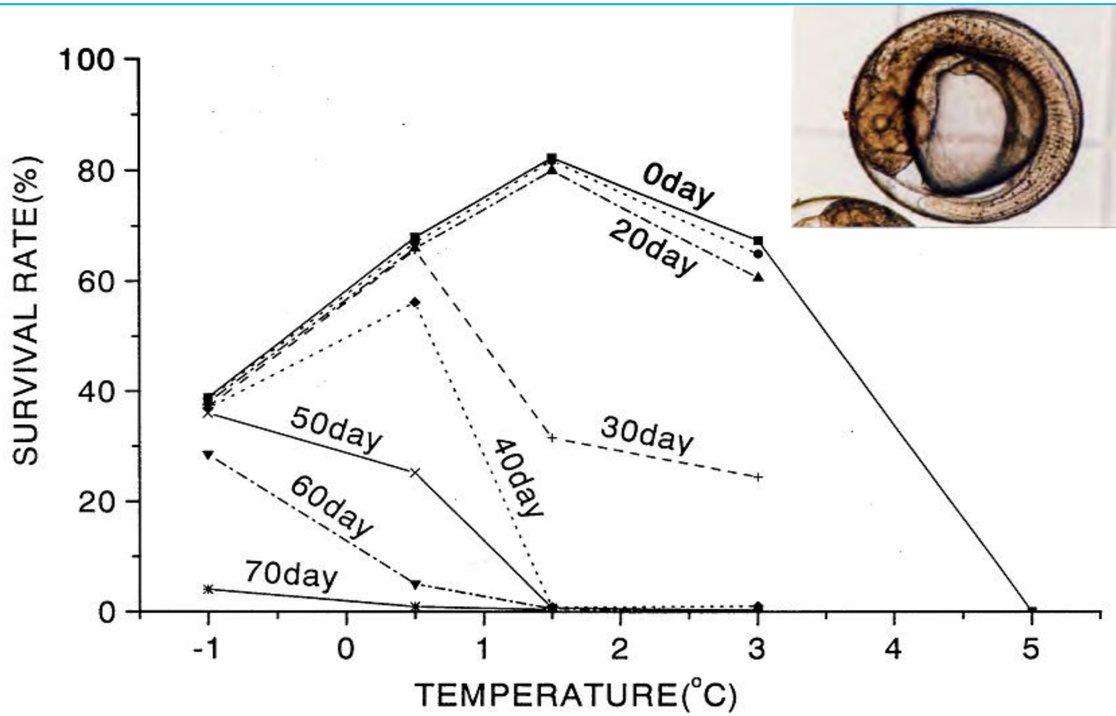


Fig. Survival rates at 10 day intervals of Arctic cod larvae from the 50% hatching date to 70 days post-hatching at temperatures between −1 to 5℃.

1. Normal egg development occurs at temperature below 3.0 ℃, and at salinities between 32 and 41.
2. Embryos can survive and develop under the ice below 0 ℃ and highly saline.
3. Hatching larvae can survive under the widely fluctuated salinities after ice melting.

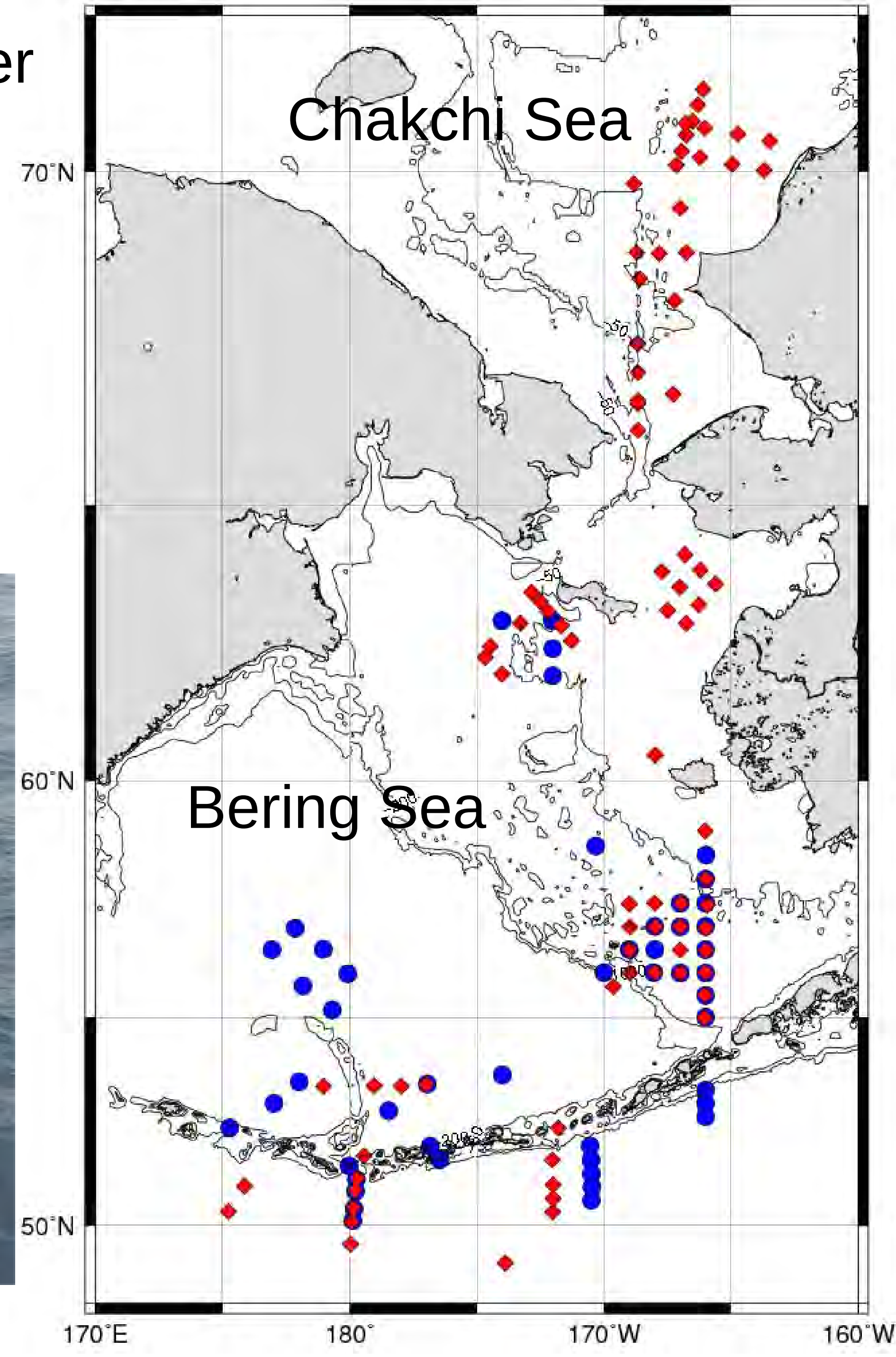
Sakurai *et al*. (1998)

Sampling locations in the summer of 2007,2008, and 2009.

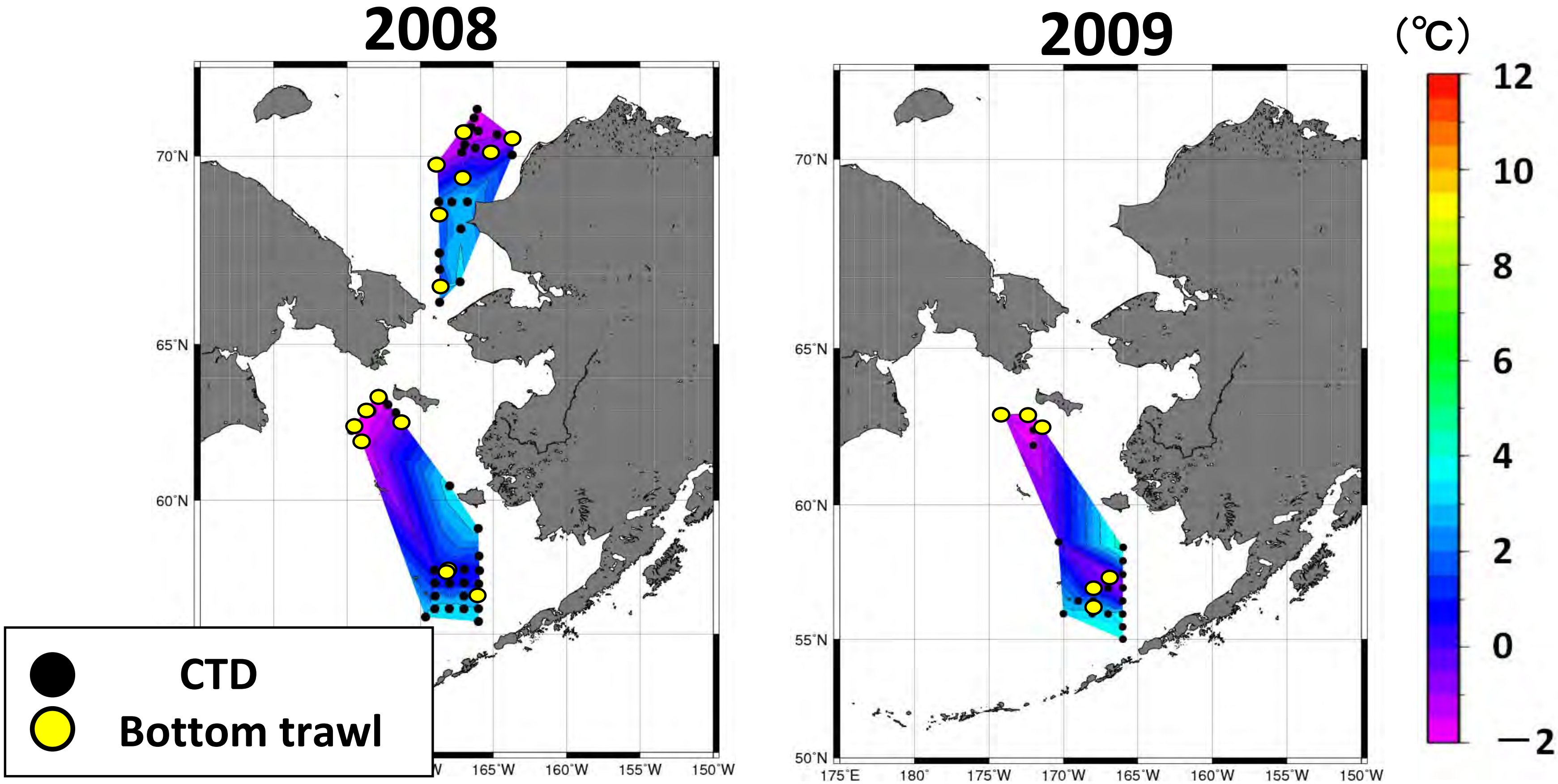
Sampling gears

*Bottom trawl

*Bong net (oblique tows, 0-75m)



Bottom temperature



South of St. Lawrence Isd・・・Cold pool（＜2℃）

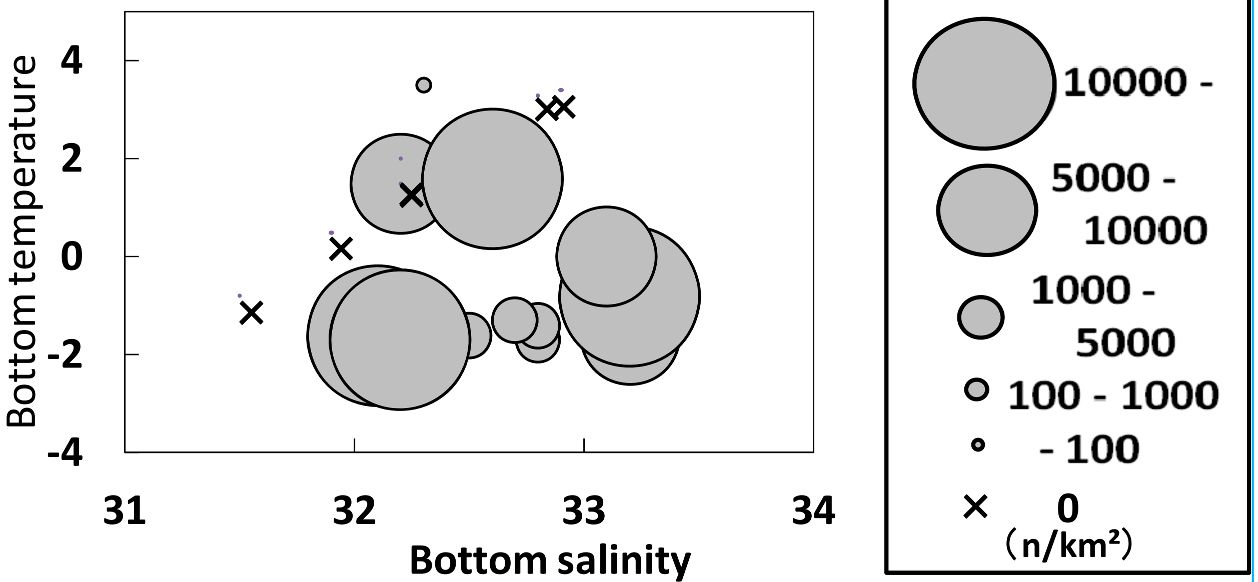
Chukchi Sea

Bering Strait ~ Coastal area・・・・（>2℃）

Northern offshore of 70° N・・・＜0℃

(Watanabe, 2010)

Occurrence of Arctic cod

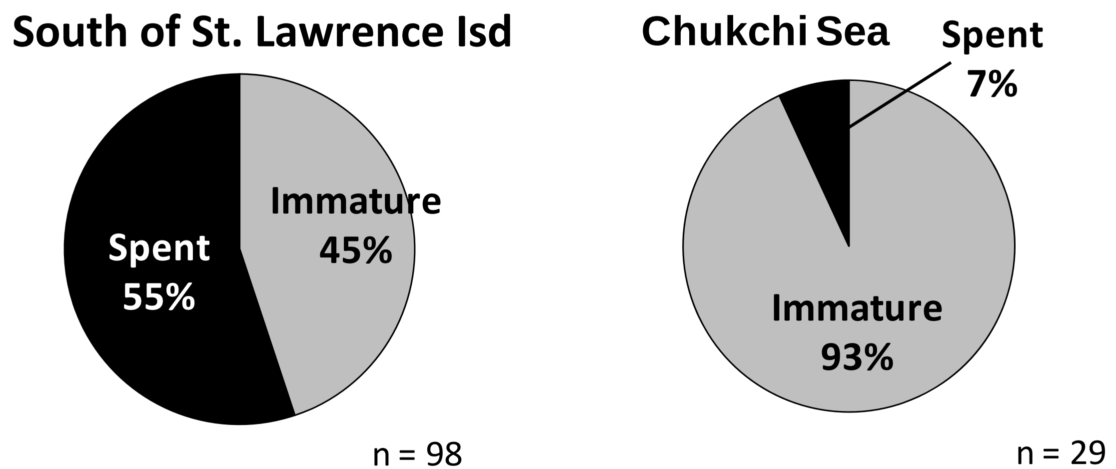


Temp : $-1.7 \sim 1.6$℃ (99.7% of total catch number)

*Arctic cod distribute in water below 2 ℃

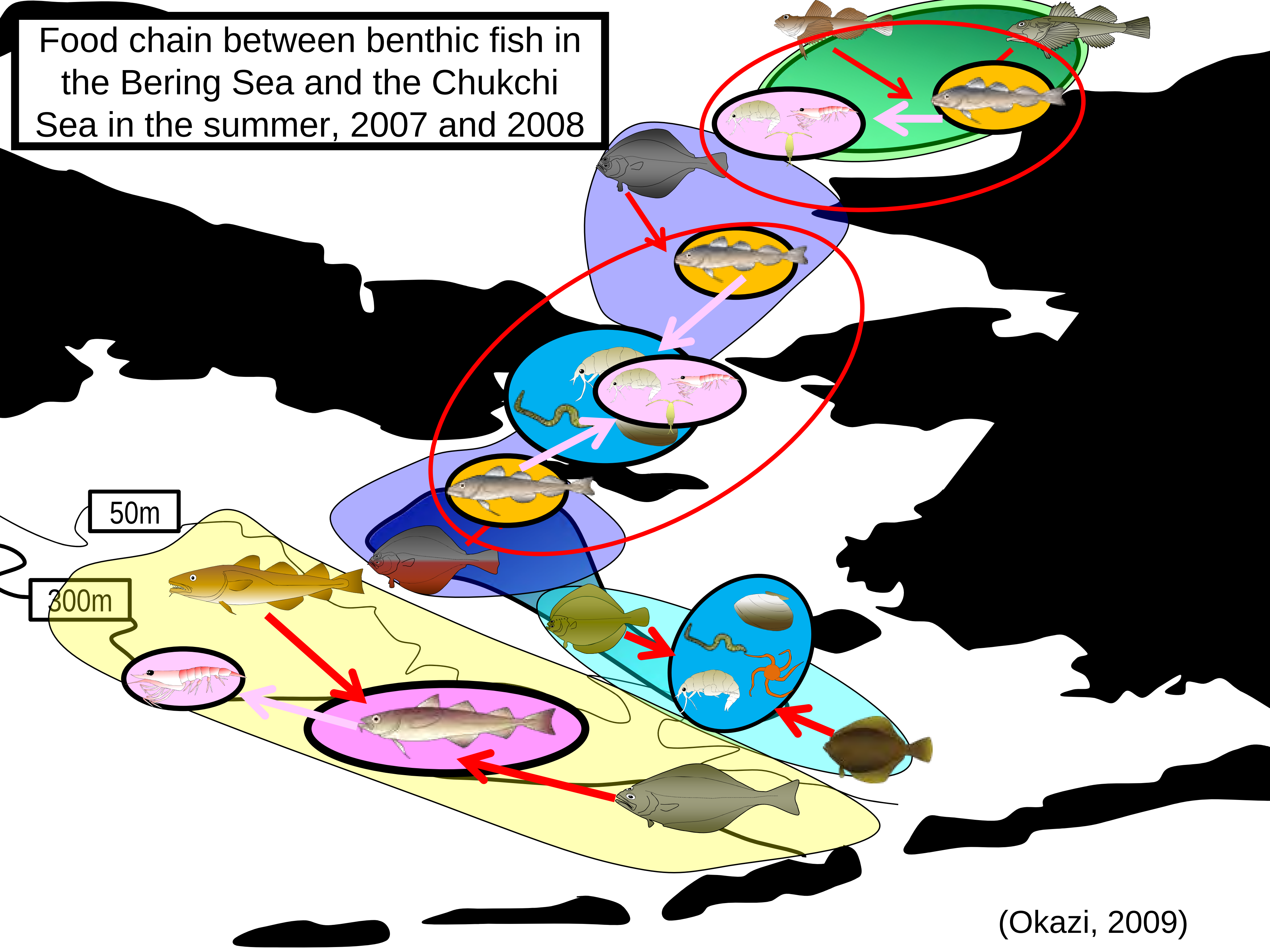
*Some of adult male and female can survive after spawning, which depend on their food availability in habitat.

Arctic cod is an important indicator species of climate change including the global warming in the marginal sea of Arctic Ocean.



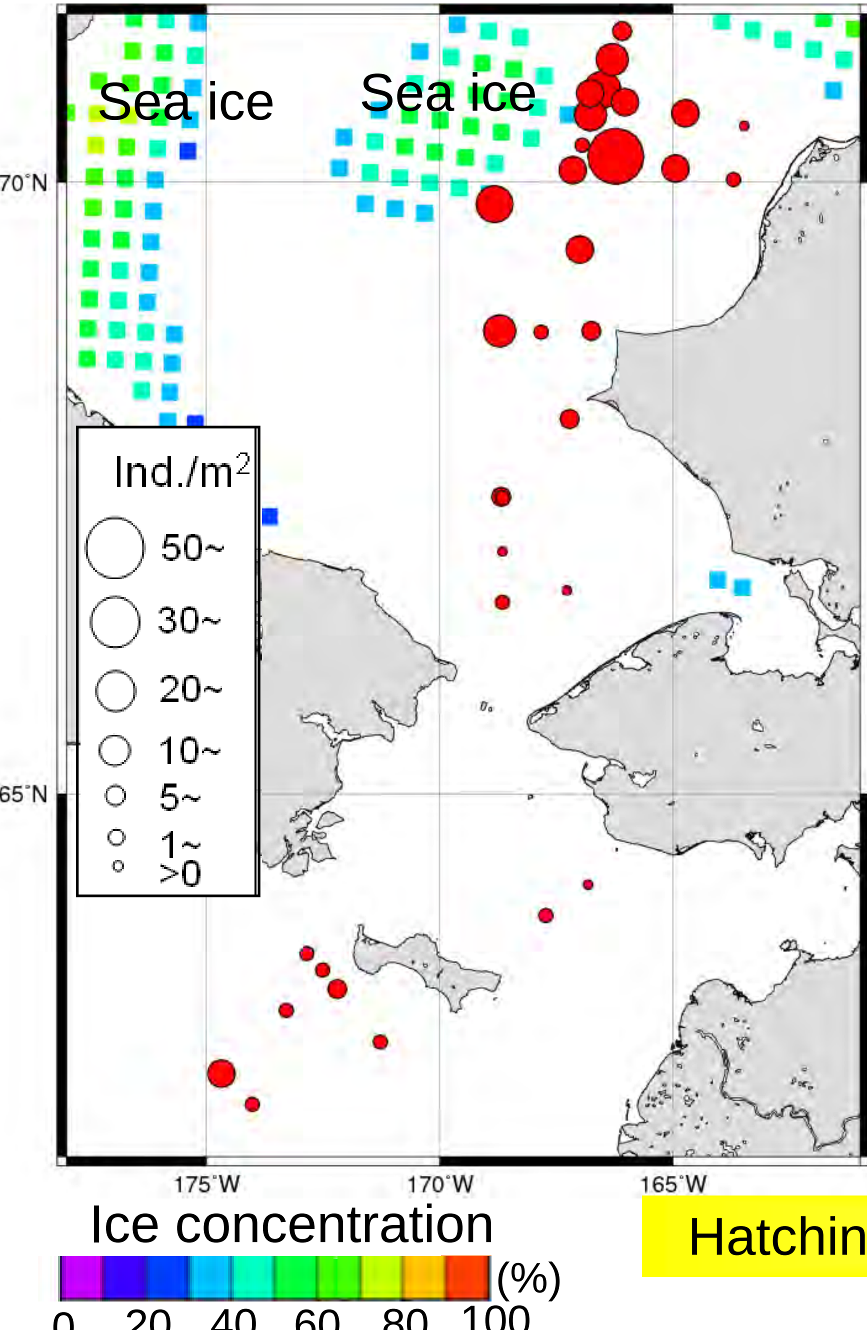
(Watanabe, 2010)

Food chain between benthic fish in the Bering Sea and the Chukchi Sea in the summer, 2007 and 2008

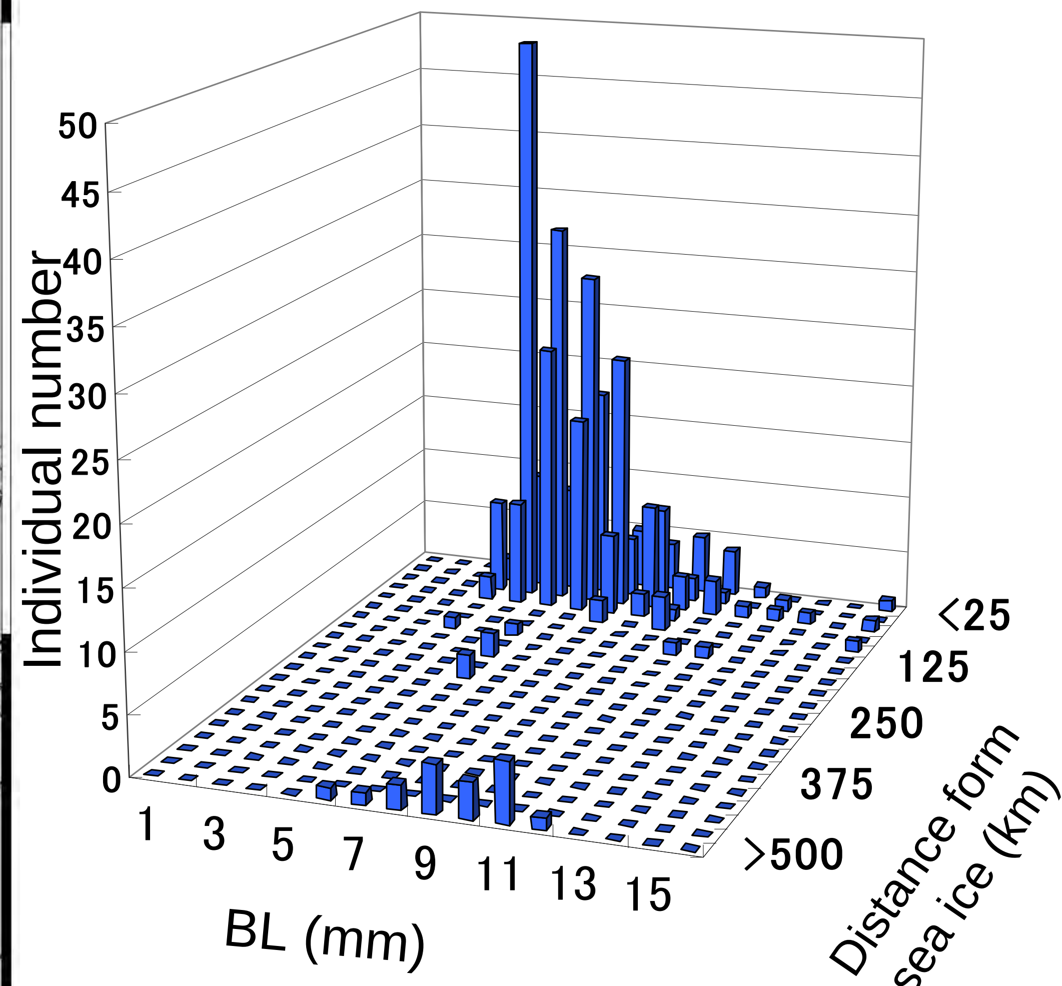


(Okazi, 2009)

Distribution of Arctic cod larvae in the summer of 2007, 2008



Hatching larvae (BL:5-6mm) occur in water near sea ice



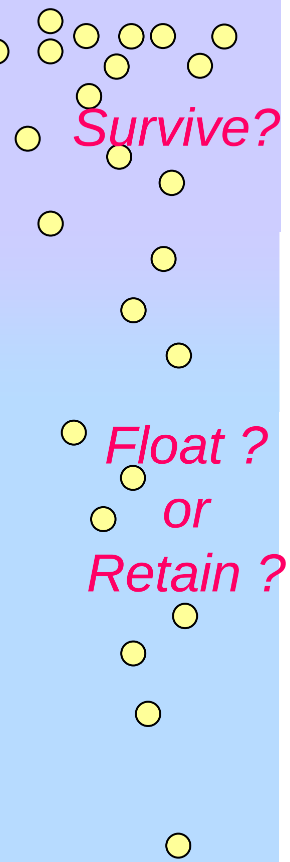
Hatching areas shift to the north with ice melting

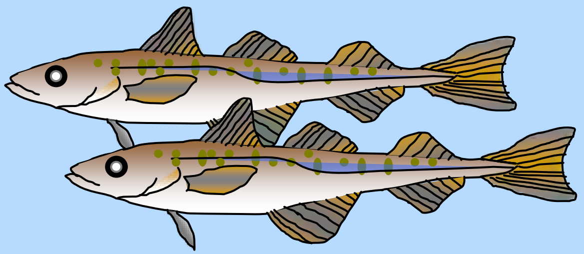
(Kurihara, 2010)

Laboratory studies on the response of walleye pollock eggs and larvae to temperature change

Objectives

- To examine the response of walleye pollock eggs and larvae to temperature change such as artificial thermocline in tank.
- To determine their preferred temperature.





Material and Methods -Collect the eggs

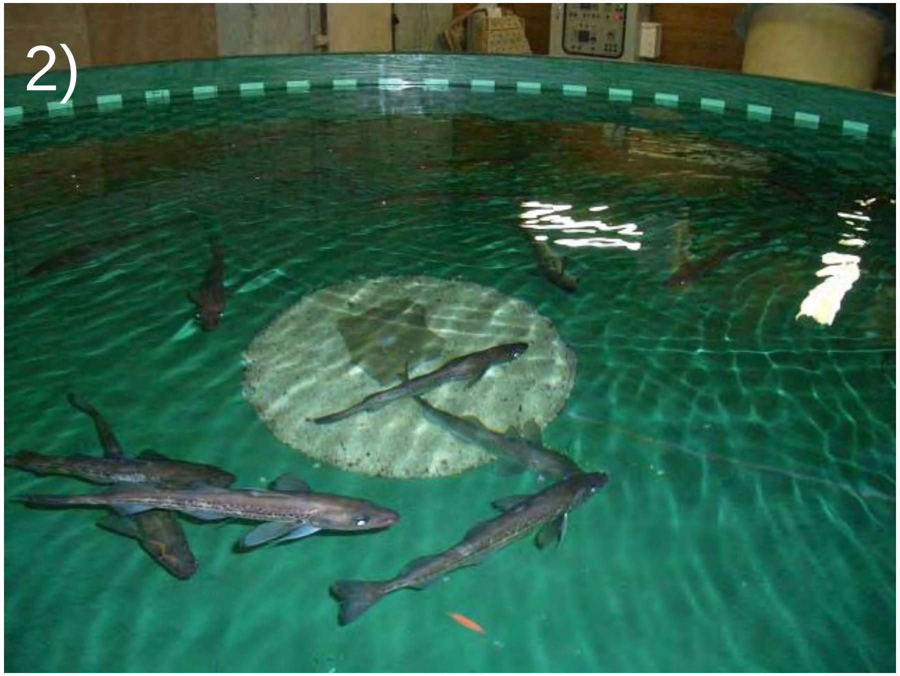
1) Adult fish Sampling :

Mouth of Funka Bay
late Jan., 2007-2012

2) Rearing the adult fish :

10 ton tank (Temp:5^{o}C, Sal:29.1 and 33.0)

3) Collect the natural spawned eggs



Material and Method : the Optimal T-S ranges for hatching

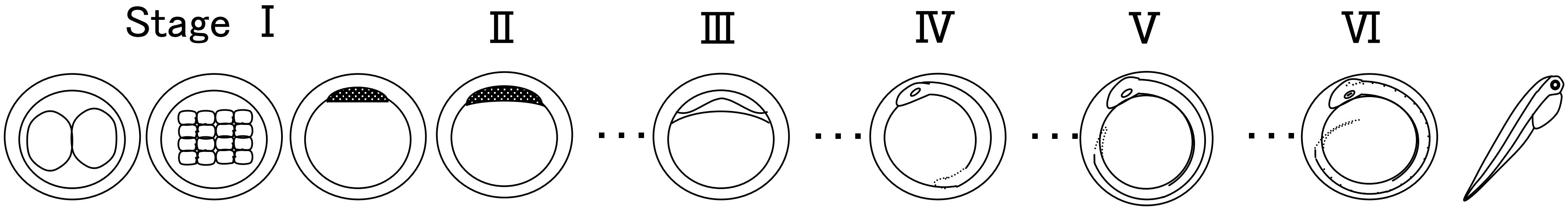
Eggs were reared at 35 conditions (mean = 507eggs / conditions)

7- Temperatures : -1.0, 0.0, 2.0, 5.0, 7.0, 9.0, 11.0 ^{o}C

5- Salinities : 24.0, 27.0, 30.0, 33.0, 35.0

Examined 1) Developmental time
2) Normal hatching rate

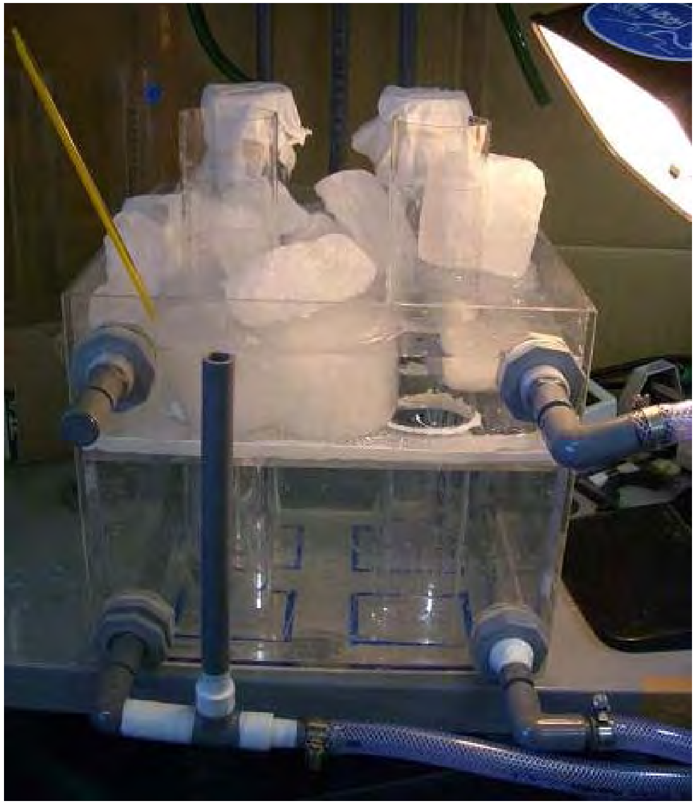
Development stages （Kendall and Kim 1993）



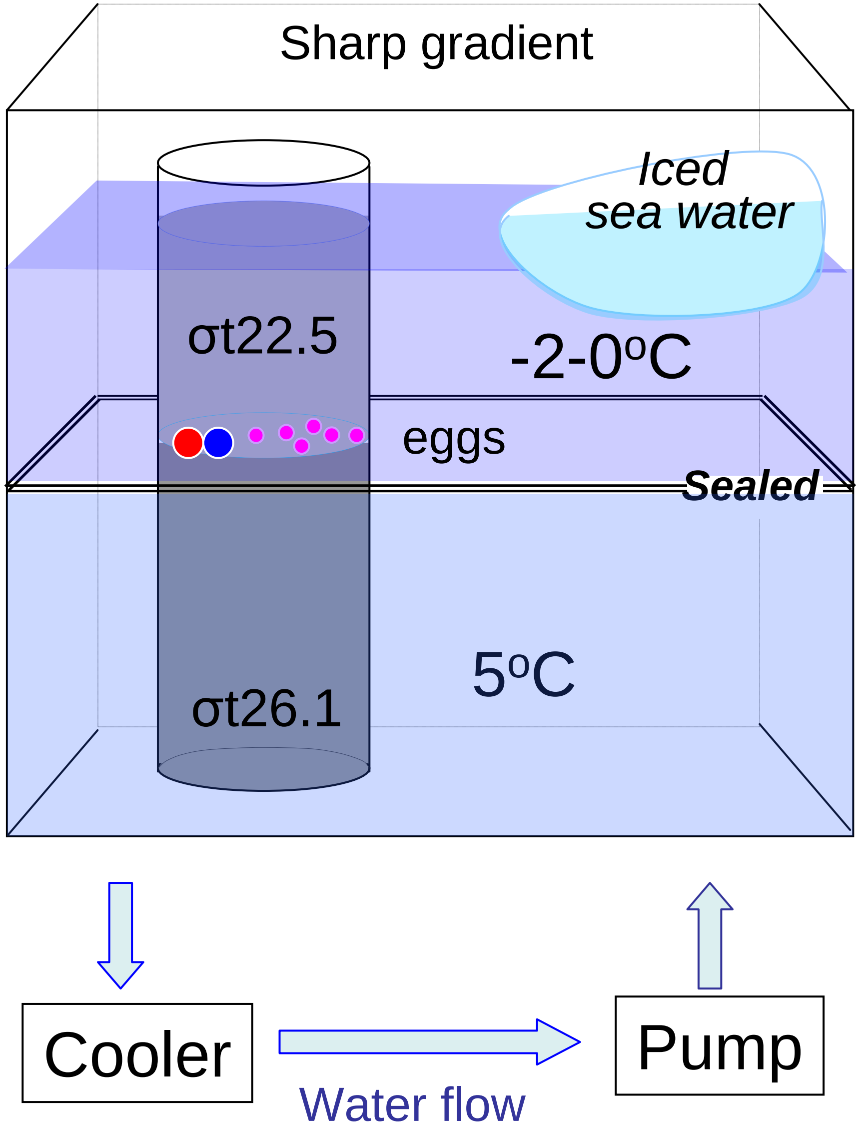
Material and Method :Movement near the thermocline

Sharp density gradient

Temperature (°C) : -2 - 0 (upper), 5 (lower)
Salinity : 28 (upper), 33 (lower)
Density (σ_t) : 22.5 (upper),26.1(lower)
Eggs (n) : 10



Actual photo of the experiment



Results : Hatching experiment under the 35 T-S conditions

Normal Hatching Rate (%)

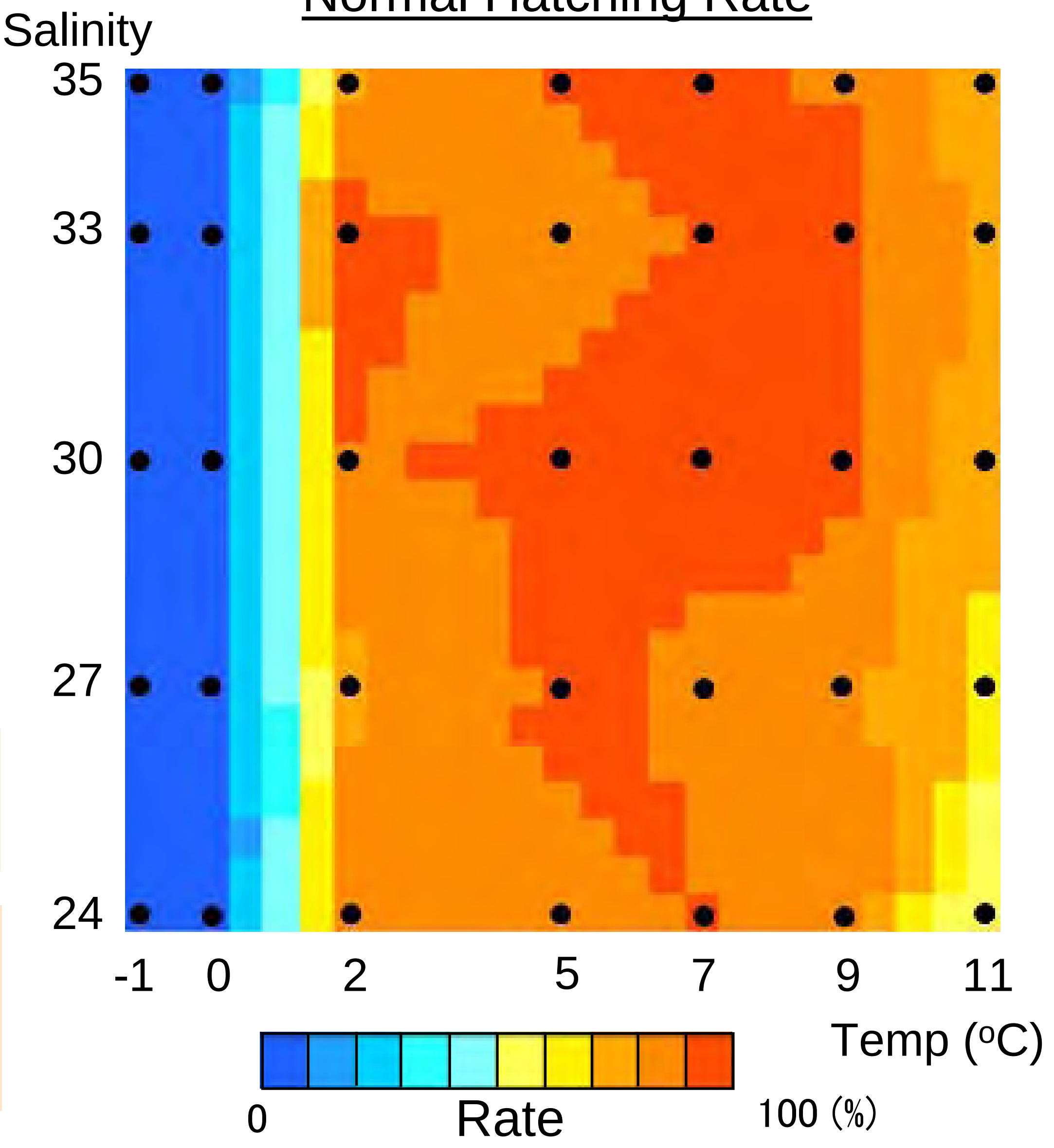
Low (0 - 4%) : -1, 0 °C
High (78-95%) : 2-9 °C

No clear difference among the salinities except 11°C

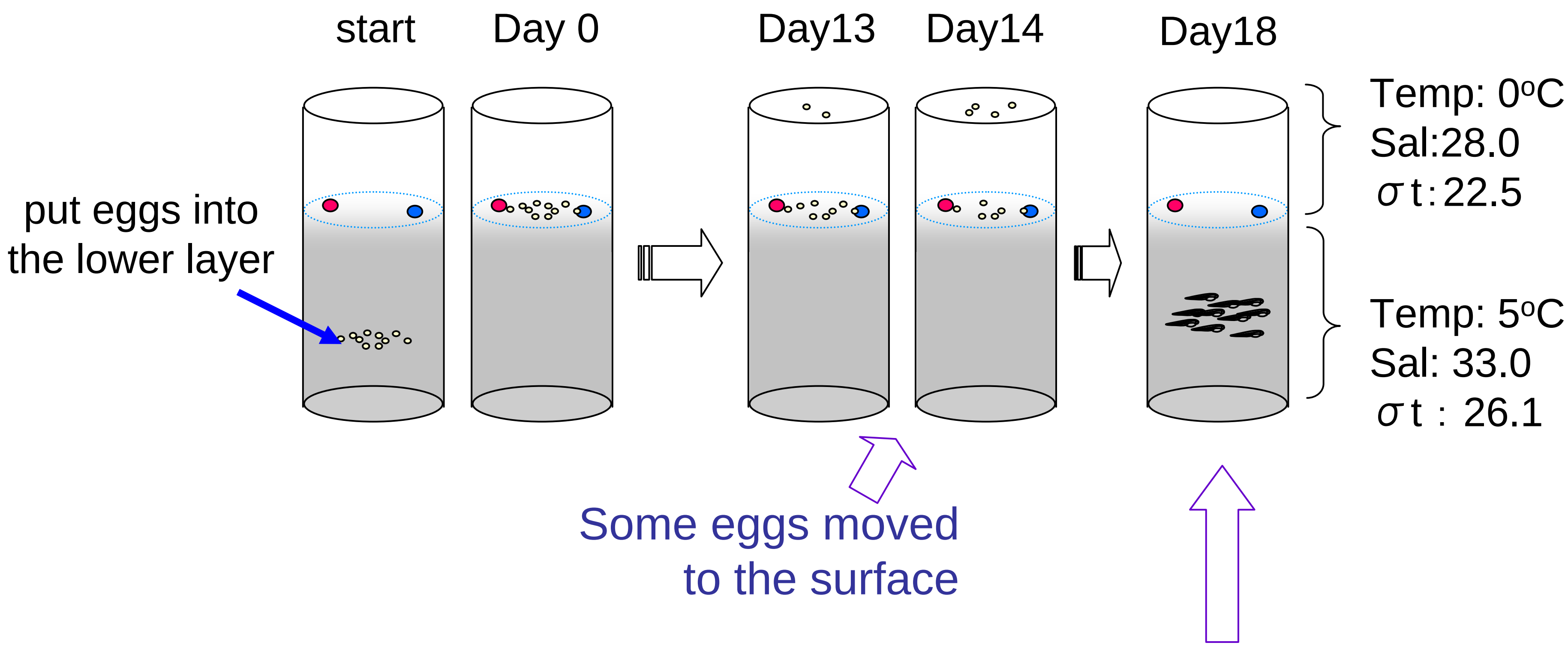
Normal hatching is controlled by temperature rather than salinity

Water mass with < 2°C is unfavorable condition for the hatching

Normal Hatching Rate



Results : Movement of the eggs near the thermocline



All eggs hatched normal.
All larvae retained in the lower layer

suggestig ... Egg can hatch normal if they underwent the cold temperature at their late developmental stage

supporting ...

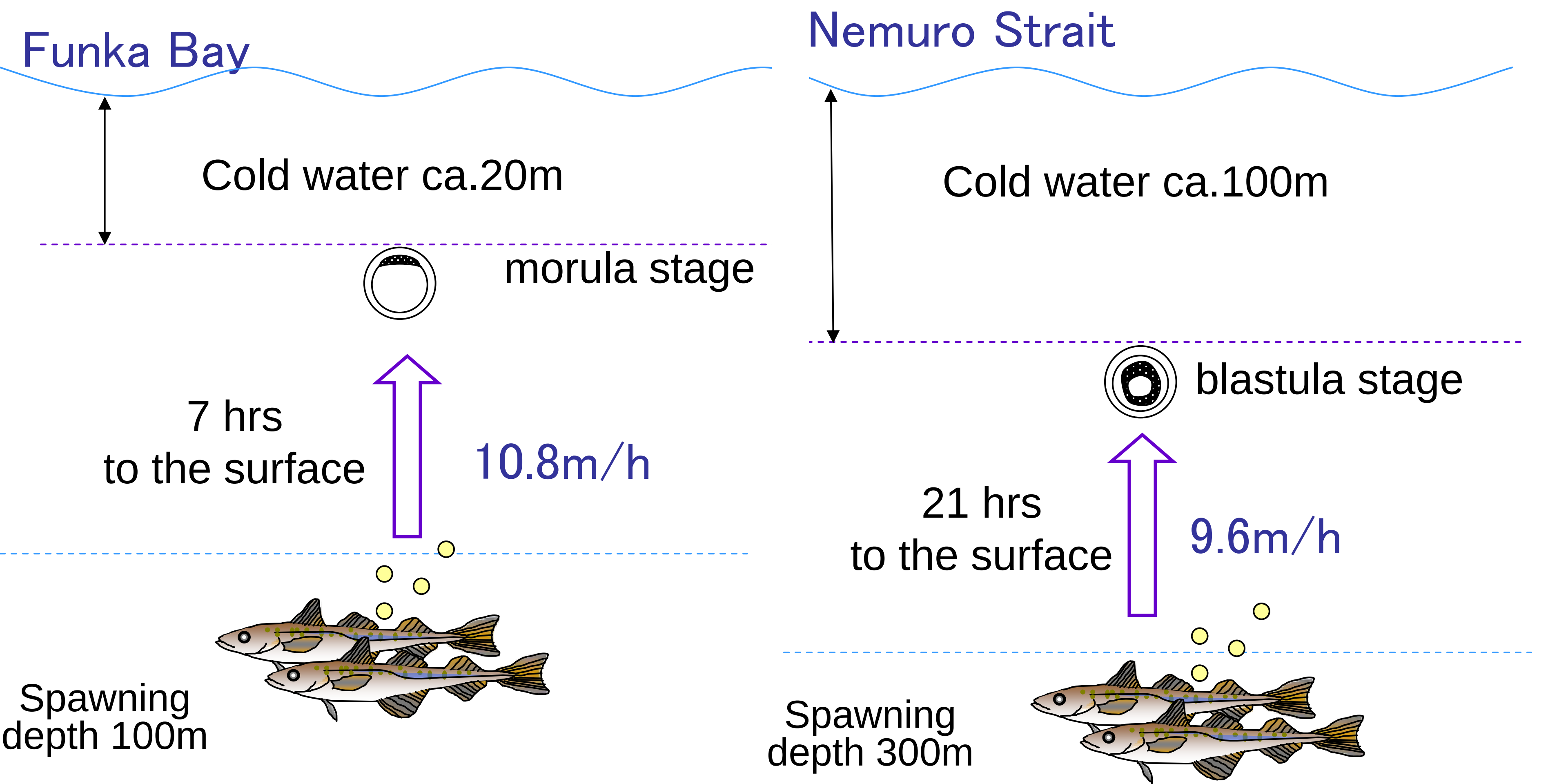
Eggs resist cold water after morula stage (Nakatani and Maeda 1984)

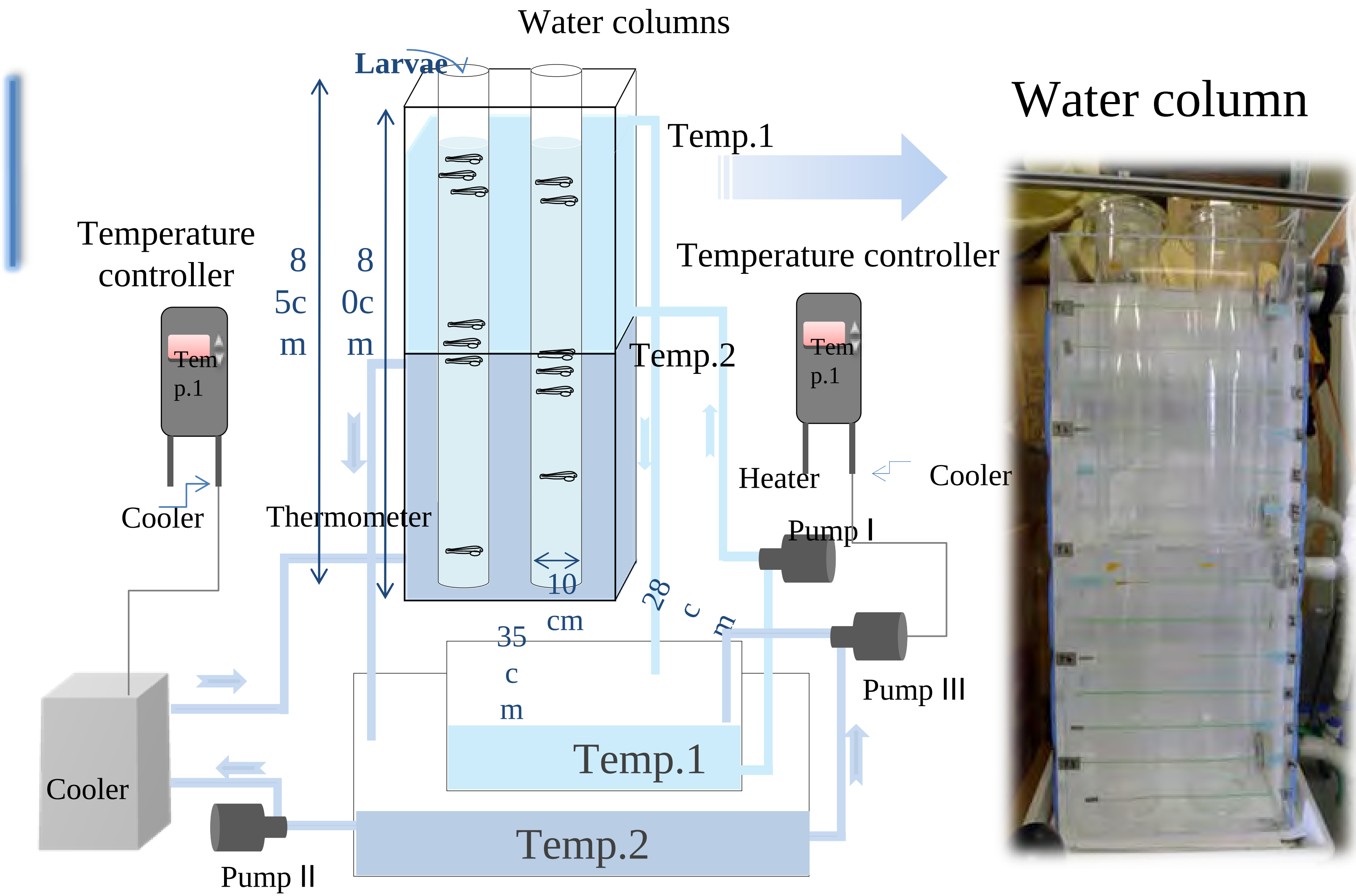
Discussion : Vertical movement of the eggs in the spawning areas

Stokes law

$$\omega = \Delta\rho g D^2 / 18\eta$$

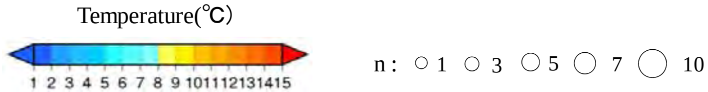
- ω :velocity
- $\Delta\rho$: difference of Dens.
- D :eggs diameter
- η : viscosity
- g :gravity

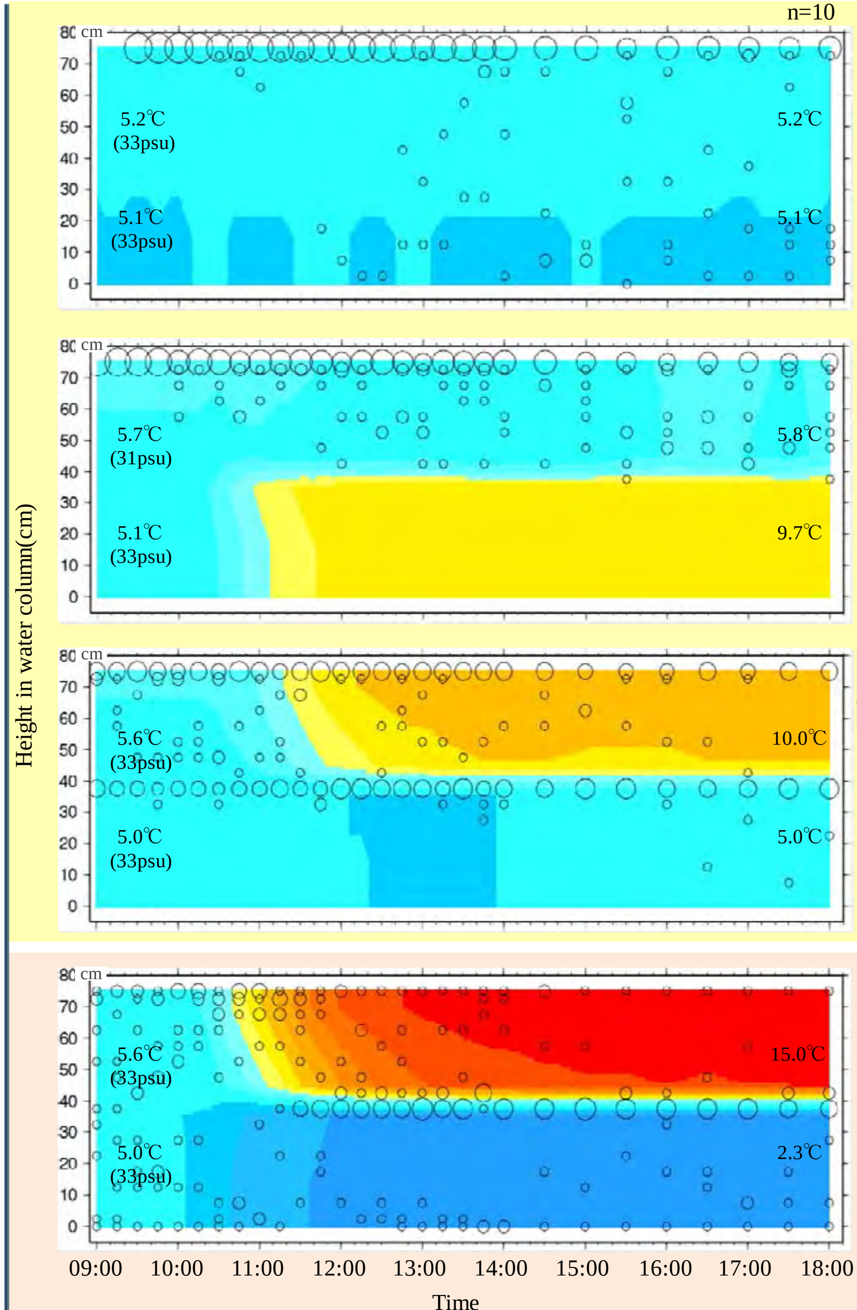




Two water column and the temperature controlling system. The column were surrounded by two water tanks, which contained circulating, temperature-controlled water.

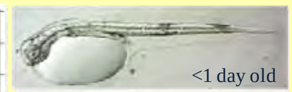
Results





4.79±0.24mm (mean±SD)

Fig.3. [control experiment] Larvae have difficulty swimming probably due to the large yolk sac. While some larvae occurred in the mid and bottom of the water column, most occurred near the surface.

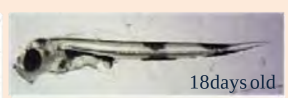


4.24±0.13mm (mean±SD)

Fig.4. Larvae occurred near the surface above warmer water.

4.82±0.19mm (mean±SD)

Fig.5. Some larvae occurred in the warm water and under the warm water, presumably larvae avoided the warm water.



5.25±0.14mm (mean±SD)

Fig.10. Extremely warm water occurred over cold water, larvae avoided the warm and cold water, and concentrated in the thermocline.

larvae≤1 day old showed less vertical change than older larvae

larvae≤15 days old avoided warm and cold water, and selected near the thermocline

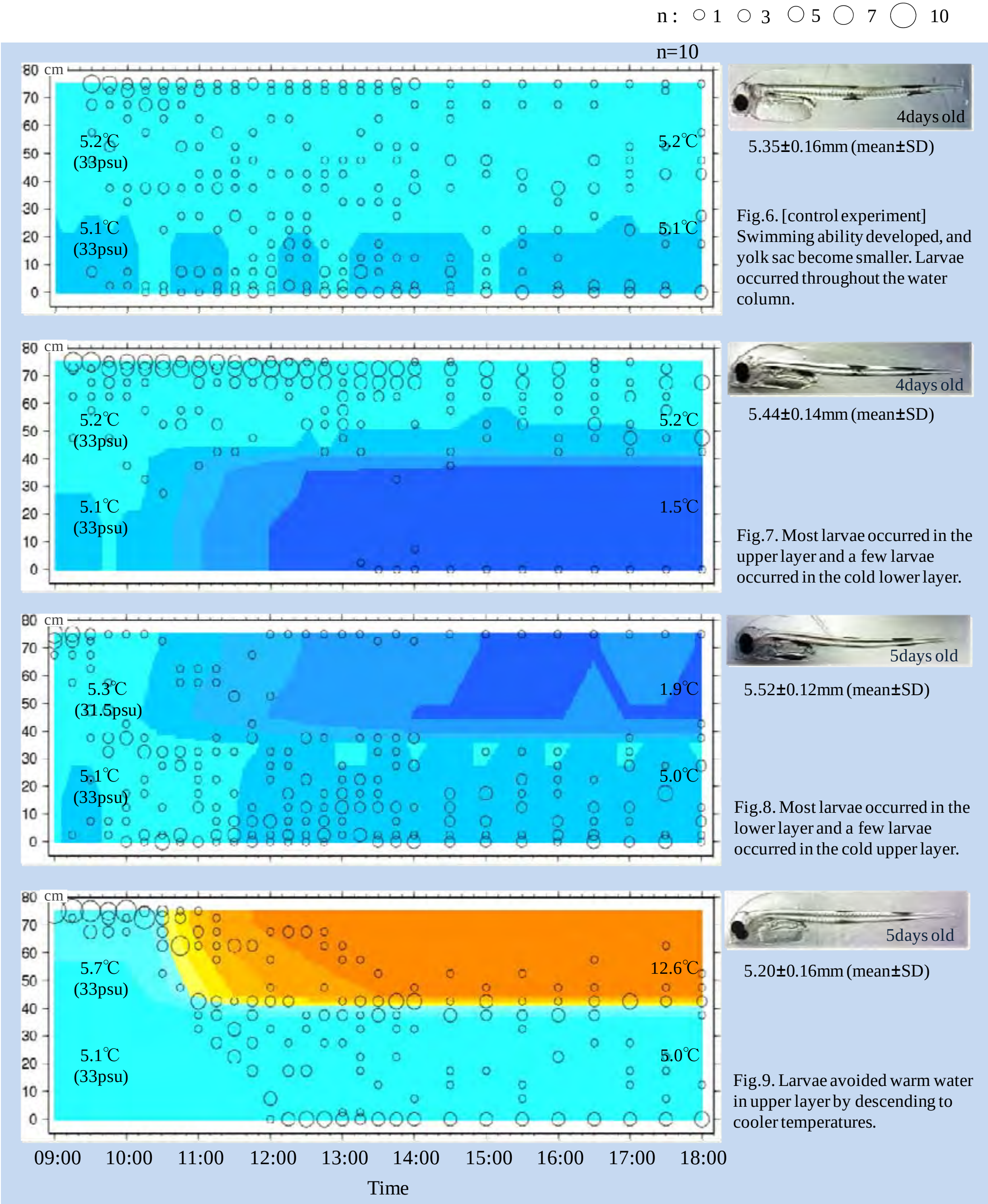


Fig.6. [control experiment] Swimming ability developed, and yolk sac become smaller. Larvae occurred throughout the water column.

Fig.7. Most larvae occurred in the upper layer and a few larvae occurred in the cold lower layer.

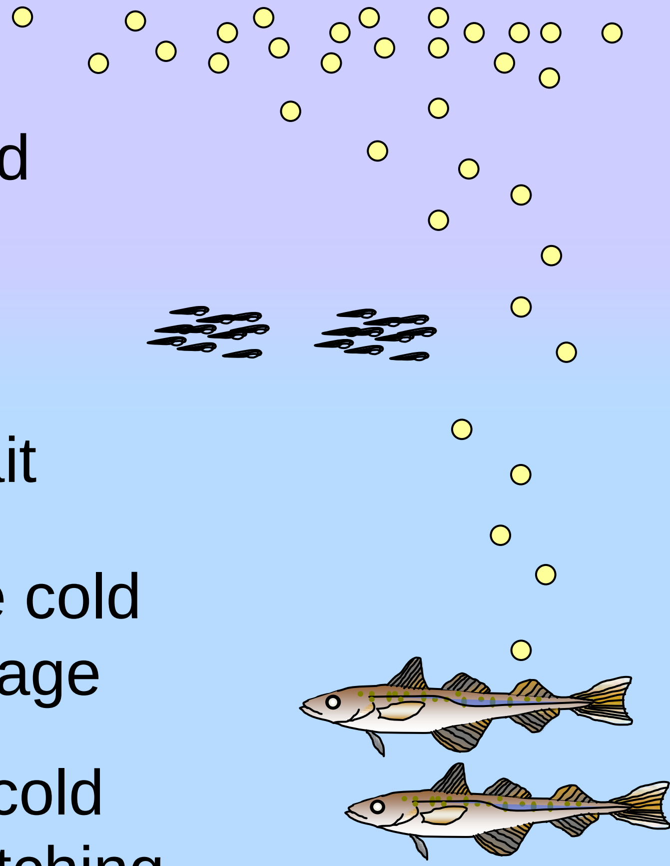
Fig.8. Most larvae occurred in the lower layer and a few larvae occurred in the cold upper layer.

Fig.9. Larvae avoided warm water in upper layer by descending to cooler temperatures.

larvae≥4 days old altered their depth to stay a favorable temperature

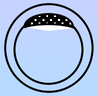
Summary (Walleye pollock)

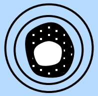
Temperature is the critical factor for hatching rather than salinity.



Eggs normally hatch at temp $\geq 2^{o}$C

Eggs probably reach to the unfavorable cold water at

morula stage  in the Funka Bay

blastula stage  in the Nemuro Strait

Egg can hatch normal if they underwent the cold temperature at their late developmental stage

The developmental stages reaching to the cold water probably affect the success of the hatching.

As the yolk was absorbed, the larvae were able to alter their position in the water column, which allowed them to select favorable temperatures.