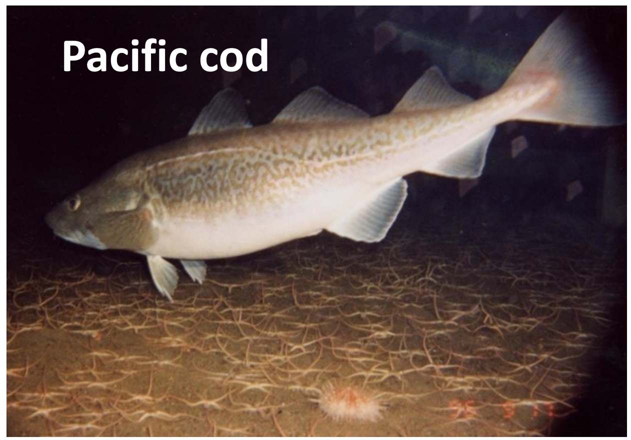
FIS Session-5, October 22, 2014

Overview of reproductive characteristics and strategies among the Pacific gadid fishes



Yasunori **Sakurai**

Faculty of Fisheries Sciences, Hokkaido University, 3-1-1 Minato, Hakodate, Hokkaido, 041-8611, Japan

E-mail: sakurai@fish.hokudai.ac.jp

Outline of our presentation

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

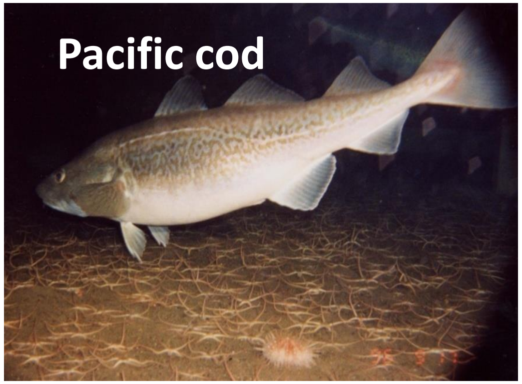
2. Comparison of reproductive characteristics among gadid fishes

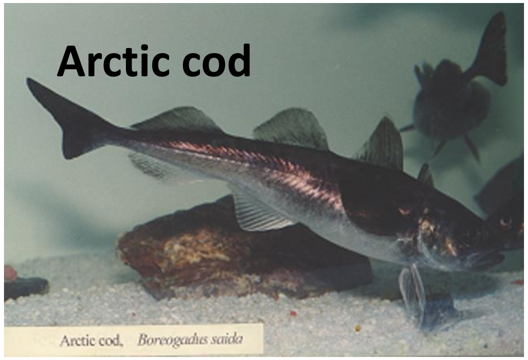
3. Reproductive characteristics of Pacific gadid fishes related to physical condition of spawning grounds

4. Why did walleye pollock decrease in the southern coast water along Korea and Japan?

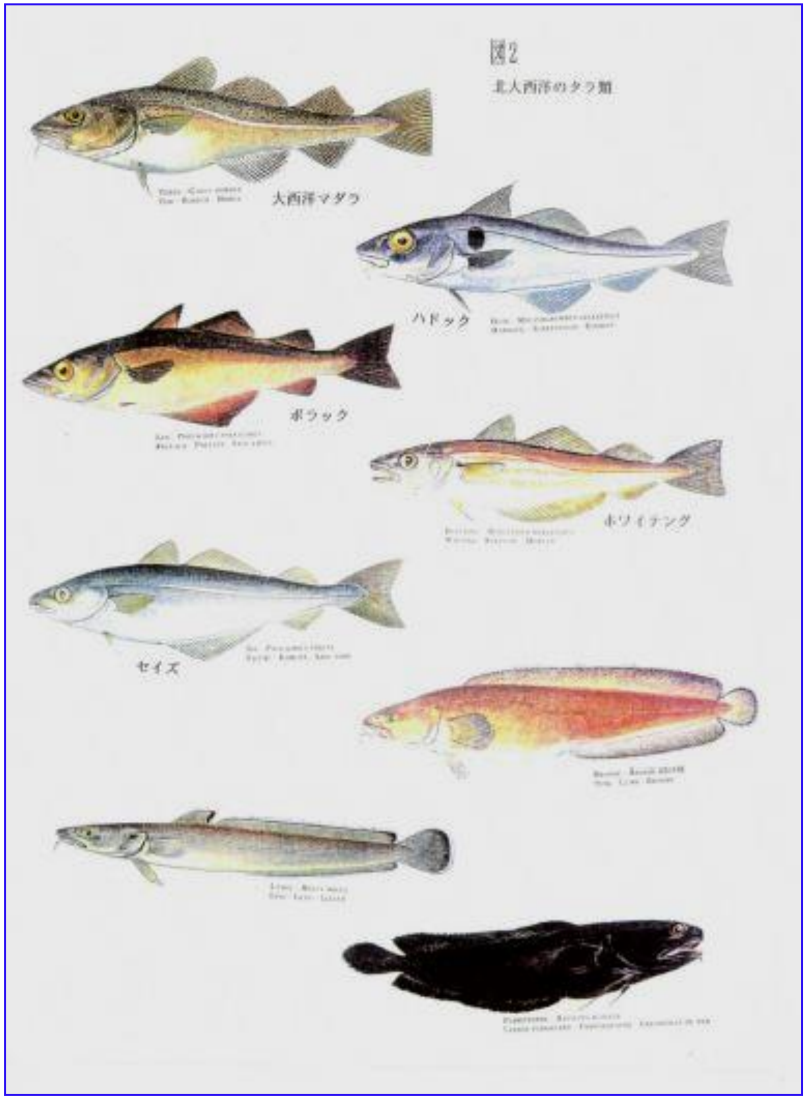
5. Recent studies on their early life stages at different environmental conditions such as those experienced during climate regime shifts and global warming

Pacific gadid fish including Arctic Ocean



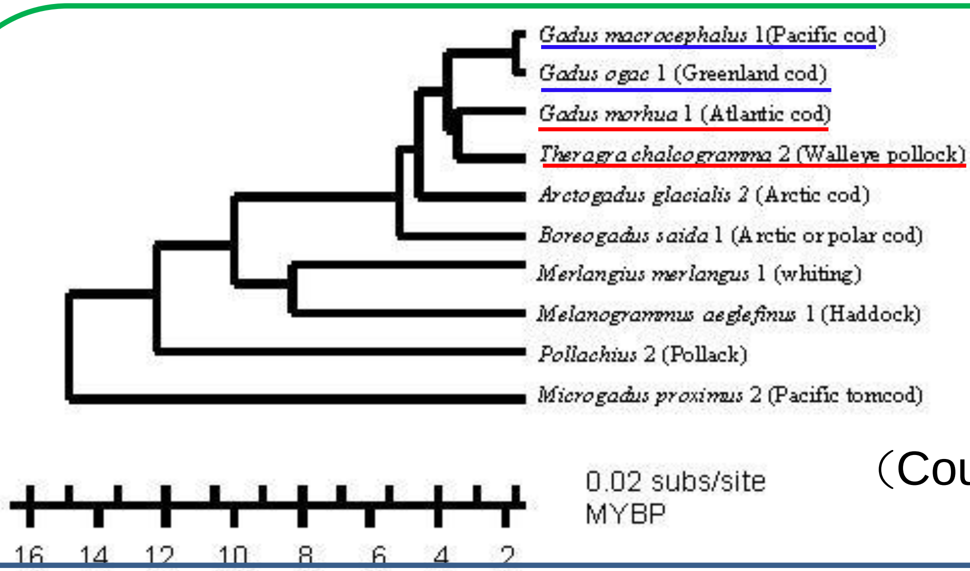


Atlantic gadid fish



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

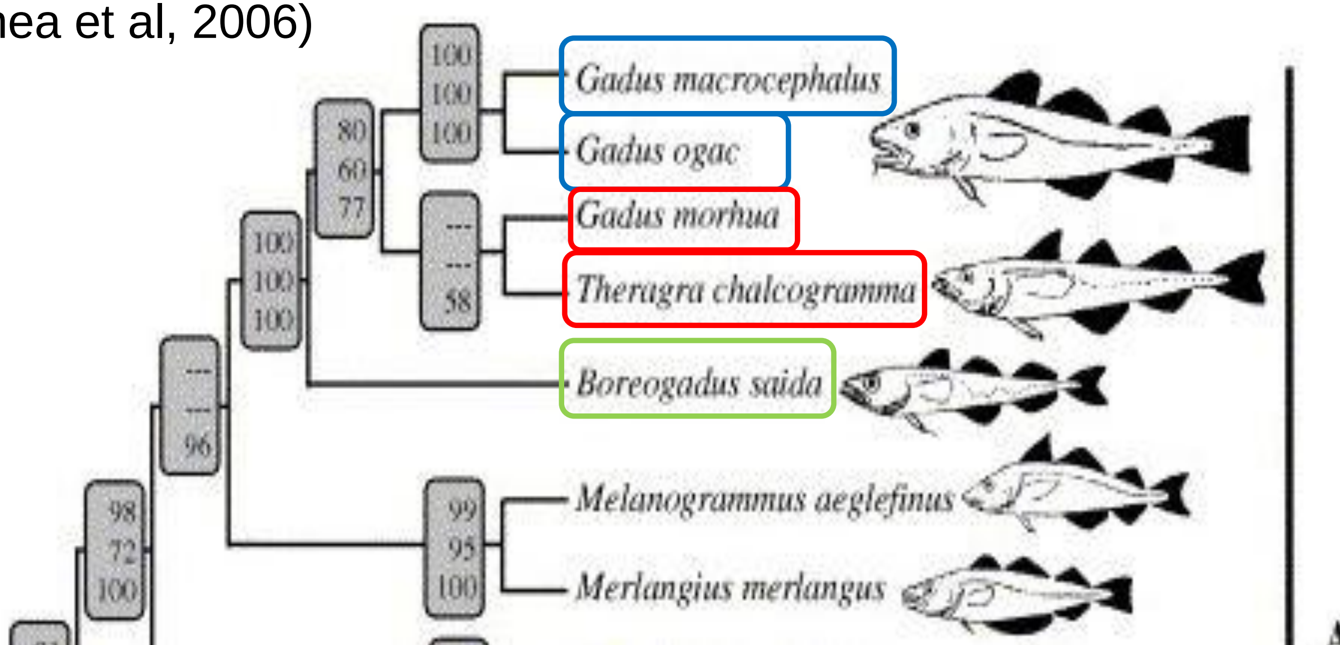
(Grant et al, 2010)



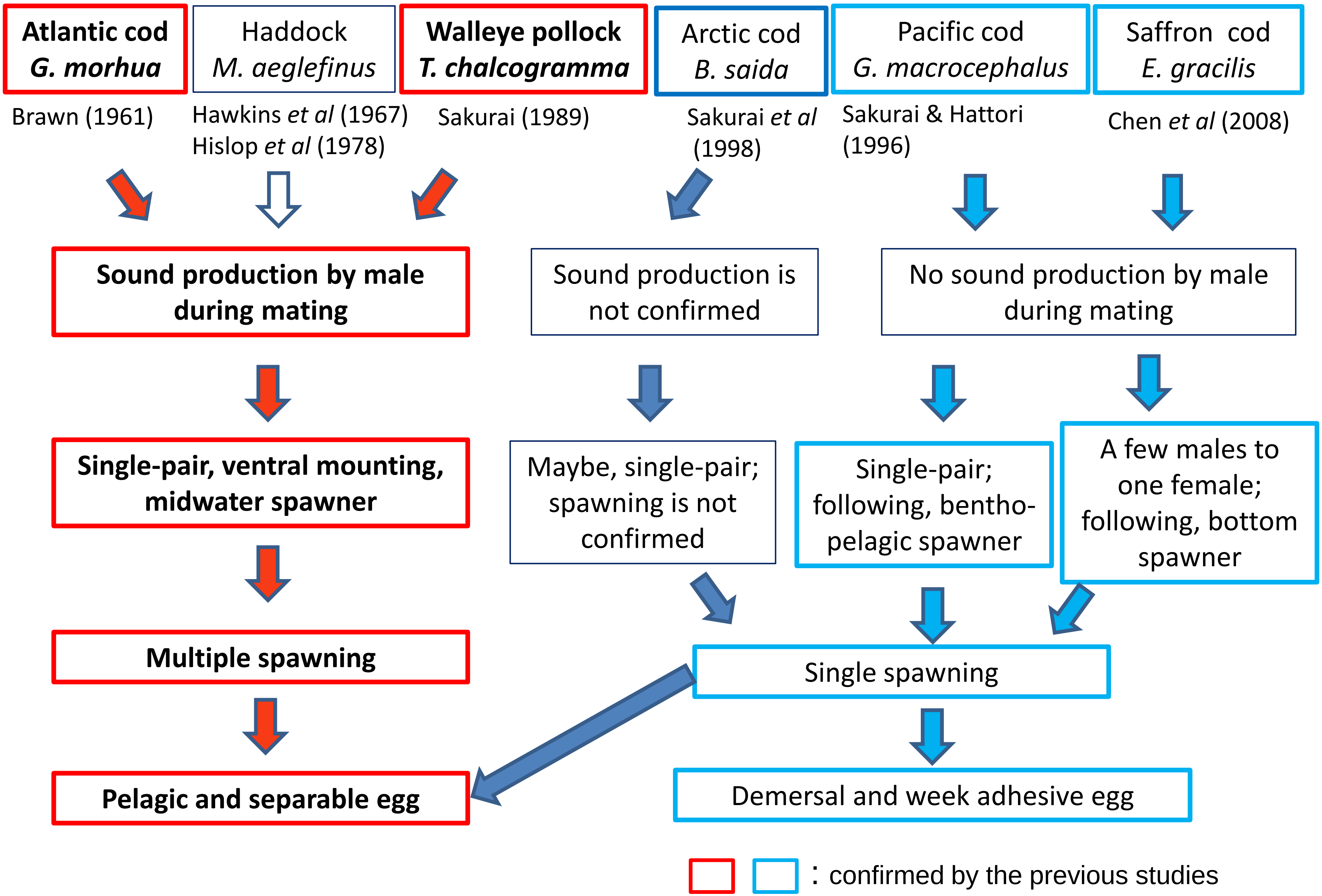
(Coulson, 2006)

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

(Teletchea et al, 2006)



Comparison of reproductive characteristics among gadid fish



Atlantic cod

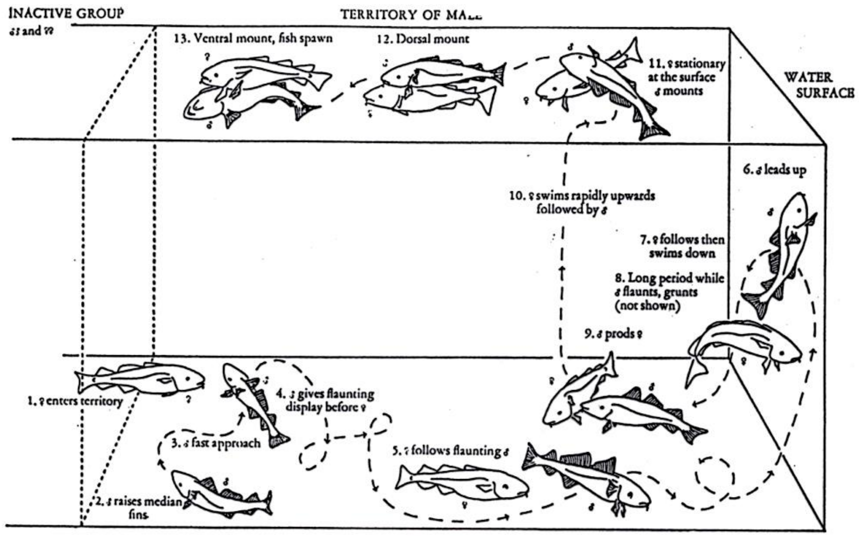


Fig. Simprified representation of the courtship and spawning behavior of Atlantic cod. (Brawn, V. M., 1961)

walleye pollock

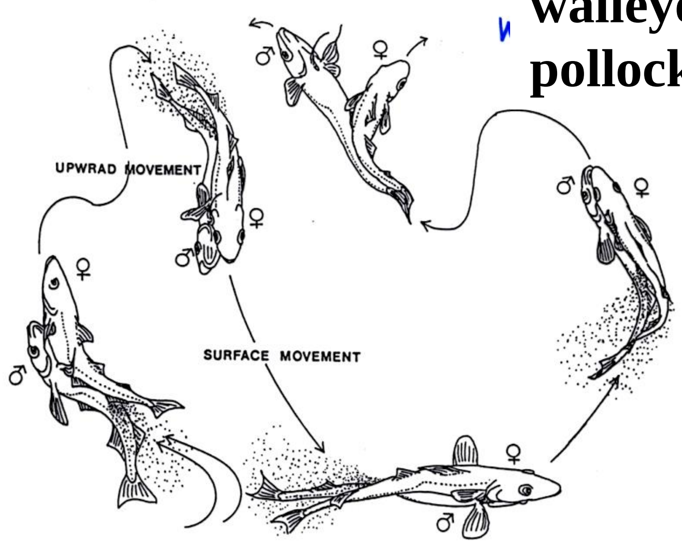
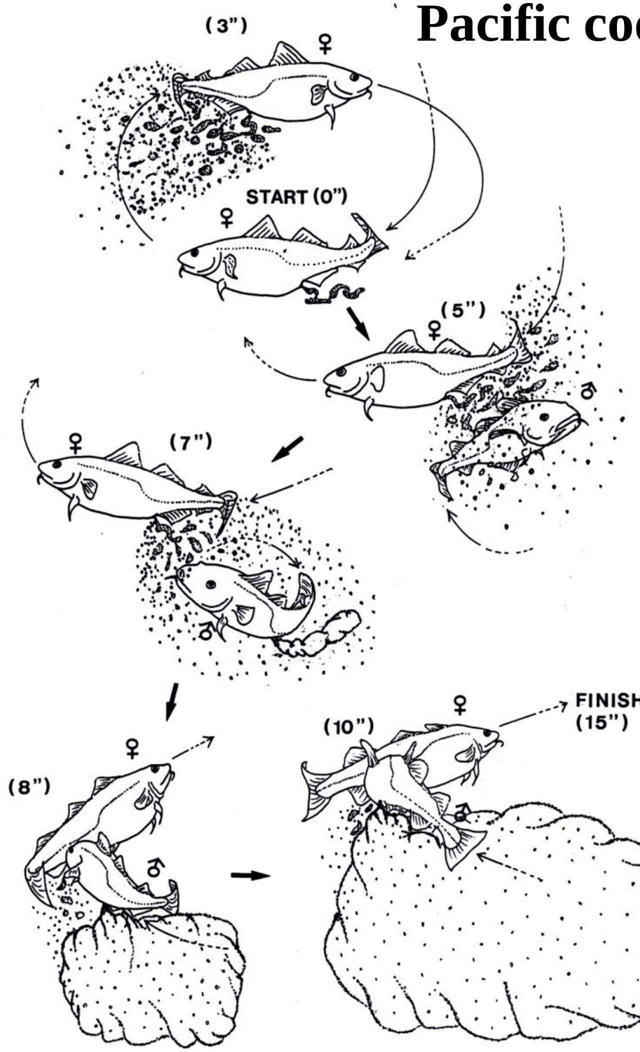


Fig. Spawning behavior of walleye pollock by ventral mounting. (Sakurai, Y., 1983)

(Sakurai, 1983)

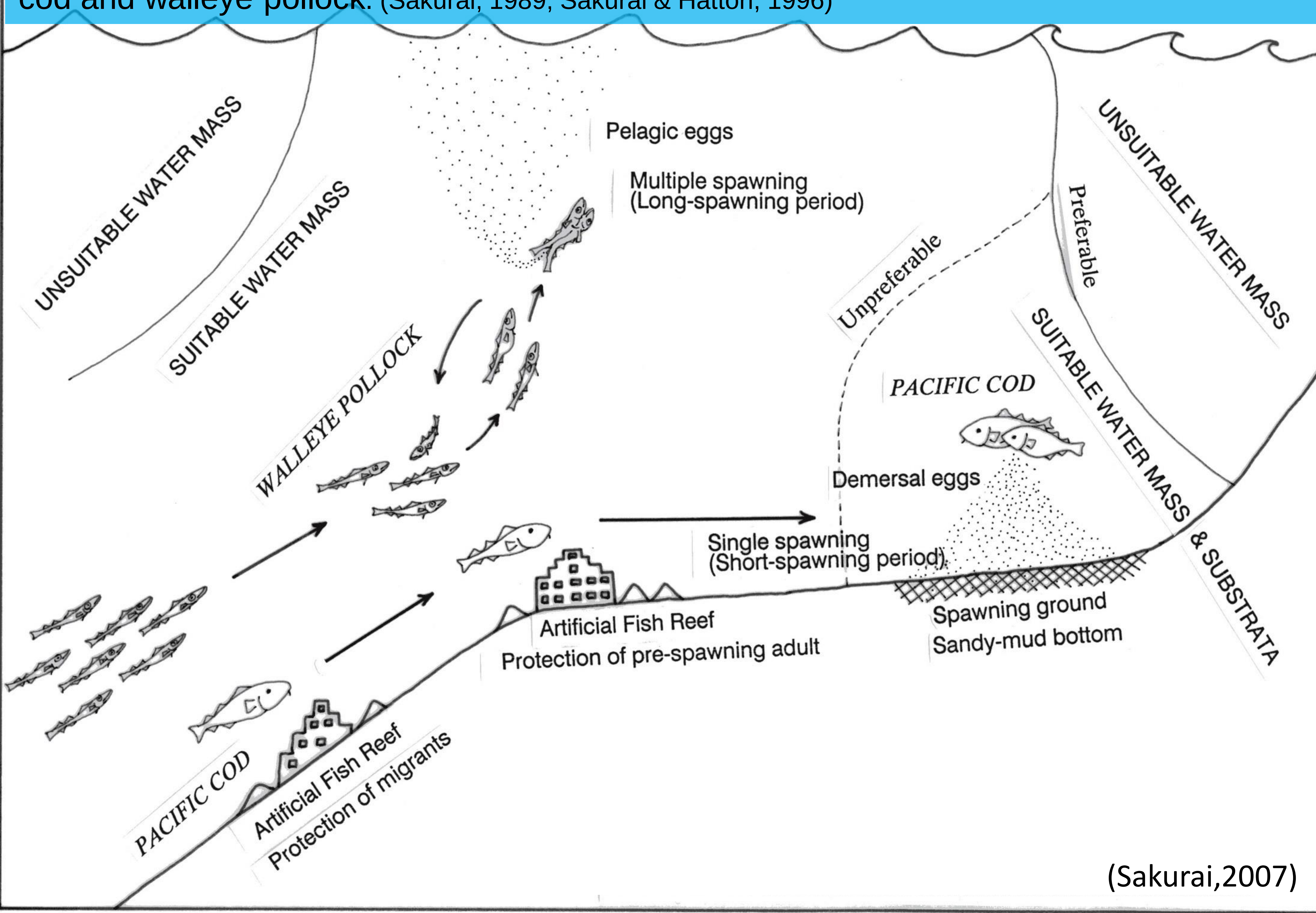
Pacific cod



Spawning behavior of Pacific cod in captivity.

(Sakurai & Hattori, 1996)

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



(Sakurai,2007)

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Temperature-mediated survival, development and hatching variation of Pacific cod *Gadus macrocephalus* eggs

X. Bian*, X. Zhang†‡, Y. Sakurai§#, X. Jin*, T. Gao†, R. Wan* and J. Yamamoto§

**The Key Laboratory of Sustainable Development of Marine Fisheries, Ministry of Agriculture, Yellow Sea Fisheries Research Institute, CAFS, Qingdao 266071, China, †College of Fisheries, Ocean University of China, Qingdao 266003, China and §Faculty of Fisheries, Hokkaido University, Hakodate, Hokkaido 041-8611, Japan*

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doi:10.1111/jfb.12292, available online at wileyonlinelibrary.com

Envelope surface ultrastructure and specific gravity of artificially fertilized Pacific cod *Gadus macrocephalus* eggs

X. Bian*, X. Zhang†‡, Y. Sakurai§, X. Jin*, T. Gao†, R. Wan* and J. Yamamoto§

**The Key Laboratory of Sustainable Development of Marine Fisheries, Ministry of Agriculture, Yellow Sea Fisheries Research Institute, CAFS, Qingdao 266071, China, †The Key Laboratory of Mariculture, Ministry of Education, Ocean University of China, Qingdao 266003, China and §Faculty of Fisheries, Hokkaido University, Hakodate, Hokkaido 041-8611, Japan*

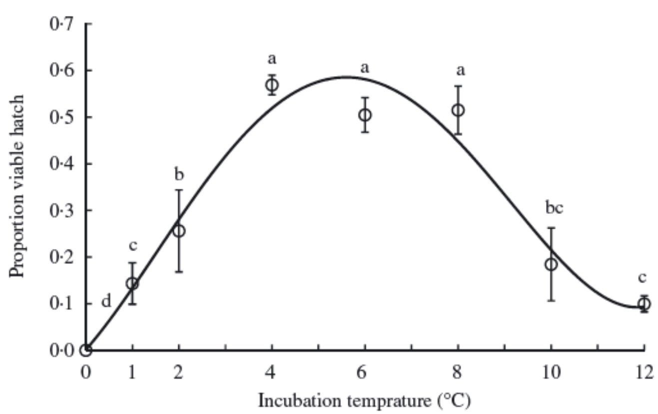


Fig. 1. Proportion of mean ± s.d. viable hatching of *Gadus macrocephalus* eggs incubated at 1, 2, 4, 6, 8, 10 and 12° C from Mutsu Bay. Polynomial regressions were fitted through all raw data to a fourth-order polynomial by least-squared iteration. The models and estimated parameters are given in Table II. Different lowercase letters above the bars indicate significant differences ($P < 0.05$).

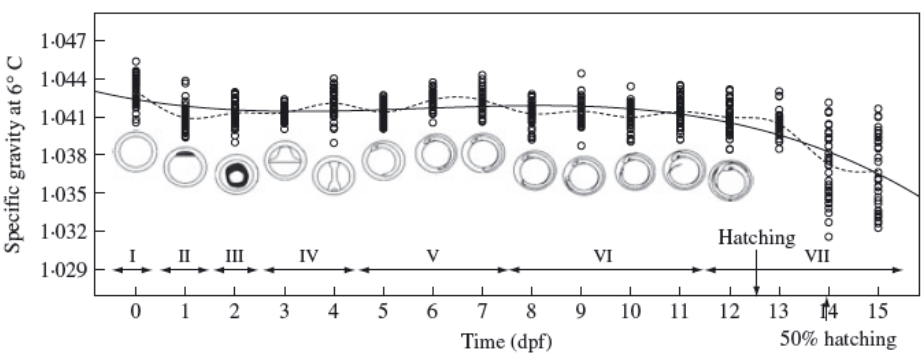
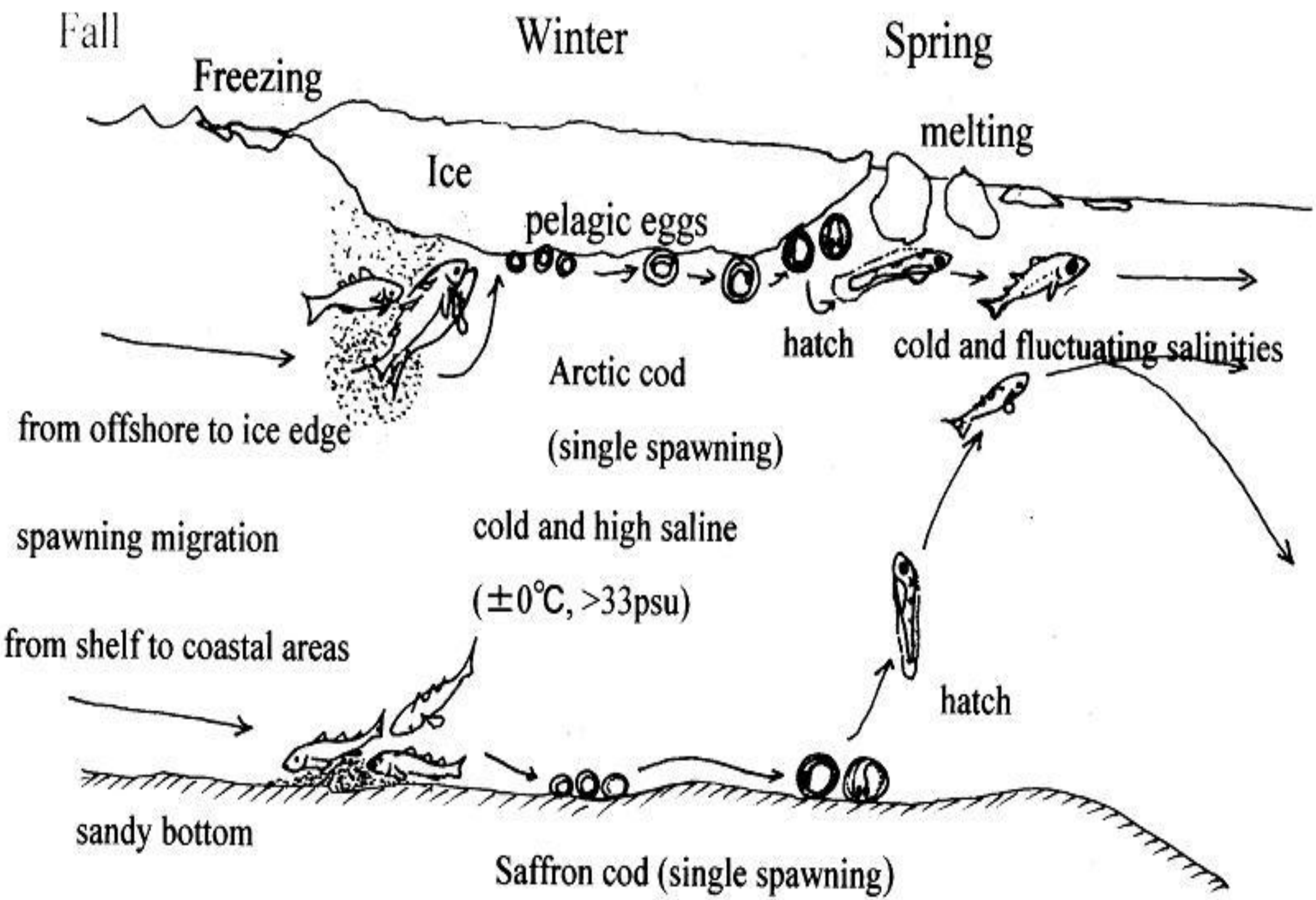


Fig. 6. Developmental changes in the specific gravity of *Gadus macrocephalus* eggs at 6° C based on single sinking speed measurements ($n = 40$, each day) using the Stokes' law equation ($0.218 < Re < 0.491$). Developmental stage of the eggs at the sampling period of a fixed time in each day was indicated by the abridged general view against the specific gravity of measurements (see Table I for the broad period of embryogenesis). After hatching, the eggs measured were those viable unhatched ones. Variations in the specific gravity of *G. macrocephalus* eggs against sampling time (in days post-fertilization, dpf) were fitted to a third-order polynomial by the least-squares iterative method. The model fitted was: $f(x) = -8E\text{-}06x^3 + 0.0002x^2 - 0.0010x + 1.0430$ ($n = 640$, $F_{3,636} = 214.492$, $P < 0.001$, $r^2 = 0.503$). ○, Observed value; ----, interpolation line; ⁀, fitted line for total observed value.

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



Reproduction and early life stage of Arctic cod

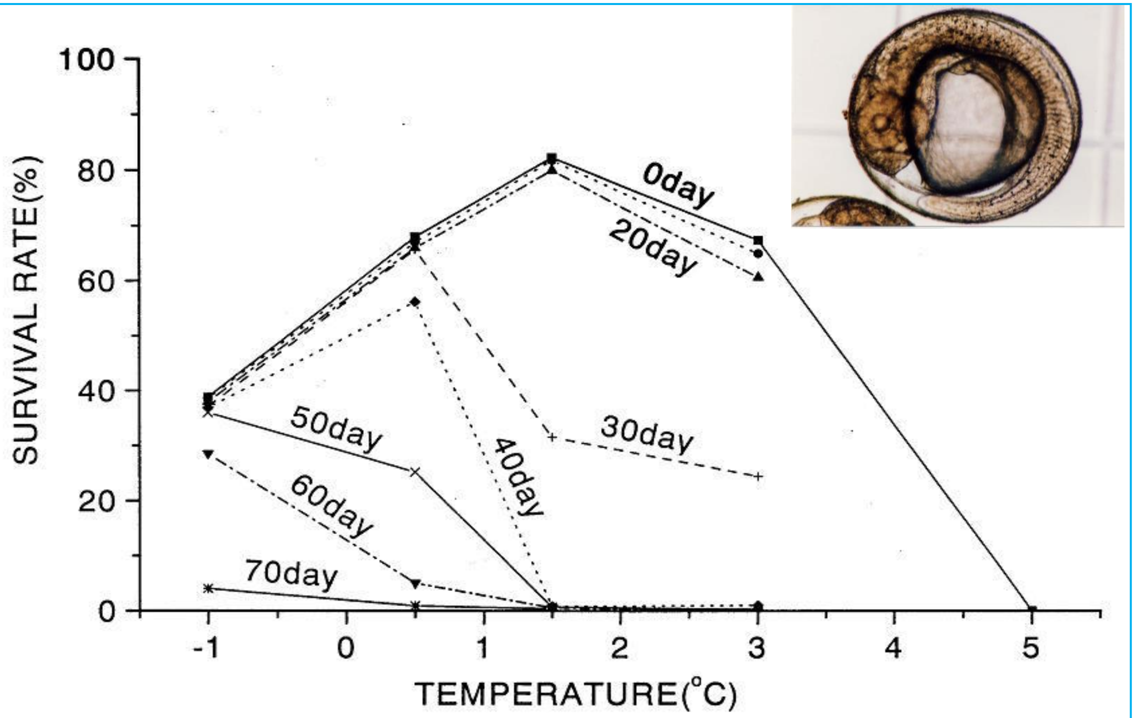
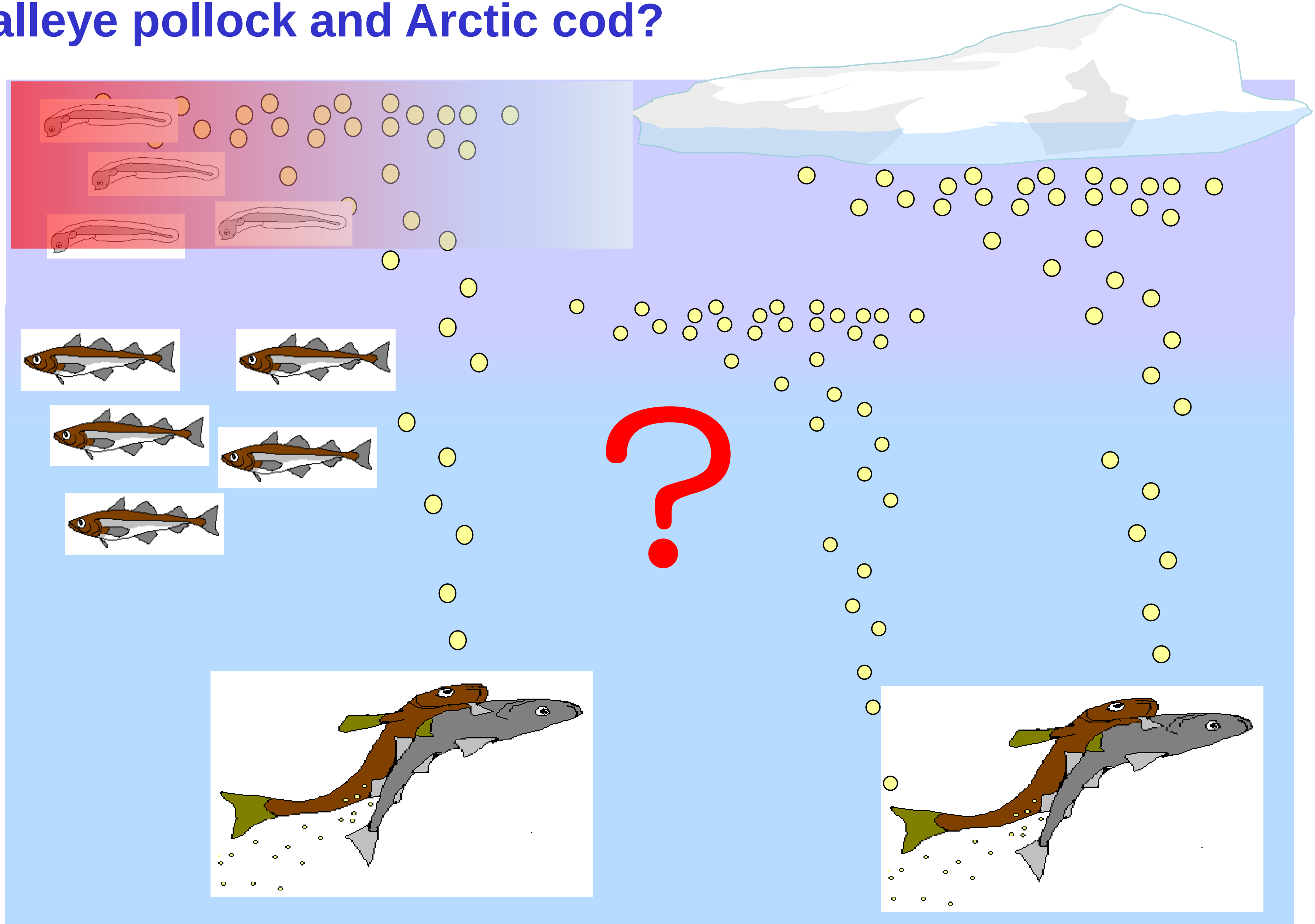


Fig. Survival rates at 10 day intervals of Arctic cod larvae from the 50% hatching date to 70 days post-hatching at temperatures between −1 to 5°C.

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

Sakurai *et al*. (1998)

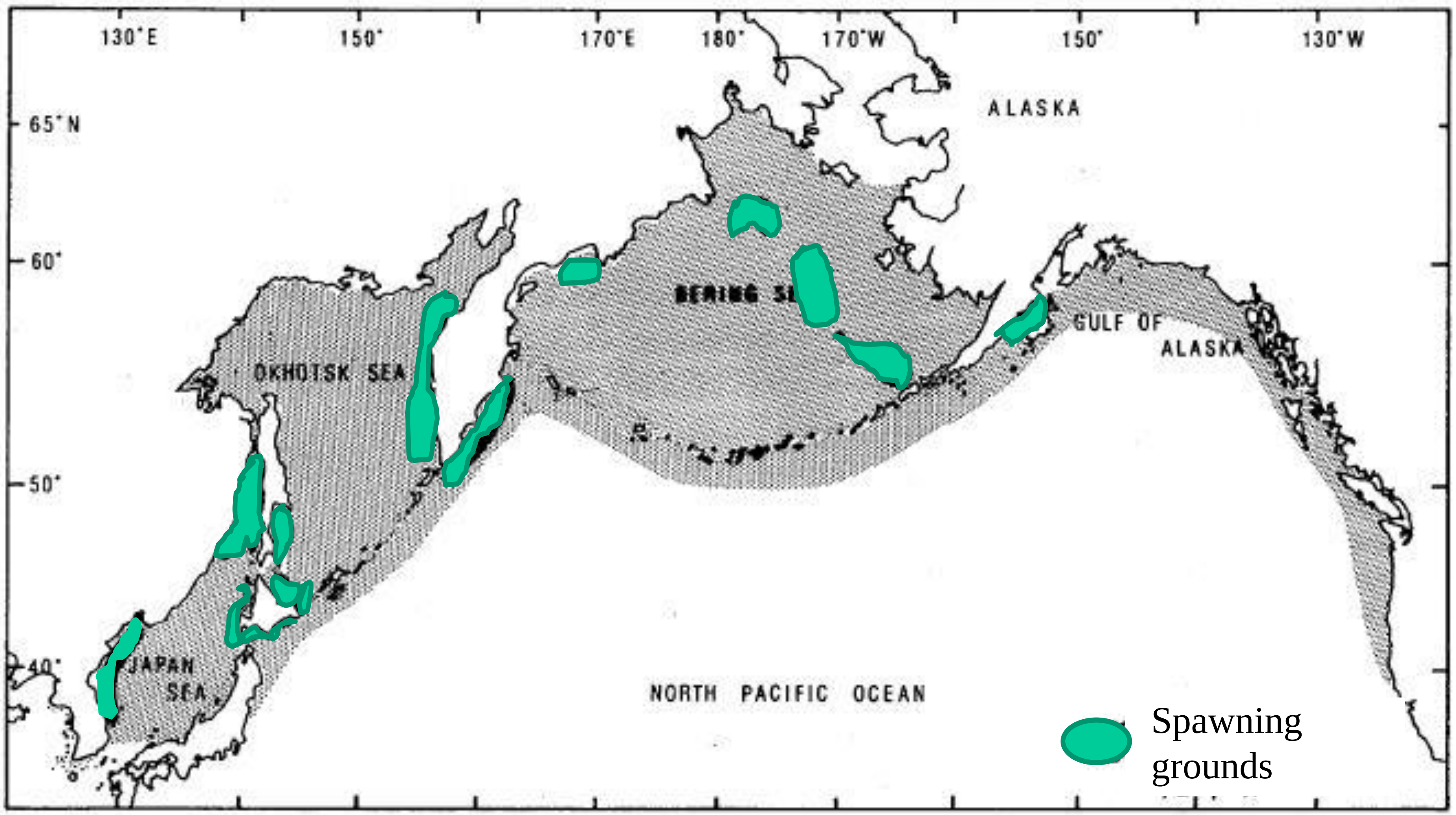
Do temperature and salinity of sea surface layer have a threshold values to survivals during the early life stages of walleye pollock and Arctic cod?



Why did walleye pollock decrease in the southern coast water along Korea and Japan?

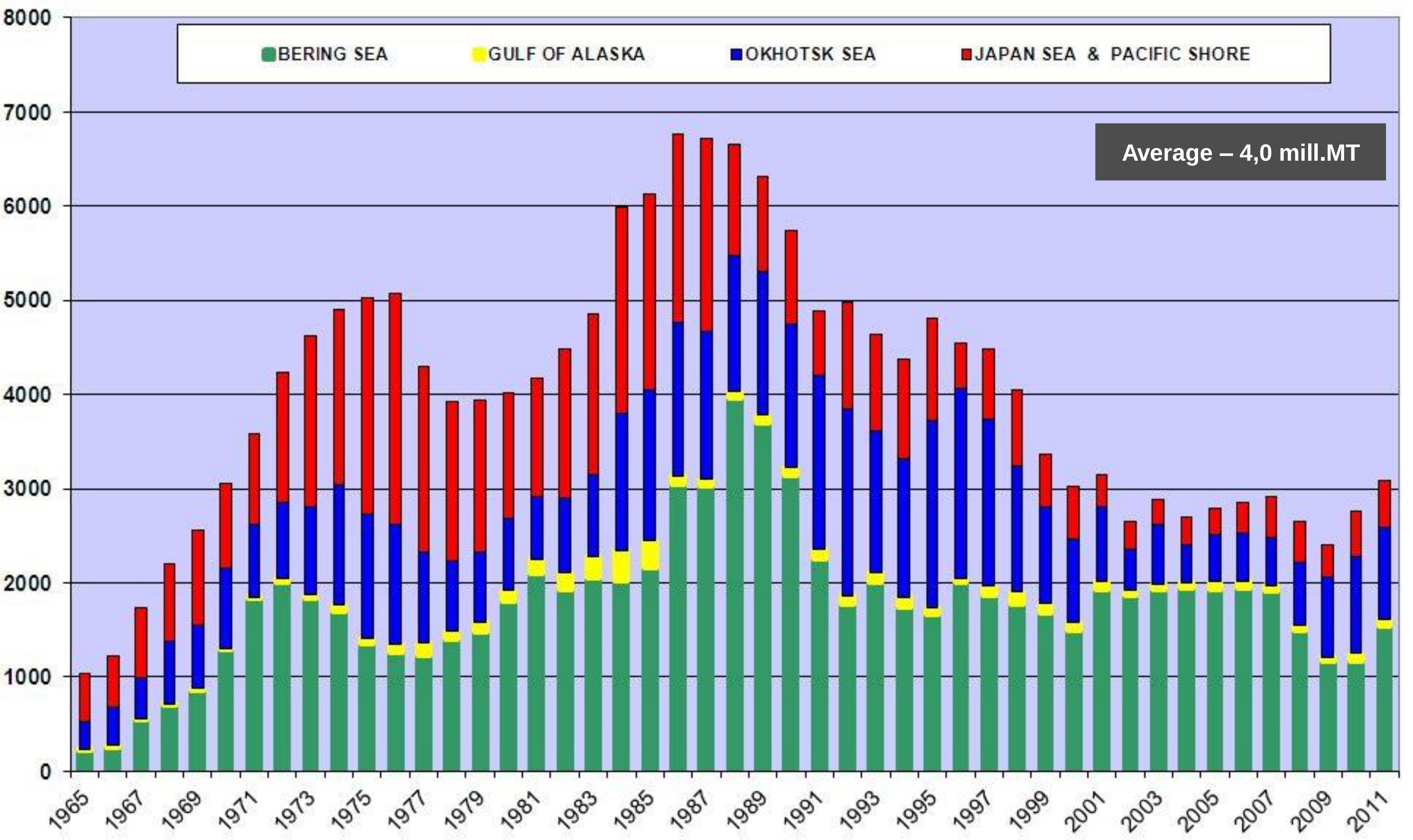
Walleye pollock

Distribution and spawning grounds of walleye pollock, *Gadus* (*Theragra*) *chalcogramma*, Pallas

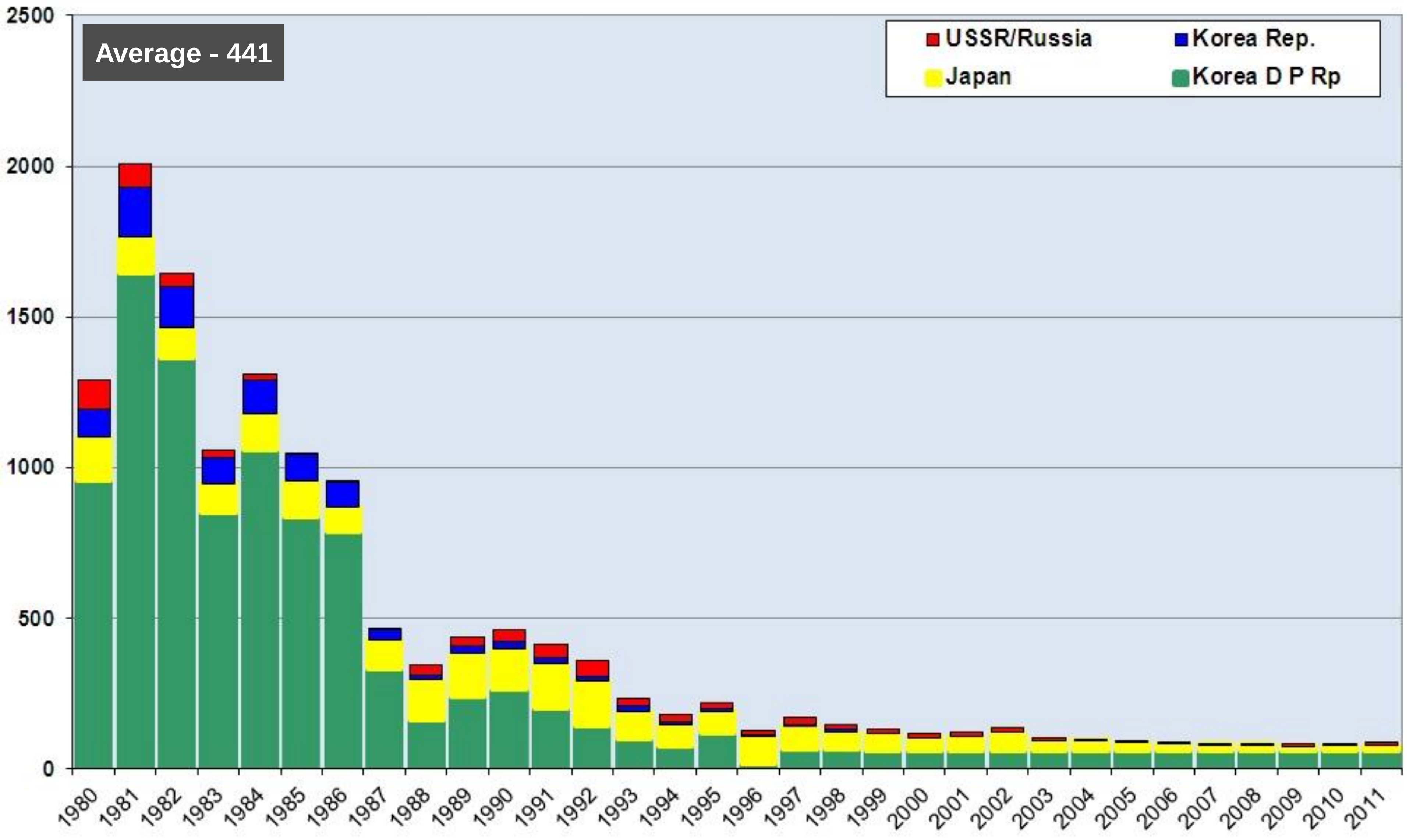


Walleye pollock landings by regions, thous.MT

(Blatov, 2014)

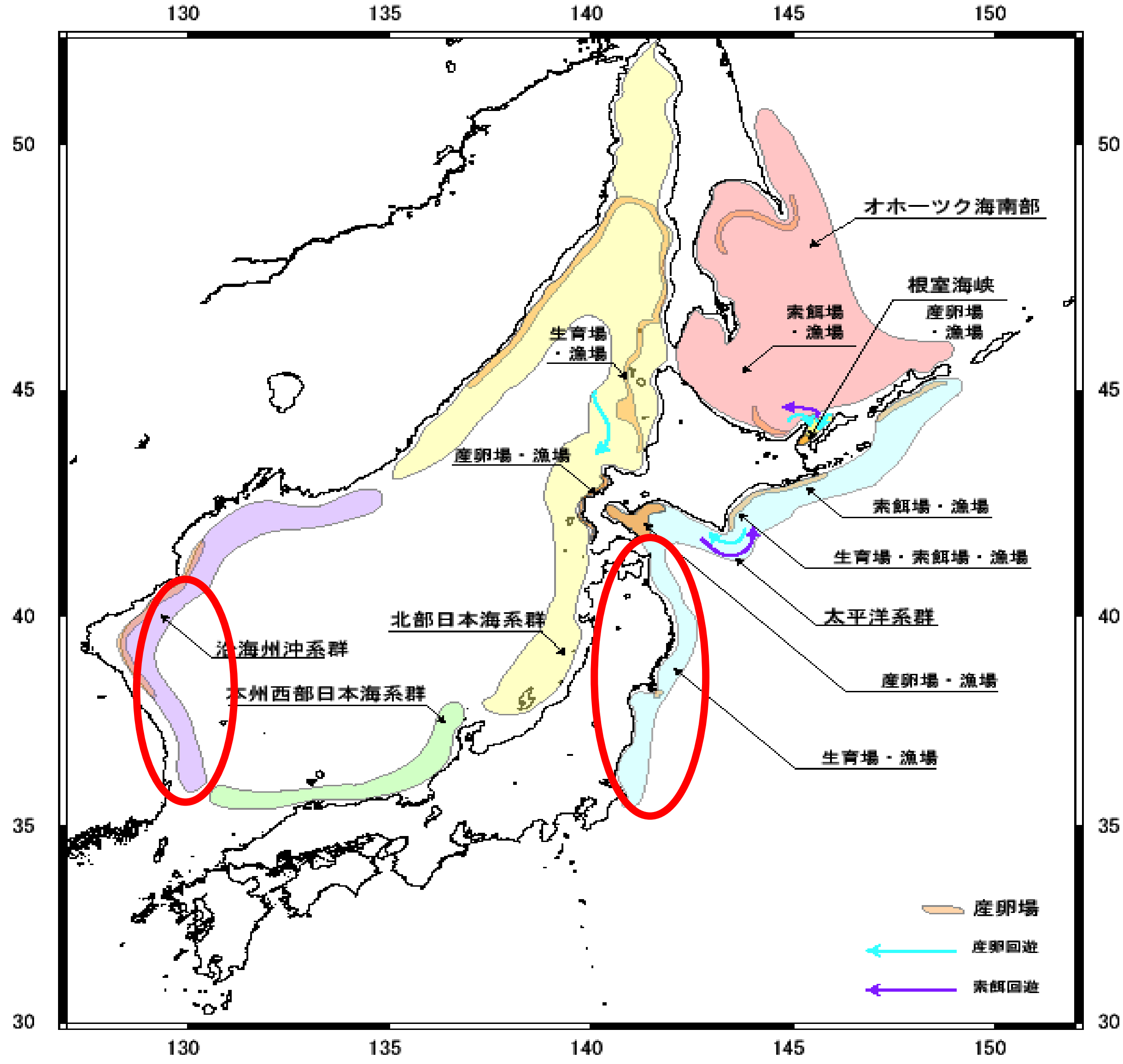


Walleye pollock catch in the Eastern/Japan Sea, thous.MT (Blatov,2104)



Source: Fadeev, Wespestad, 2001; FAO,2011, Makino, pers. comm.

The east coast stocks of Japan and Korea were decreasing after the late 1980s regime shift from cool to warm regime!



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Interannual fluctuations in recruitment of walleye pollock in the Oyashio region related to environmental changes

Osamu Shida[a,*], Tomonori Hamatsu[b], Akira Nishimura[b], Akifumi Suzaki[c], Jun Yamamoto[d], Kazushi Miyashita[d], Yasunori Sakurai[c]

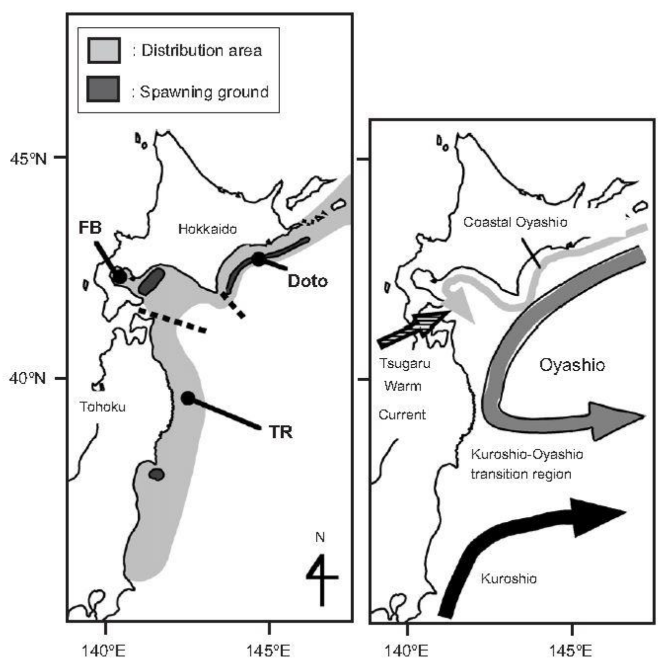


Fig. 1. The distribution and spawning grounds of the Japanese Pacific walleye pollock stock, and the main circulation features. The Dashed lines show the borders of the Doto area, Funka Bay (FB) area and the Tohoku region (TR).

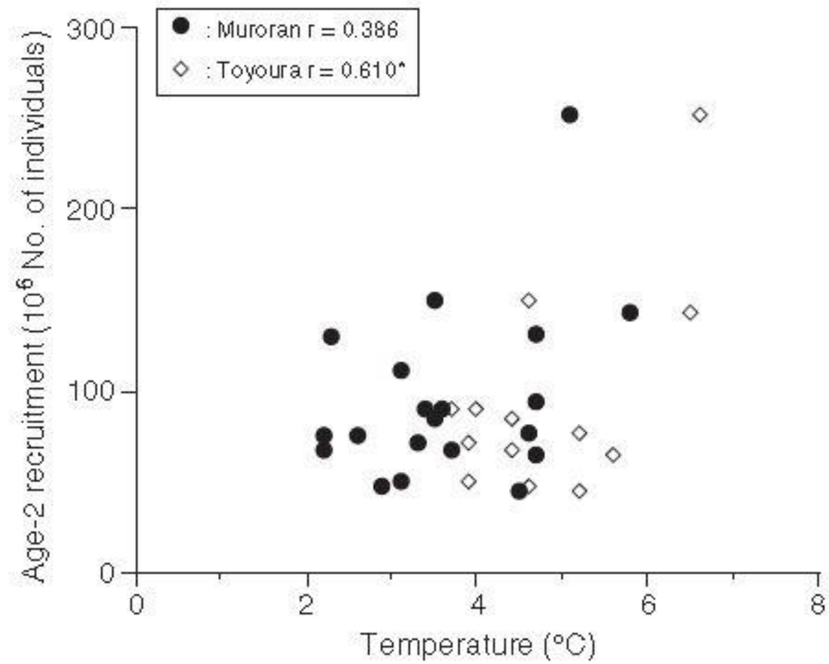


Fig. 6. The relationship between the average temperature for January February at the mouth of Funka Bay (Muroran) and inside Funka Bay (Toyoura; ca. 1986), and the number of age-2 recruits. * Significant at the 5% level.

Ratios of normal and abnormal hatch of walleye pollock at the different temperature and salinity in the captive experiment.

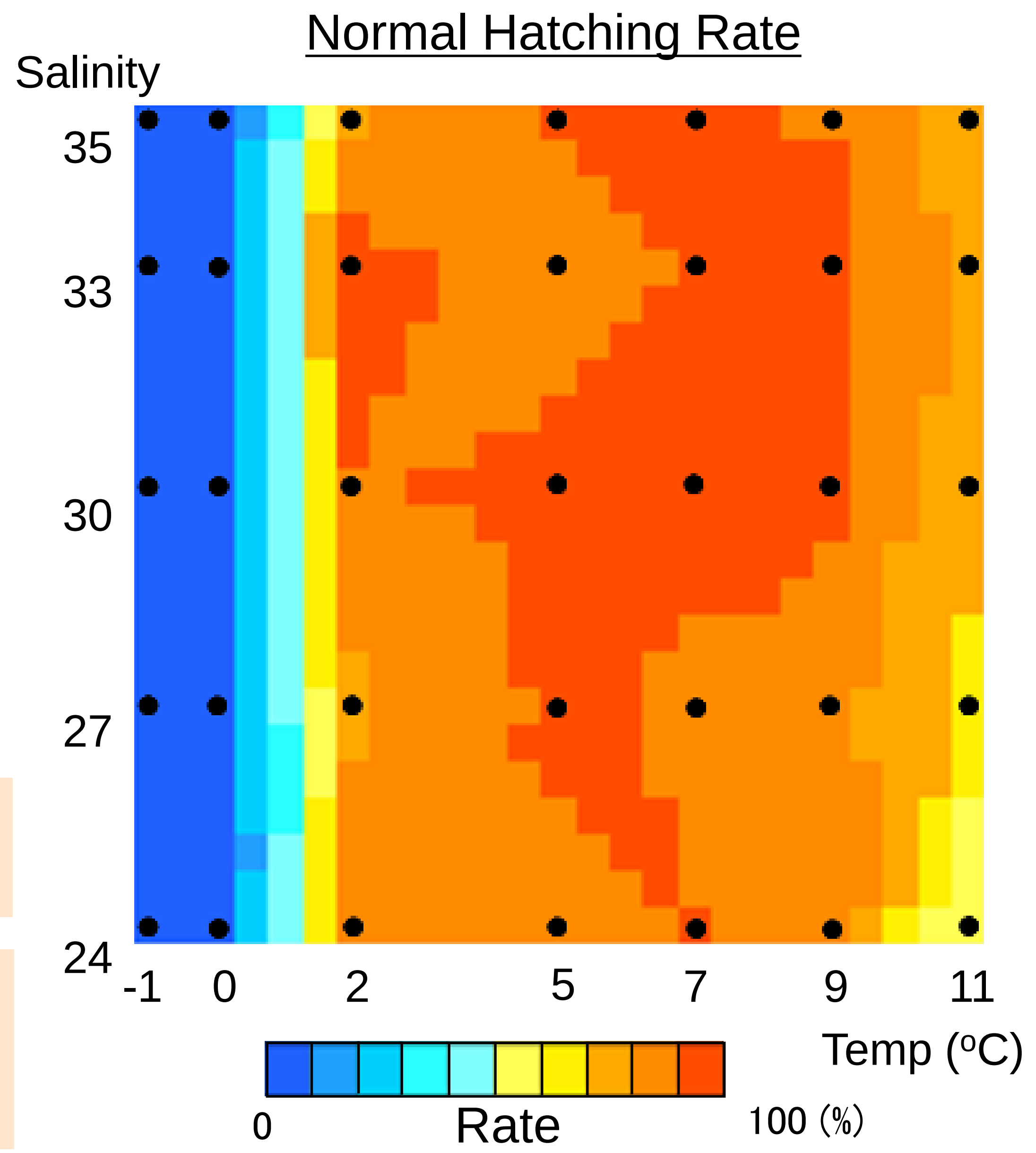
Normal Hatching Rate (%)

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

No clear difference among the salinities except 11°C

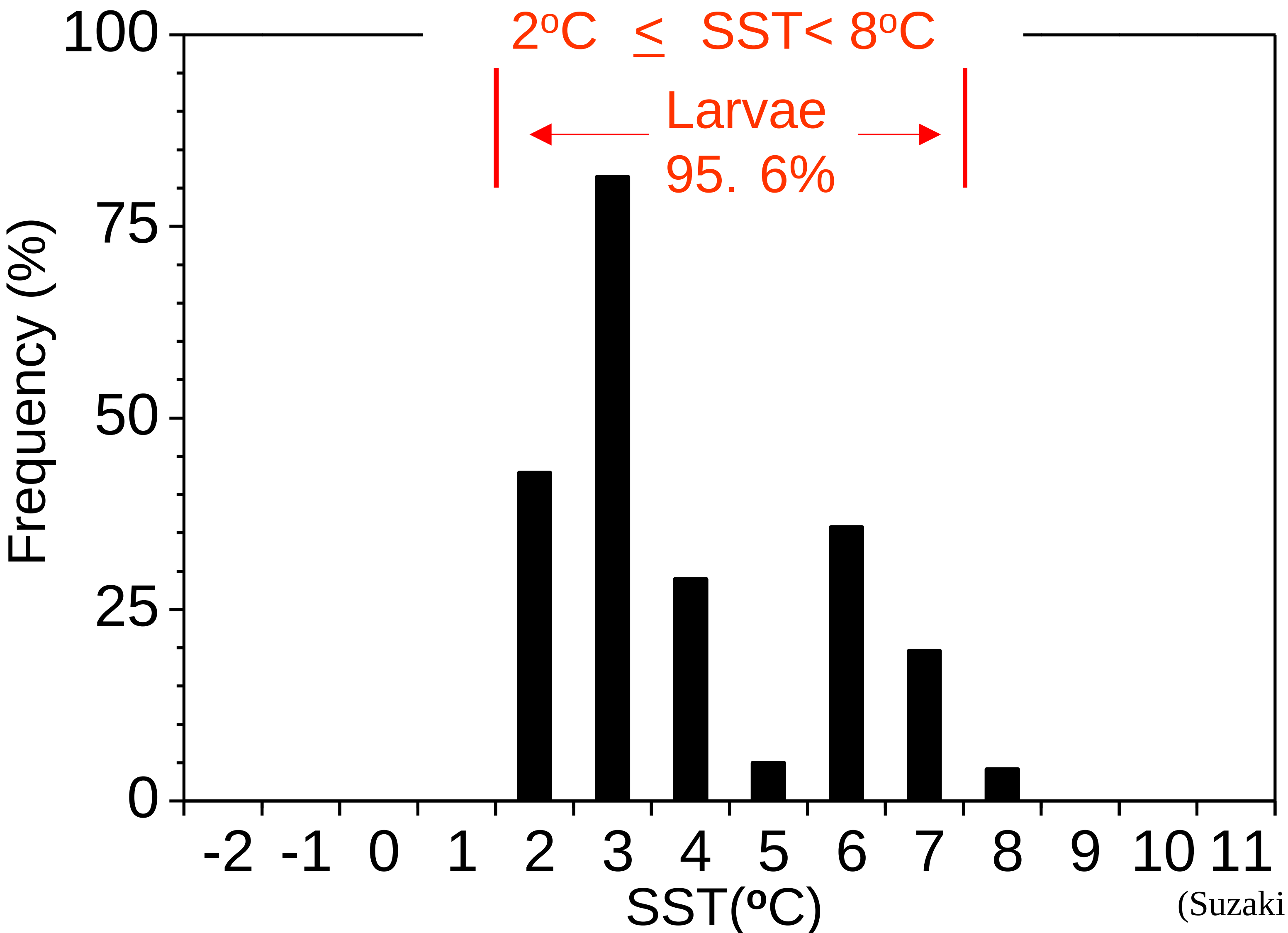
Normal hatching is controlled by temperature rather than salinity

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



HK Yoo, in review

Survival rate of larvae=number of larvae/number of eggs x 100
(at each sampling station)



(Suzaki et al., 2002)

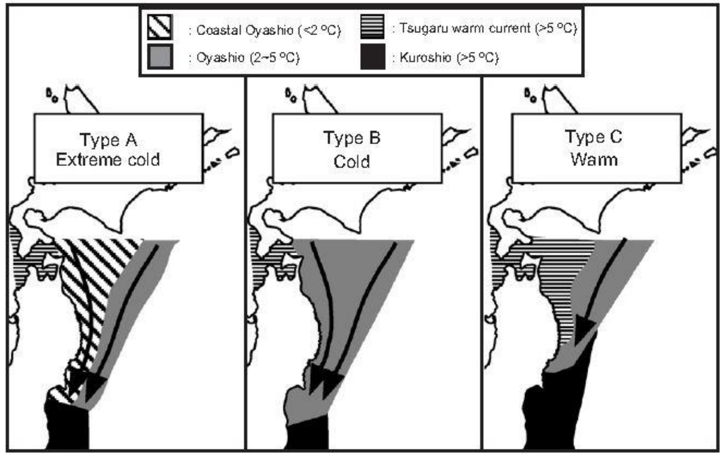


Fig. 7. The three types of oceanographic conditions in the Tohoku region categorized by Suzaki (2003). Arrows indicate direction of current flows.

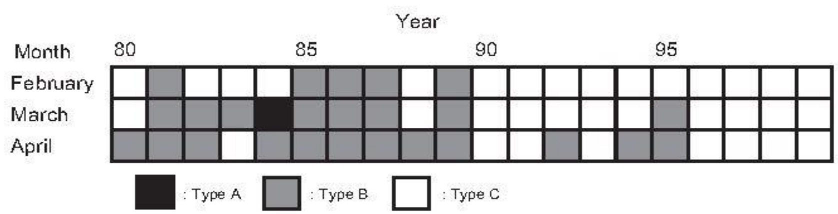


Fig. 8. Interannual variation in the types of oceanographic conditions in the Tohoku region from February to April (Suzaki, 2003).

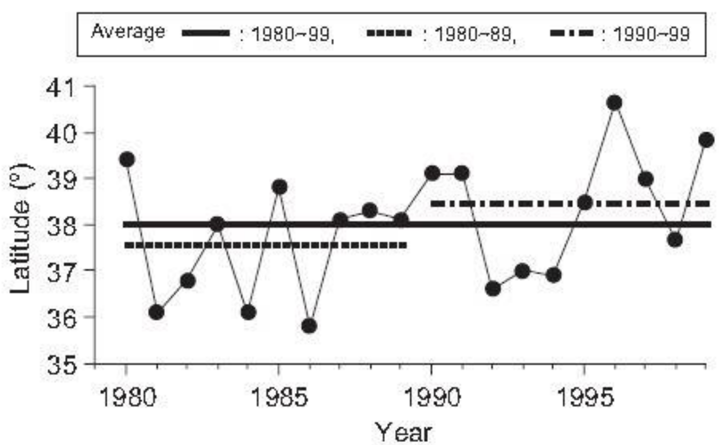


Fig. 9. Interannual variation in the latitude of the southern limit of the Oyashio (Nihira et al., 2003).

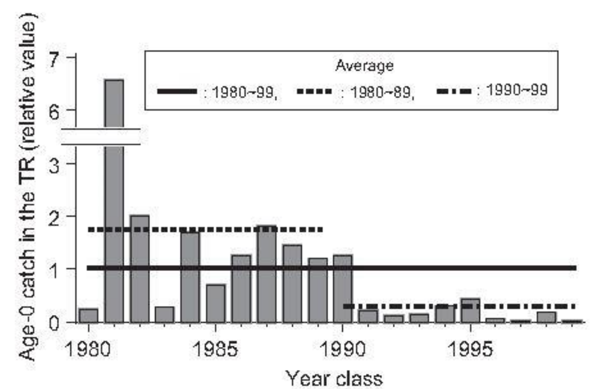
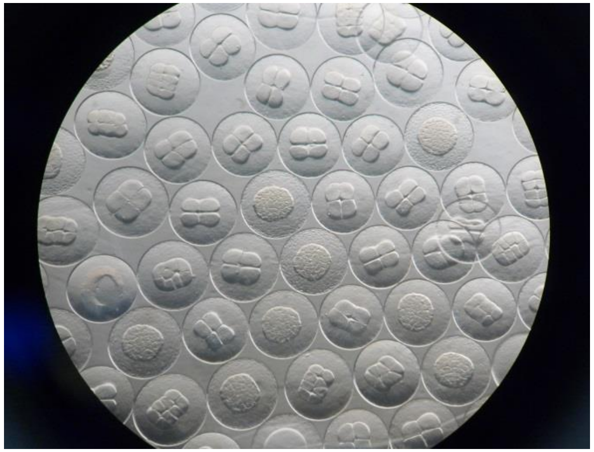
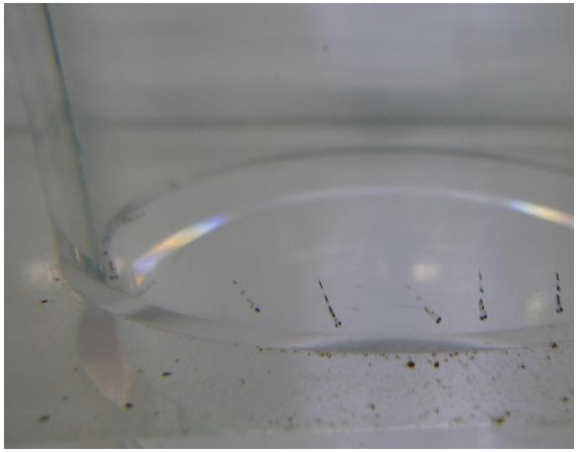


Fig. 10. Interannual fluctuation in the relative catch of age-0 walleye pollock in the Tohoku region by commercial fisheries as an index of age-0 abundance in this region (Tohoku National Fisheries Research Institute, unpublished data). The unit is the relative value, which is scaled to the average value from 1980 to 1999 as 1.

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

Hae-Kyun Yoo, Jun Yamamoto, Yasunori Sakurai



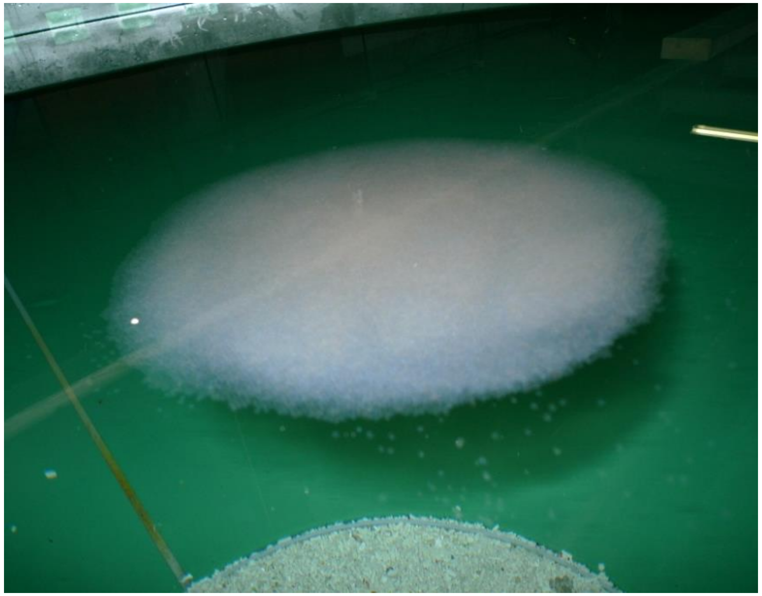


Materials and methods:
Collect the eggs

Rearing of the adults

- 10 ton tank
- temperature 5^{o}C
- salinity 33

Collection of the natural spawned eggs



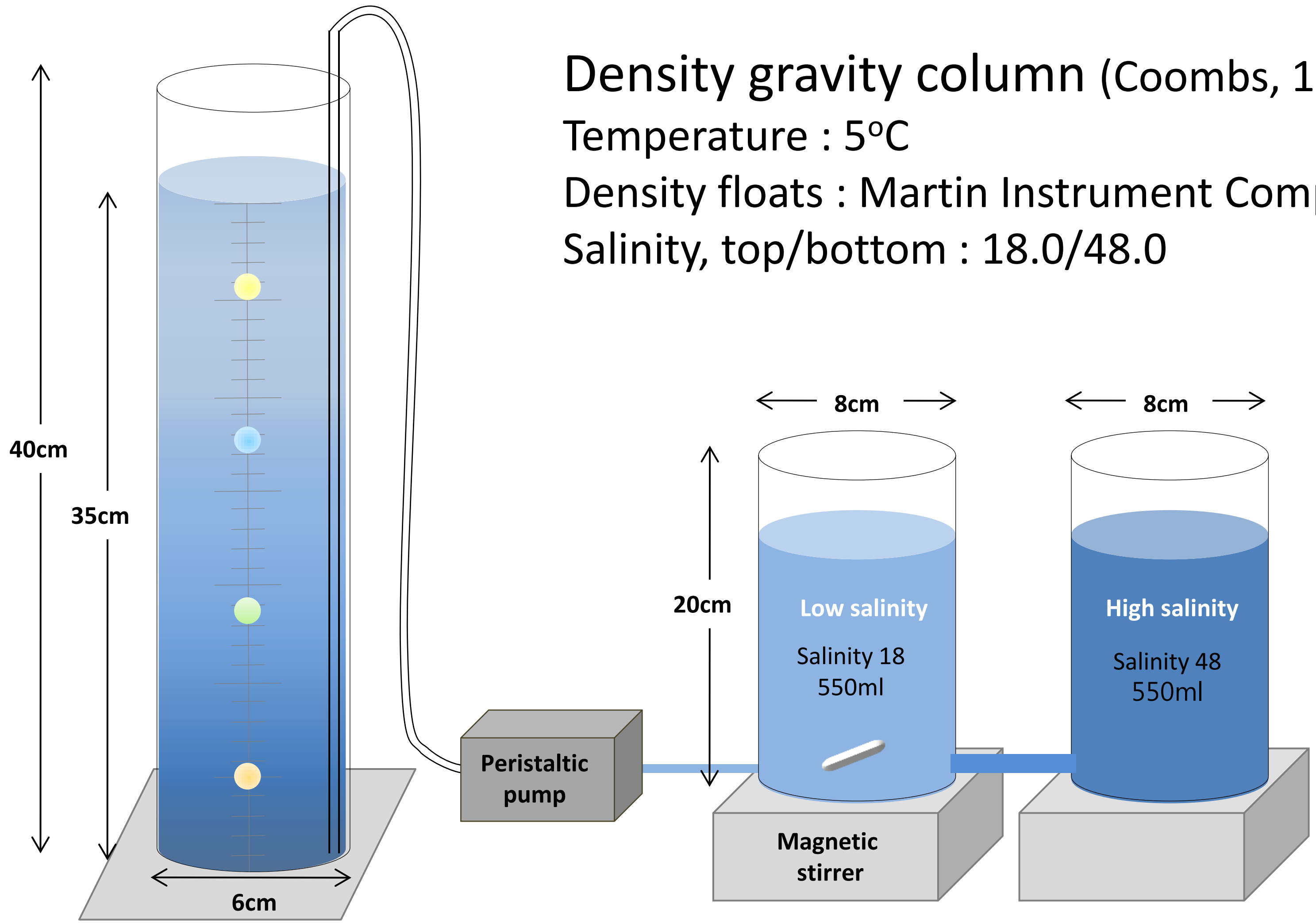
Materials and methods: Experiment 1
Density (σt) of egg during development

Density gravity column (Coombs, 1981)

Temperature : 5°C

Density floats : Martin Instrument Company

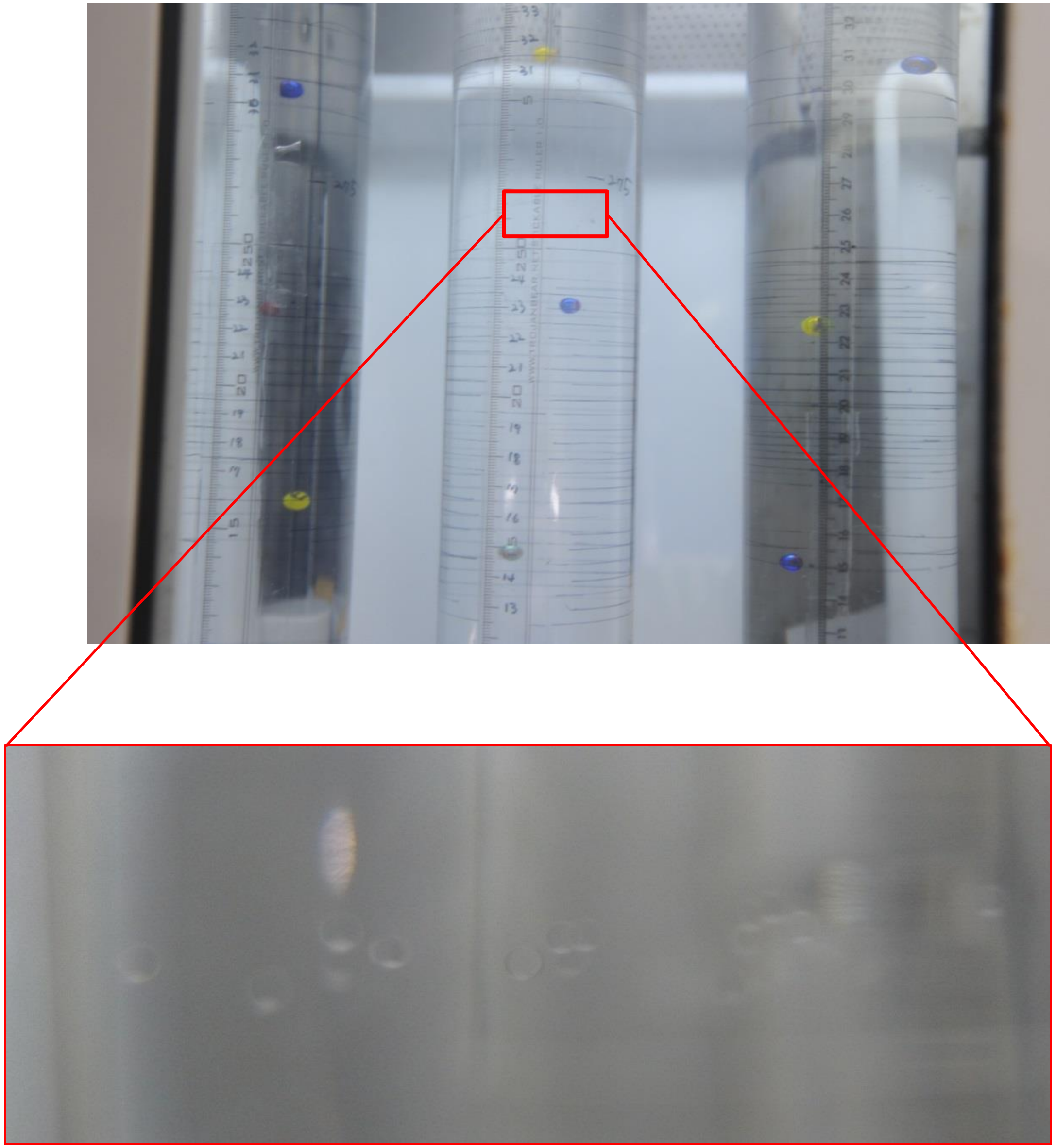
Salinity, top/bottom : 18.0/48.0



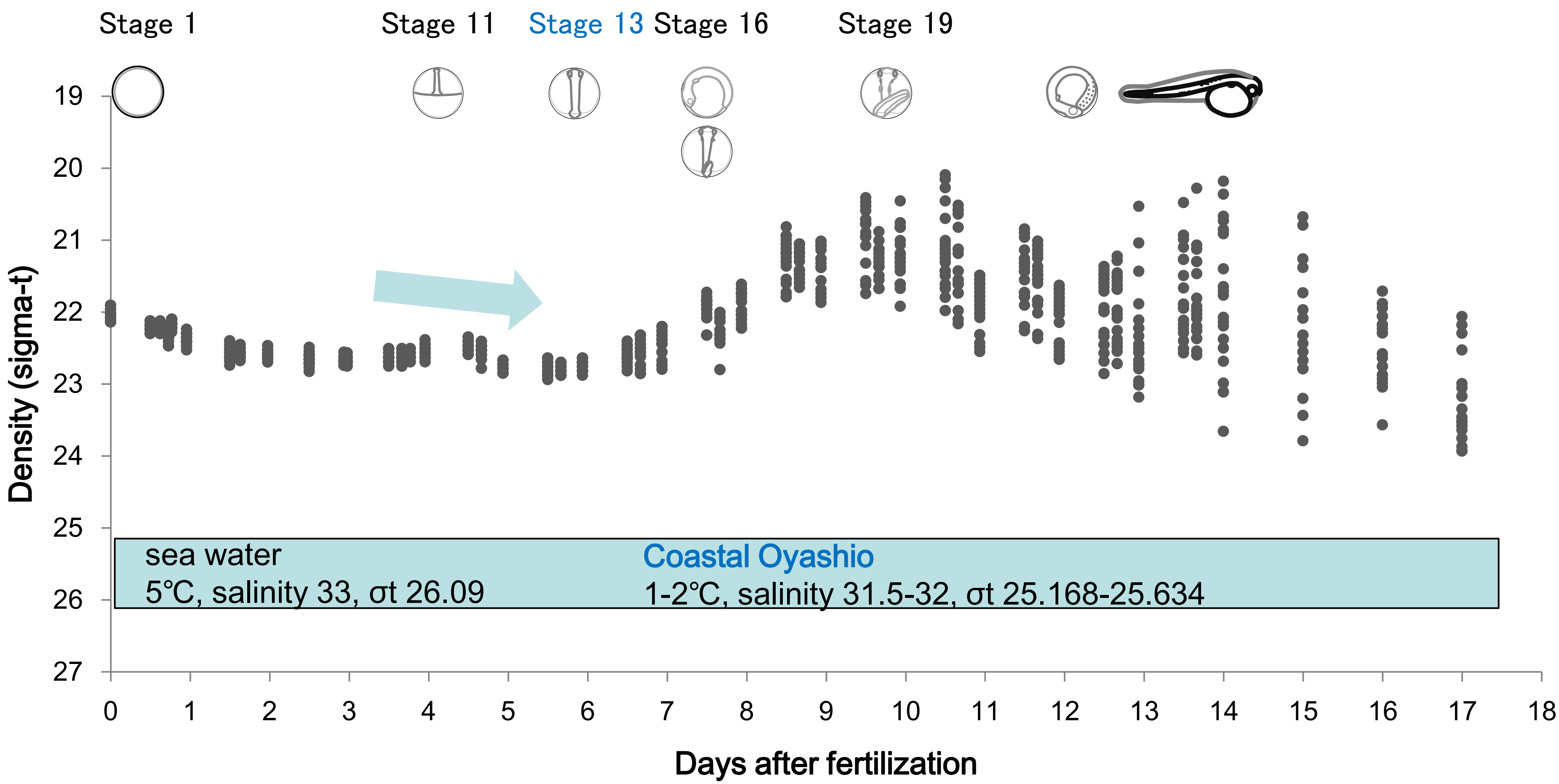
Filtered seawater

Materials and methods: Experiment 1
Density (σt) of egg during development

- 20 fertilized eggs were gently inserted from the top of the column
- The eggs were compared with the positions of four density floats of known specific gravity



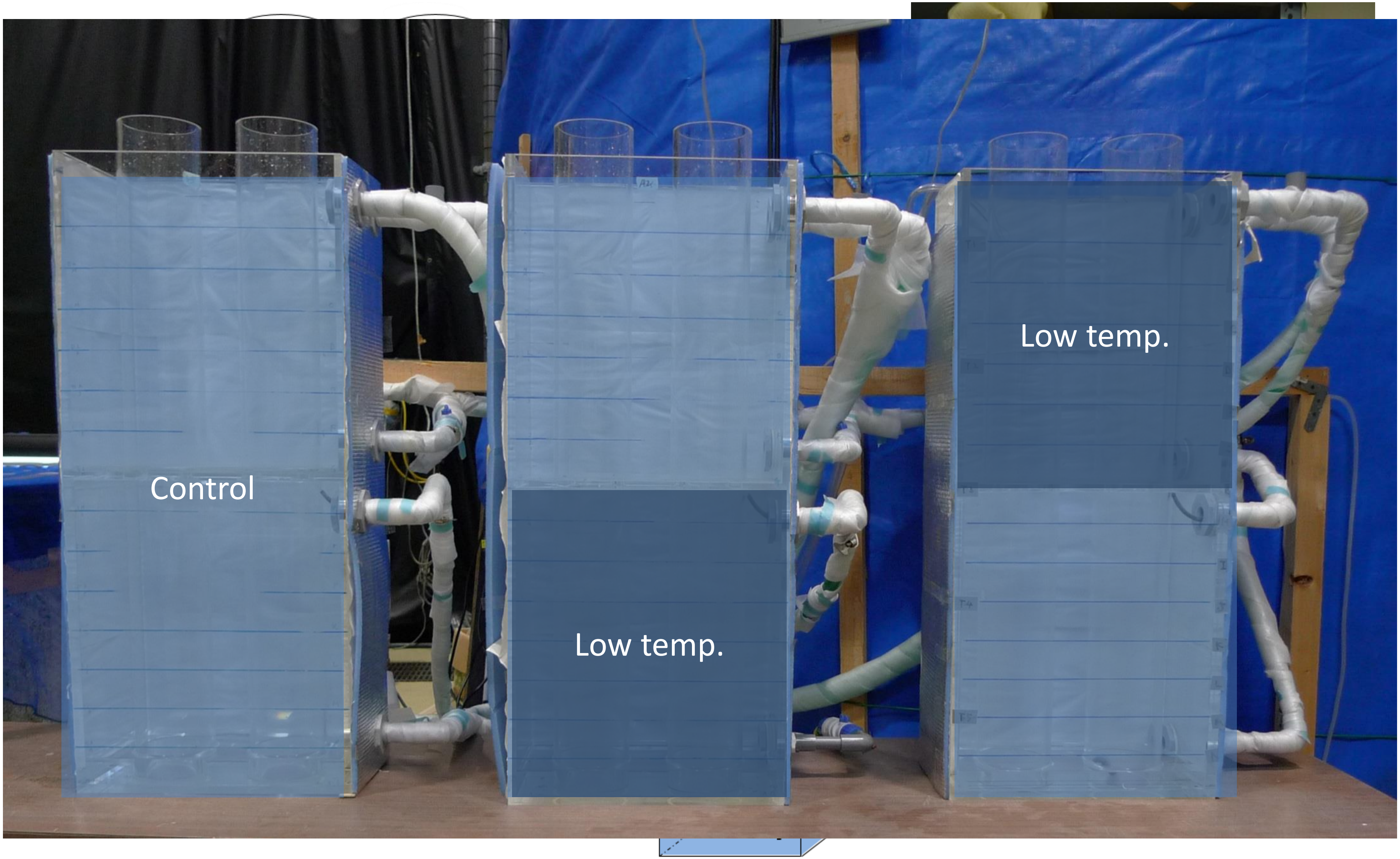
Results: Experiment 1
Density (σt) of egg during development



The density ranged from 20.0 – 23.9 (σt), and slightly increased from stage 1 through stage 13

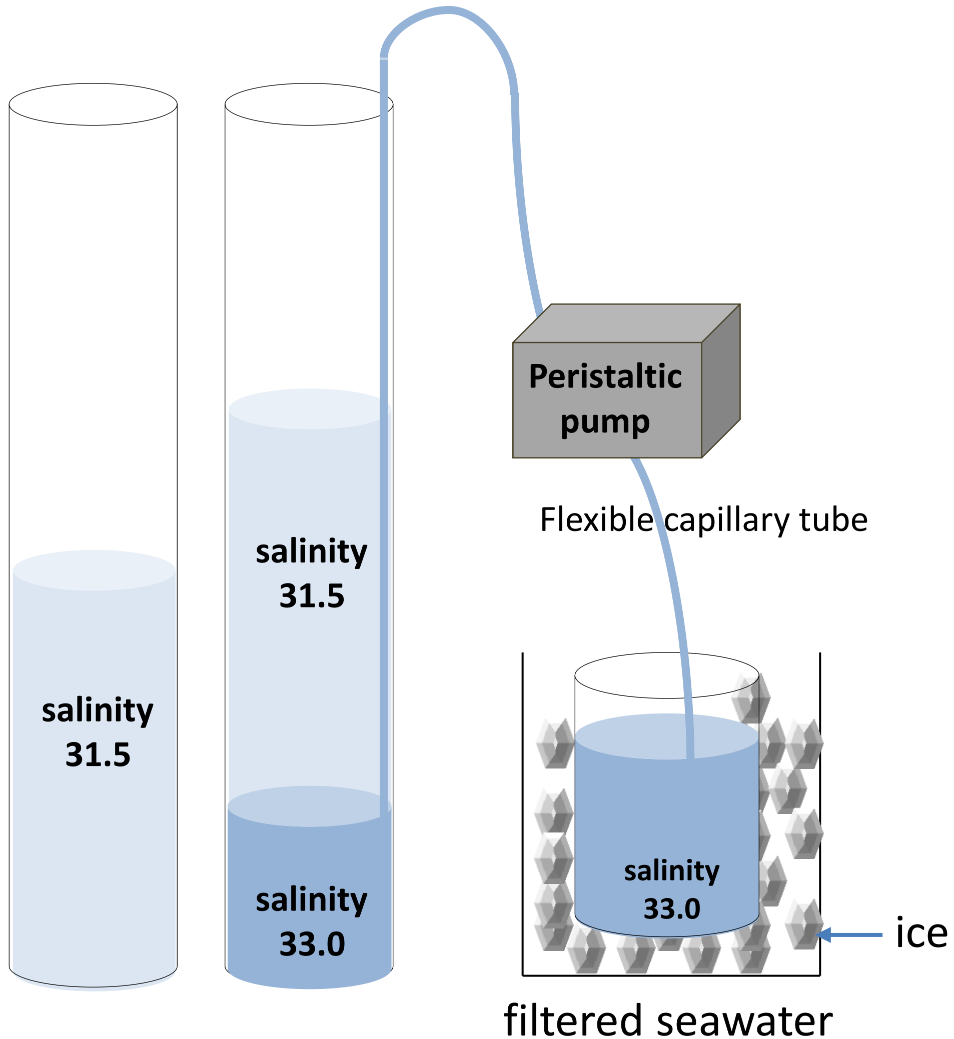
Eggs are exposed to the surface cold water in the early developmental stage.
But, eggs resist cold water after morula stage (Nakatani and Maeda 1984)

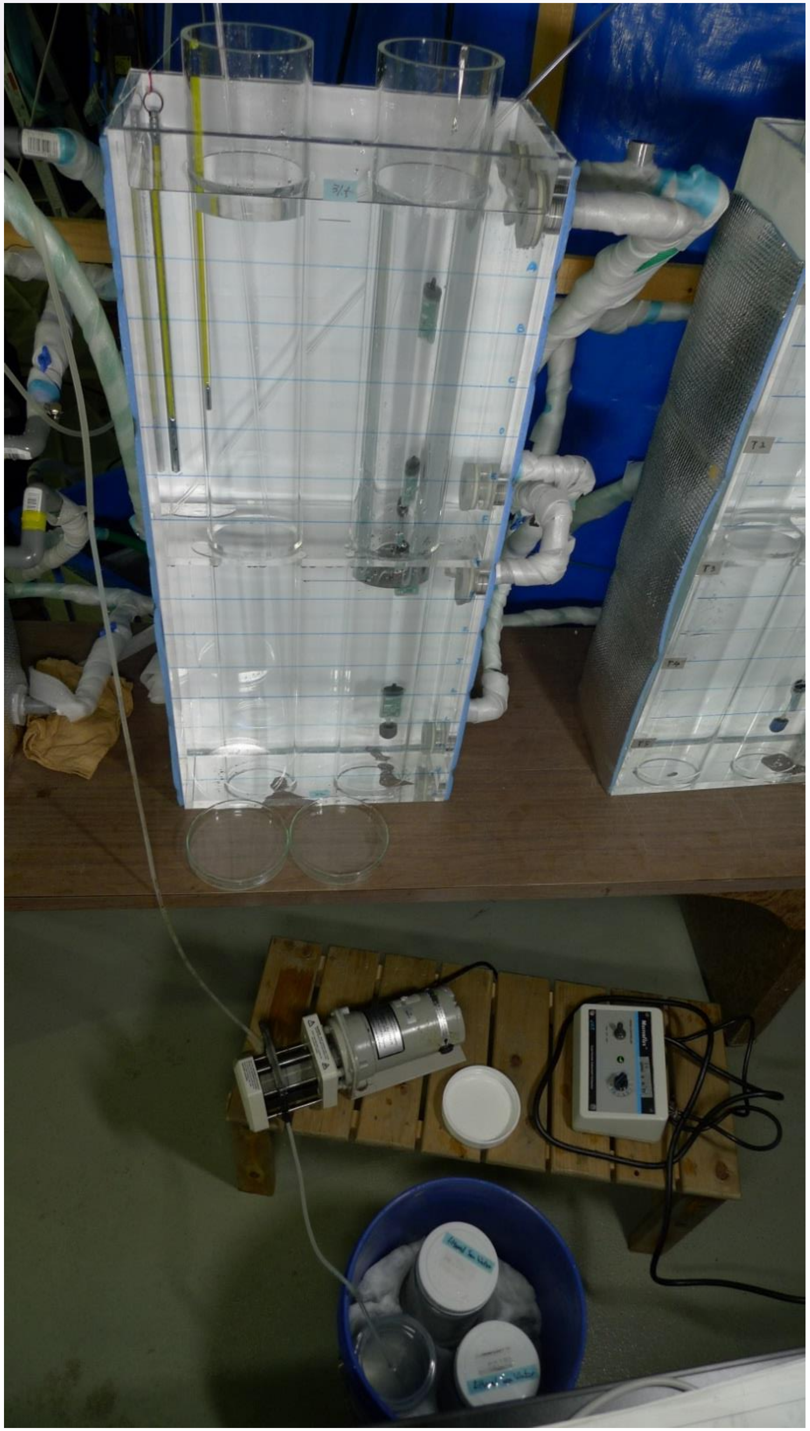
Materials and methods: Experiment 3
Thermocline tank system



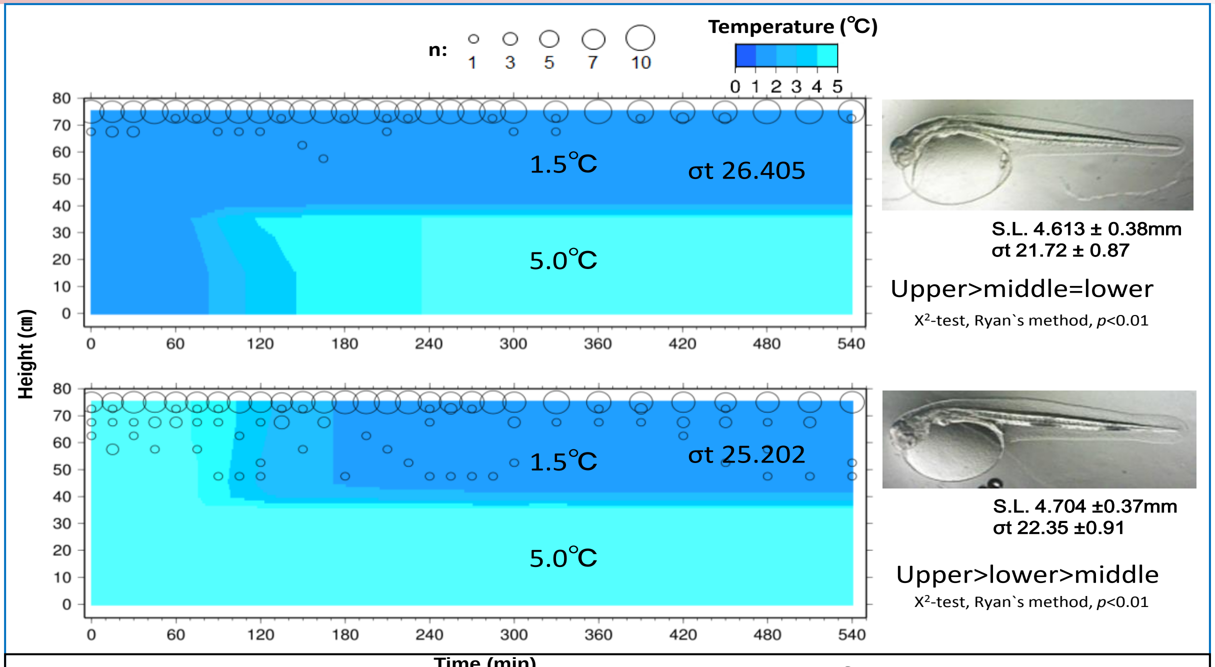
Materials and methods: Experiment 3
Thermocline tank system

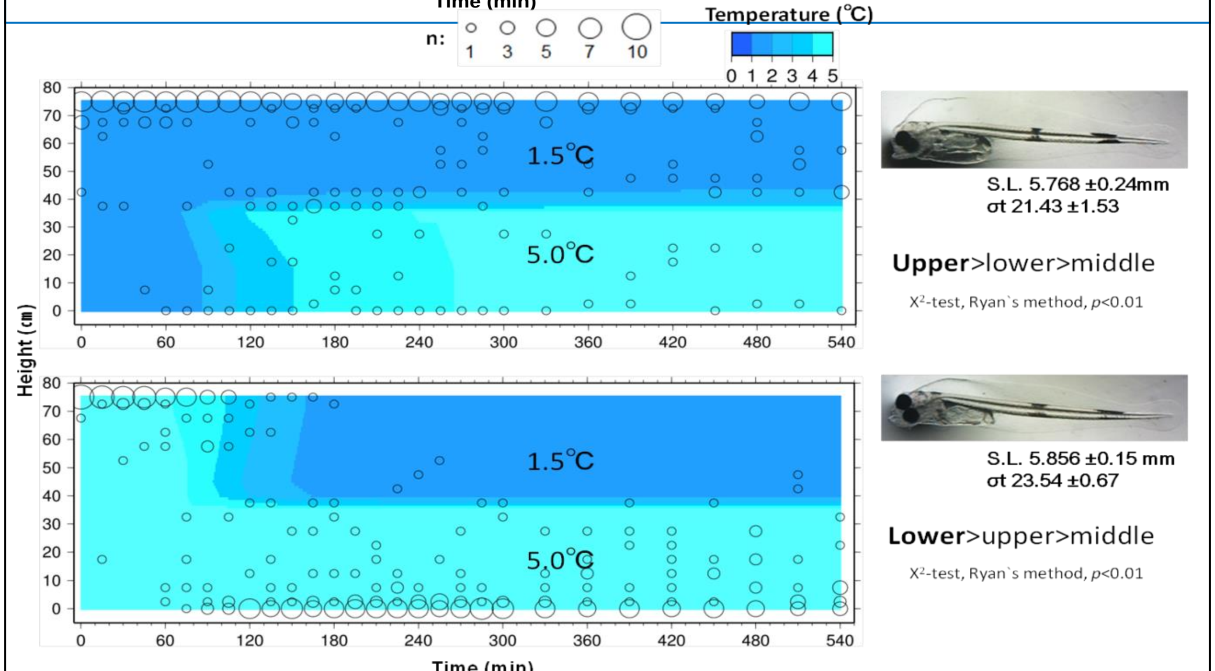
Generation for thermoclines





Results: Experiment 3Yolk sac larvae (<1day to 15 days)





Results

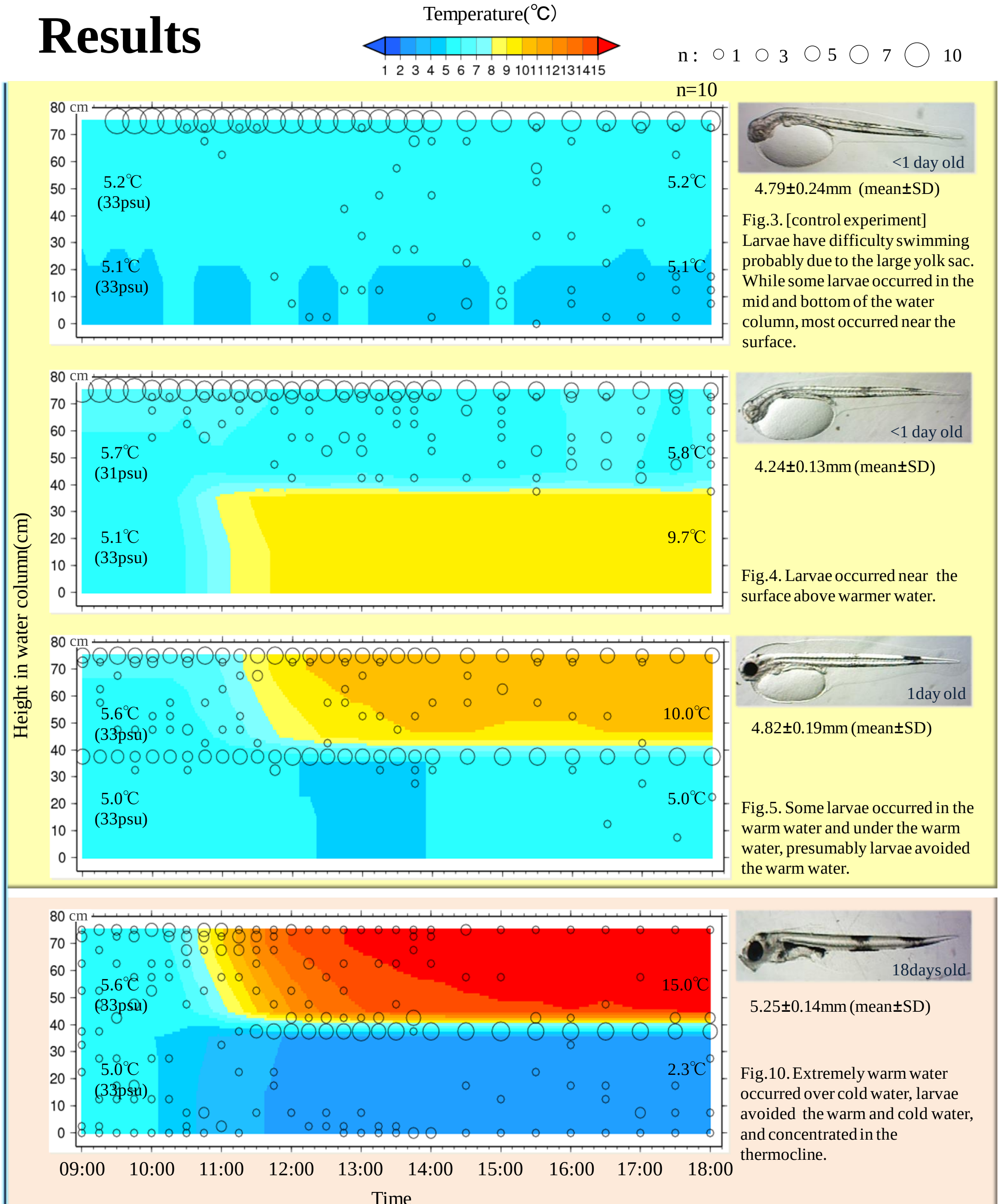


Fig.3. [control experiment] Larvae have difficulty swimming probably due to the large yolk sac. While some larvae occurred in the mid and bottom of the water column, most occurred near the surface.

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

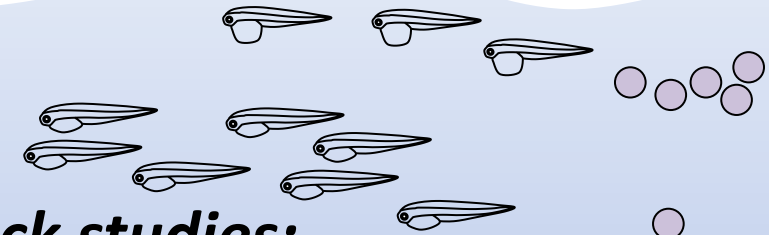
Fig.5. Some larvae occurred in the warm water and under the warm water, presumably larvae avoided the warm water.

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

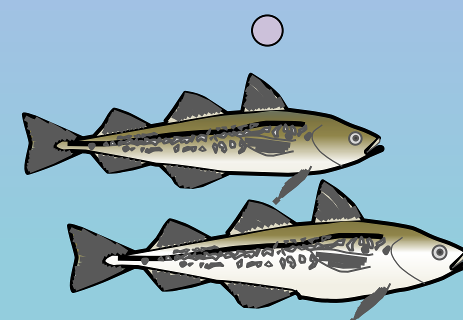
larvae≤15 days old avoided warm and cold water, and selected near the thermocline

Summary



An example of captive walleye pollock studies;

- Eggs are exposed to cold or warm surface water in their early developmental stages
- Lower ($<2^{o}C$) and higher (>10-$12^{o}C$) water temperature was unfavorable condition for the larval survival
- ≤1day old larvae indicated less vertical change than older larvae
- As the larvae developed, and yolk-sac absorbed, the larvae were able to alter their position in the water column, which allowed them to avoid unfavorable temperatures.
- We need more information on their early life stages of gadid fishes at different environmental conditions such as those experienced during climate regime shifts and global warming



Thank you for your attention

Photo by Haruuna Ueki, Off Rausu