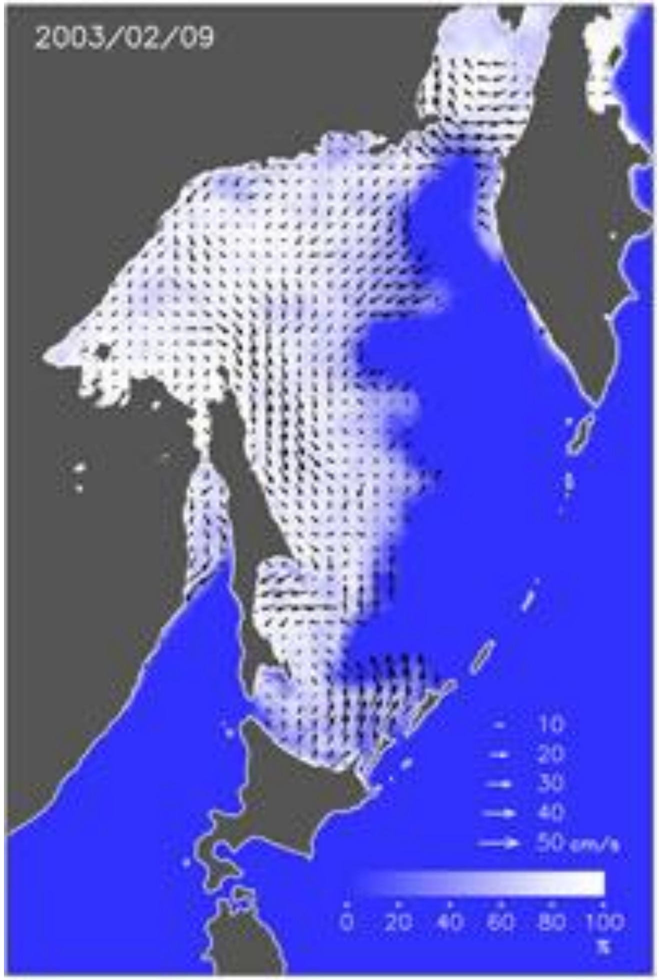
Hokkaido University
Arctic Research Center

INTERNATIONAL YEAR OF THE SALMON

Influence of climate warming for migration, growth and survival of Japanese chum salmon in the North Pacific Ocean and the Okhotsk Sea



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北海道大学
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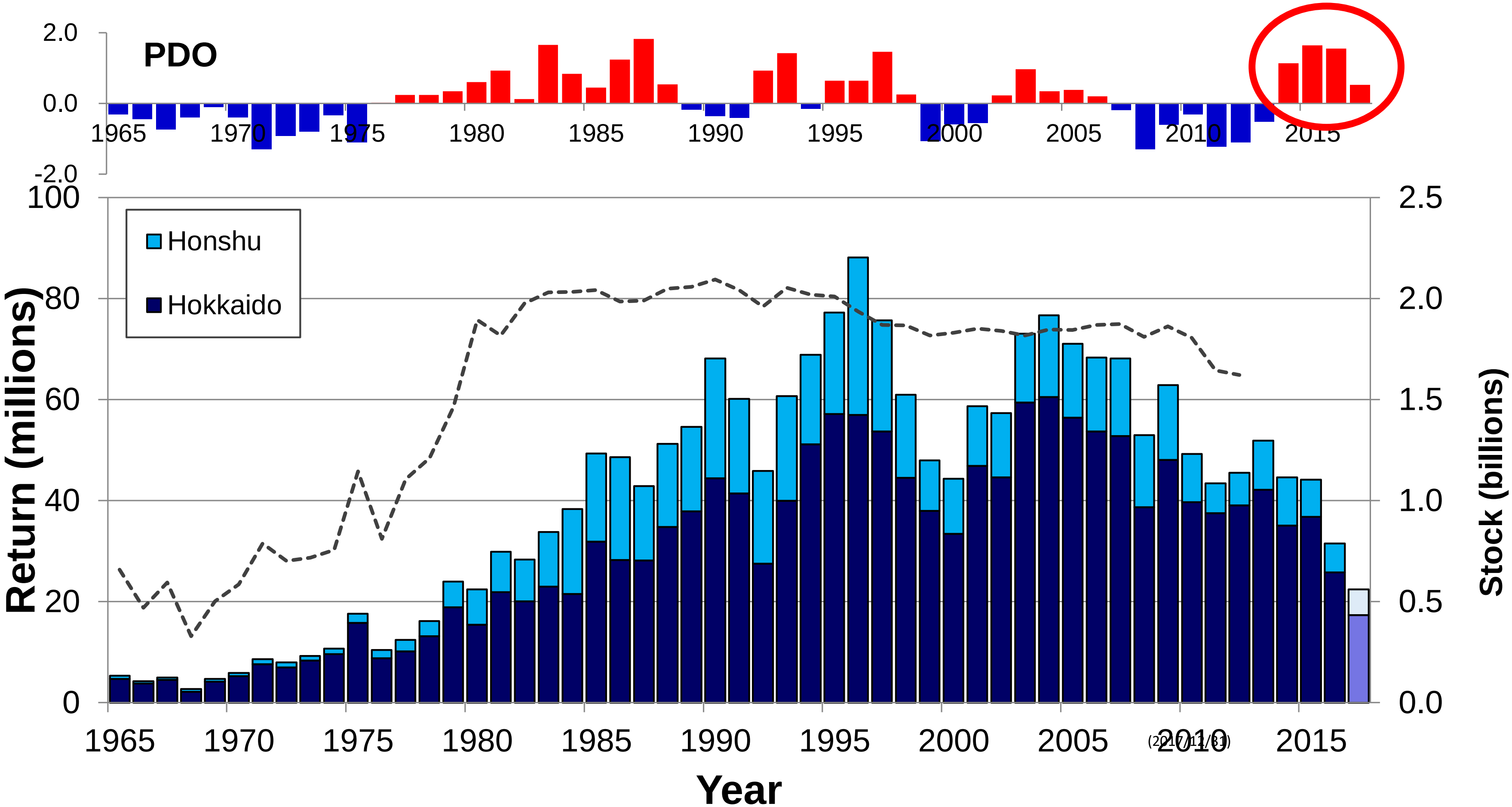
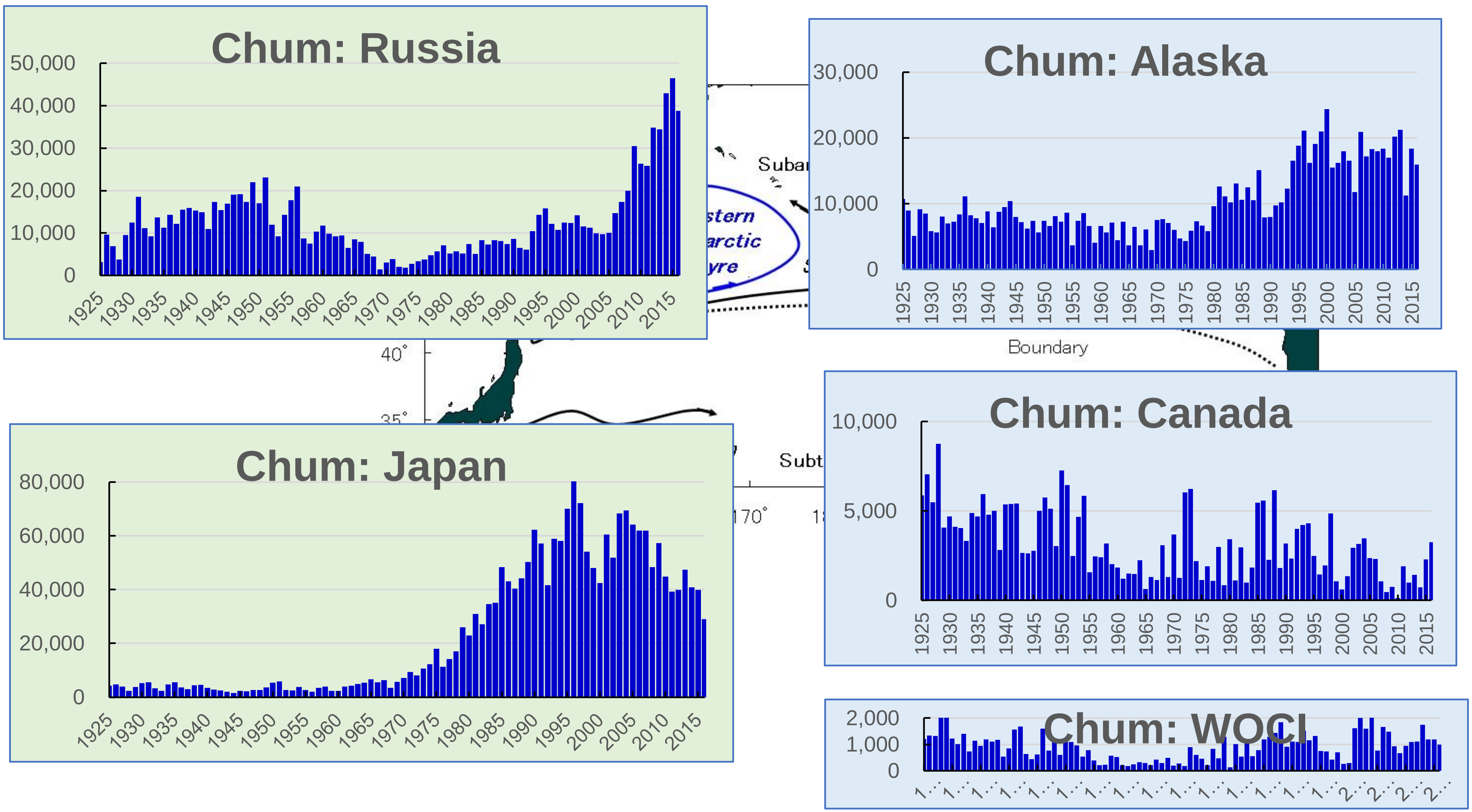
■ **Temporal changes in return of Japanese chum salmon and PDO (1965-2017)**



■ Annual change in catch of chum salmon in the North Pacific

- Southern populations: Decreasing
- Northern populations: Increasing or high stable

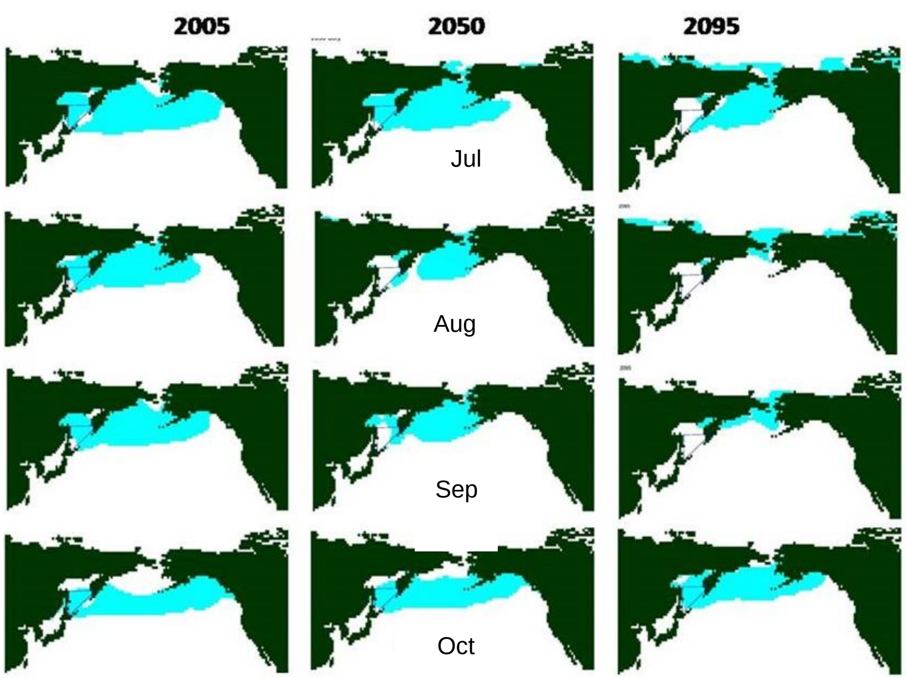


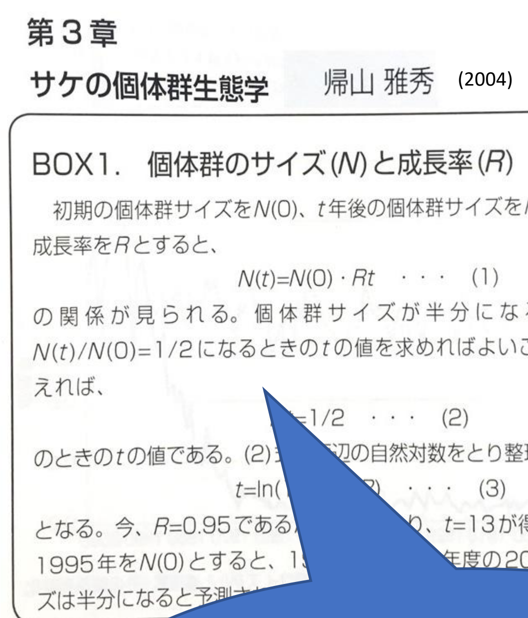
Data Source: NPAFC

■ It was predicted ………

- “Population size of Japanese chum salmon became a half of the maximum by around 2010 because of the new climate regime shift.” (Kaeriyama 2004)
- “The global warming will affect the distribution of chum salmon in the North Pacific in this century” based on the IPCC SRES-A1B scenario. (Kaeriyama 2008)

Prediction of areas of optimum temperature for chum salmon based on the IPCC SRES-A1B scenario (Kaeriyama 2008)





第３章

サケの個体群生態学　帰山 雅秀 (2004)

BOX1.　個体群のサイズ(*N*)と成長率(*R*)

初期の個体群サイズを*N*(0)、*t*年後の個体群サイズを*N*

成長率を*R*とすると、

$N(t)=N(0) \cdot Rt$　・・・　(1)

の関係が見られる。個体群サイズが半分にな

N(*t*)/*N*(0)=1/2になるときの*t*の値を求めればよいこ

えれば、

=1/2　・・・　(2)

のときの*t*の値である。(2)　辺の自然対数をとり整理すると、

t=ln(　　)　・・・　(3)

となる。今、*R*=0.95である　り、*t*=13が得られる。すなわち、

1995年を*N*(0)とすると、1　年度の2008年に個体群サイ

ズは半分になると予測さ

Hokkaido chum salmon

Max: 60 millions in 2004

Half period: 30 millions in 2016

R=-0.0656

■ Objects and Methods

● Objects

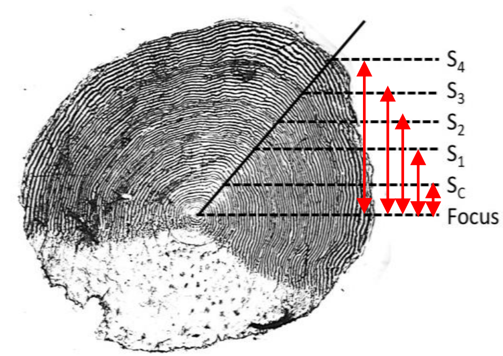
- To verify my prediction on the global warming
- To address potential progress of the global warming effect on Japanese chum salmon

● Material & Method

- Sea surface temperature (SST) in the North Pacific:
  1) COBE-SST in Japan Meteorological Agency (1º×1º, 1975-2017)
  2) NOAA-ESRL-PSC (1948-2017)
- Growth back-calculation using the scale analysis of adult chum salmon returning to the Tsugaruishi River in the Sanriku Coast (1996-2017)

● Definition

- Adaptable temperature (AT): 5-12 ºC
- Optimum temperature (OT): 8-12 ºC
- Using the data on growth rate, feeding behavior, and CPUE for chum salmon



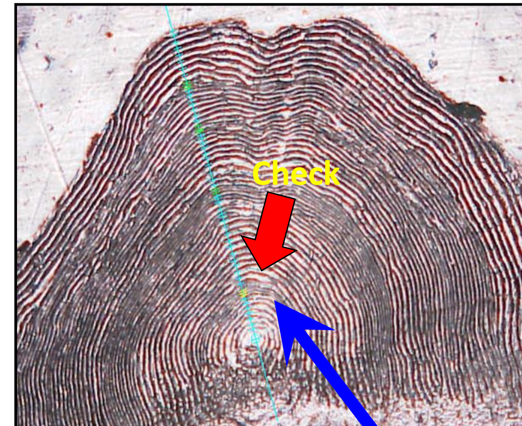
$L_i = FL - (TS-S_i)/(TS-114) \times (FL-4)$

FL: fork length, TS: ΣS_i, (Seo et al. 2011)

気象庁 Japan Meteorological Agency

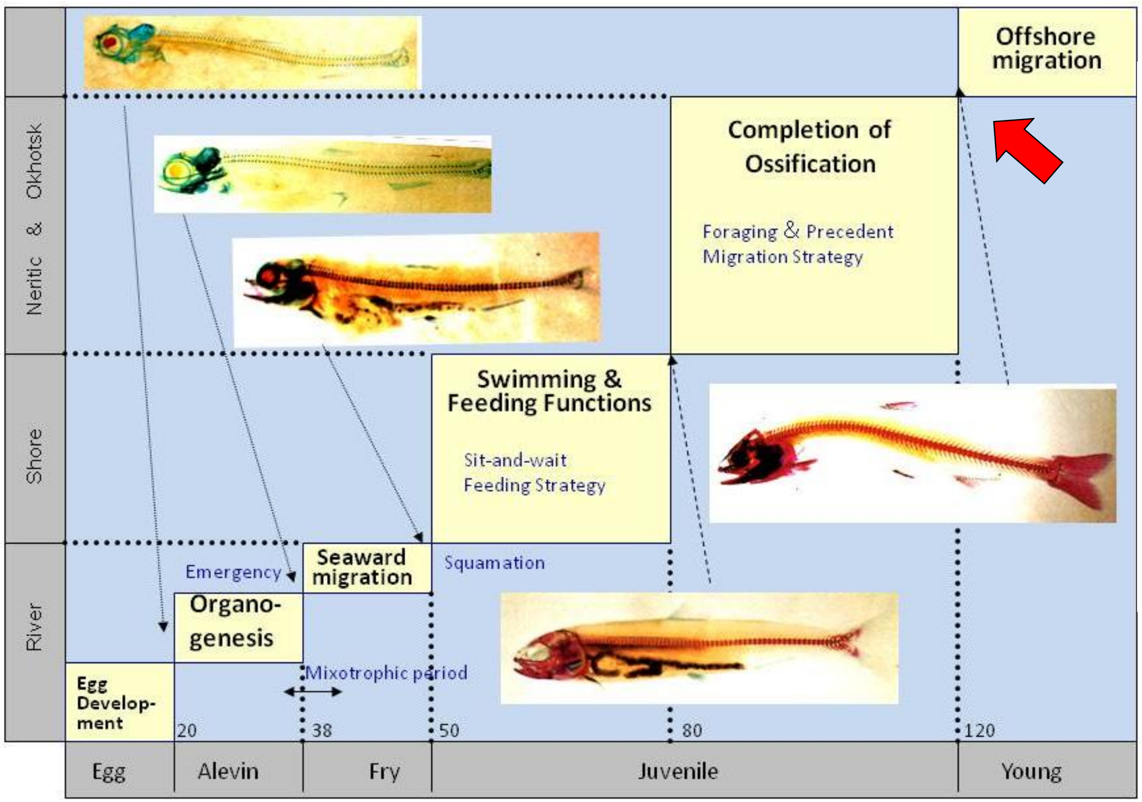
Earth System Research Laboratory Physical Sciences Division

■ Migration pattern of juvenile chum salmon released from Hokkaido

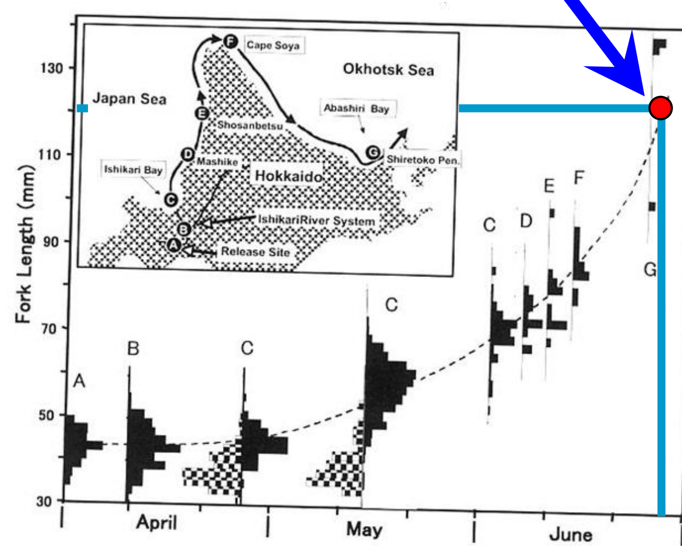


<u>Migration pattern of juvenile chum salmon</u>

- Foraging & precedent migration in the coast
- Juvenile stay in coastal seas around Japan as the post-fingerling stage (mean 10 cm, range 8-12 cm in FL) by the end of June

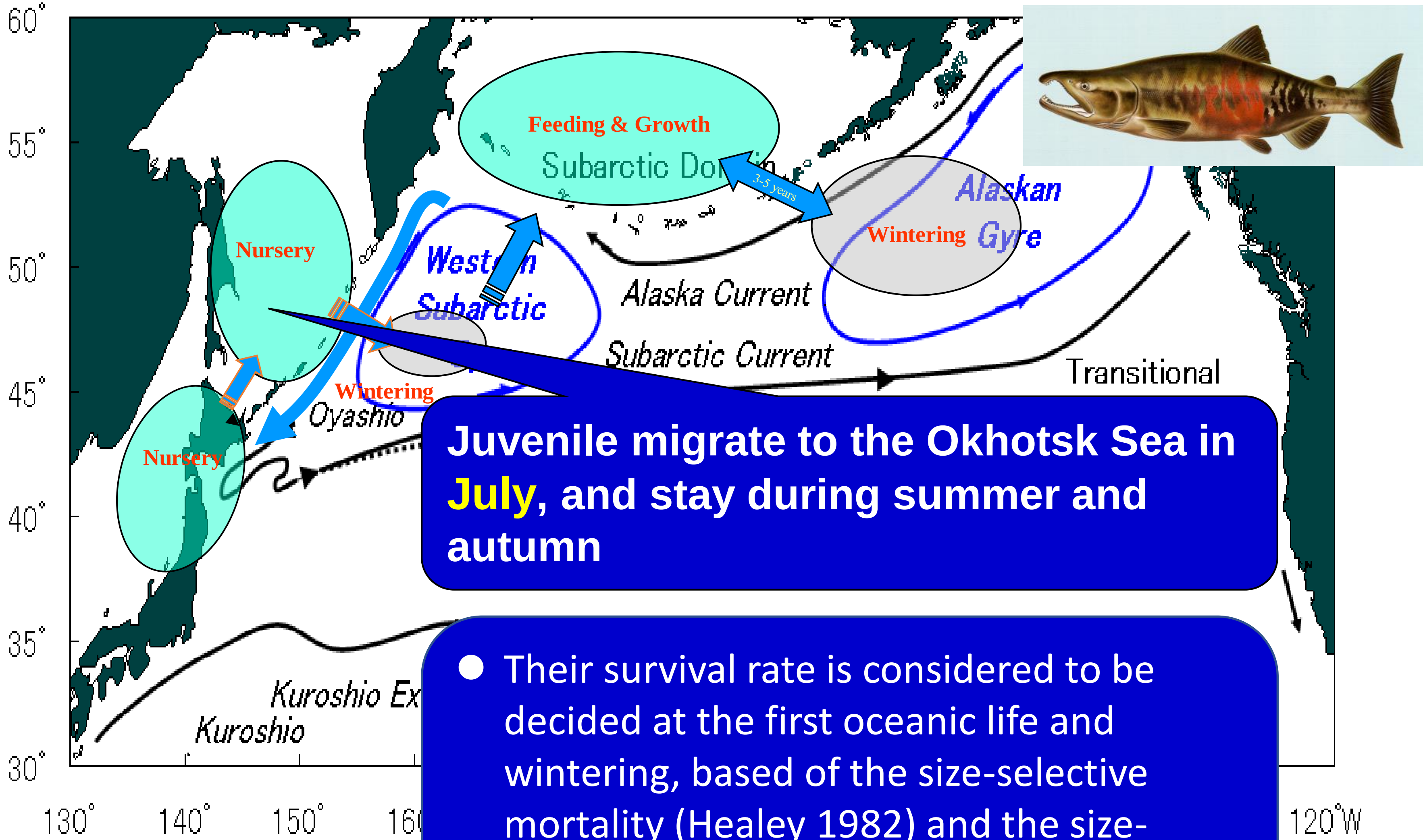


The development stage of chum salmon in the early life period (Kaeriyama 1986)



(Mayama & Ishida 2003)

■ Migration route of Hokkaido chum salmon



Juvenile migrate to the Okhotsk Sea in July, and stay during summer and autumn

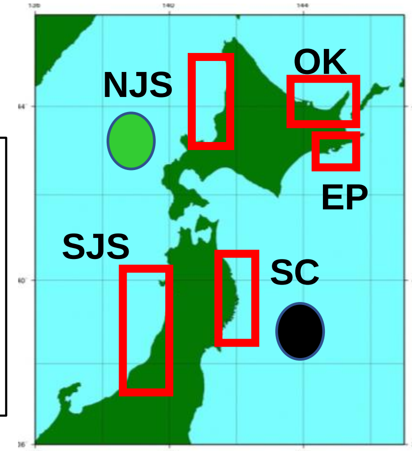
- Their survival rate is considered to be decided at the first oceanic life and wintering, based of the size-selective mortality (Healey 1982) and the size-related mortality (Beamish et al. 2004) respectively.

■ Temporal change in resident duration for juvenile chum salmon in coastal seas around Japan

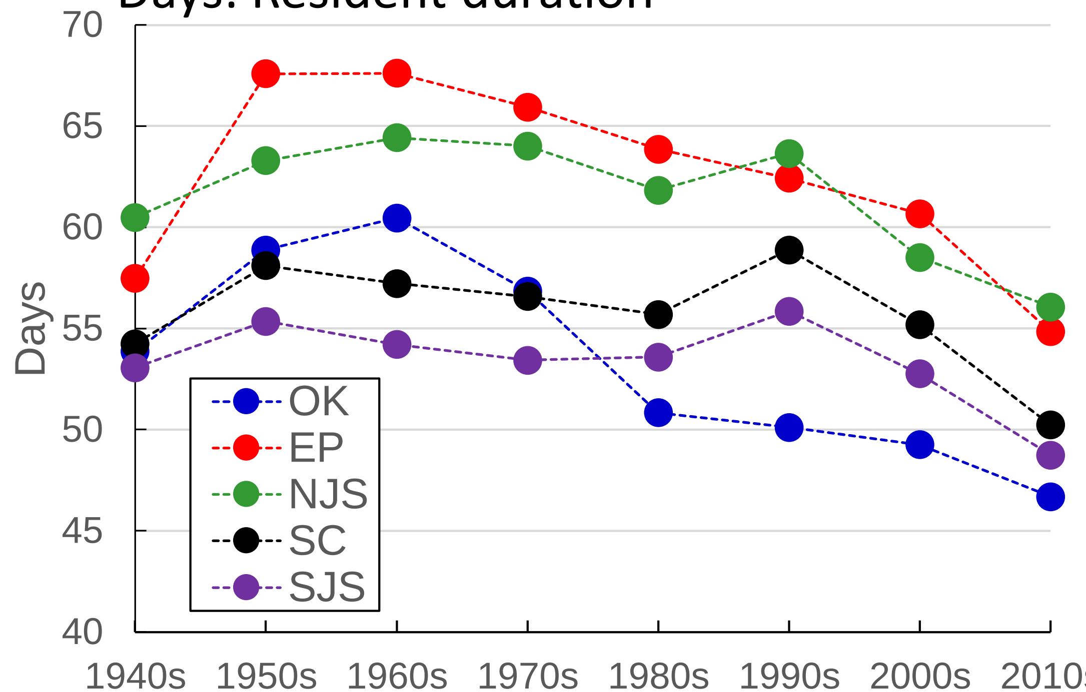
Area	Difference	R^2
OK	3	0.018^{NS}
EP	8	0.082^{NS}
NJS	8	0.408*
SC	9	0.216*
SJS	7	0.037^{NS}

- The resident duration (RD) is decreasing year by year.
- Since the 1990s, the RD decreased more than one week in most of coastal seas, except for the Okhotsk coast
- In Northern Japan Sea and Sanriku coasts, chum salmon reduced the survival rate with decreasing the RD since the 1990s

- OK: Okhotsk Sea Coast
- EP: Eastern Pacific Coast
- NJS: Northern Japan Sea Coast
- SC: Sanriku Coast
- SJS: Southern Japan Sea Coast

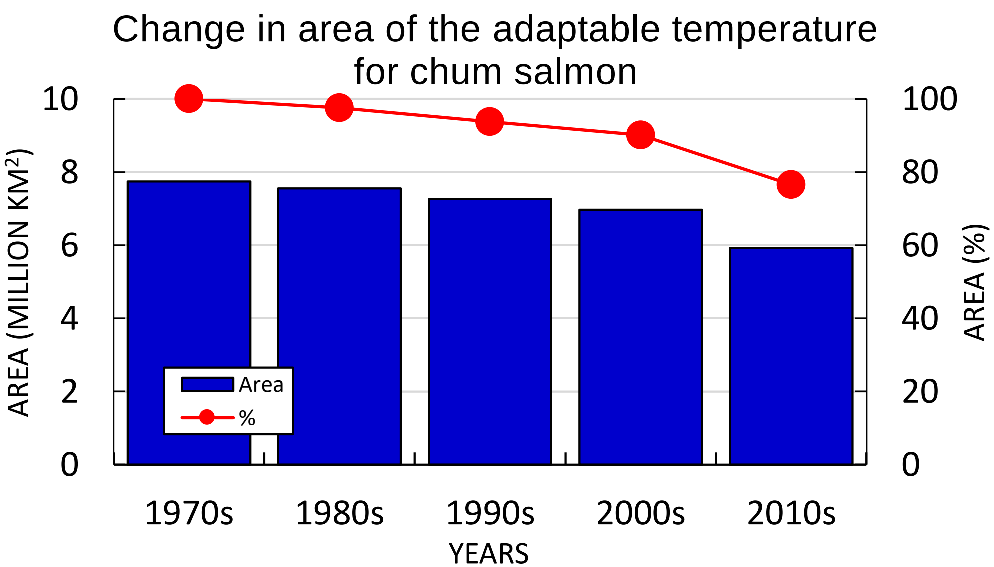


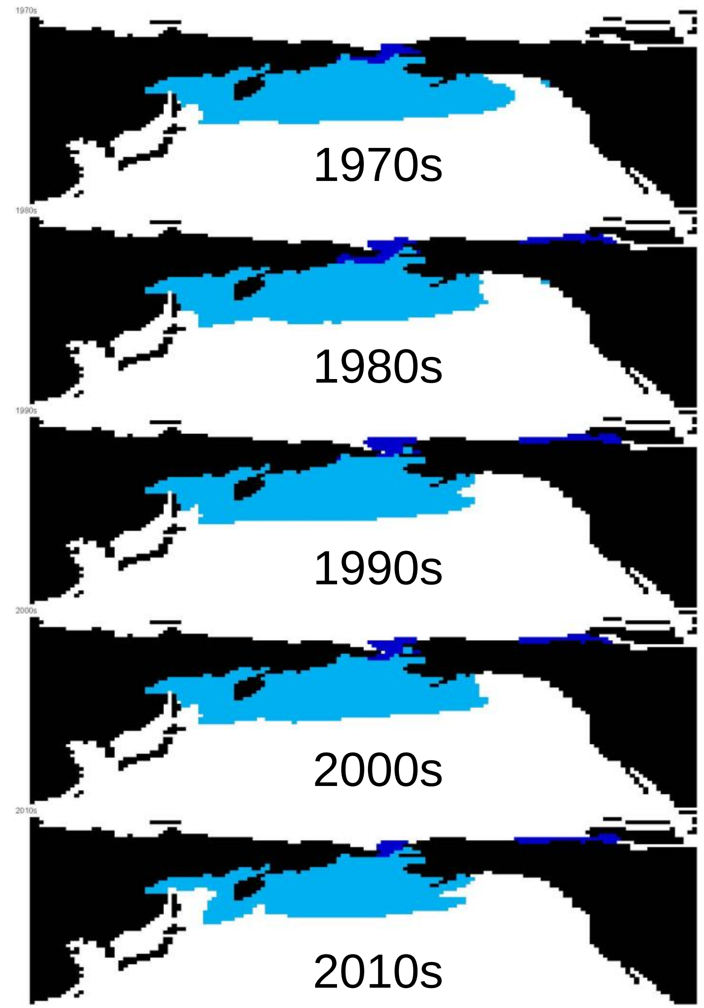
Days: Resident duration



Temporal changes in areas of adaptable and optimal temperatures in August for chum salmon in the North Pacific Ocean

Area of optimum temperature (8～12 ºC)
Area of adaptable temperature (5～12 ºC)

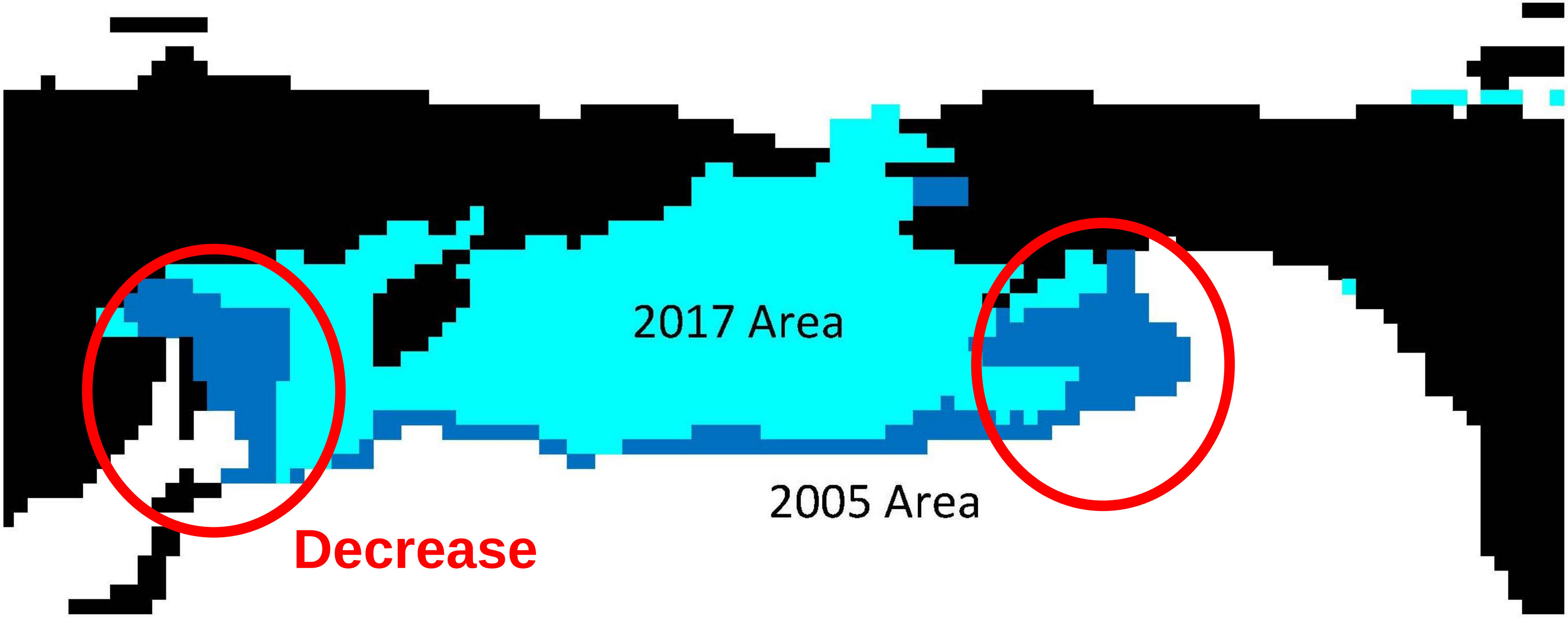




SST Database: COBE-SST of Japan Meteorological Agency

- Since the 2000s, the area has drastically declined in the North Pacific Ocean.

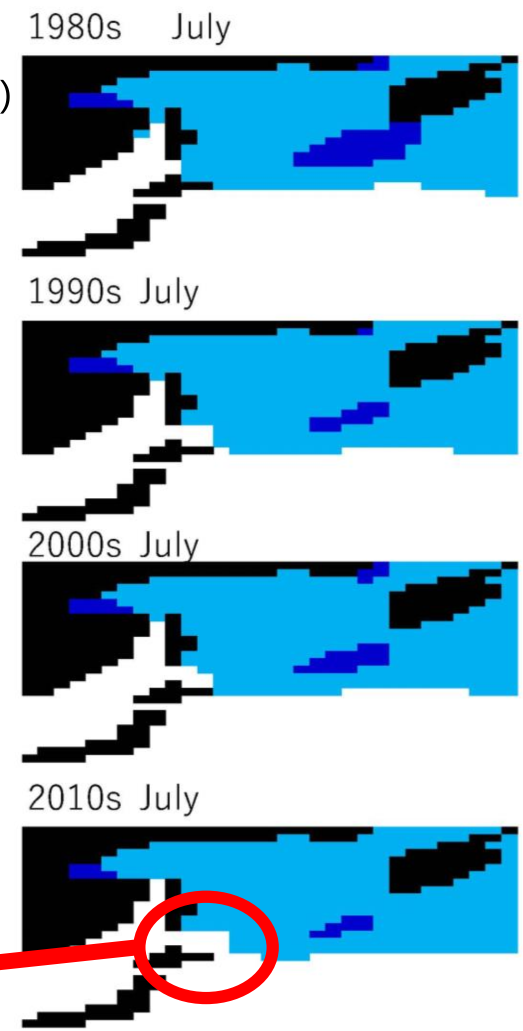
■ Change in area of adaptable temperature (AT) for chum salmon in August of 2005 (■) and 2017 (■) in the North Pacific Ocean



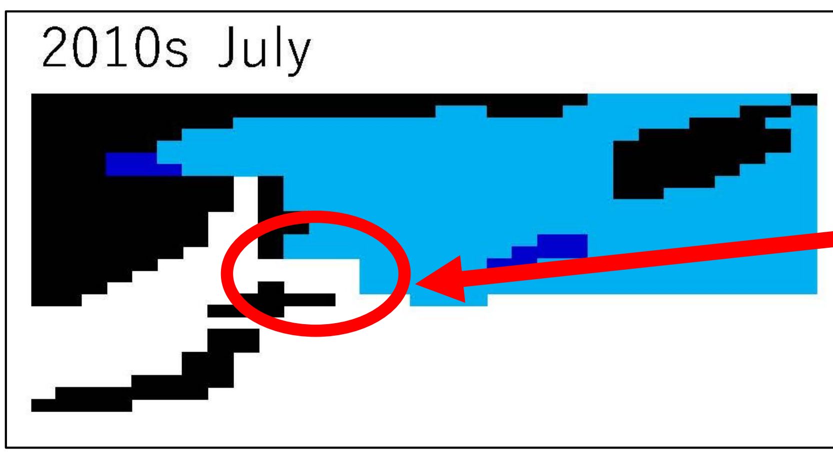
- The area of adaptable temperature in 2017 markedly decreased in the Okhotsk Sea and the Gulf of Alaska
- The global warming will progress to affect the distribution area of chum salmon

■ Temporal change in areas of adaptable and optimum temperatures in July in the Okhotsk Sea

Area of optimum temperature (8～12 ºC)
Area of adaptable temperature (5～12 ºC)



- Since the 2010s, the area of optimal temperature quietly departed from Hokkaido Island
- This indicates that Japanese juvenile chum salmon will be difficult to migrate to the Okhotsk Sea in July, with the progress of global warming.



■ Temporal changes in areas of adaptable (■ AA) and optimum (■ AO) temperatures of juvenile chum salmon in the Okhotsk Sea from May to October

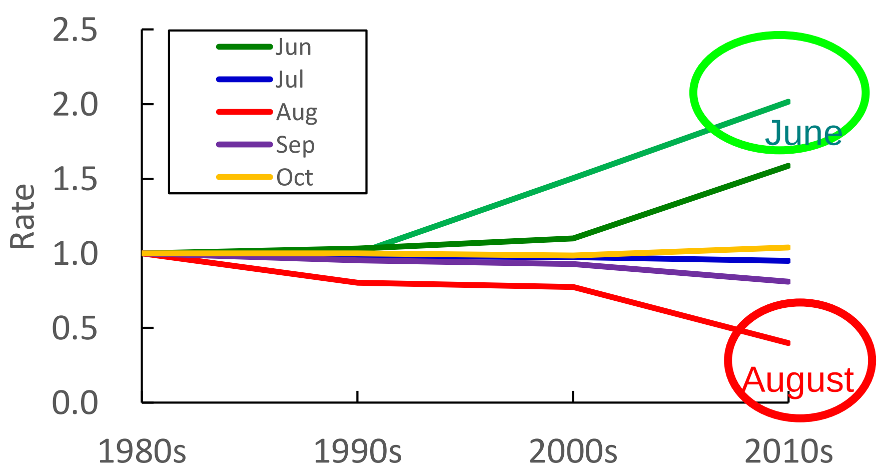
- Russian juvenile chum salmon migrate to the sea from May to June
- Since the 2000s, the June AA: increase

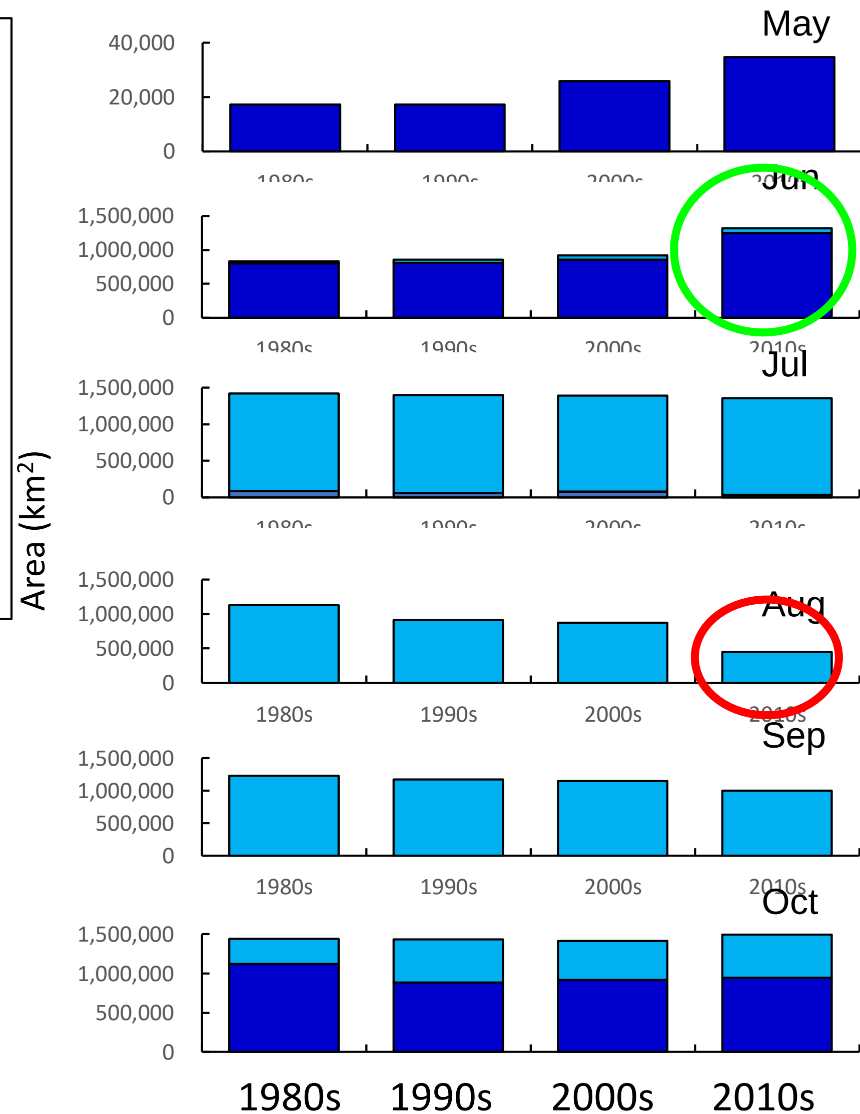
→ **Survival rate of Russian juvenile is rising**

- In August, the AO became less than half since the 2010s.

→ **Carrying capacity is declining**

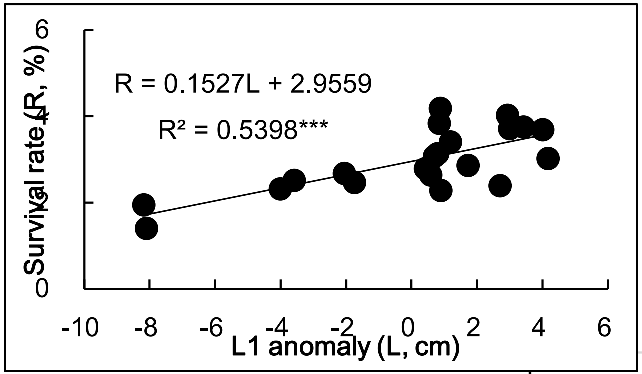
→ **Biological interaction between wild and hatchery salmon will occur**

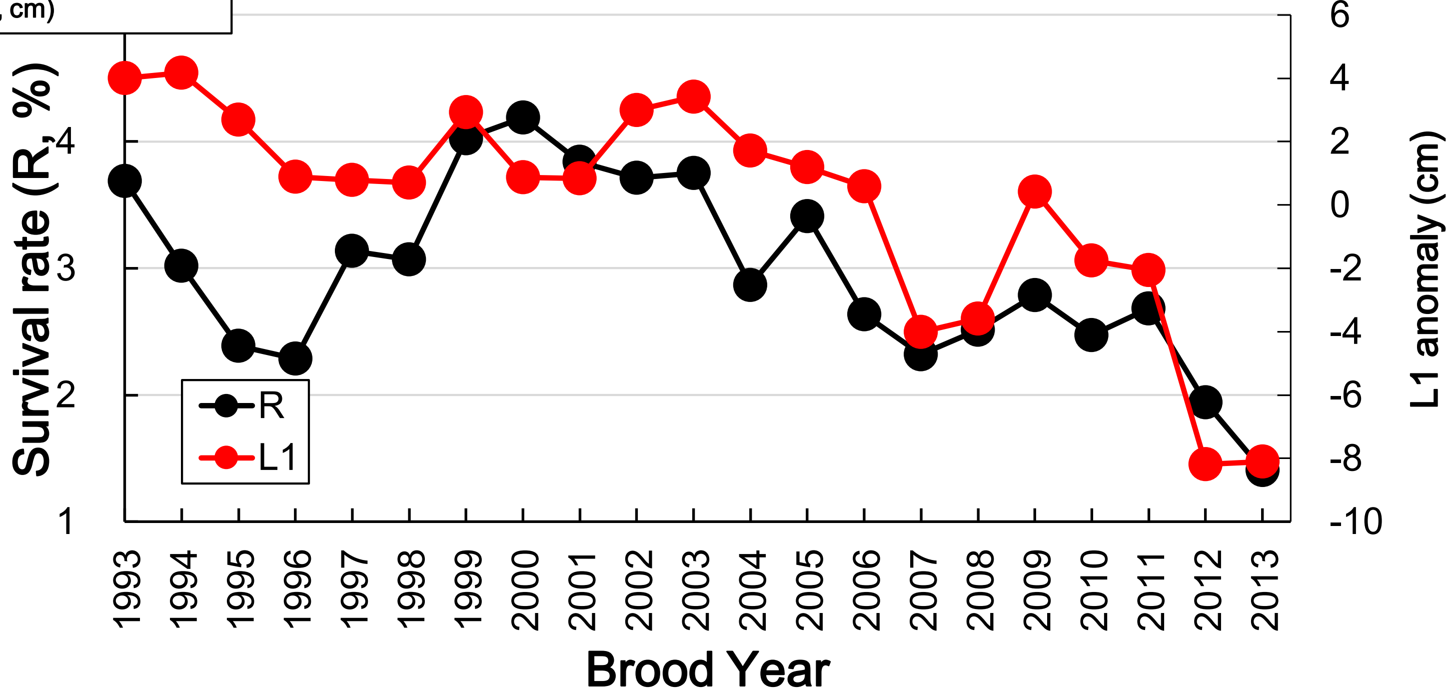


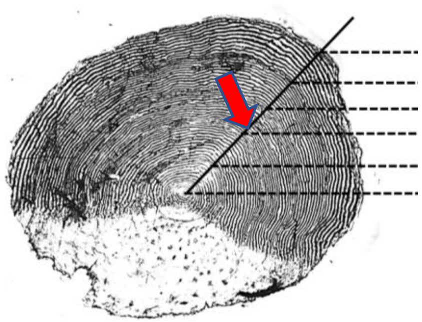


■ Temporal changes in survival rate and growth anomaly at age-1 (L1) of Japanese chum salmon since the 1993 brood year

- The causal linkage between survival rate and the growth at age-1 is observed
- A decline of survival for Japanese chum salmon will be affected by the decrease of growth at the age-1 in the coastal seas around Japan and the Okhotsk Sea

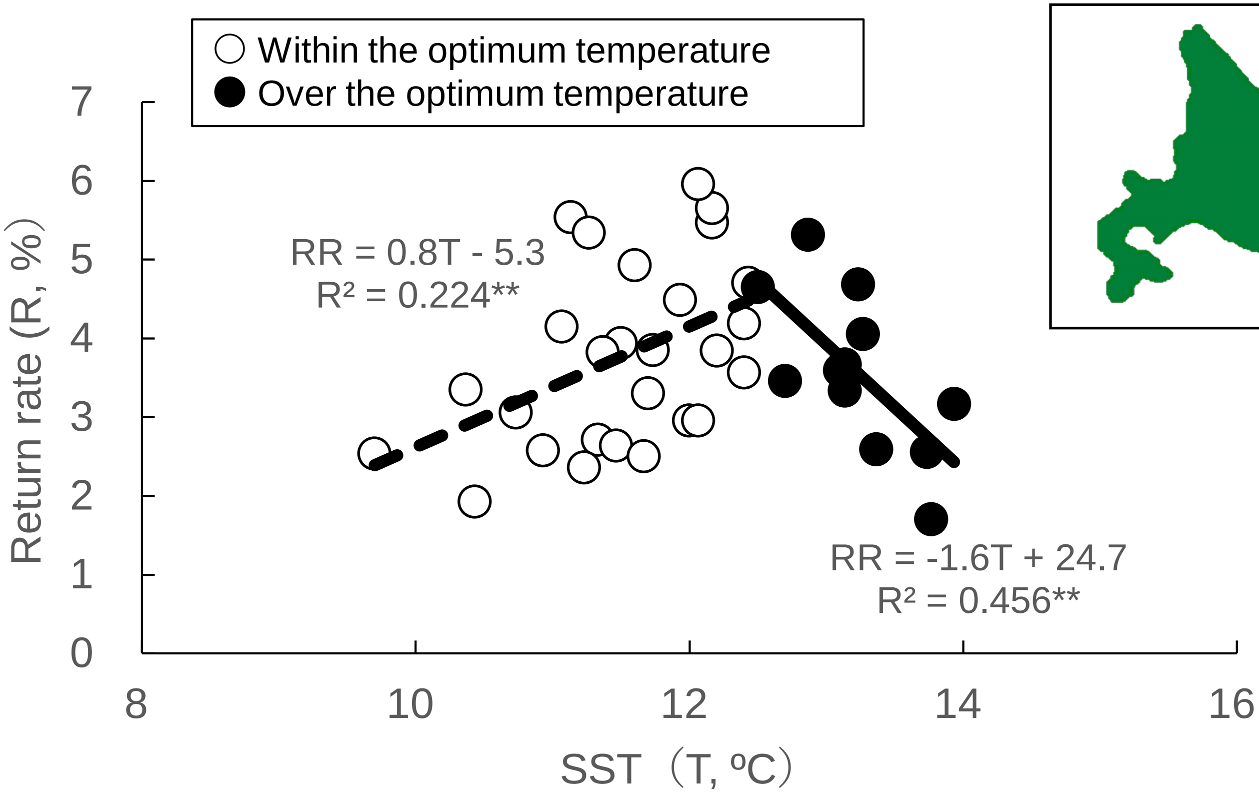


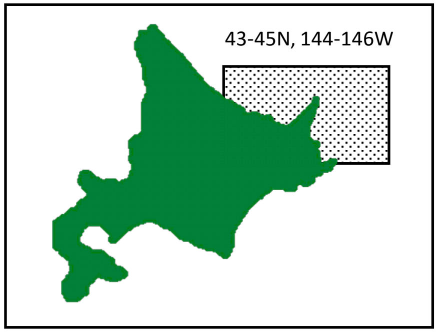




Growth at age-1 was back-calculated by scales of chum salmon returning to the Tsugaruishi River.

■ Relationship between July SST in the Okhotsk Sea Coast and return rate of Hokkaido chum salmon in 1974-2013 brood year





- The relationship indicates the significant positive correlation <u>within</u> the optimum temperature
- The survival rate sharply declined <u>over</u> the optimum temperature

■ Wild salmon have higher trophic level than hatchery population in case of the Yurappu River chum salmon

- ●Wild salmon had higher δ15N than hatchery fish.
- ●Hatchery salmon had more significant variation of δ13C than wild fish

- ●Wild salmon had higher trophic level than hatchery fish.
- ●Wild salmon will distribute and forage at higher-productive area (e.g., coast).
- ●Hatchery salmon will travel further offshore than wild fish.

*速度論的同位体効果

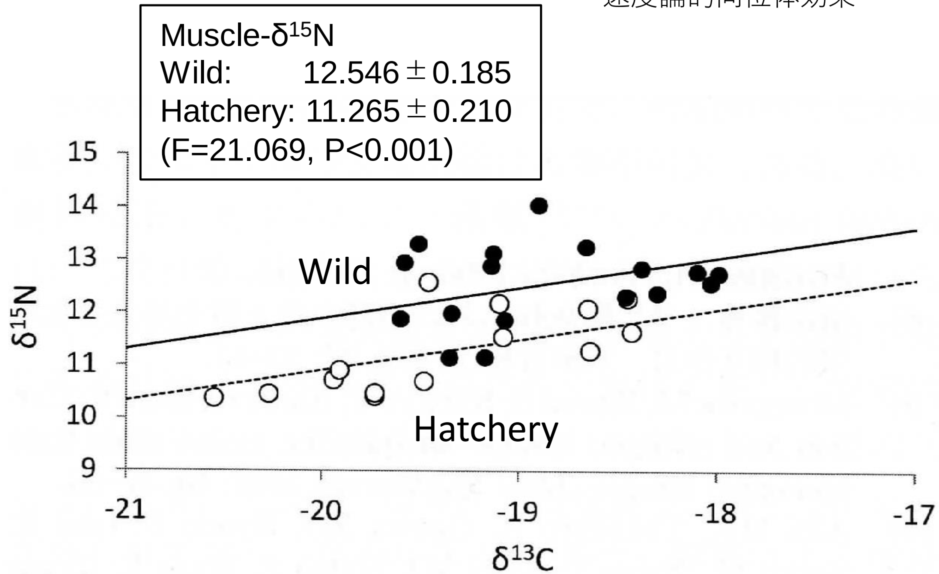


Fig. 2 Relationship between carbon and nitrogen stable isotopes of presumably wild (●) and hatchery (○) chum salmon returning to the Yurappu River.

(Qin et al. 2013)

●**Population-specific differences in migration**

- Steelhead (Quinn et al. 2012)
- Baltic (Atlantic) salmon (Kallio-Nyberg et al. 1999)
- Chinook salmon (Quinn et al. 2011)

- ● Wild salmon has higher adaptability than hatchery salmon
- ● Conservation of the wild salmon is very important

SUMMARY & CONCLUSION

- Japanese chum salmon:
  - has decreased the survival rate since the 2000s.
  - will be difficult to migrate to the Okhotsk Sea since the 2010s with progress of the global warming.

- Near future, all Russian and Japanese juvenile chum salmon will have following issues during summer in the Okhotsk Sea, depending on progress of the global warming and decrease of the carrying capacity:
  - a intraspecific interaction between wild and hatchery salmon,
  - a population density-dependent effect.

- In Japan, the conservation of wild chum salmon is of primary importance, because the wild salmon has higher adaptability than hatchery salmon under the changing climate.

■ Sustainable conservation management for chum salmon

Back-casting approach

● Goals

1.Conservation & use

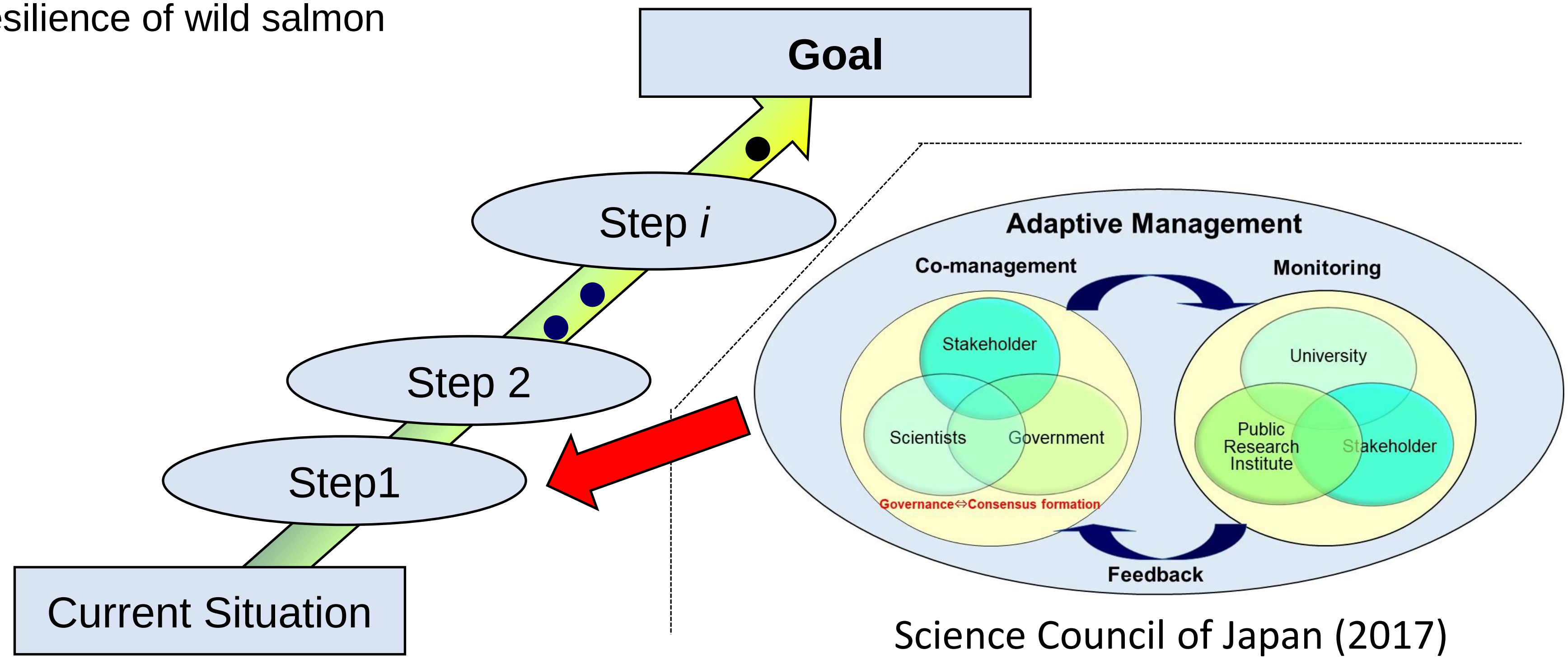
- Conservation and recovery of wild salmon
- Innovation of salmon fisheries & hatchery stocking

2. Interaction between aquatic ecosystem & salmon

- Climate change (e.g., Global warming, Regime-shift): sea & freshwater ecosystems
- Change in aquatic ecosystem affecting the life history & population dynamics of salmon

3. Restoration & resilience for wild salmon and river ecosystem

- Restoration for impoverished river ecosystem
- Resilience of wild salmon



Science Council of Japan (2017)