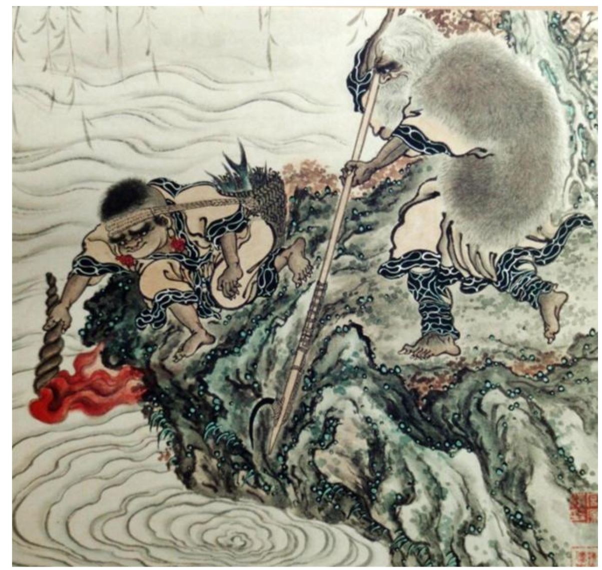
Sustainability and risk management of Pacific salmon under the changing climate and catastrophic earthquake and tsunami in coastal ecosystems around Japan



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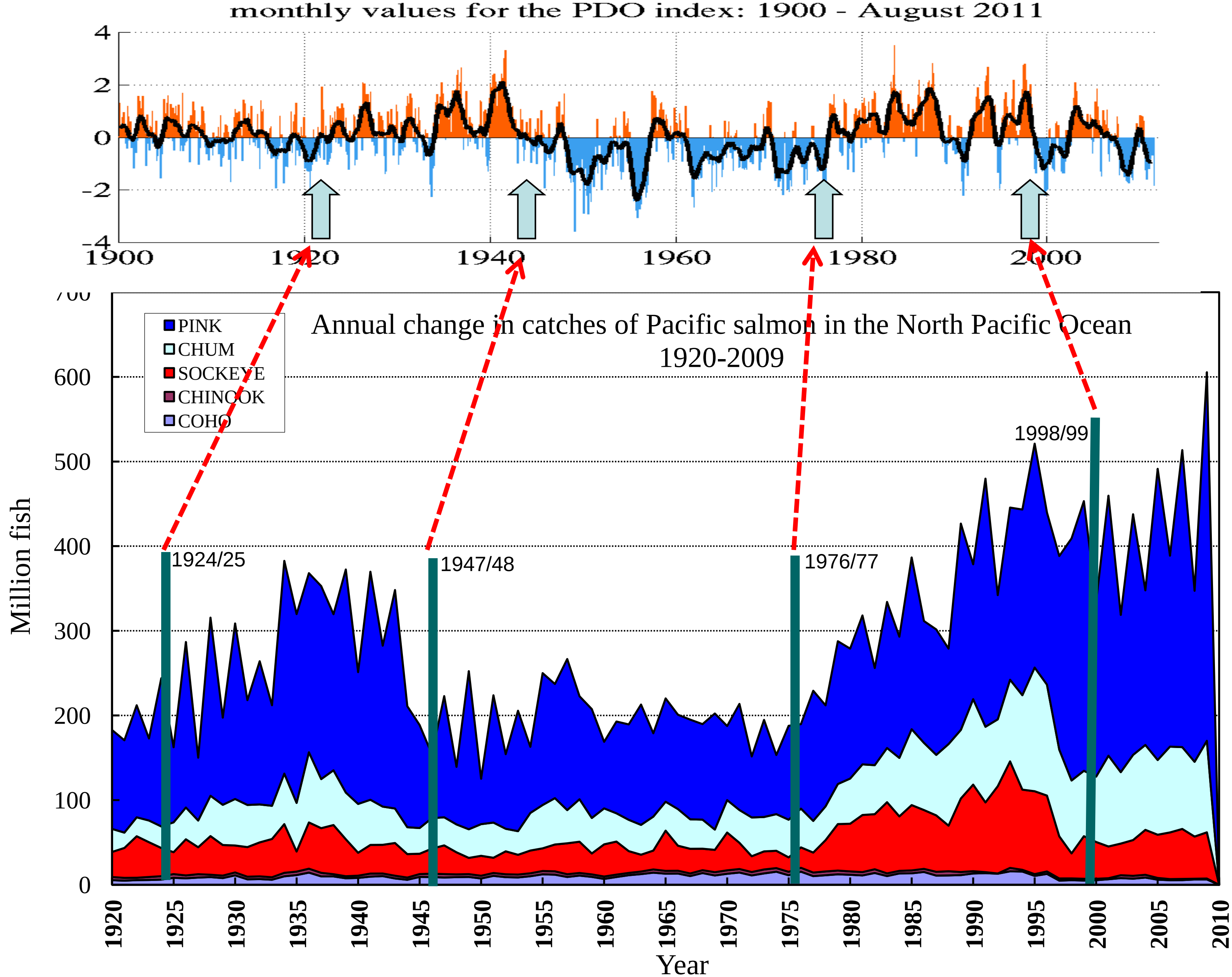
Topics

- Climate change and production trend of Pacific salmon
- Human impacts for Pacific salmon:
  - Hatchery salmon
  - Global warming
- Conclusion

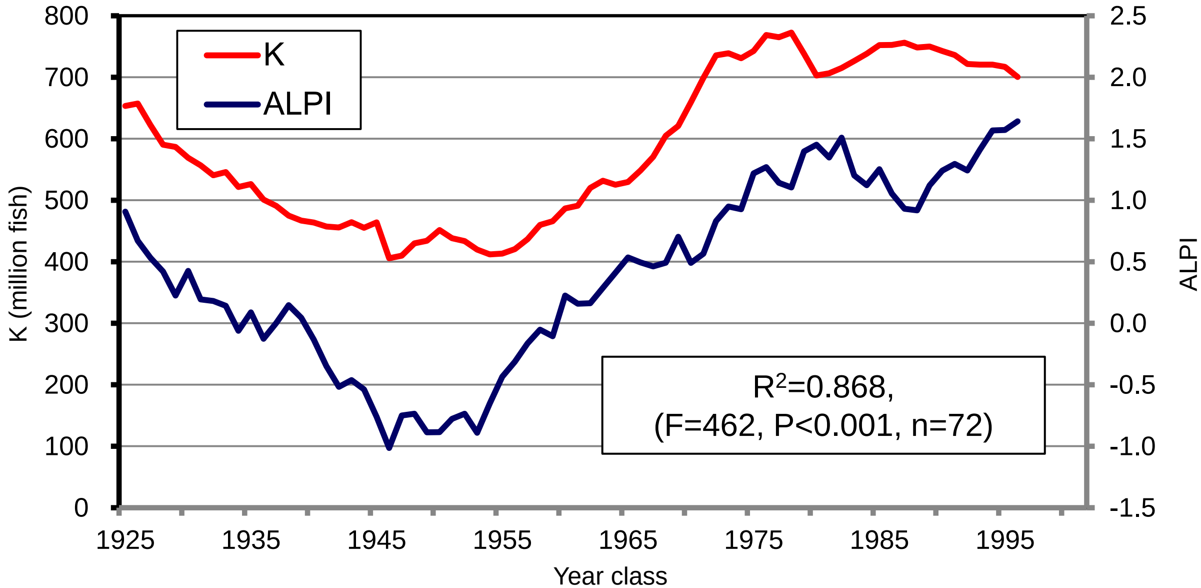
Climate change and production trend of Pacific salmon

Production trend of Pacific salmon

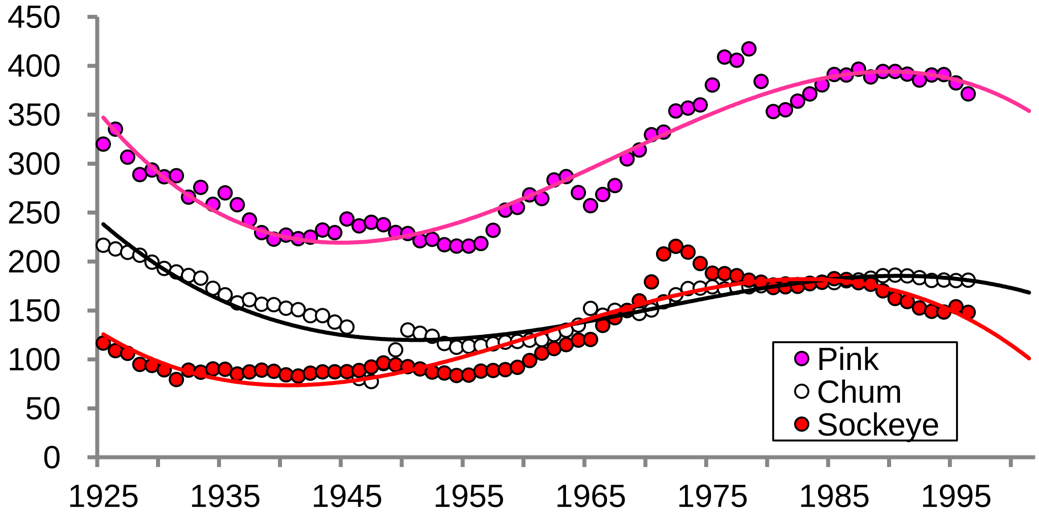
Synchronizing with the climate regime shift



Temporal changes in ALPI and carrying capacity (K) of three species (sockeye, chum, and pink salmon)



Salmon carrying capacity significantly synchronized with the long-term climate change

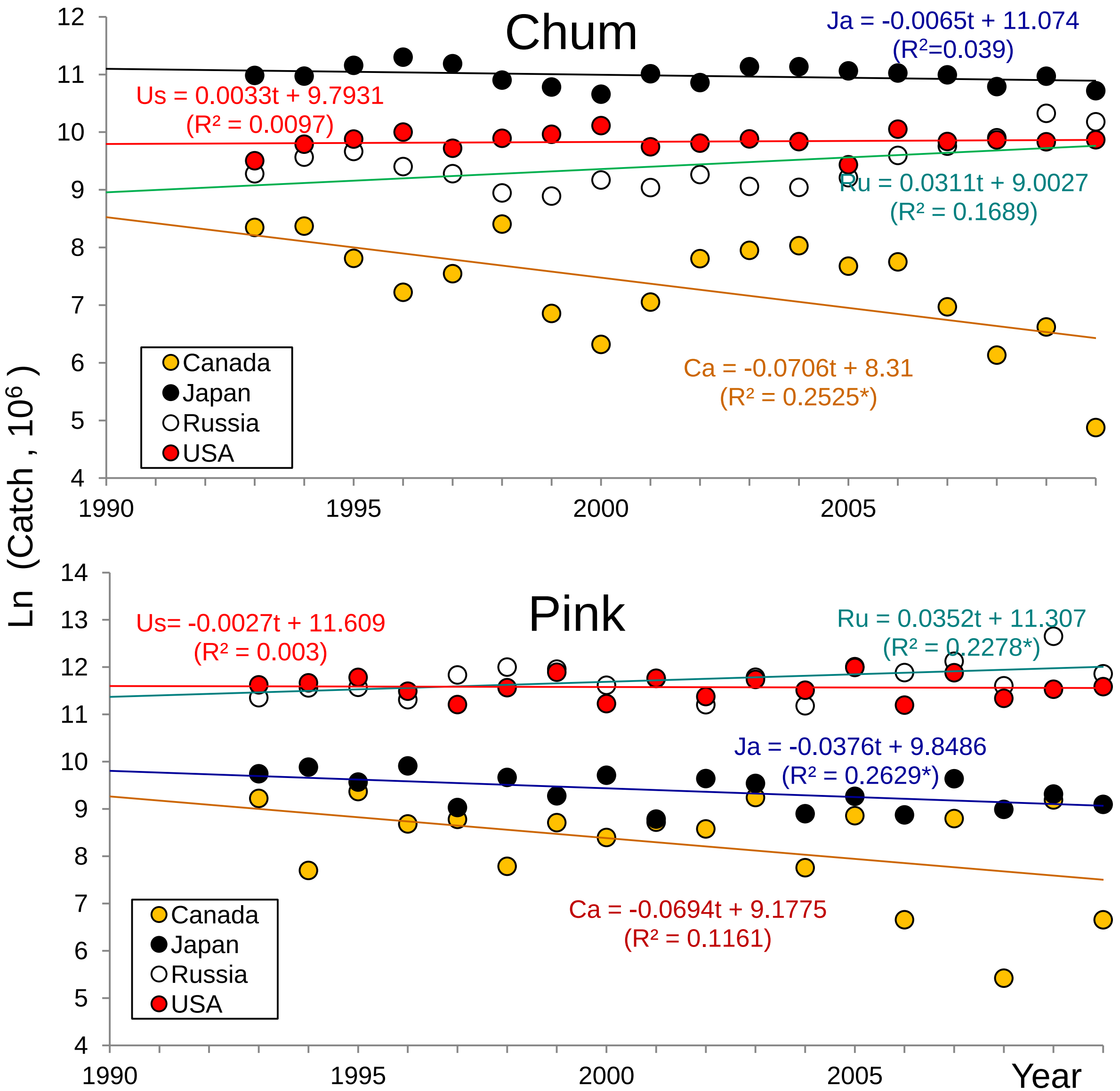


Carrying capacity trend

- ■Pink: stable?
- ■Chum: stable?
- ■Sockeye: decrease

Annual change in catch of chum and pink salmon in the North Pacific in 1990-2010

(by NPAFC Database)



Chum salmon	
Canada	Decrease
Japan	Decrease?
Russia	Increase
USA	Stable?

Pink salmon	
Canada	Decrease
Japan	Decrease
Russia	Increase
USA	Stable?

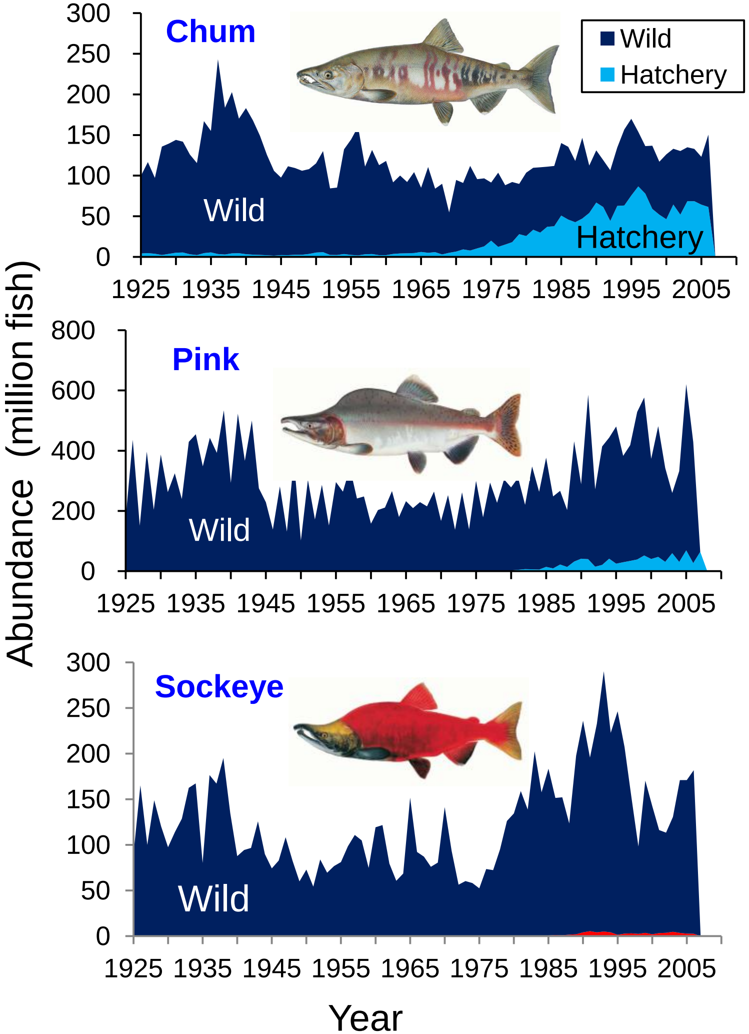
Southern populations: Decrease
Russian populations: Increase

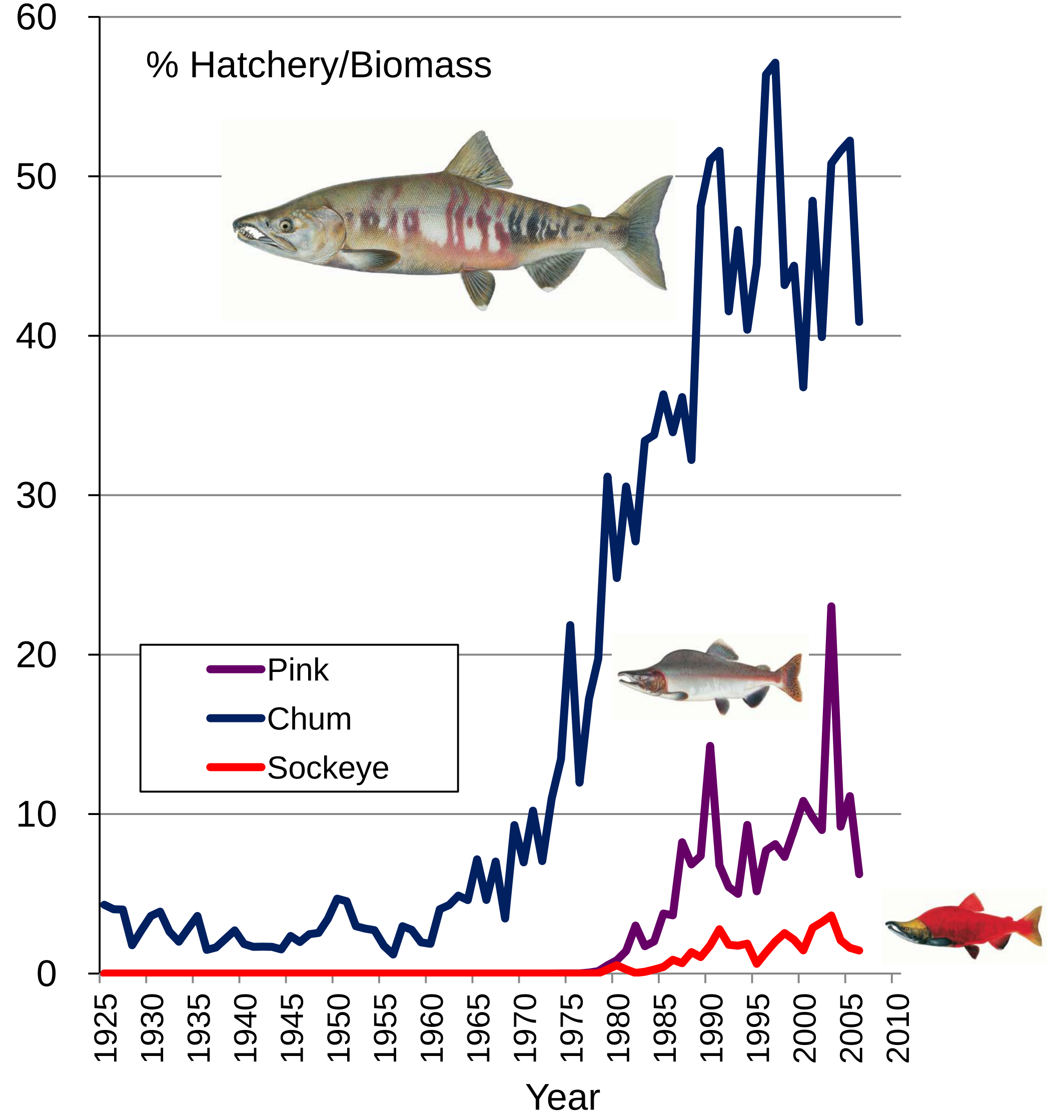
Human impacts for Pacific salmon: Hatchery salmon

Hatchery Salmon Effects

Hatchery salmon
Pink <20%
Chum < 60%
Sockeye <10%

Annual changes in abundance of wild/hatchery salmon





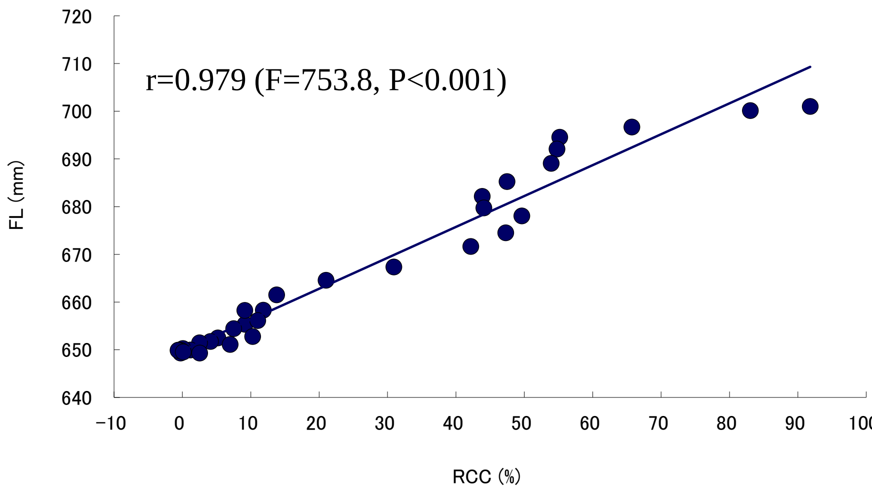
Carrying capacity and density-dependent effect of chum salmon

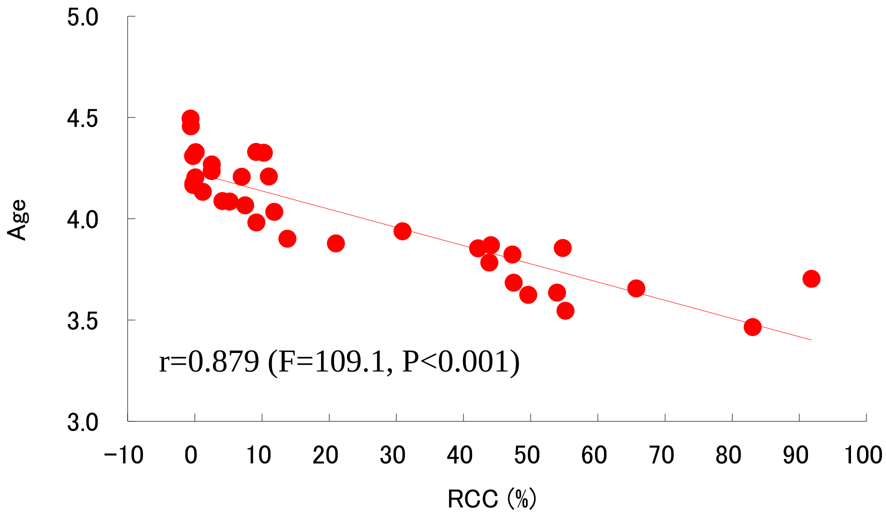
RCC=(CC-B)/CC×100

RCC: Residual Carrying Capacity
CC: Carrying Capacity
B: Biomass
FL: Fork length (mm)
AGE: Mean age at maturity

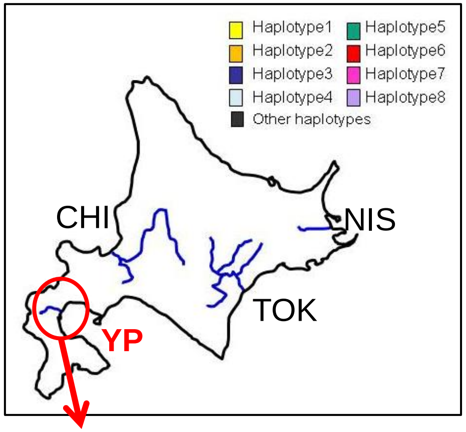
This result suggests that
- carrying capacity of chum salmon is closely related not only with the long-term climate change, but also the density-dependent effect,
- the density-dependent growth will also affect breeding characters (e.g., body size and fecundity) of the wild salmon

Hokkaido chum salmon

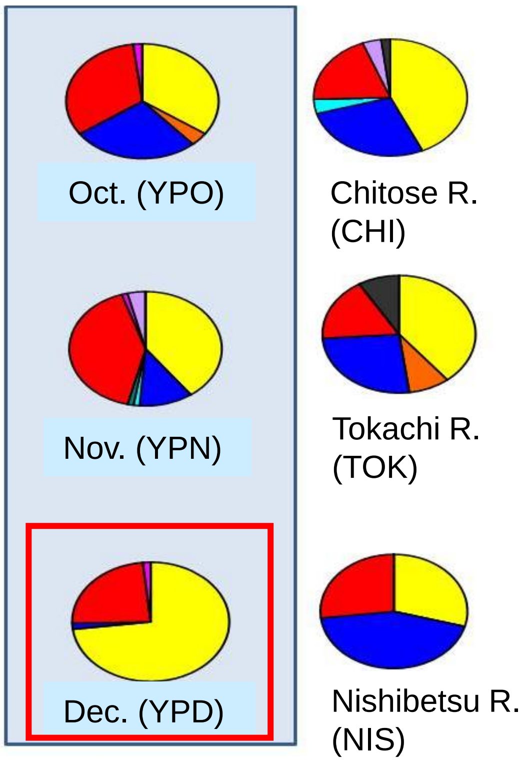




Genetic Influence of Hatchery Salmon



Yurappu River



Genetic differentiation of Yurappu River chum salmon

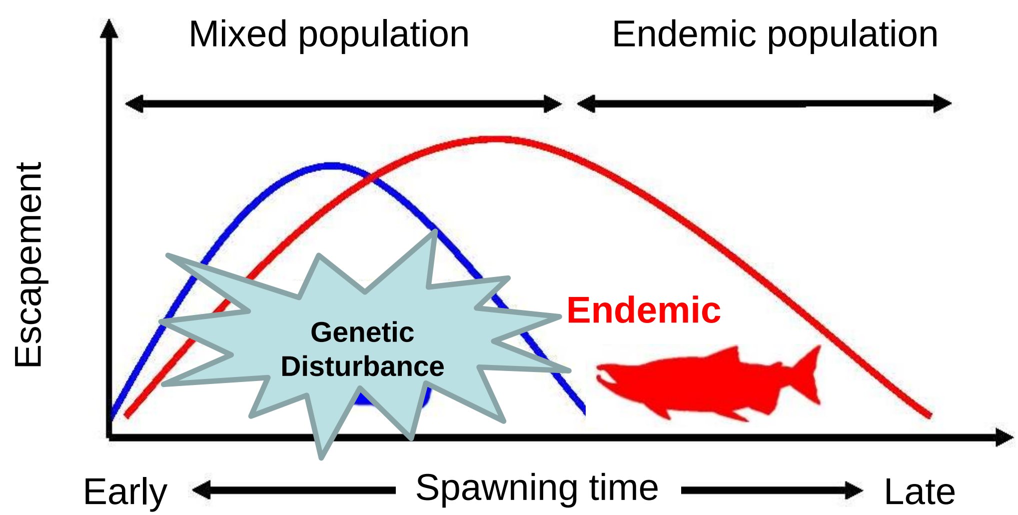
Variable nucleotide sites in the 481 bp 5' portion of mtDNA control region

Pairwise population F_{st} estimated between chum salmon populations

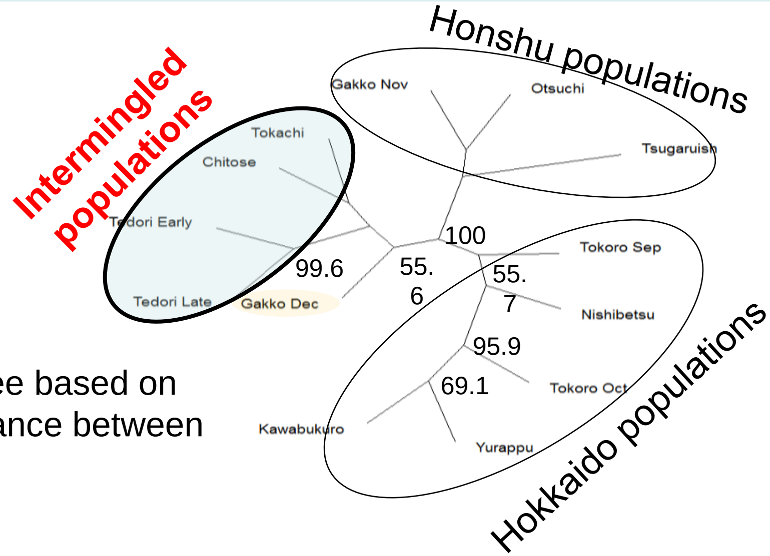
	CHI	TOK	NIS	YPO	YPN	YPD
CHI	0.000					
TOK	0.000	0.000				
NIS	0.013	0.034	0.000			
YPO	0.000	0.000	0.030	0.000		
YPN	0.039	0.027	0.145*	0.013	0.000	
YPD	0.211**	0.160**	0.486**	0.168**	0.059**	0.000

*P<0.05 **P<0.01

Yurappu River chum salmon remains a native stock in the late-run, but is intermingled with populations introduced from other rivers by the artificial hatchery program.



Genetic Influence of Hatchery Salmon (2) Tedori R.



Unrooted tree based on genetic distance between haplotypes.

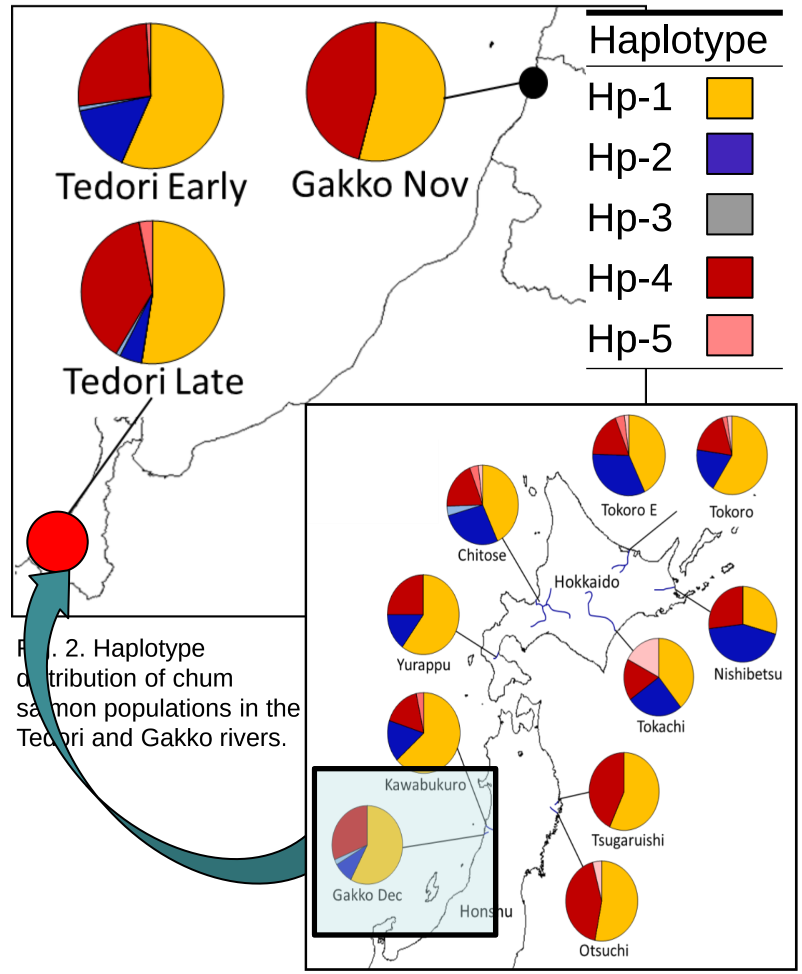


Fig. 2. Haplotype distribution of chum salmon populations in the Tedori and Gakko rivers.

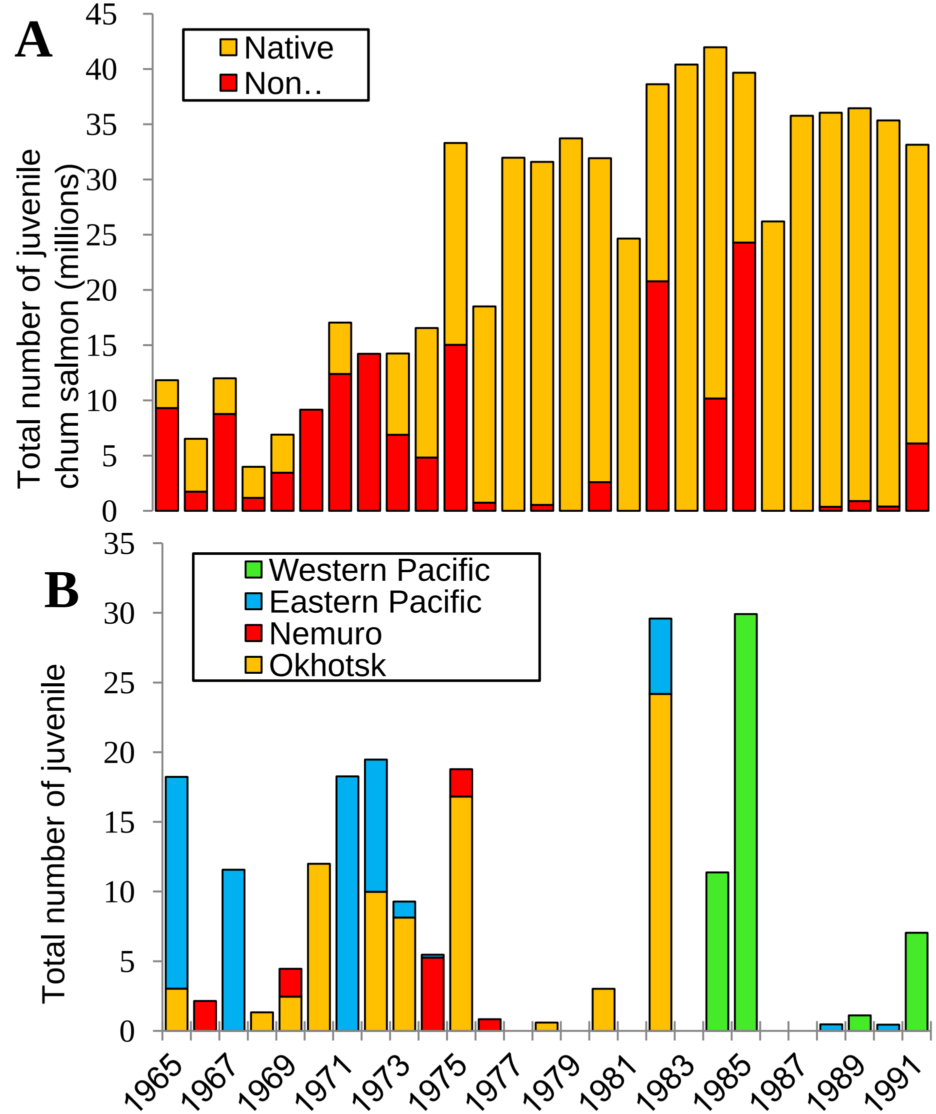
Fig.3. Haplotype distribution of chum salmon populations in Japan/ (modified from Sato et al. 2001)

- **Tedori River** received a massive seed-transplantation of chum salmon from the Chitose Salmon Hatchery during 1980s and 1990s.
- Tedori River chum salmon were closely related with Chitose and Tokachi River populations, and did not show the genetic differentiation with Tokoro River population, despite no-seed- transplantation from this river in Hokkaido.
- This result shows that a part of Tedori River chum salmon receive gene flow and disturbance following the seed transplantation from not only Chitose River, but also other rive populations in Hokkaido.

Genetic-disturbance for Japanese chum salmon

Chitose Salmon Hatchery

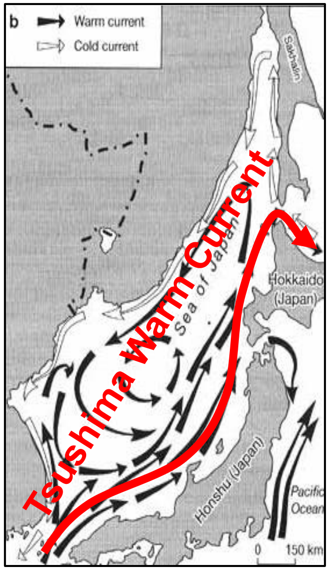
- Chitose Salmon Hatchery (CSH) play a role of a center of salmon hatchery program and main base of salmon seed transplantation in Japan.
- Chitose River chum salmon population extremely decreased and could not reproduce by 1960s because of the overfishing.
- The CSH released a lot of juvenile transported from almost all populations around Hokkaido during 1960s and 1980s.
- So, the massive seed transplantation from the CSH caused that almost all early-run populations were genetically disturbed in Japan since the 1980s.

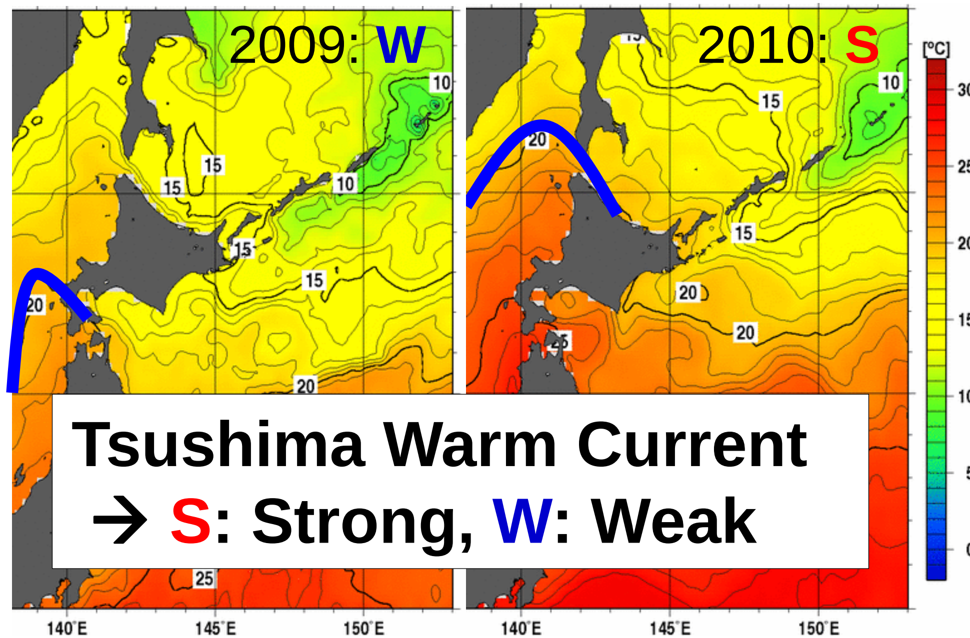


A. Total number of both native and non-native juvenile chum salmon released into the Chitose River. **B.** Total number of juveniles transplanted from each region and released into the Chitose River.

Human impacts for Pacific salmon: Global warming

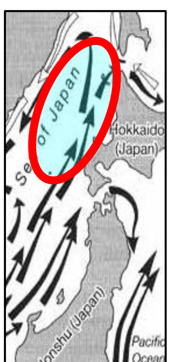
Mean SST isothermal diagrams around Japan in September

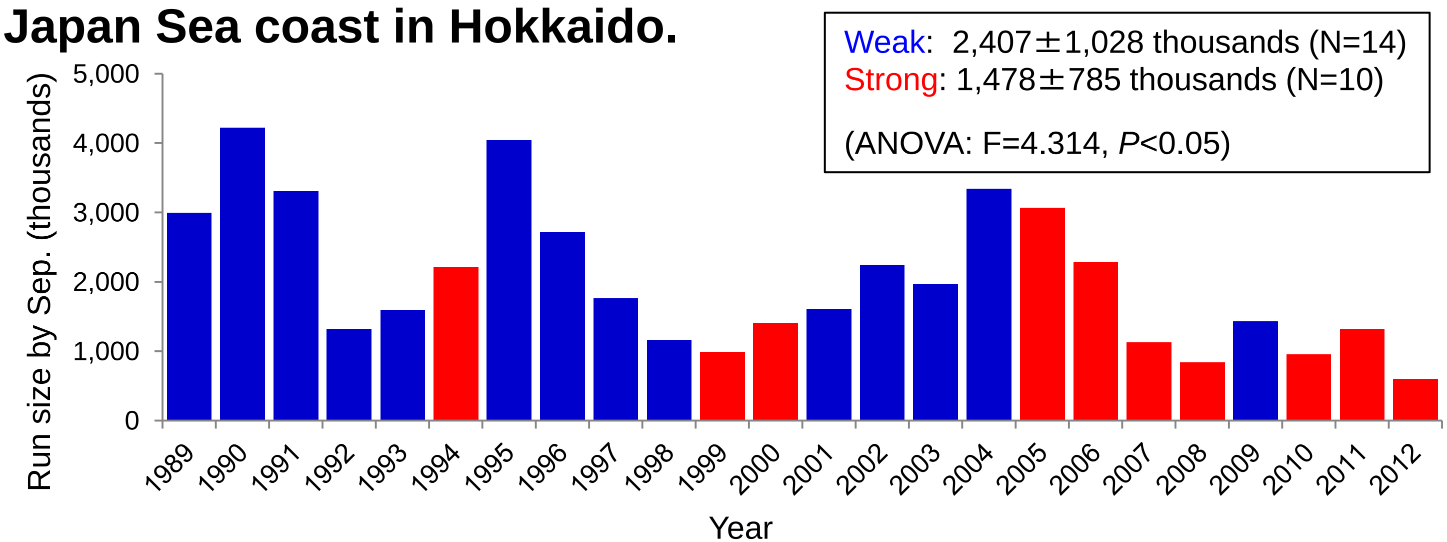




1989: W	2001: W
1990: W	2002: W
1991: S	2003: W
1992: W	2004: W
1993: W	2005: S
1994: S	2006: S
1995: W	2007: S
1996: S	2008: S
1997: W	2009: W
1998: W	2010: S
1999: S	2011: S
2000: S	2012: S

Annual change in the run size of early-population chum salmon returning to the Japan Sea coast in Hokkaido.





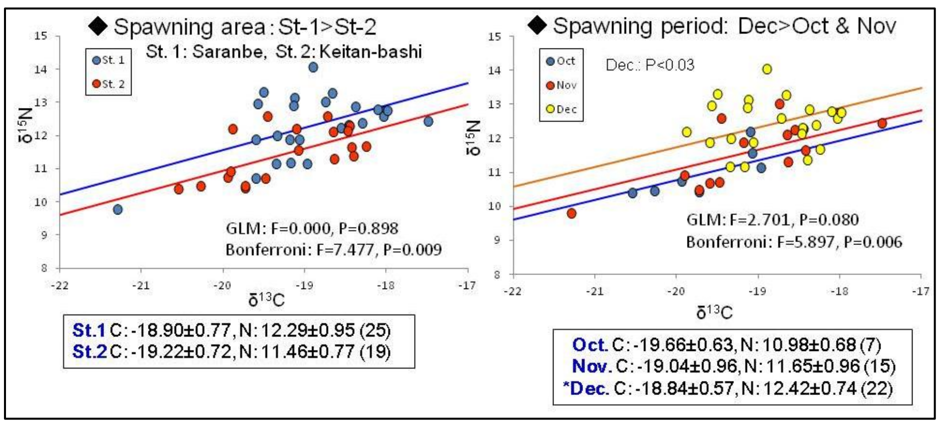
Long-term change in escapement pattern of Hokkaido chum salmon

- 1970-80s: Bimodality (Early & Late runs)
- 1990s-ealy 2000s: Late run disappeared by hatchery selection for salmon fisheries industry
- **Since 2006:** Faint sigh on decline in early run and increase in late run in order to the global warming

- Early run: Mixed (& artificial disturbed) population
- Late run: Wild population

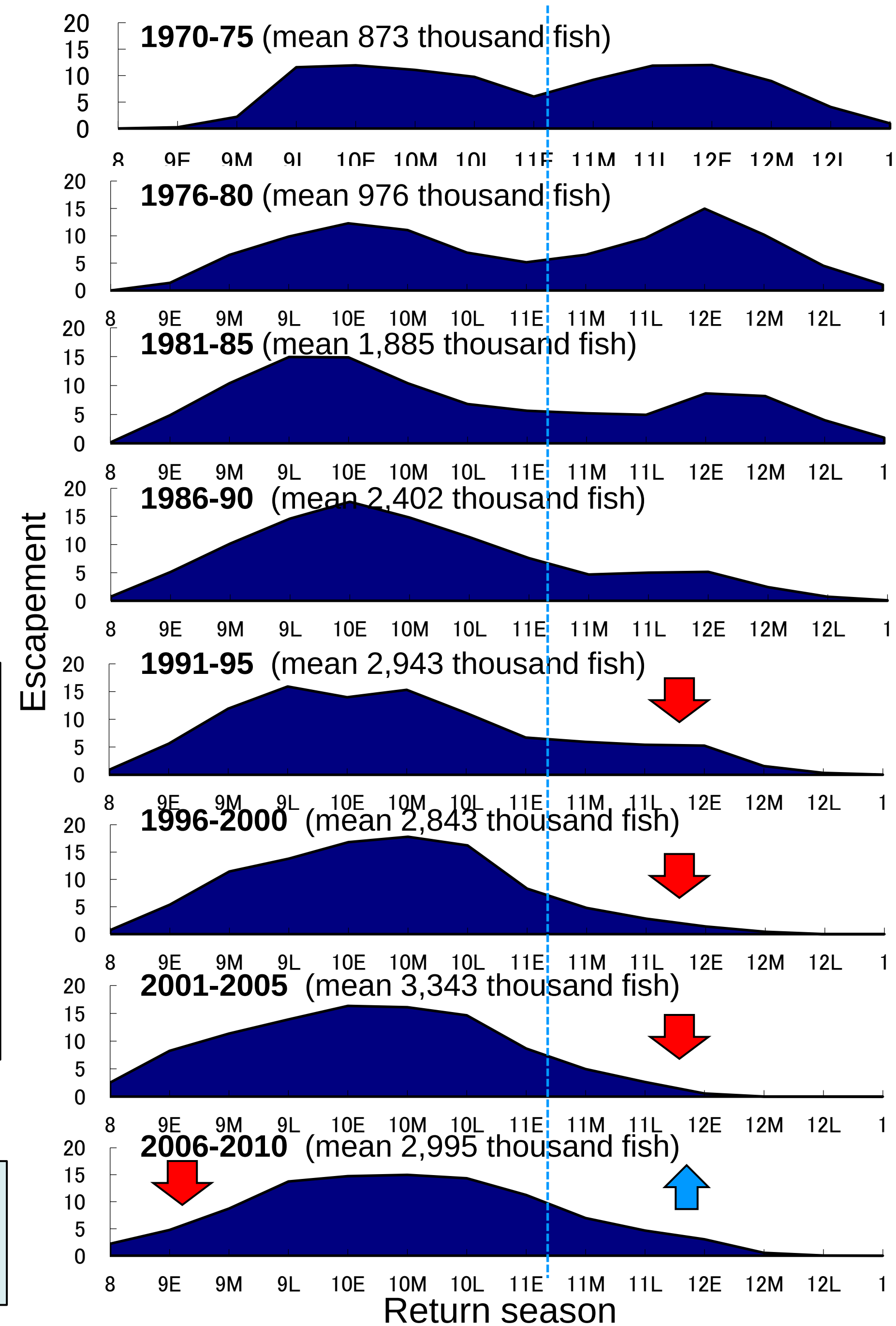
Trophic level: Wild>Hatchery salmon

in the Yurappu River

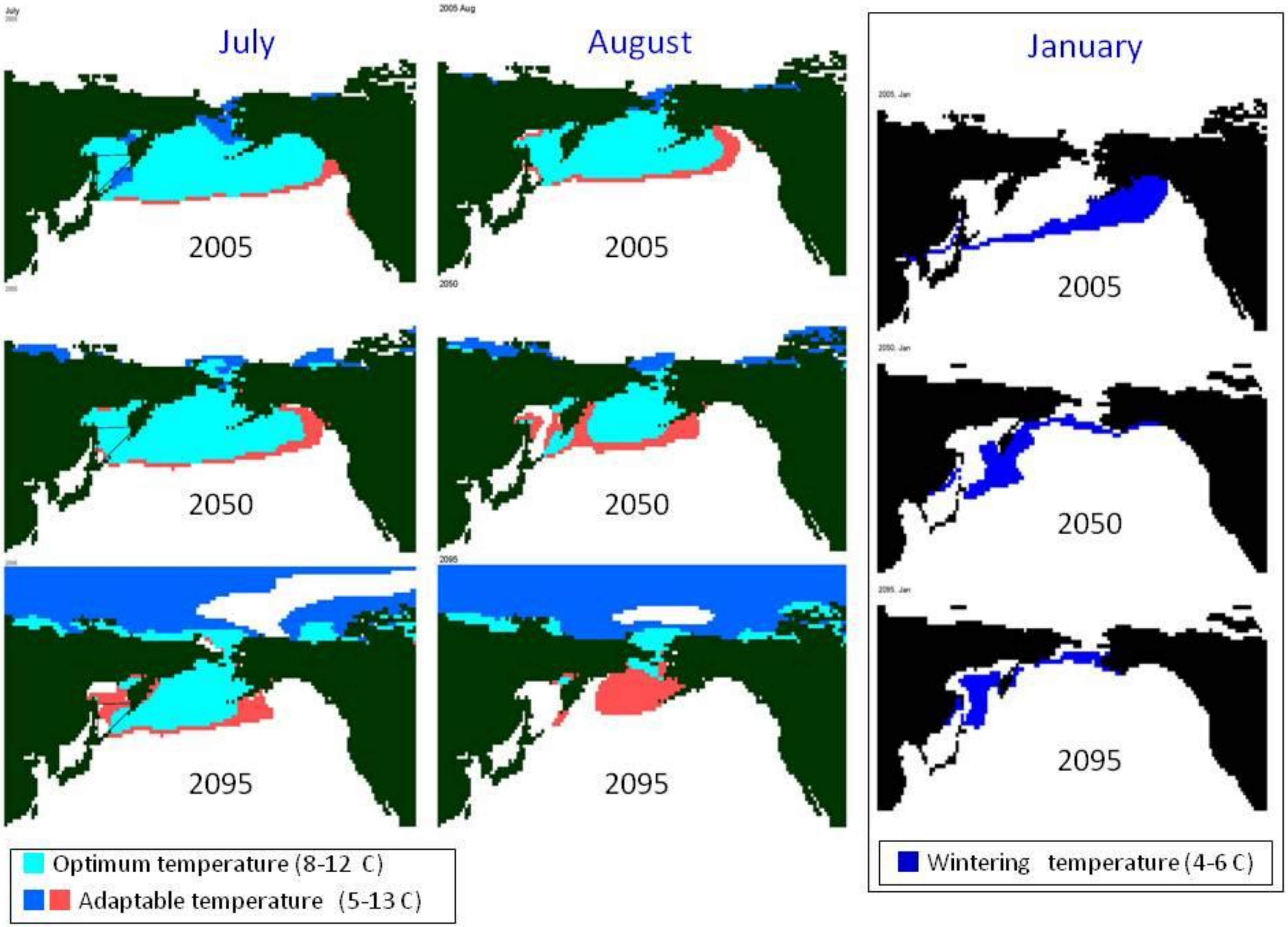


Please see a poster of FIS-P-4.

Wild population:
Important Genetic Resources



Prediction about the Global Warming effect on chum salmon in the North Pacific Ocean based on the SRES-A1B scenario



(Kaeriyama 2012)

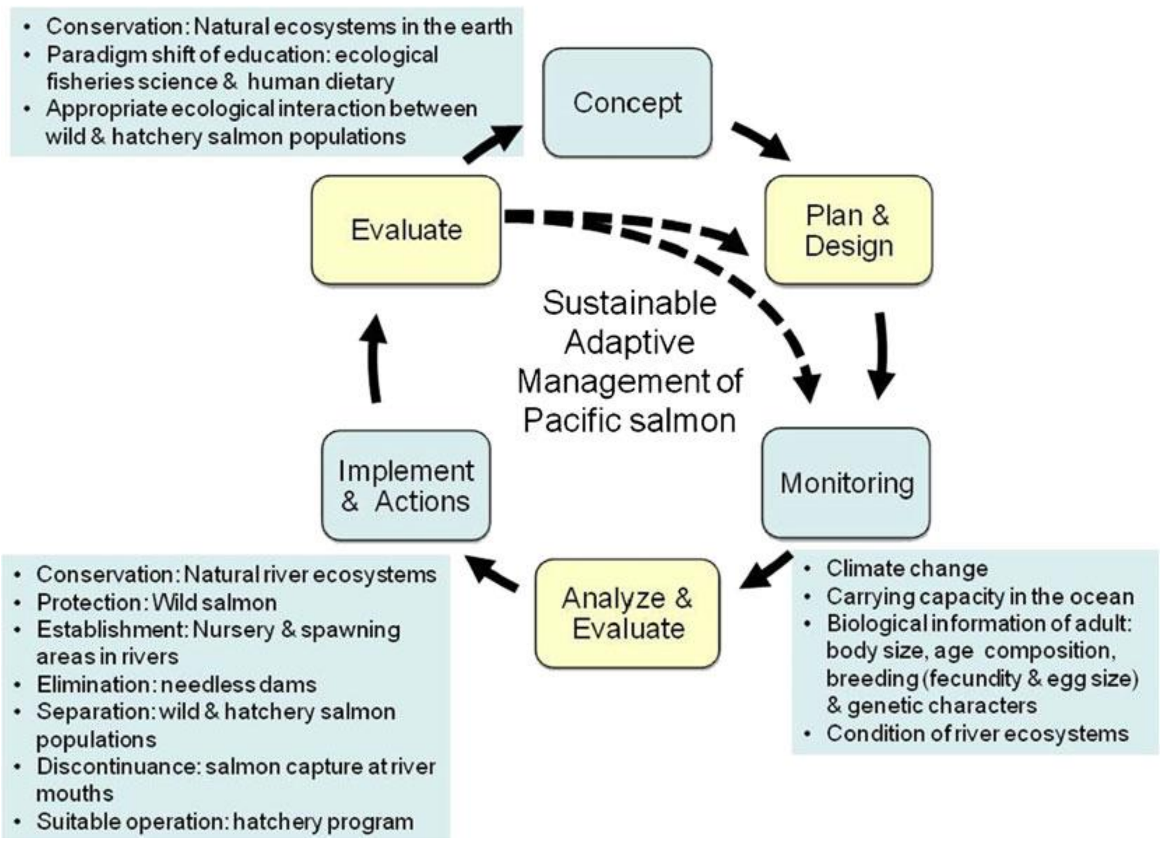
Global Warming Effect on Chum Salmon in the North Pacific

- **At present,** the global warming is affecting:
  - Positively & directly for increases in growth at age-1 and survival of Hokkaido chum salmon through the SST (sea surface temperature) during summer and autumn in the Okhotsk Sea since the late 1980s
  - Negatively for the spawning migration of early-run populations returning to Japan since the late 1990s

- **In the Future,** the global warming will affect:
  - Decrease in their carrying capacity for reducing distribution area in the Bering Sea
  - Moving to the northern area (e.g., the Chukchi Sea)
  - Strong density-dependent effect will occur
  - Wintering area change from the Gulf of Alaska to the Northwestern Subarctic Gyre
  - Hokkaido chum salmon population will lose migration route to the Okhotsk Sea by 2050 and will be crushed by 2100

Conclusion

Conceptual Diagram on the Sustainable Adaptive-Management of Pacific Salmon in Japan



Feedback control

Monitoring

- Climate change
- Biological information (body size, age composition, breeding & genetic characters
- Condition of river ecosystem, etc.

Action plan (& Modeling)

- Conservation: Natural freshwater ecosystems
- Protection: wild salmon
- Sustainable hatchery program

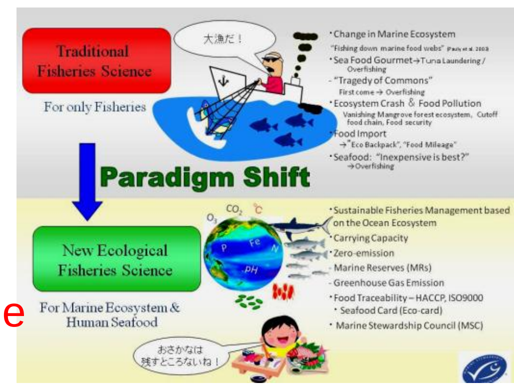
Sustainability for ocean ecosystem conservation and seafood security

■ Will we be able to use the ocean organisms as seafood in the future?

- ➢ We should recognize to live in the earth *ex dono* ecosystem service, and know natural threats
- ➢ Carrying capacity in the marine ecosystem → "More than enough is too much"
- ➢ Fisheries Industry : Economic efficiency→Ecosystem Approach

■ What do we need for seafood security and marine ecosystem sustainability in present and future?

- ➢ Education
  - Paradigm shift from the traditional fisheries science to the new ecological fisheries science in the advanced education
  - Dietary education for kids食育
    → e.g. "local production for local consumption" 地産地消



■ How do we establish the sustainable fisheries and aquaculture management based on the ecosystem approach?

- ➢ Risk Management: Adaptive management & Precautionary principle

1) Adaptive learning: Learning by doing, Responsibility of risk exposition

2) Feedback control: Monitoring, Modeling
   - Fisheries: Long-term climate change (e.g., Global warming, Regime shift), Carrying capacity
   - Aquaculture: Food security, Conservation of marine ecosystem, Water pollution