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# Climate Variability and chum salmon production and survival in the North Pacific

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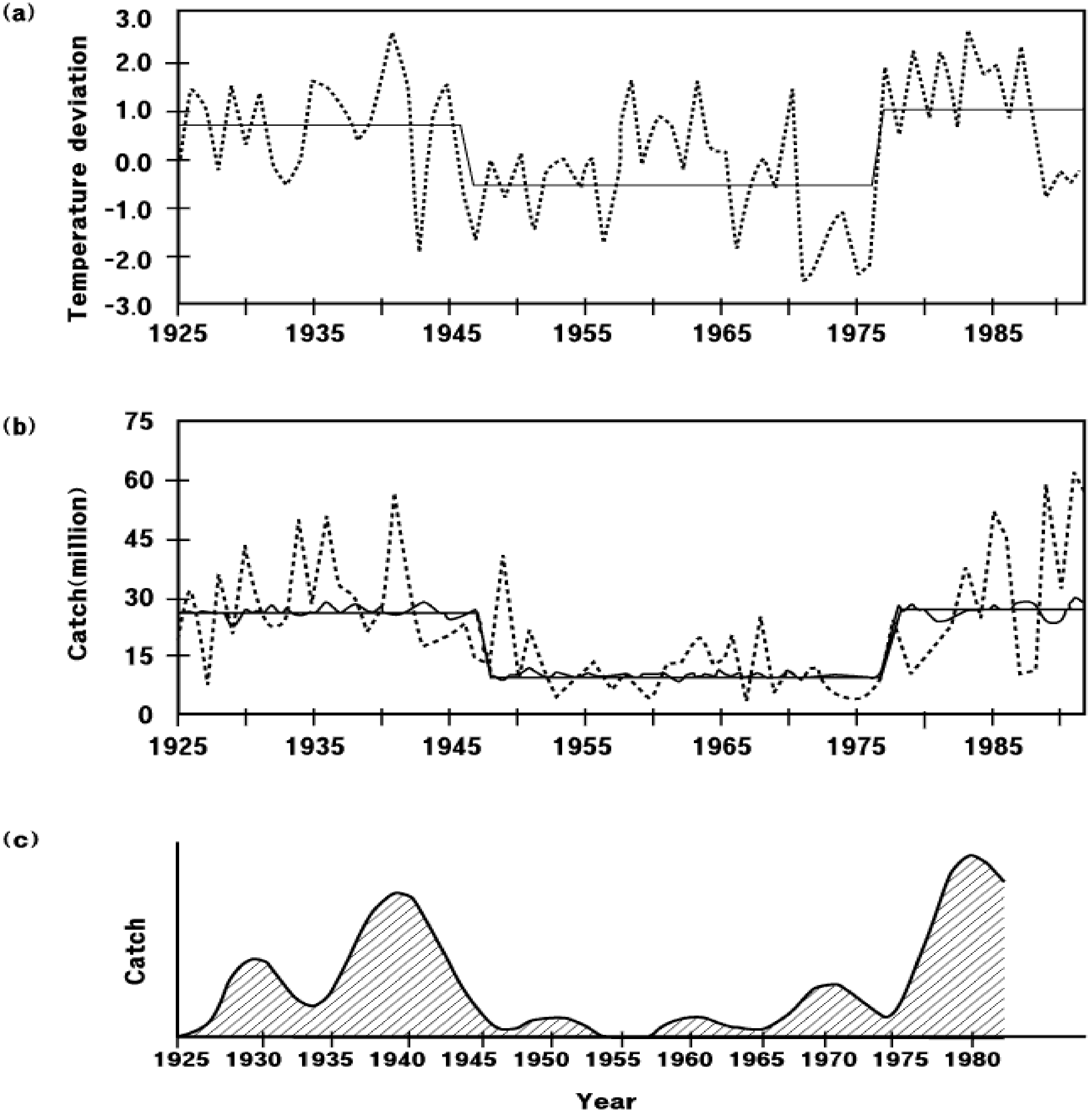
# Relationship between climate, ocean environment, and marine ecosystems

**Climate change** → **Changes in ocean environment** → **Ecosystem reconstruction**

**Climate change**
- increase in greenhouse gas
- atmospheric warming

**Changes in ocean environment**
- SST increase
- ocean currents change
- sea levels rise

**Ecosystem reconstruction**
- changes in distribution and physiology
- fluctuations in production




**Air temperature at Kodiak**

**Pink salmon catch in Alaska**

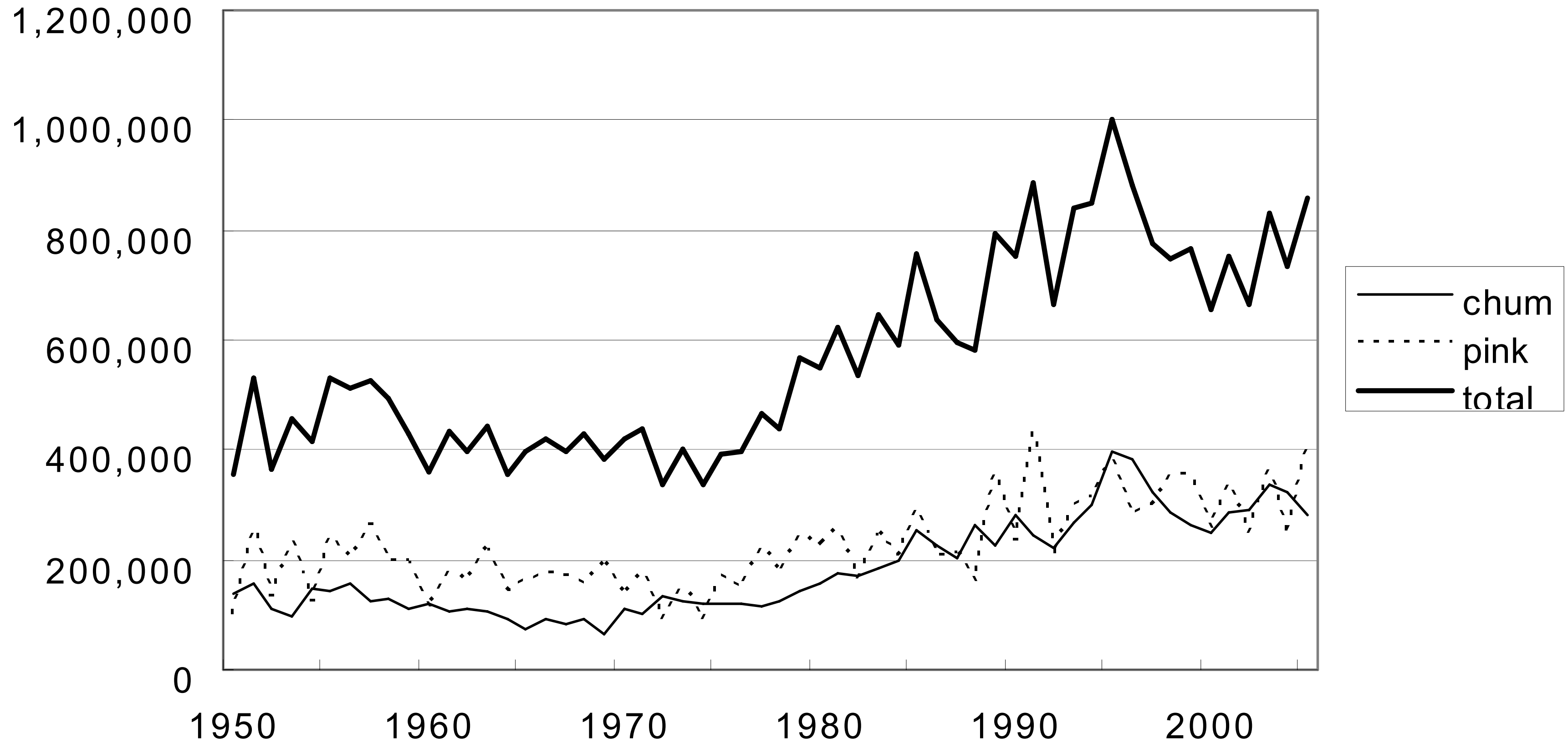
**Tele-connection!?**

**Pink salmon catch in North Korea**

# Chum salmon, *Oncorhynchus keta*

- **Chum salmon is one of the most abundant salmon species in the North Pacific, so that this species is economically and ecologically important.**

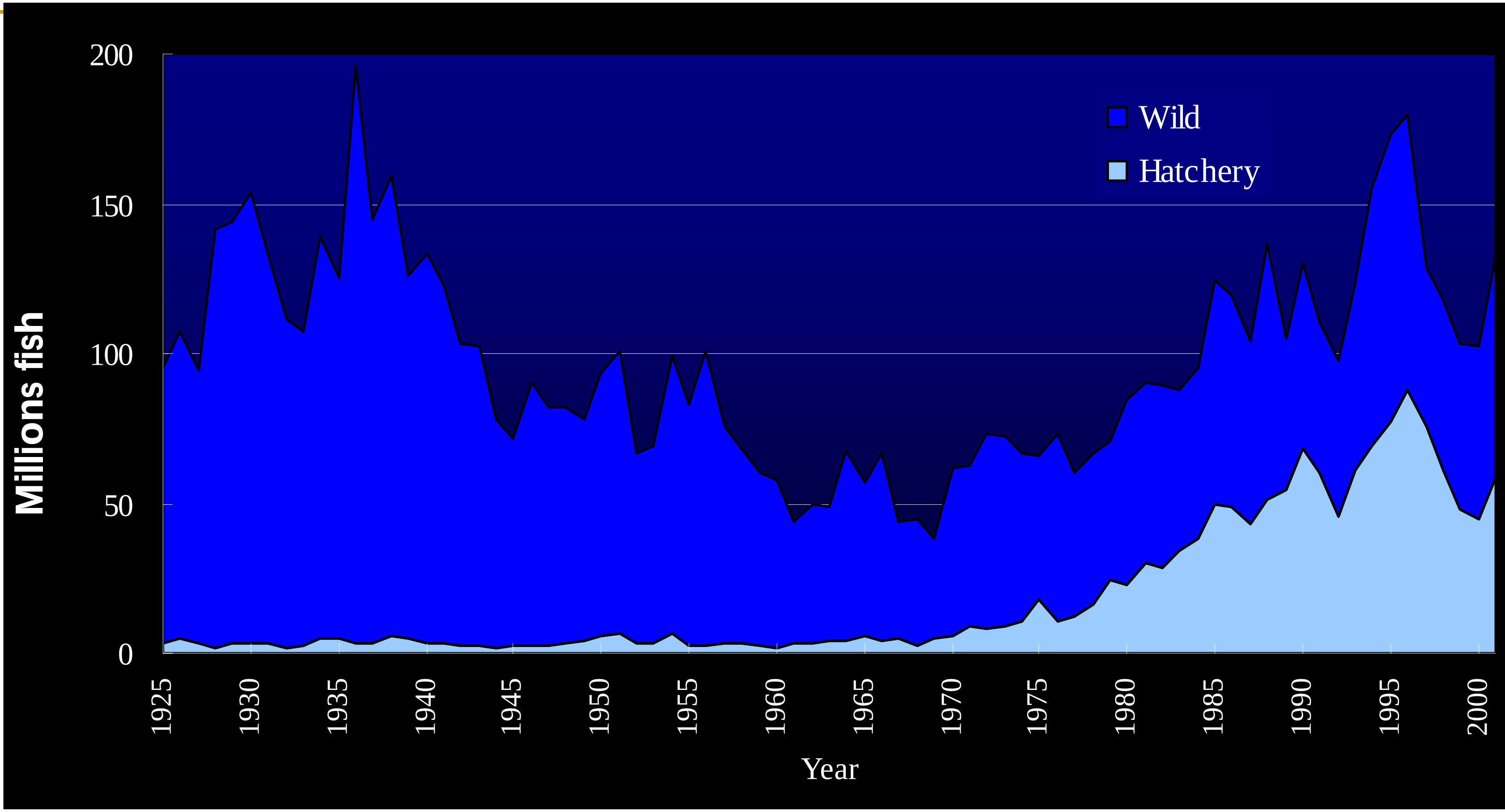
## Catches of chum salmon (thin), pink salmon (dashed), total salmons (thick) in the North Pacific, 1950~2005.



# Chum salmon, *Oncorhynchus keta*

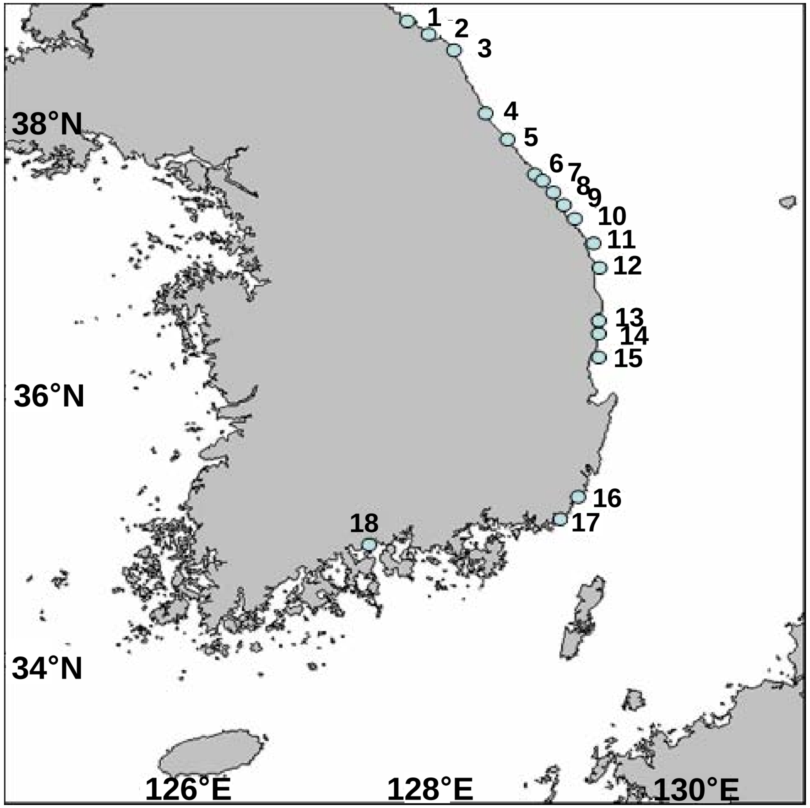
- Chum salmon is one of the most abundant salmon species in the North Pacific, so that this species is economically and ecologically important.

- **Salmon enhancement program in Korea has focused on this species since mid 1980s.**



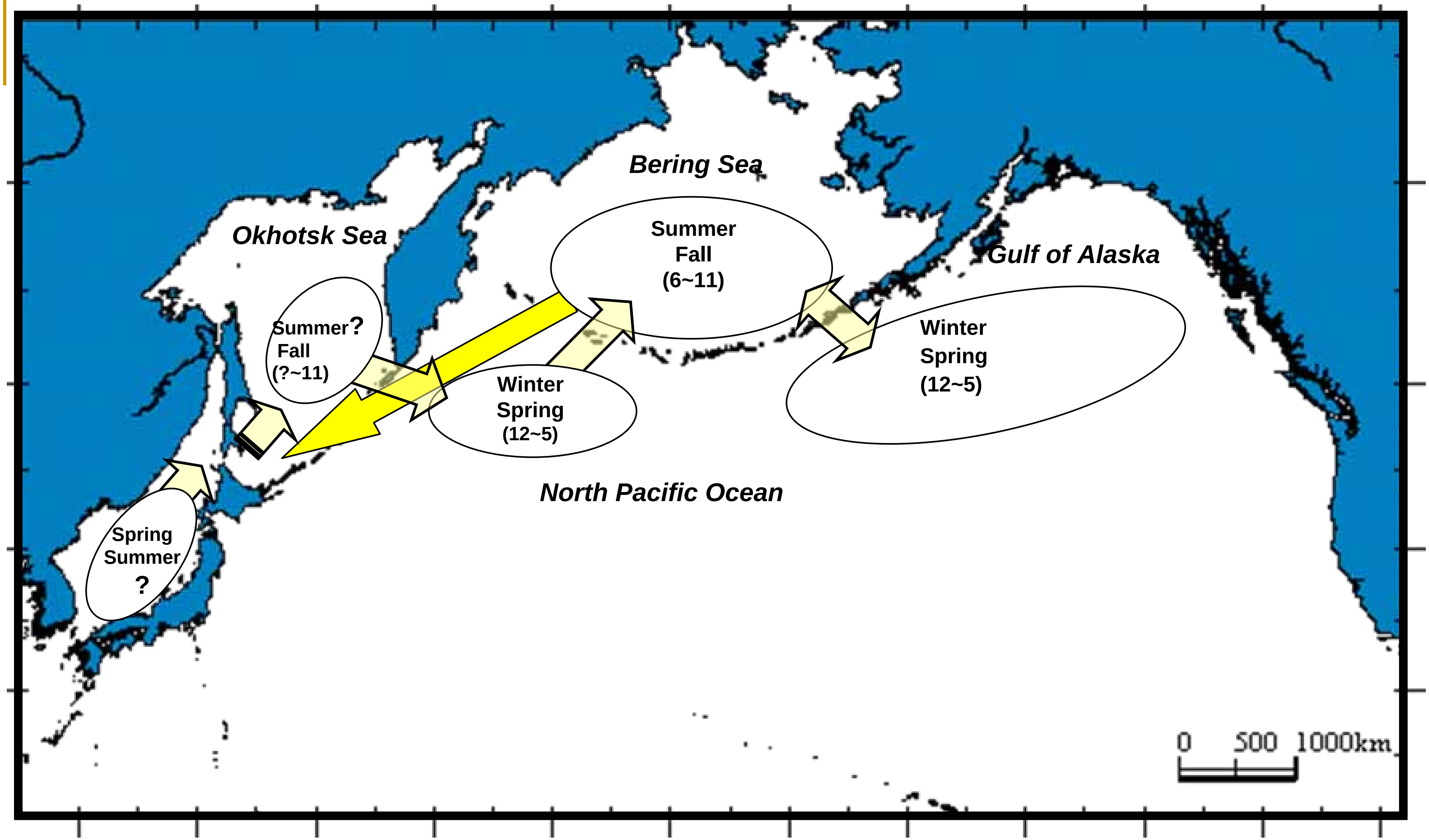

**Change in abundance of hatcheries and wild chum salmon in the North Pacific Ocean (Kaeriyama, 2003)**

- **Such increases in catch might be due to better environmental conditions as well as enhancement programs of each nation.**




1. Nam-gang (Nam river)
2. Myeongpa-cheon (Myeongpa stream)
3. Buk-cheon (Buk stream)
4. Namdae-cheon (Namdae stream): Yangyang
5. Yeongok-cheon (Yeongok stream)
6. Nakpung-cheon (Nakpung stream)
7. Jusu-cheon (Jusu stream)
8. Jeon-cheon (Jeon stream)
9. Osip-cheon (Osip stream): Samcheok
10. Maeup-cheon (Maeup stream)
11. Gagok-cheon (Gagok stream)
12. Wangpi-cheon (Wangpi stream)
13. Namdae-cheon (Namdae stream): Uljin
14. Songcheon-cheon (Songcheon stream)
15. Osip-cheon (Osip stream): Yeongdeok
16. Taehwa-gang (Taehwa river)
17. Ilgwang-cheon (Ilgwang stream)
18. Seomjin-gang (Seomjin river)

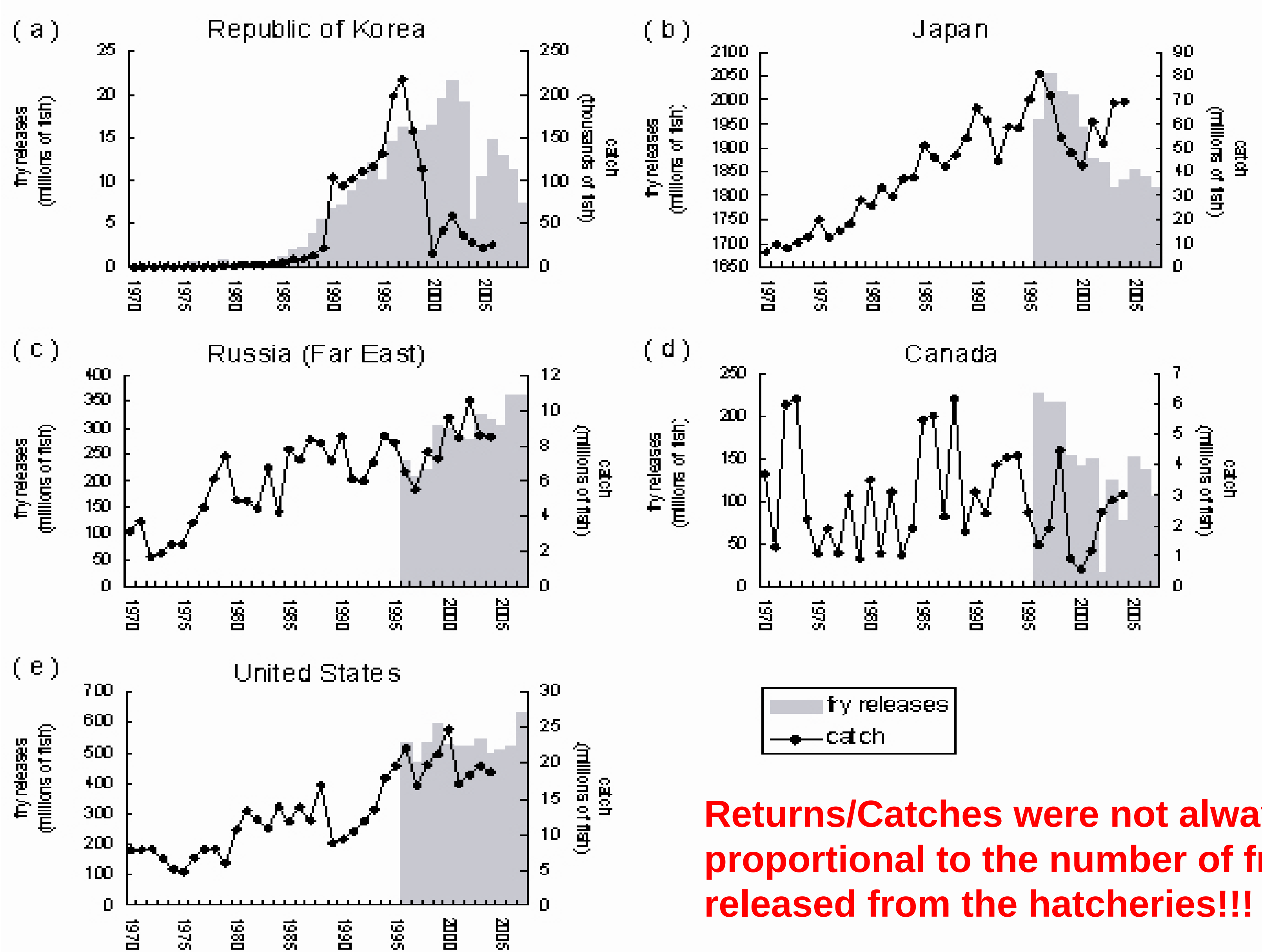
## 18 streams where fry chum salmon are released in spring in Korea




**Schematic migration model of chum salmon released from Korea (modified from Urawa et al., 2000).**

# Chum salmon, *Oncorhynchus keta*

- Chum salmon is one of the most abundant salmon species in the North Pacific, so that this species is economically and ecologically important.
- Salmon enhancement program in Korea has focused on this species since mid 1980s.
- **Environmental variability might be a major forcing for determining stock condition and behavior of chum salmon.**




**Returns/Catches were not always proportional to the number of fry released from the hatcheries!!!**

**The numbers of fry released at year *i* and returning adults of chum salmon at year *i*+3. Catch of returning adults at year *i*+3 was matched with fry released at year i in the graphs.**

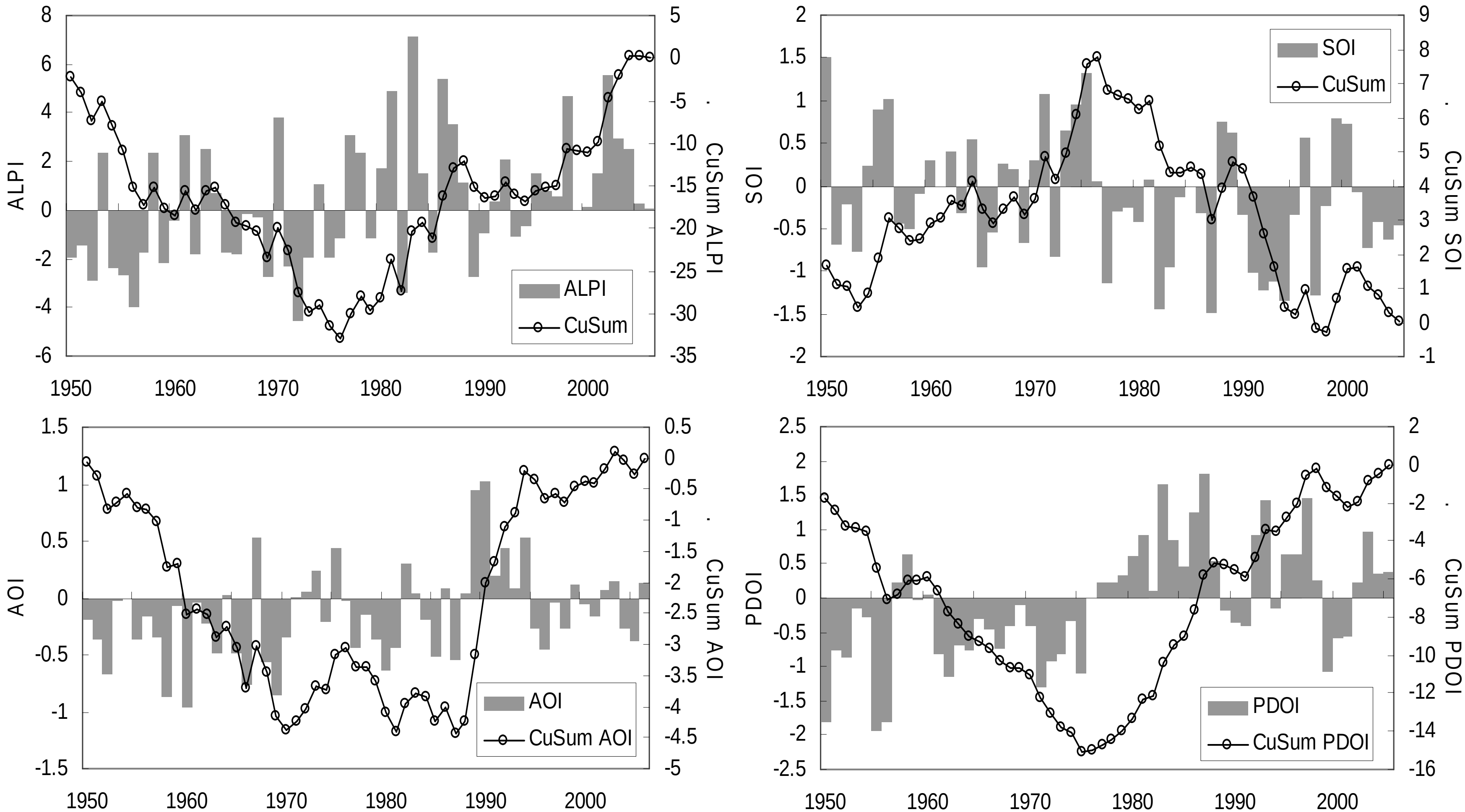
# Objectives:

**Investigation on relationship between chum salmon biology and climate variability in the North Pacific**

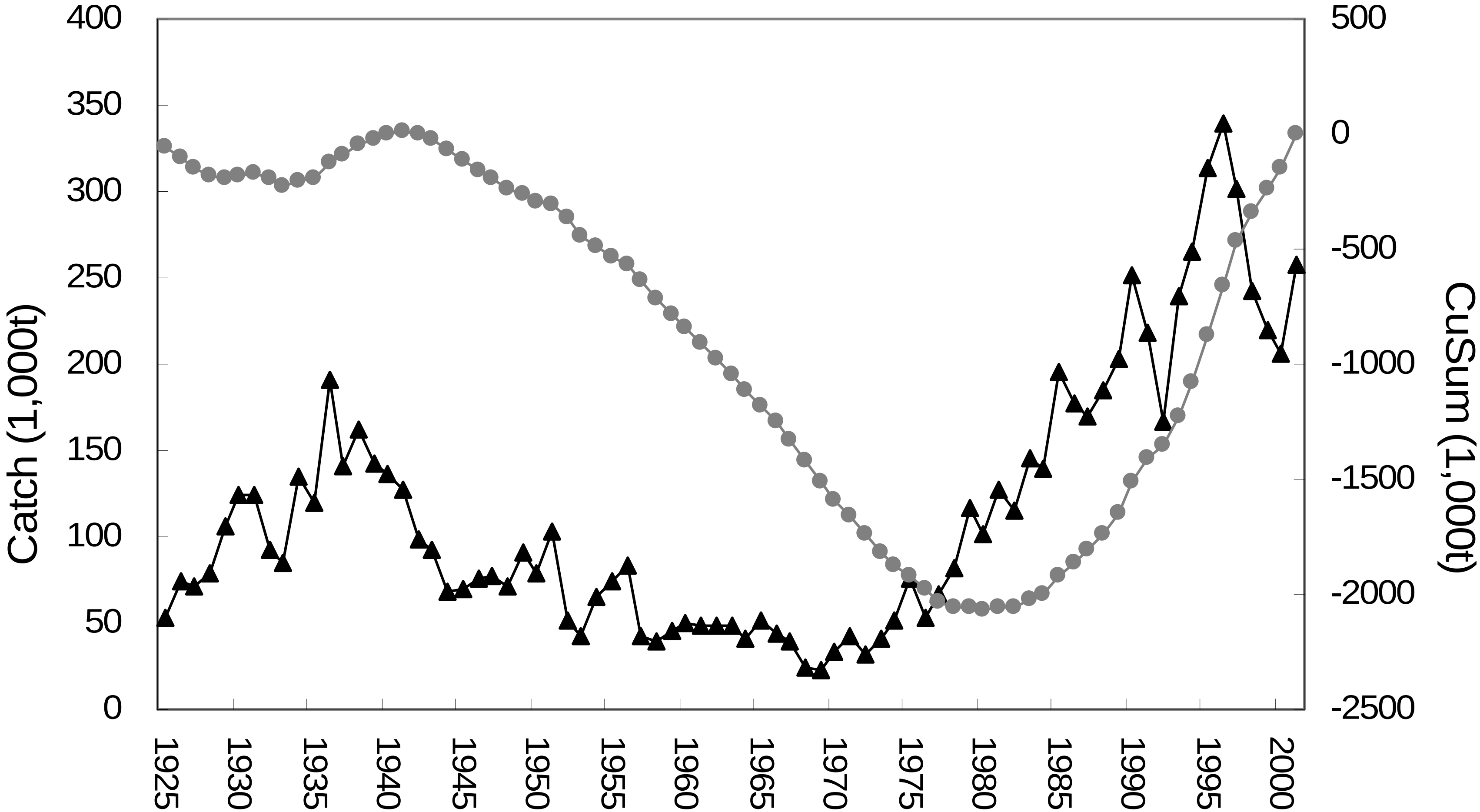
# Methods and materials:

- **Climate/Ocean Indices:**
  - **ALPI**
  - **SOI**
  - **AOI**
  - **PDOI**
- **Biological parameters on chum salmon:**
  - **Catch**
  - **Growth**
  - **Return rate**

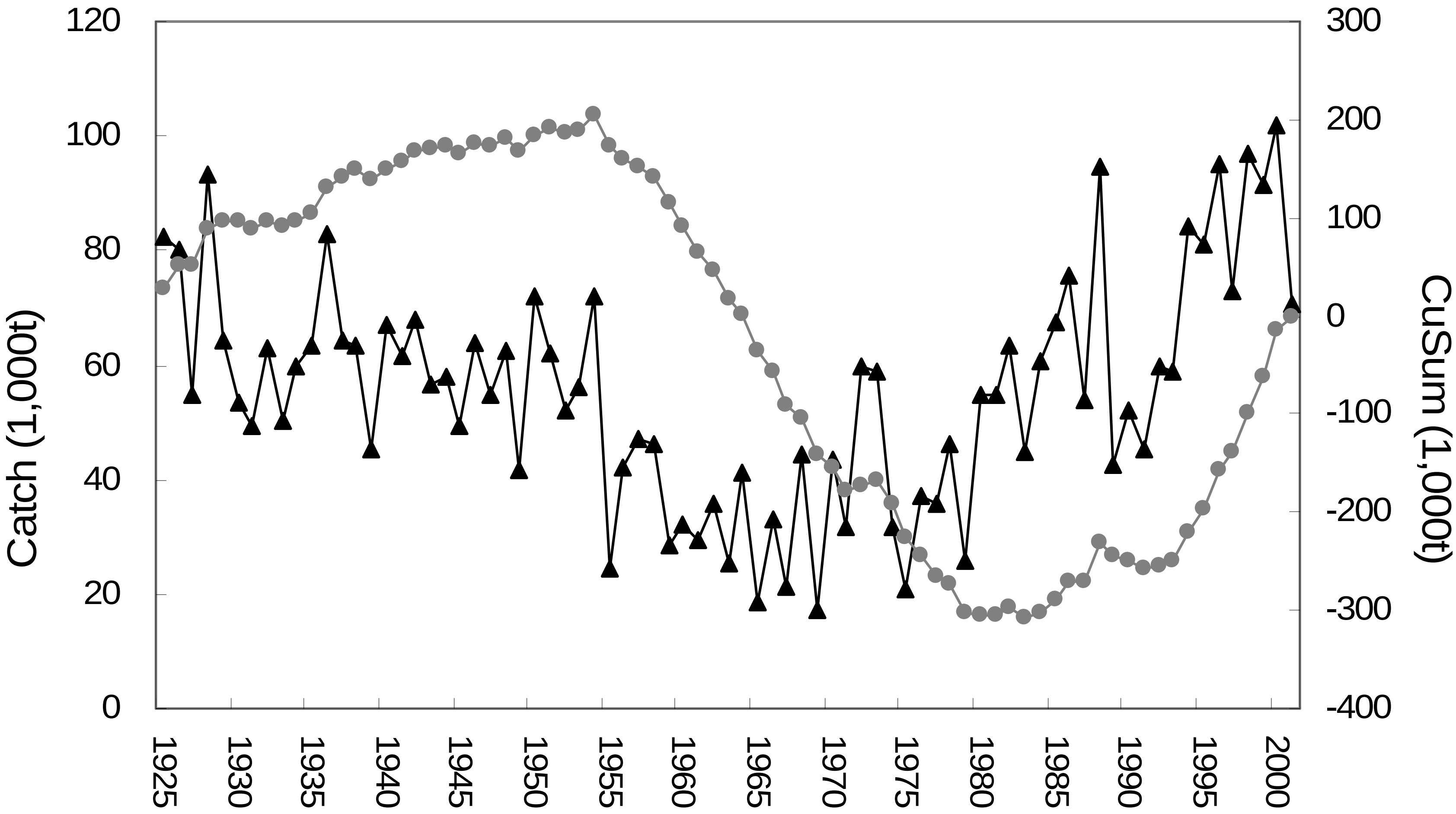
# Four major climate/Ocean indices in the Pacific Ocean




**Most graphs show the changes in 1976, 1988, and 1998.**




## Asia yield with CuSum of chum salmon, 1925-2001

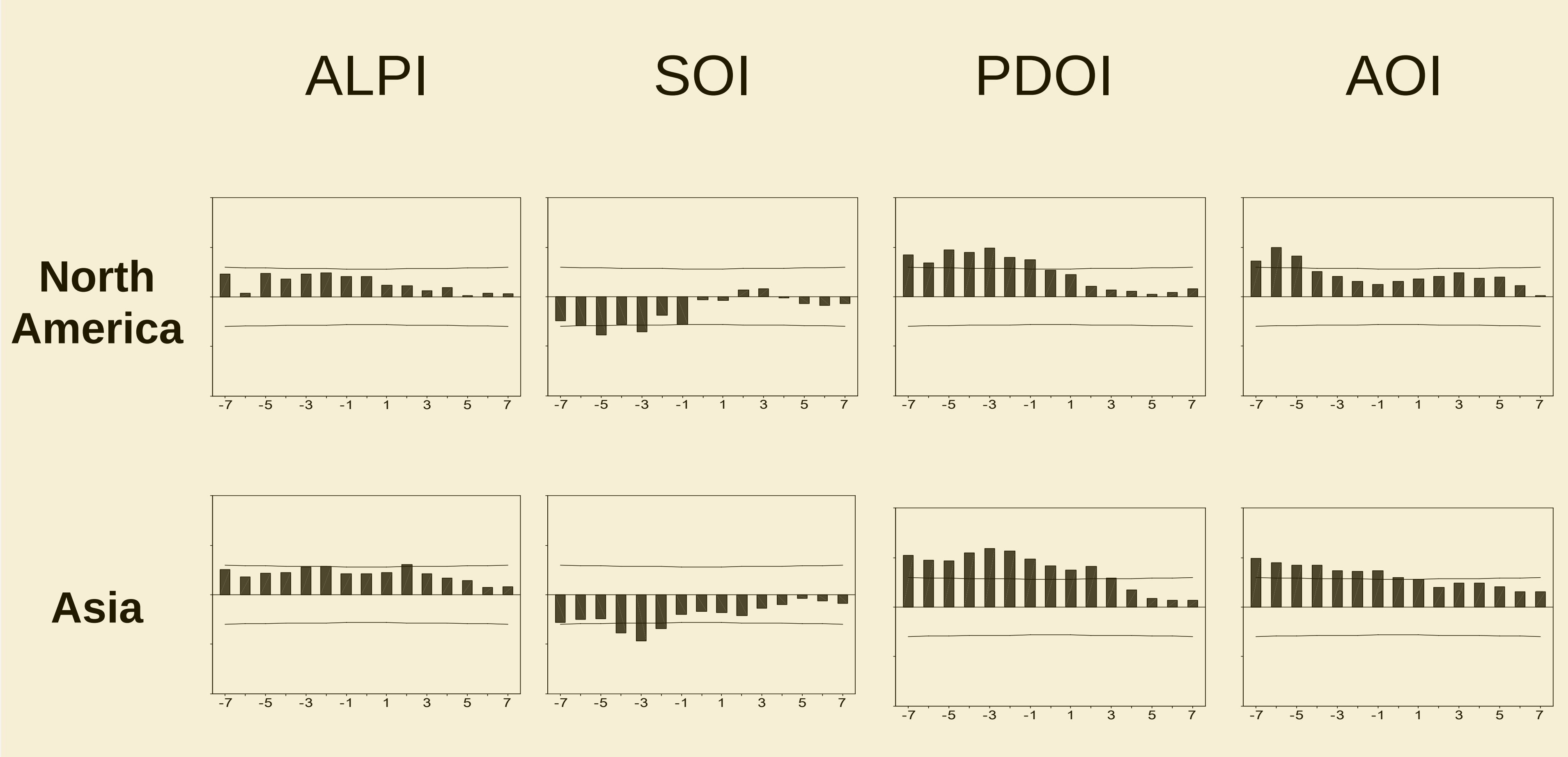



**North America yield with CuSum of chum salmon, 1925-2001**

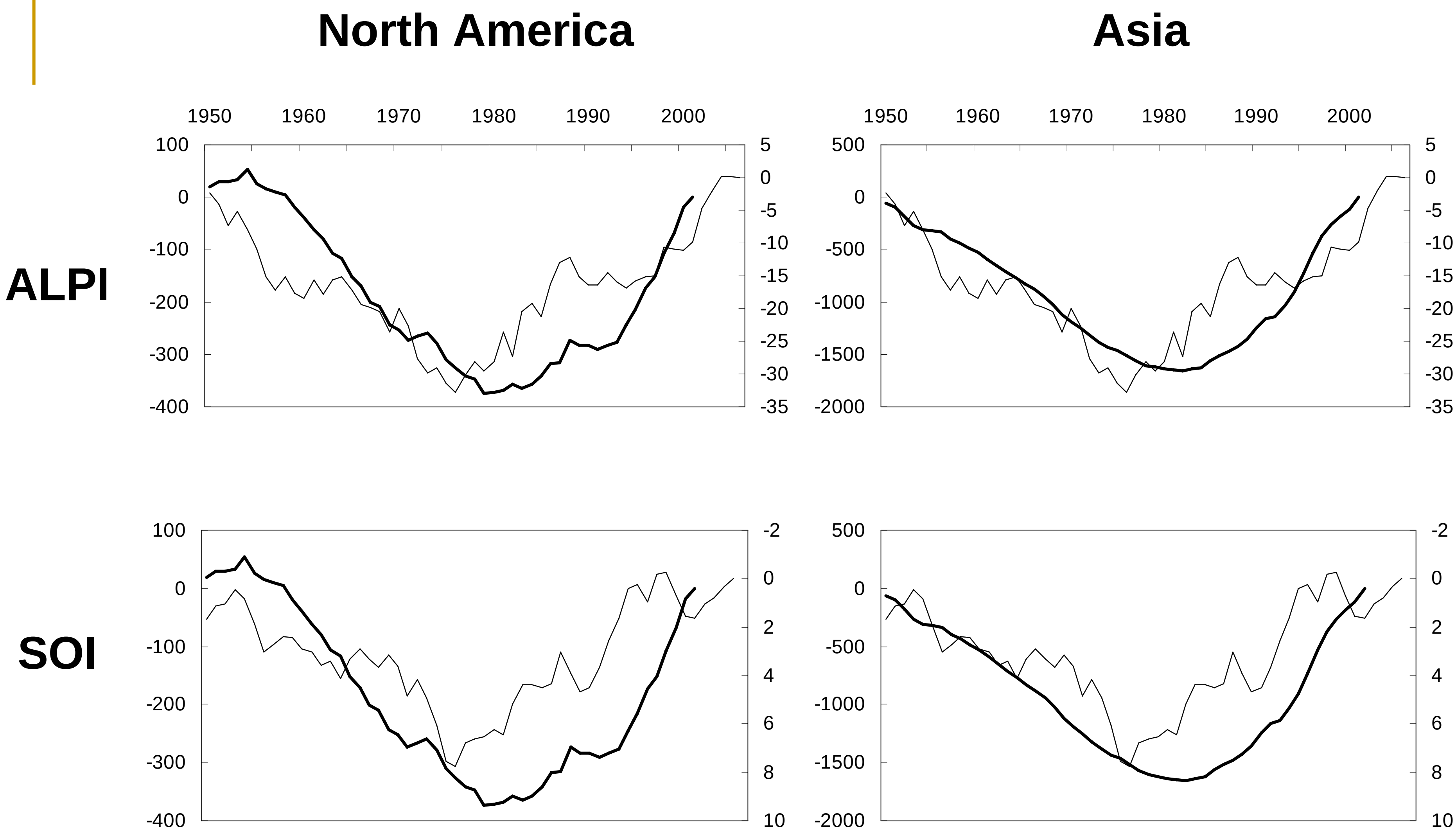
## Correlations between chum salmon production and Environmental Indices over the Pacific Ocean during 1950~2001

| | ALPI | SOI | PDOI | AOI |
|---|---|---|---|---|
| North America | 0.202 | -0.029 | 0.326** | 0.157 |
| Asia | 0.212 | -0.167 | 0.349** | 0.301* |
| Pacific total | 0.224 | -0.145 | 0.379** | 0.286* |

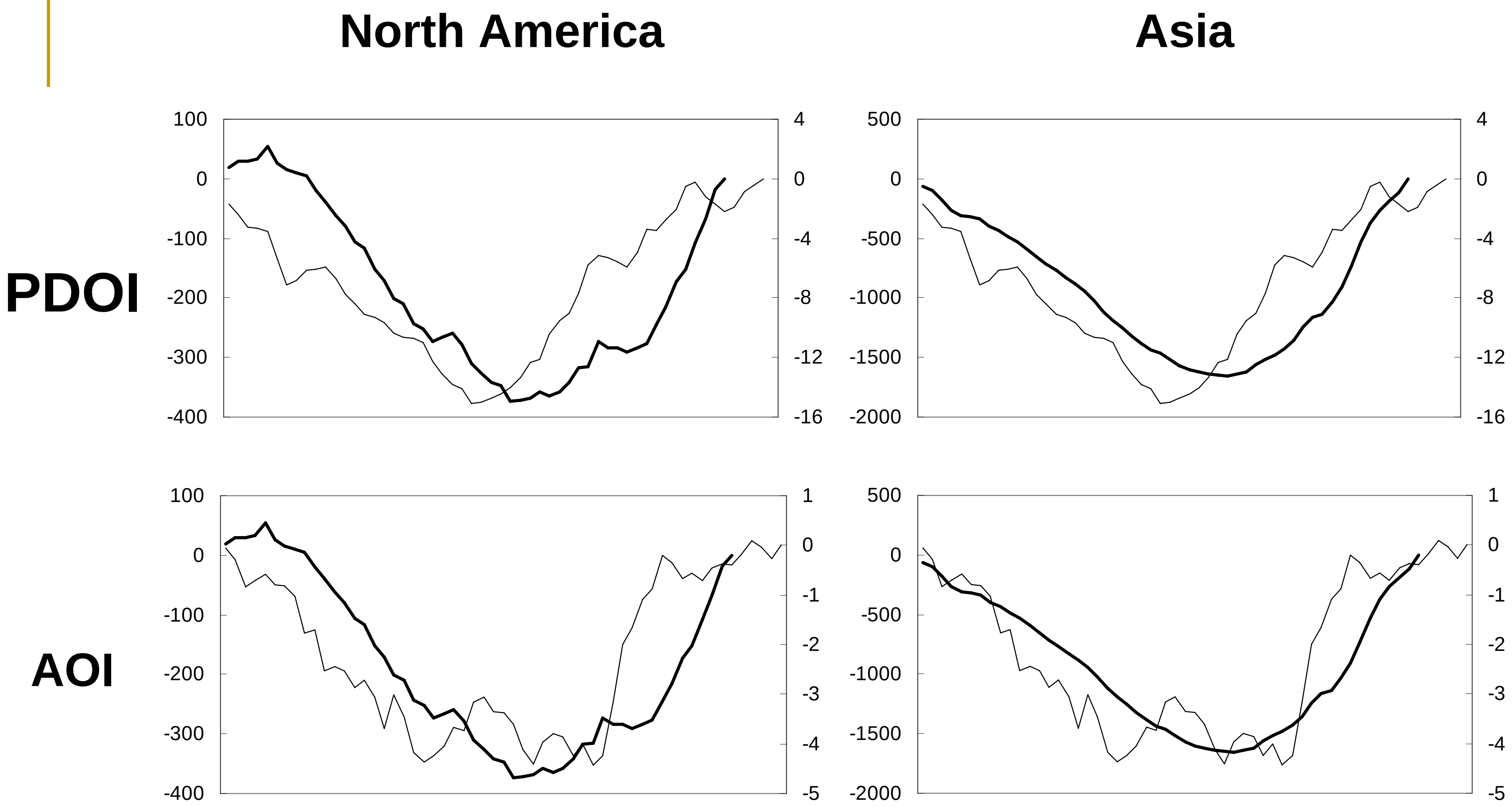
# Time-lag effect




**Result of cross-correlation function analysis between regional chum salmon catches and four environmental indices during 1950~2001**




**Trend of CuSum of regional chum salmon catches (thick lines) and four environmental indices (thin lines) during 1950~2001**

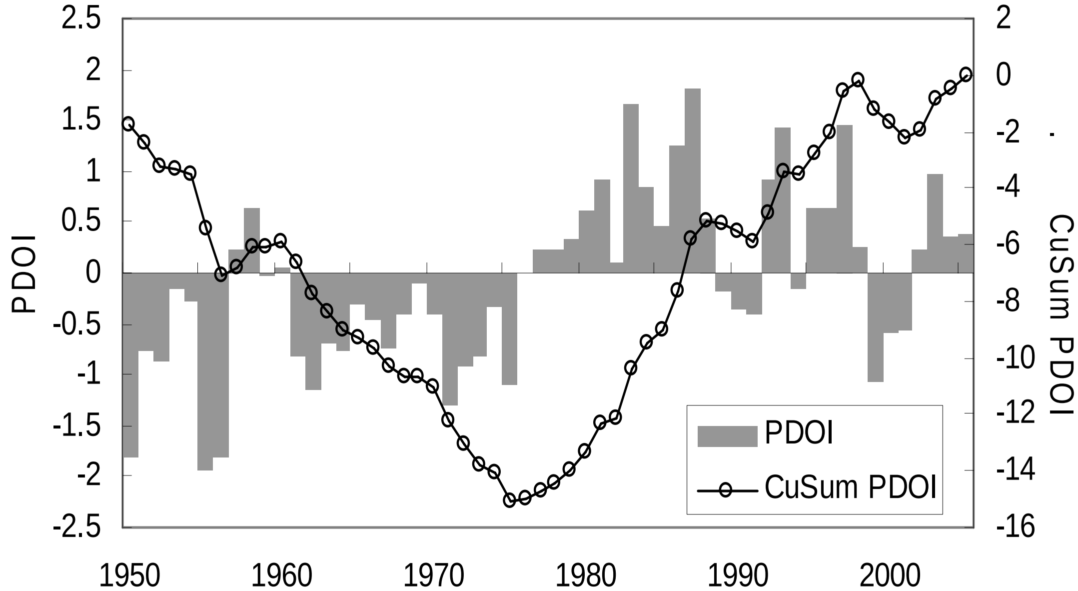



**Trend of CuSum of regional chum salmon catches (thick lines) and four environmental indices (thin lines) during 1950~2001**

# Conclusion I:

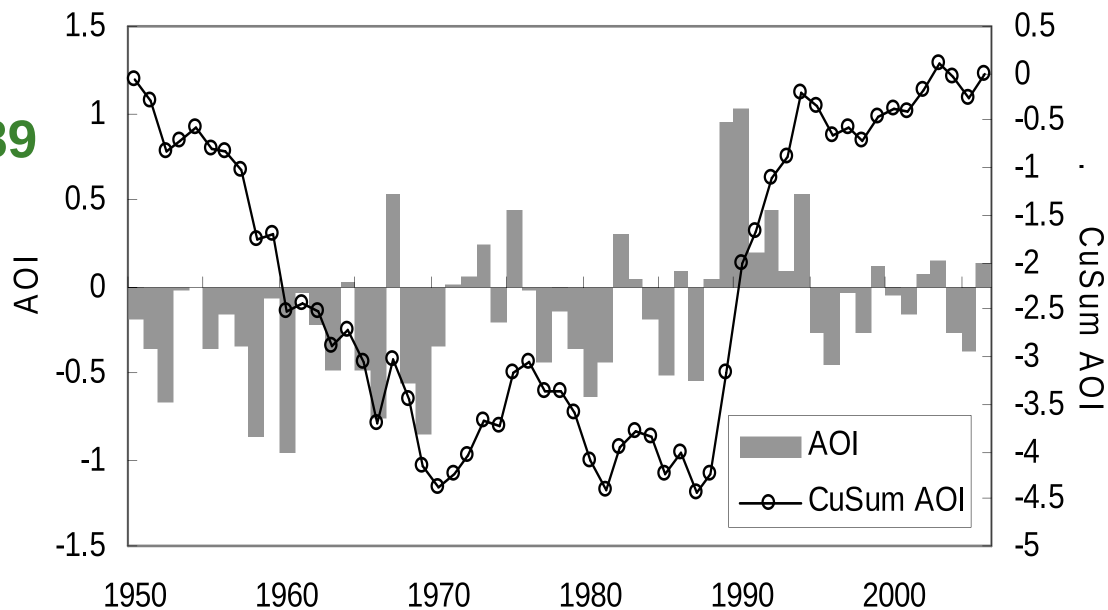
- **There was a major change in climate during the mid 1970s, and chum salmon population responded to this climate event with a time-lag.**

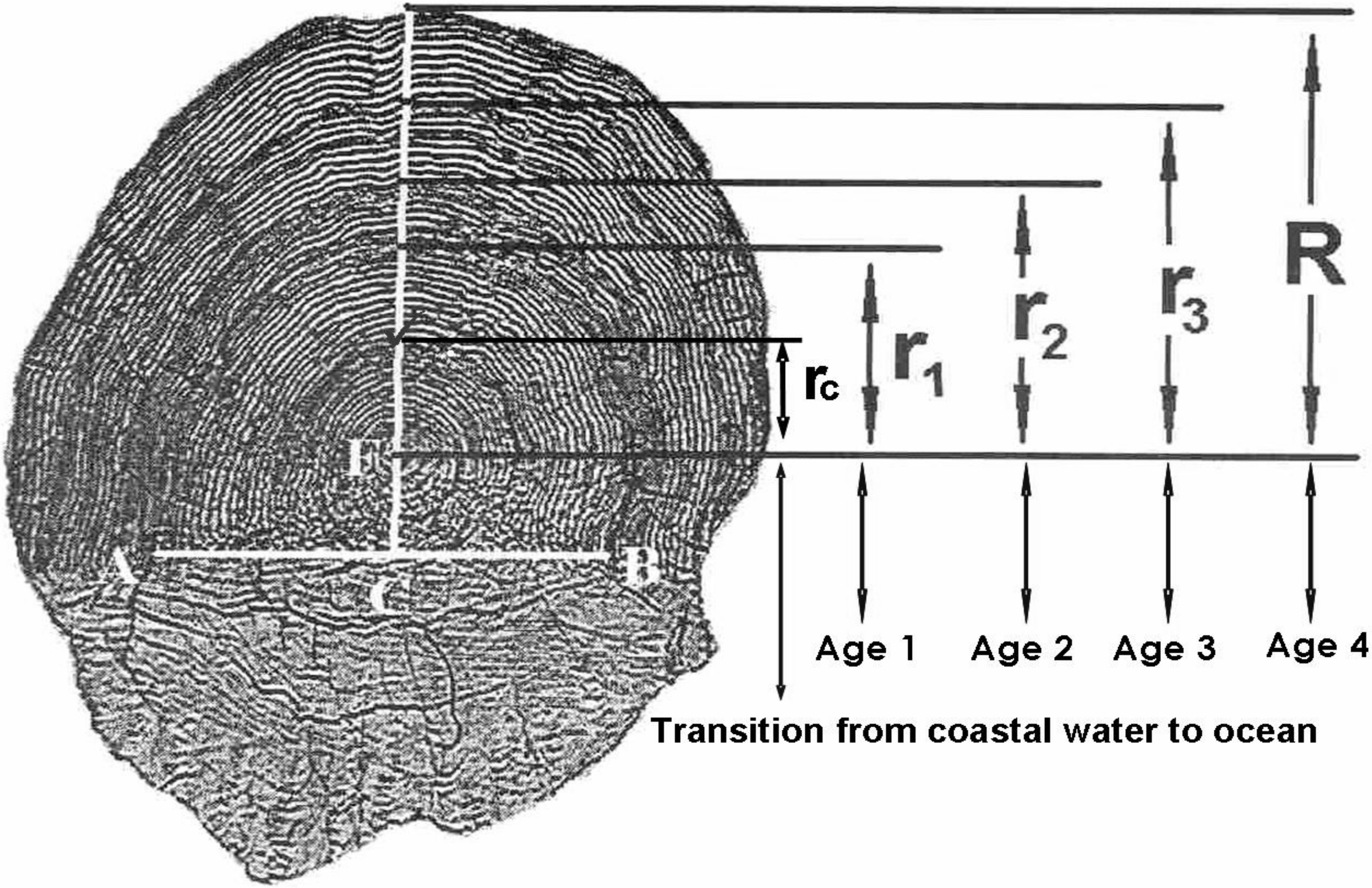
- **The PDO and chum salmon returns showed a highly significant correlation with a time-lag of 3 years, while the AOI with a time-lag of 6~7 years.**



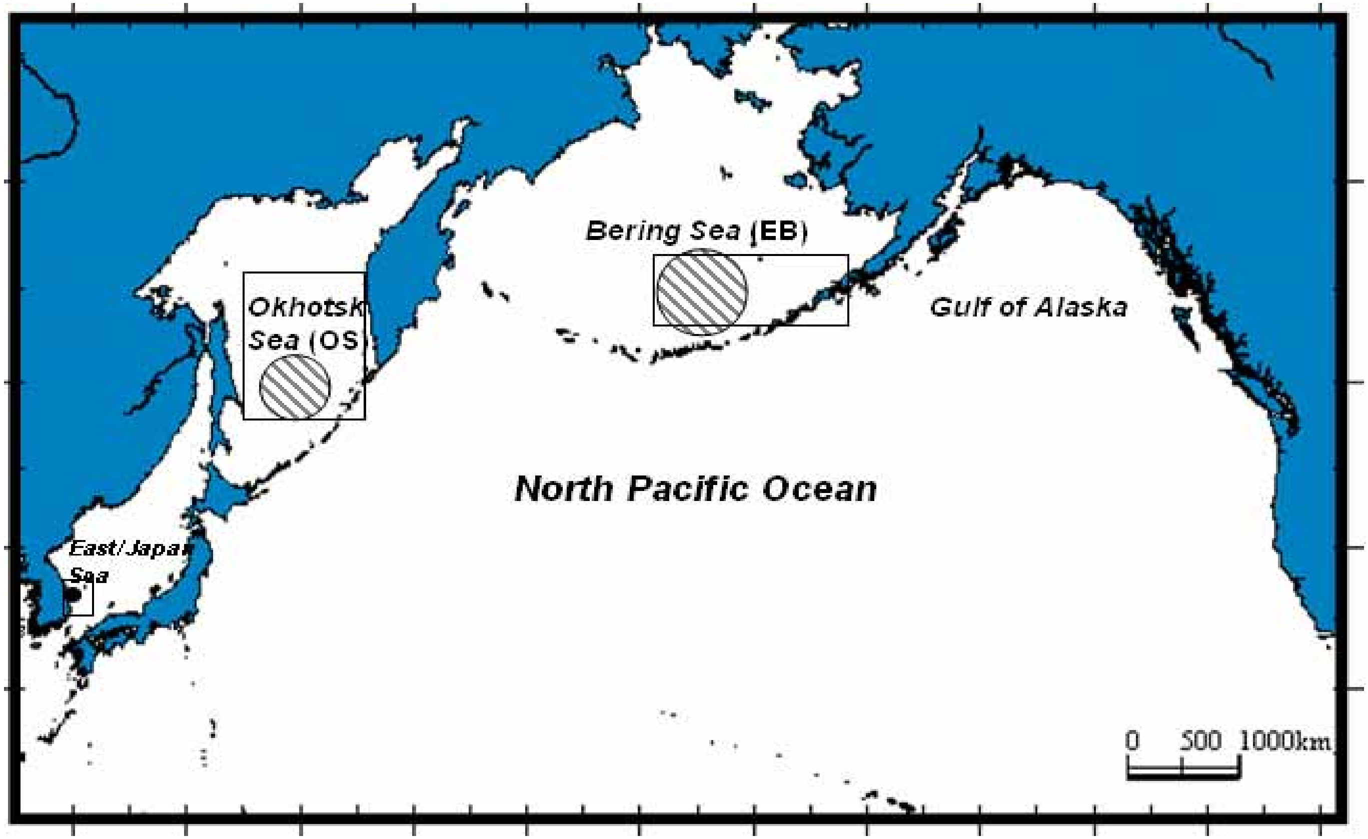

## Changes in 1976/1977

## Changes in 1988/1989



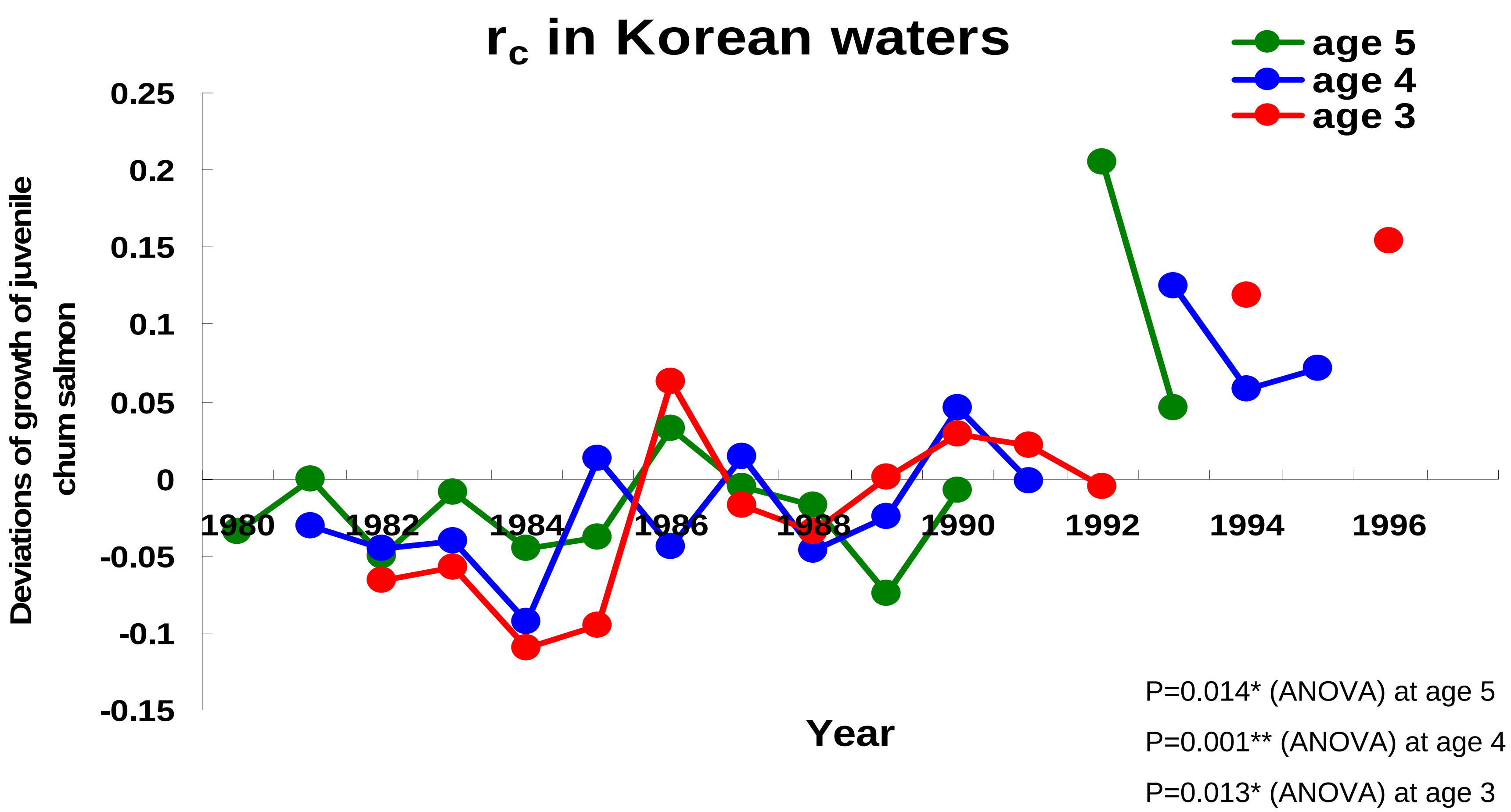


R
r3
r2
r1
rc
F
A
B
C
Age 1
Age 2
Age 3
Age 4
Transition from coastal water to ocean



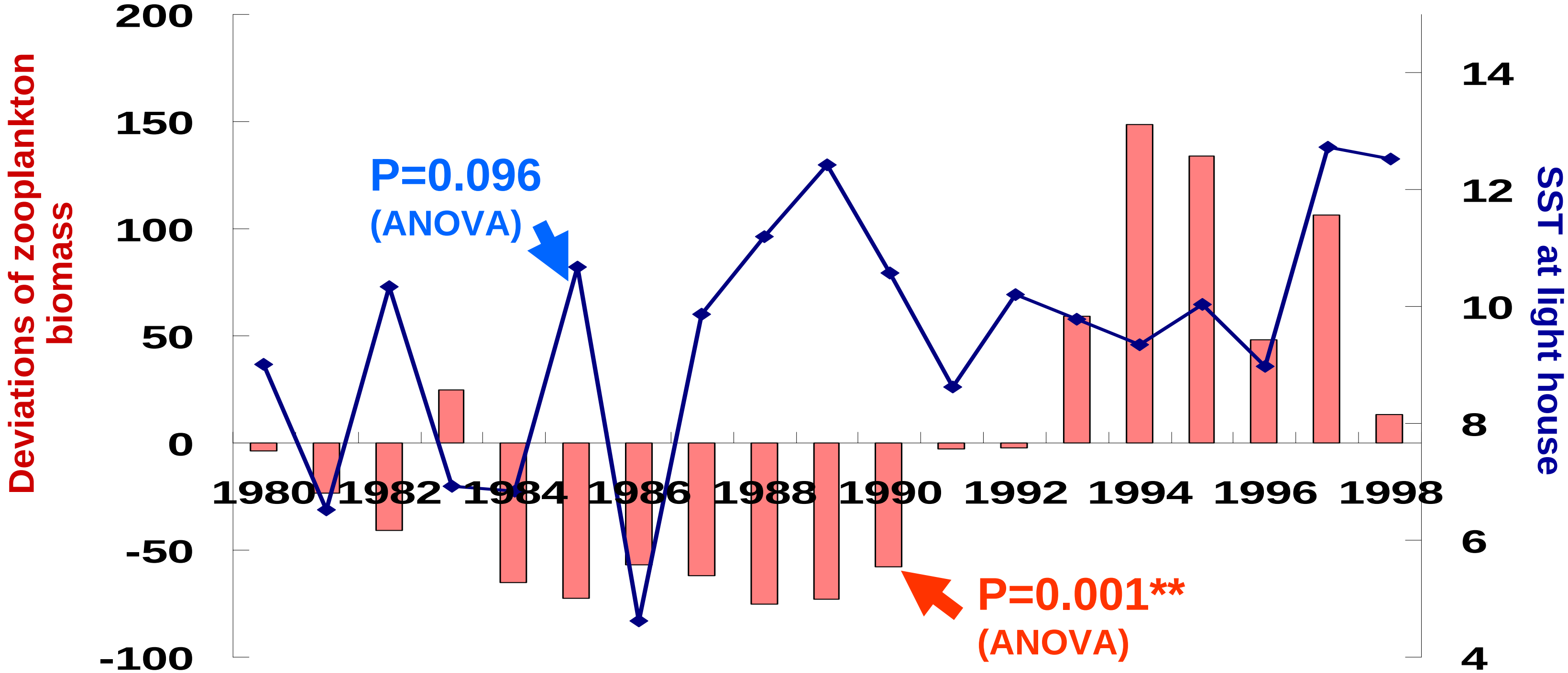

- SST information was collected from rectangular areas in the Bering Sea (52-58°N, 0-160°W) and the Okhotsk Sea (48-58°N, 145-155°E) using NCEP/NCAR Reanalysis. SSTs in Korean waters were measured at a light house near the hatchery (●).

- Zooplankton data for Korean waters, the Okhotsk Sea, and the Bering Sea were extracted from 36-38°N and 128-131°E of KODC, Shuntov & Dulepova (1996), and Sugimoto & Tadokoro (1997), respectively.

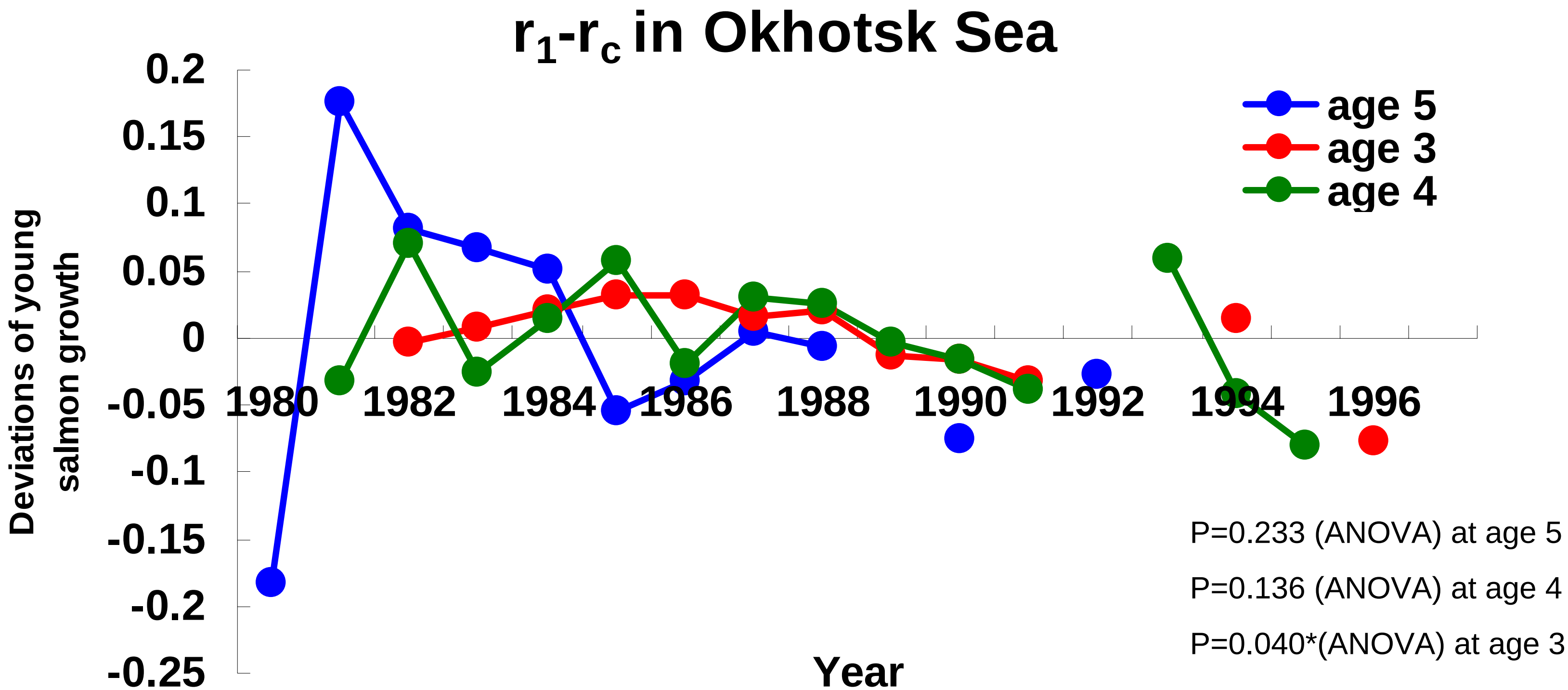



**Deviations of growth of juvenile chum salmon in coastal water including freshwater/river mouth. Growth information was derived from returning female salmon to mother stream at age-3 and age-4 during 1984-1998. The x-axis represents the year of growth.**

# zooplankton biomass and SST in Korean waters

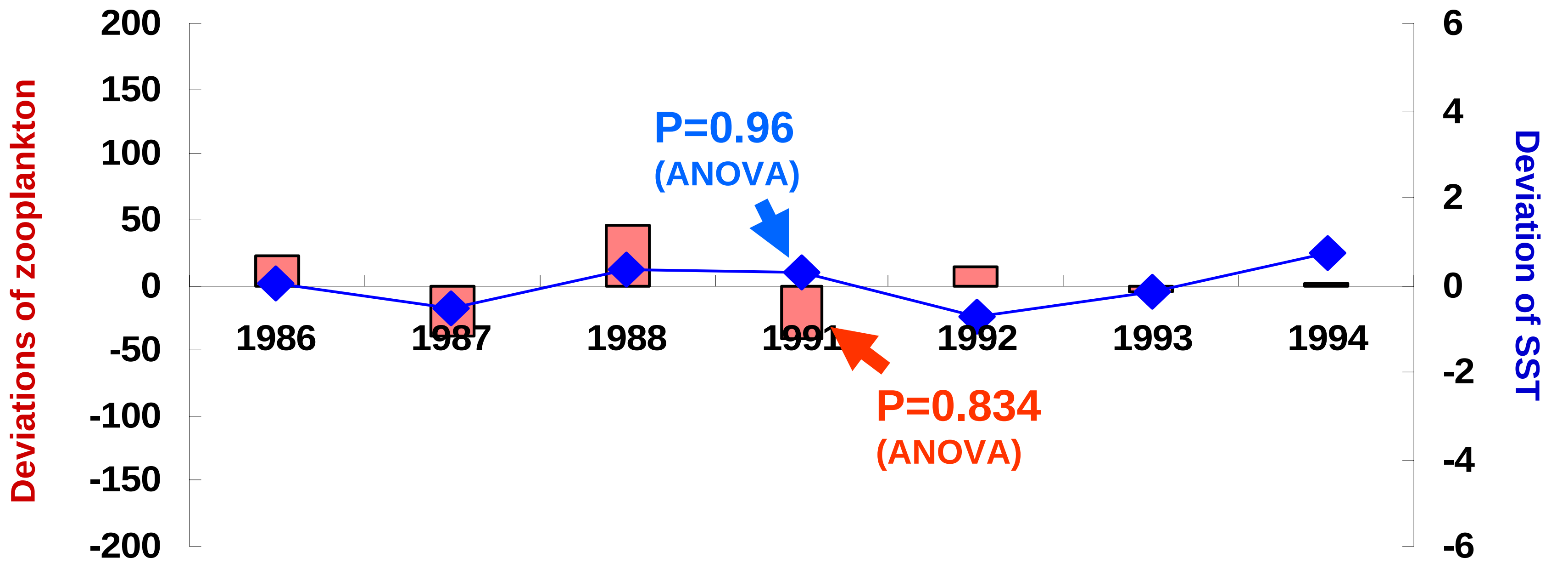



**SST (line) at light house in April (mean value=9.54°C) and deviations of zooplankton biomass (bar) off the east coast of Korea (mean value=98.98 mg/m3). Data were extracted from KODC.**



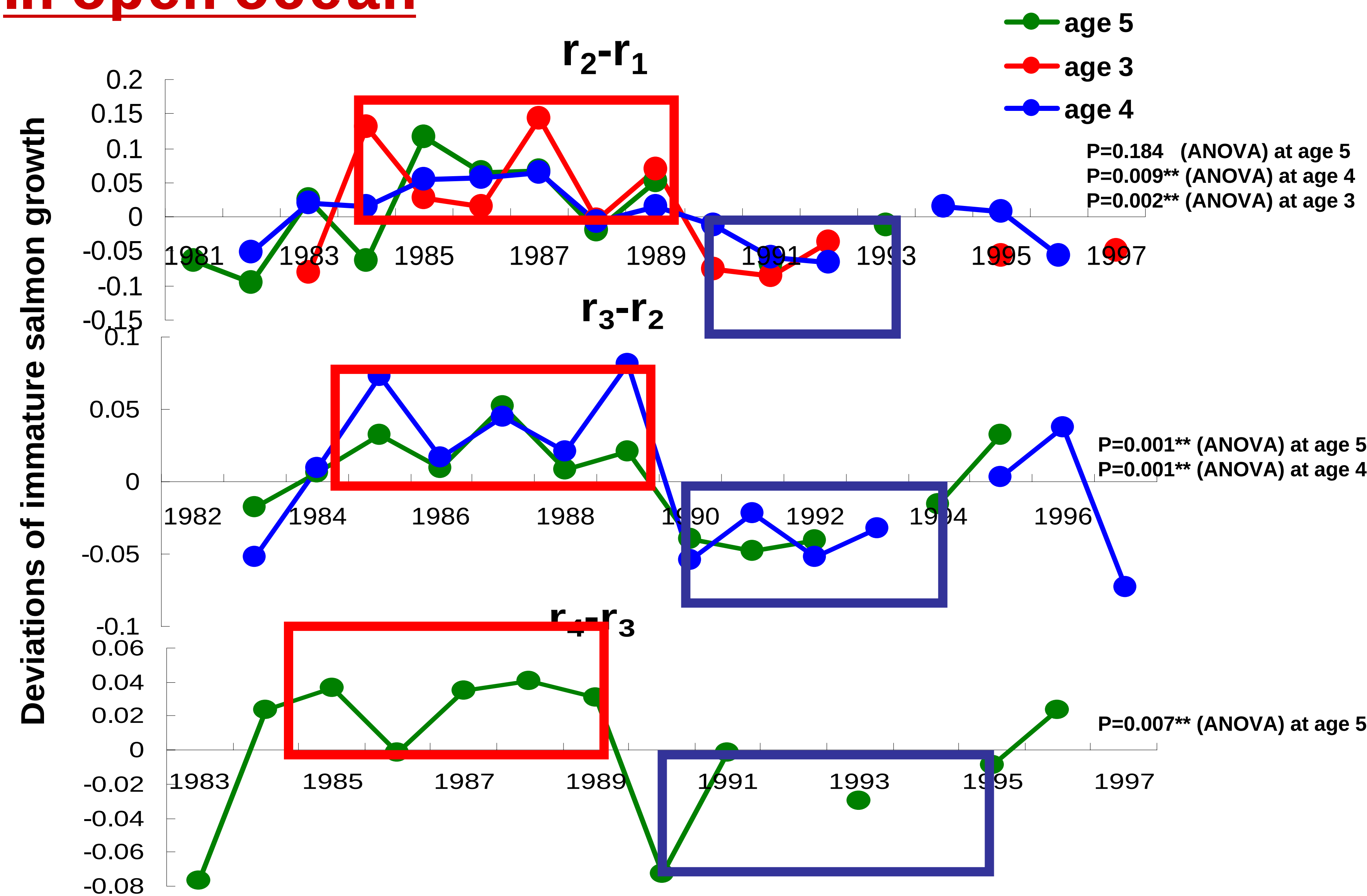

**Deviations of growth of young salmon in Okhotsk Sea. Growth information was derived from returning female salmon to mother stream at age-3 and age-4 during 1984-1998. The x-axis represents the year of growth.**

## zooplankton biomass and SST in Okhotsk Sea



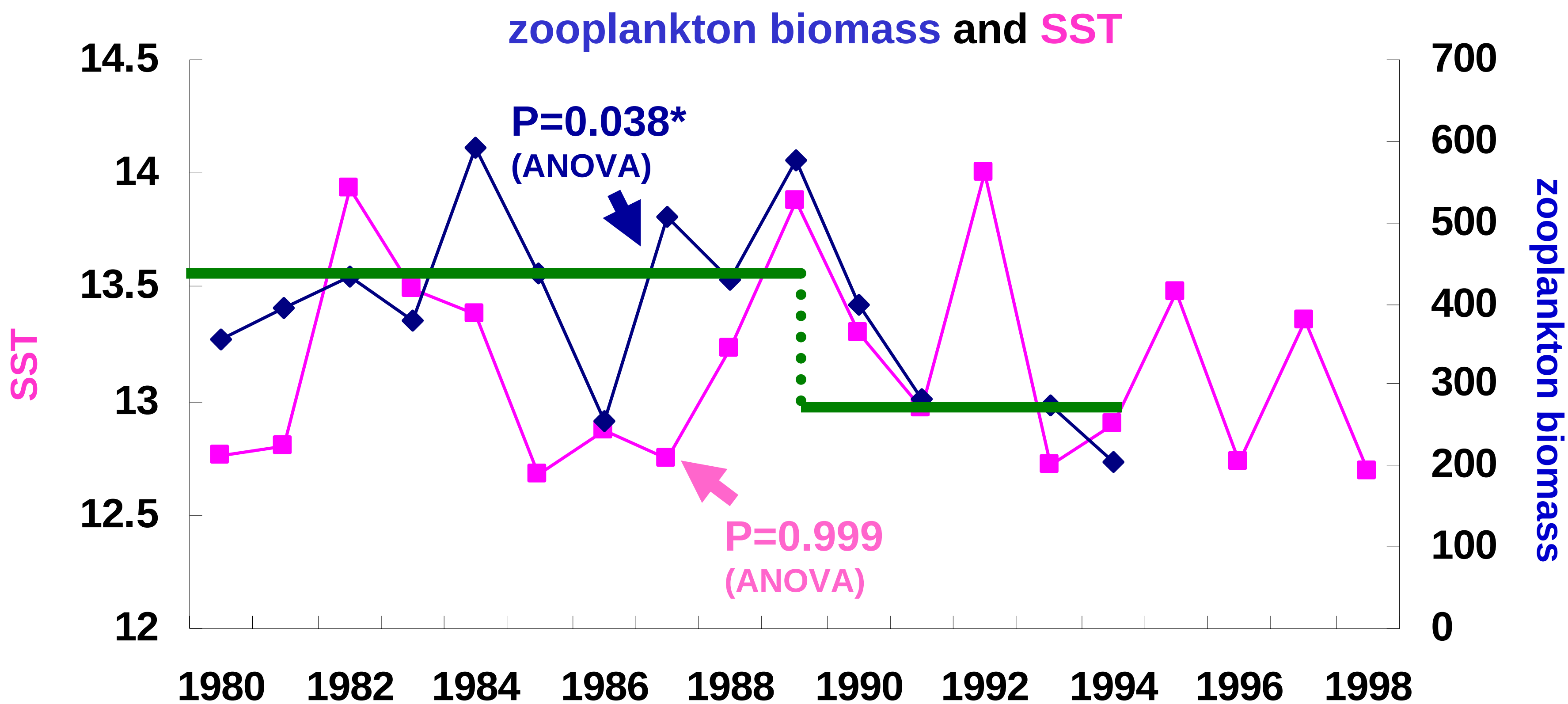

Deviation of SST in Okhotsk Sea during August and November (mean value=8.01°C) and zooplankton biomass in Okhotsk Sea (mean value=214.6 g/sq.m). Zooplankton and SST data were extracted from Shuntov & Dulepova (1996) and NECP/NCAR Reanalysis, respectively.

# In open ocean



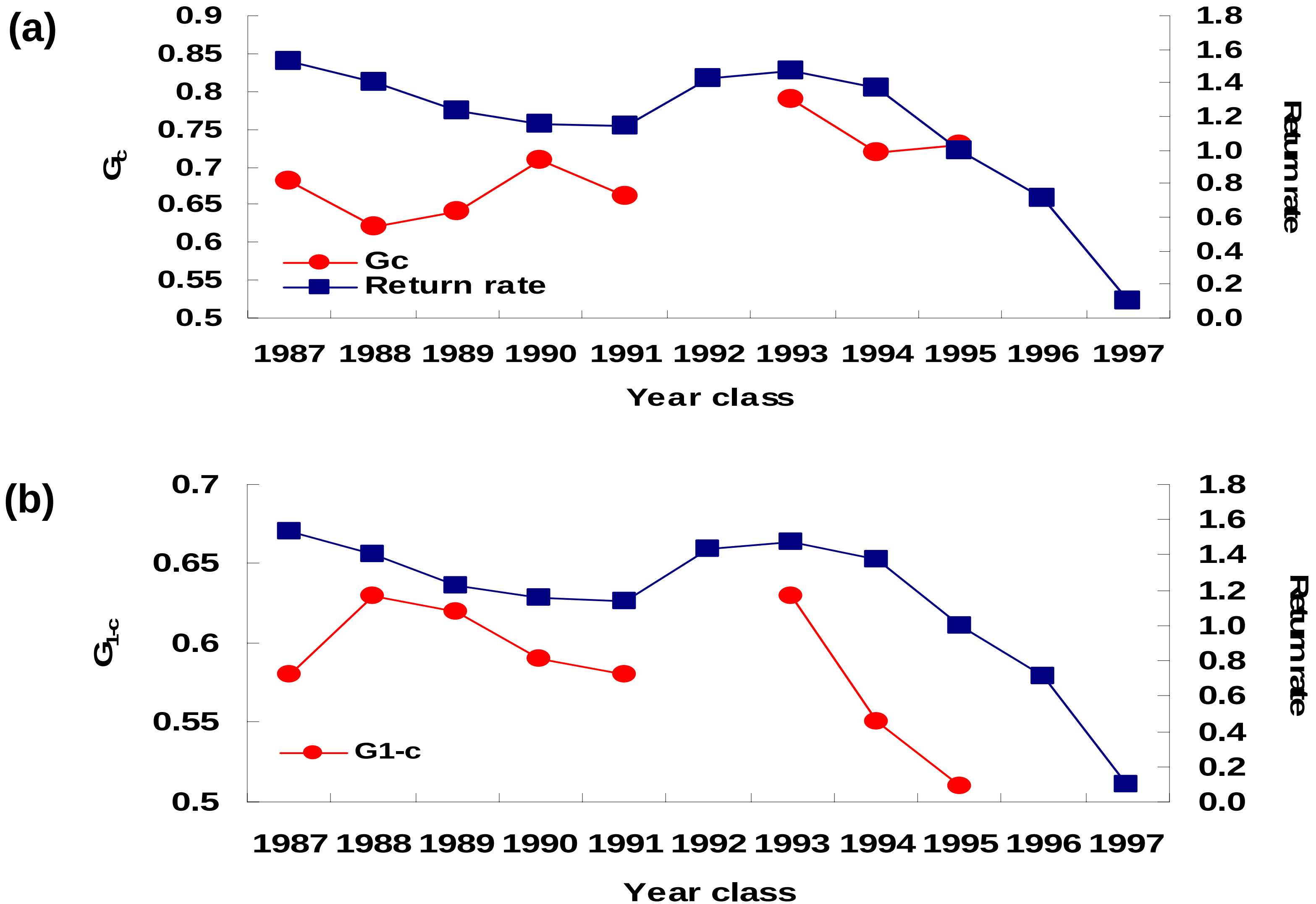

**Deviations of immature salmon growth in open ocean at age 2 to 4. Growth information was derived from returning female salmon to mother stream at age-3, 4 and 5 during 1984-1998. The x-axis represents the year of growth.**

# In open ocean

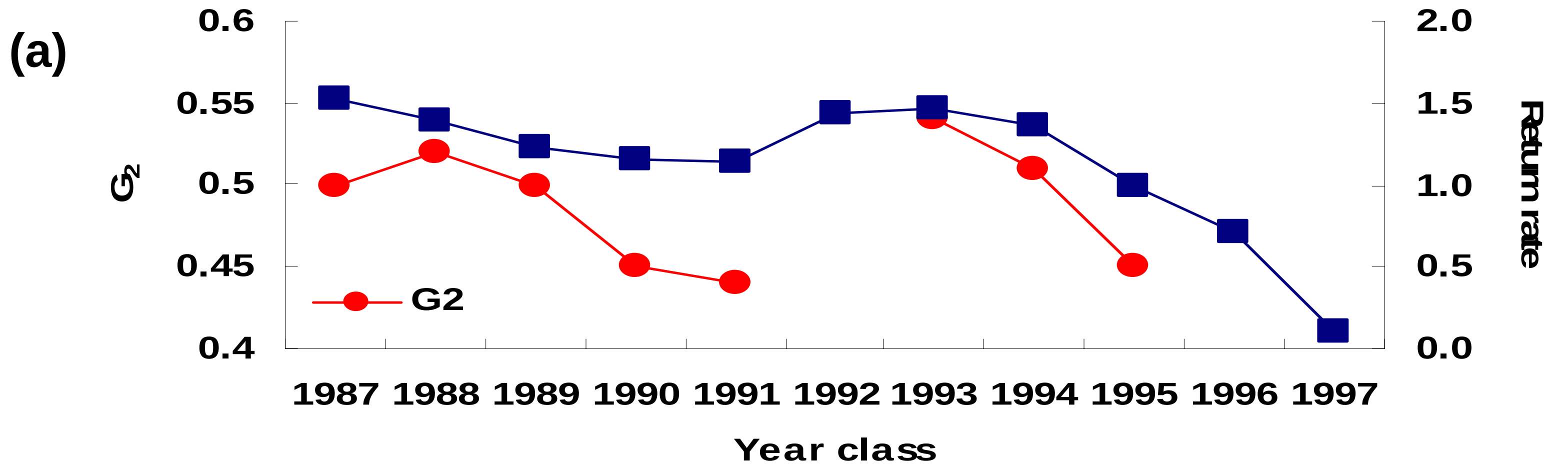


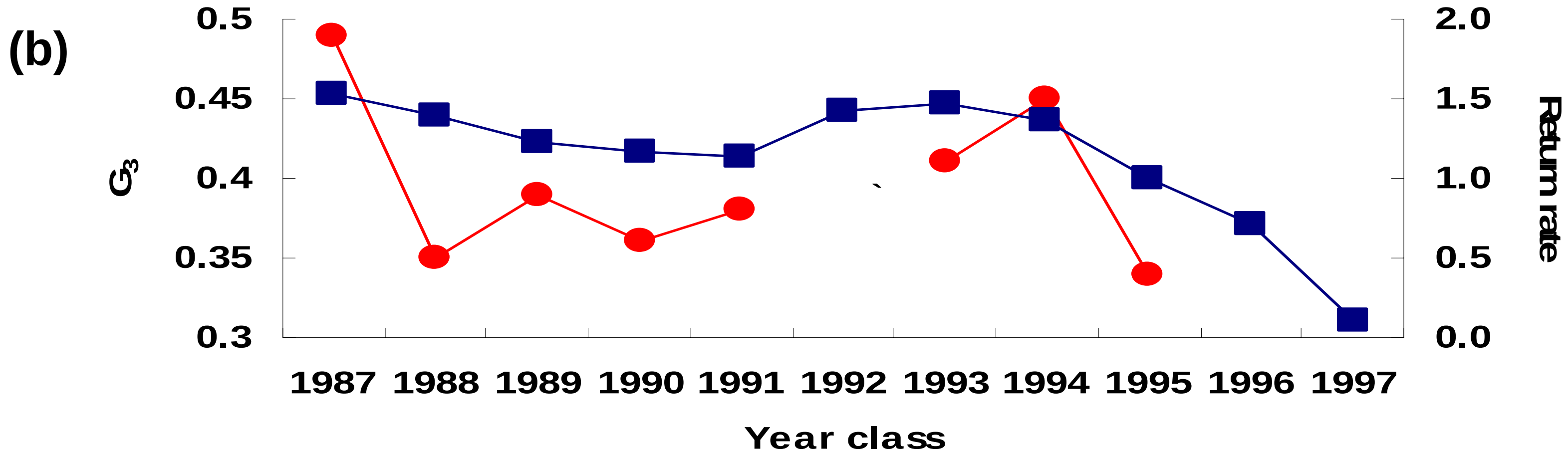

**Year-to-year variations in the mean zooplankton biomass (blue line) and SST (red line) in eastern Bering Sea from NCEP/NCAR Reanalysis and Sugimoto & Tadokoro. (1997), respectively.**

# Return rate and growth during (a) fry and (b) age-0 juvenile



# Return rate and growth during (a) age-2 and (b) age-3



# Conclusion II:

**Growth of chum salmon seemed to link with change of zooplankton biomass.**

- **In coastal water, growth of juvenile chum salmon was better in the 1990s than in the 1980s.**
- **Growth conditions in the Okhotsk Sea seemed to be stable during the 1980s-1990s period.**
- **In the Bering Sea, climate change around 1989 caused in reduction of zooplankton biomass, and consequently lower salmon growth in the early to mid 1990s.**

# Conclusion III:

## Return rate of chum salmon seemed to link with growth during immature stages.

- ✓ **The favorable environments for fry chum salmon might cause better growth in the coastal areas, but higher growth rate during the early life stage does not seem to be related to the improved return rate of spawning adults.**

- ✓ **Rather, growth in immature stages in the Okhotsk Sea and the Bering Sea has a significant correlation with return rate indicating size-related mortality process.**

# Thanks for your attention!!