Comparison of the growth pattern for Japanese chum salmon in the Okhotsk Sea and the Bering Sea

Okhotsk Sea Coast of Hokkaido

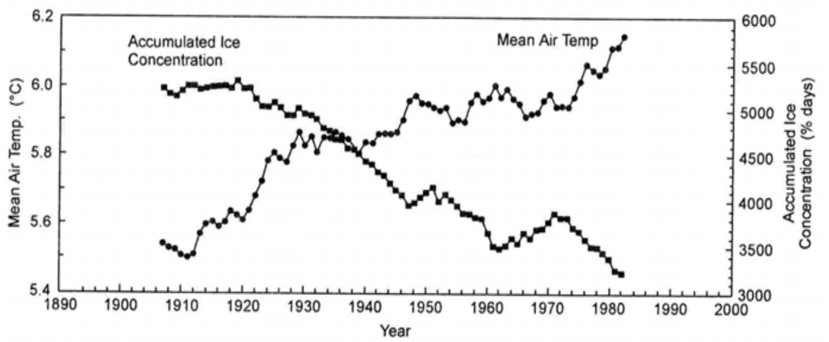
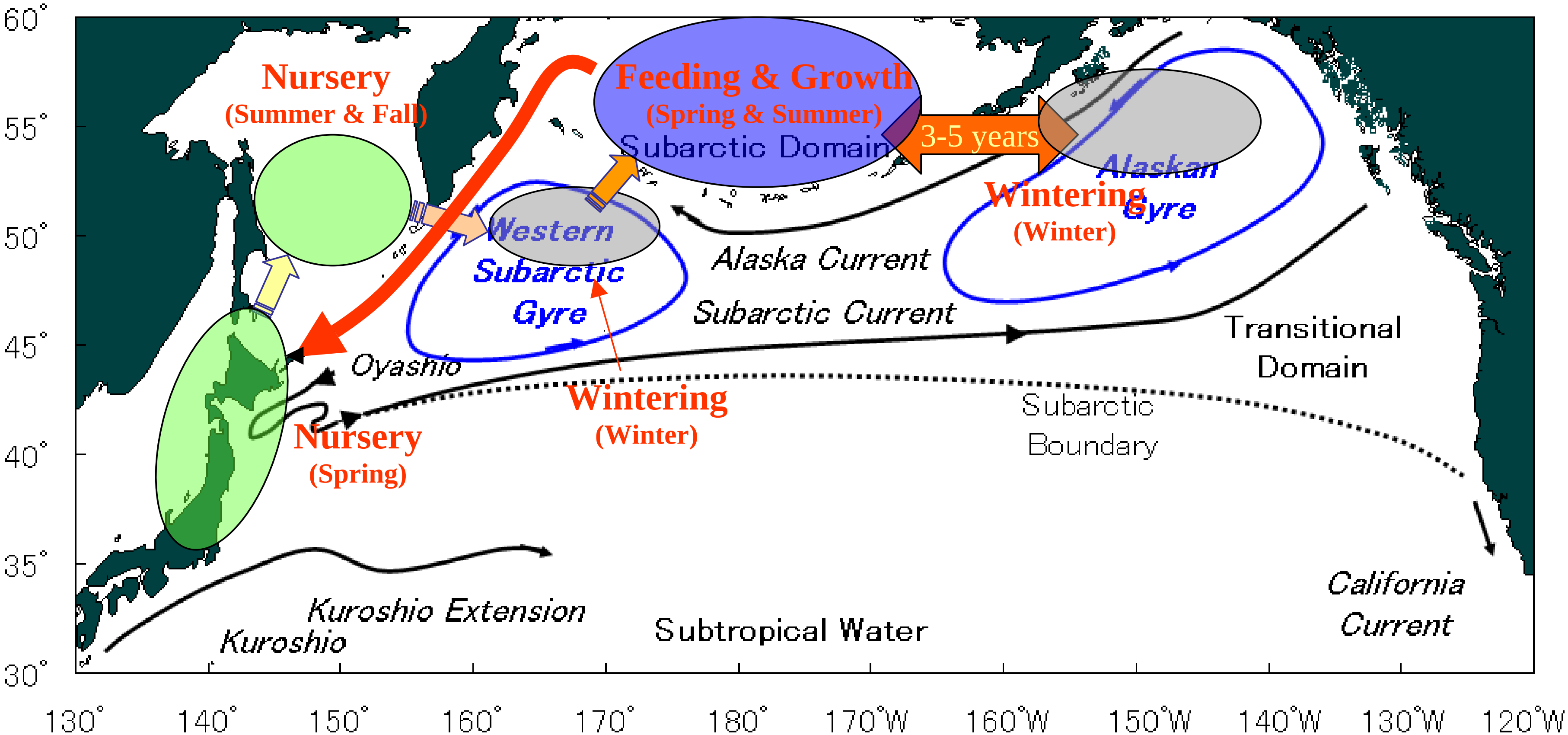


Fig. 2 Thirty year running averages of the yearly mean air temperature (●) and accumulated ice concentration (■) at Abashiri, Hokkaido. (Aota 1999)

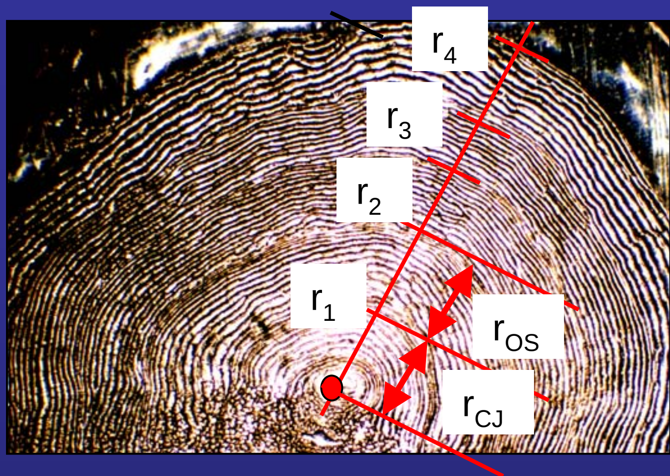
Masahide Kaeriyama[1], Sei-ichi Saito[1], and Akihiko Yatsu[2]

[1] Graduate School of Fisheries Sciences, Hokkaido University
[2] National Research Institute of Fisheries Science

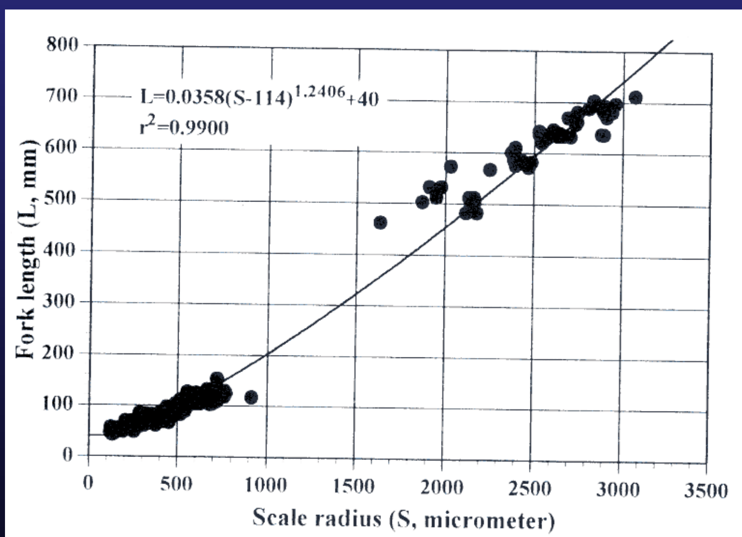
Migration route of Japanese chum salmon



Urawa (2000) modified



Scales of age-4 adult chum salmon returning to the Ishikari River, Hokkaido.



Relationship between scale length and fork length of chum salmon in Japan (Kaeriyama 1998)

Scale sample:

Female adult chum salmon in the Ishikari River (Age-4)

1970-2001 (except for 1973 & 1985)

Total scales 817 (30 scales in a year)

$$S_t = \sum_{i=1}^{t} r_i$$

$$FL_t = 0.0358\,(S_t - 114)^{1.2406} + 40$$

$$L_t = FL_t - FL_{t-1}$$

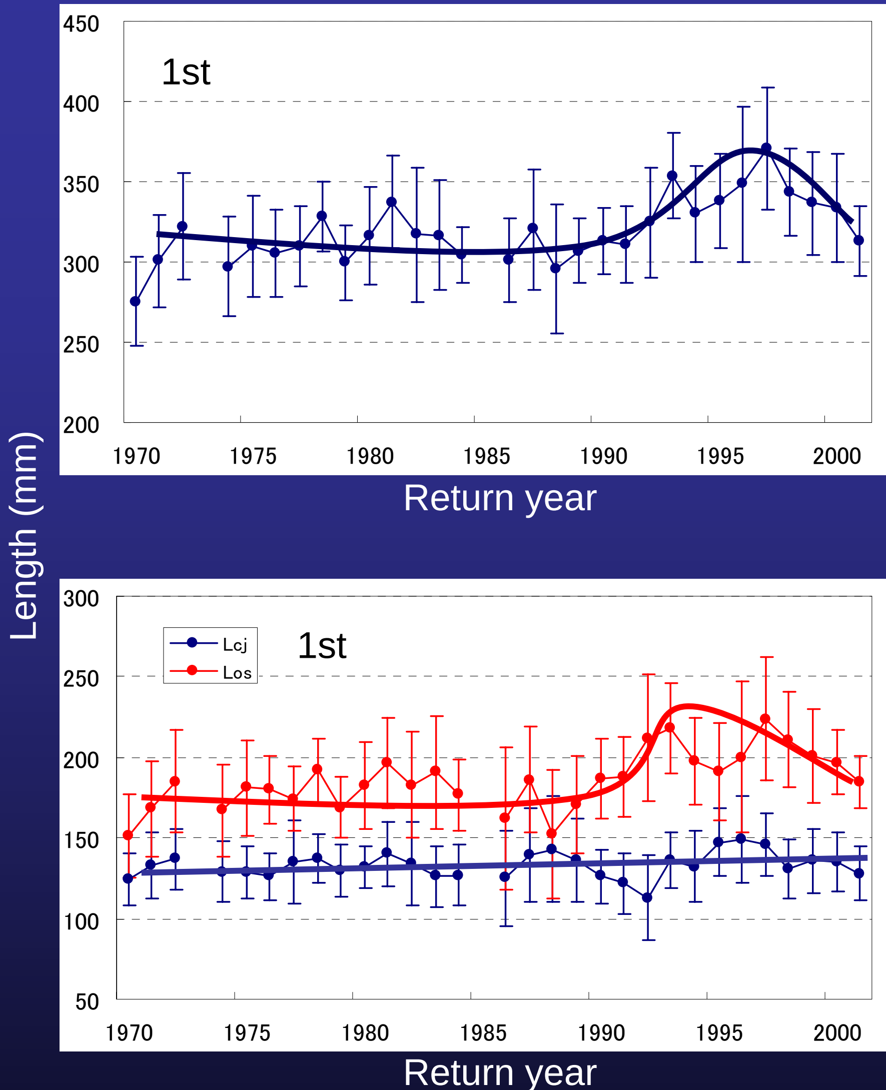
$$L_{cj} = 0.0358\,(r_1 - 114)^{1.2406} + 40$$

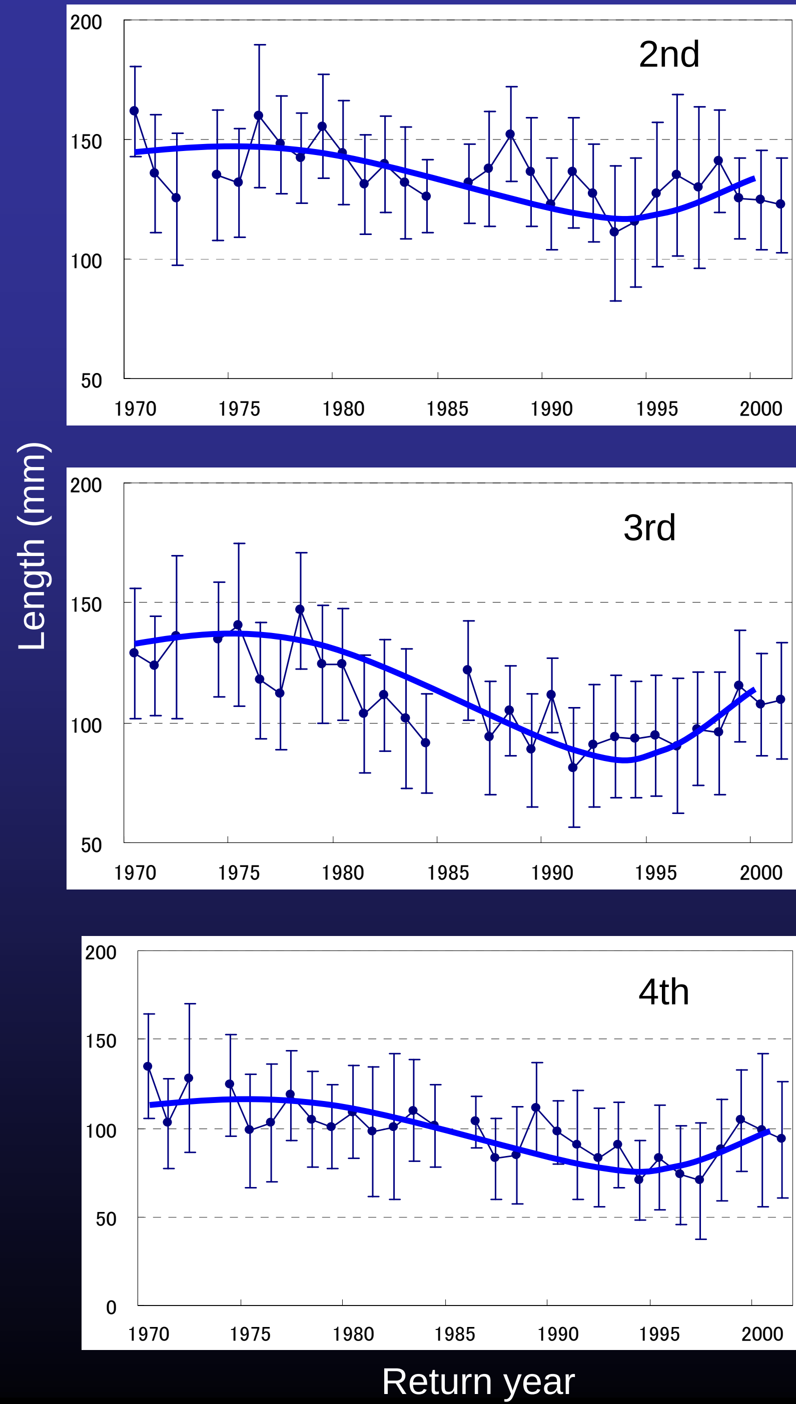
$$L_{os} = L_1 - L_{cj}$$

SST: (1) 1950-2004: Meteorological Agency of Japan, 25-49˚N, 121-180˚E

(2) 1985-2004: AVHRR/NOAA data, 50-56˚N, 145-155˚N

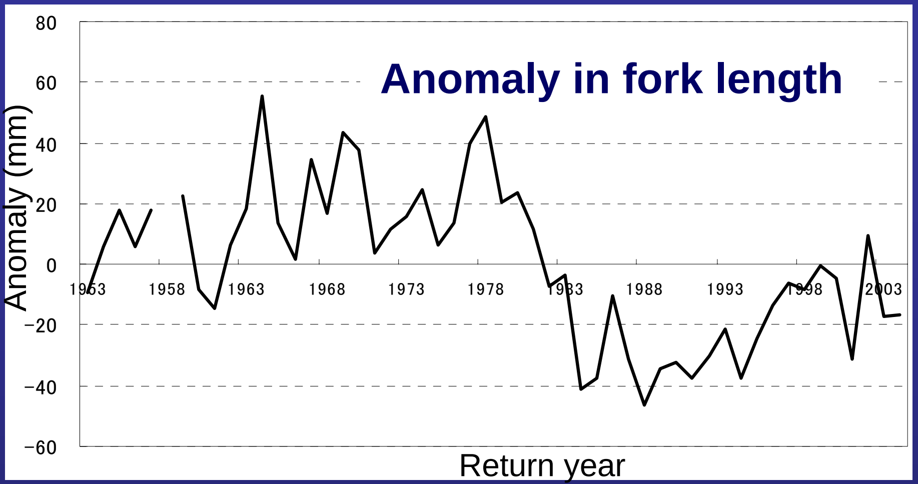
Chlorophyll-a: 1998-2004, SeaWiFS, 50-56˚N, 145-155˚N



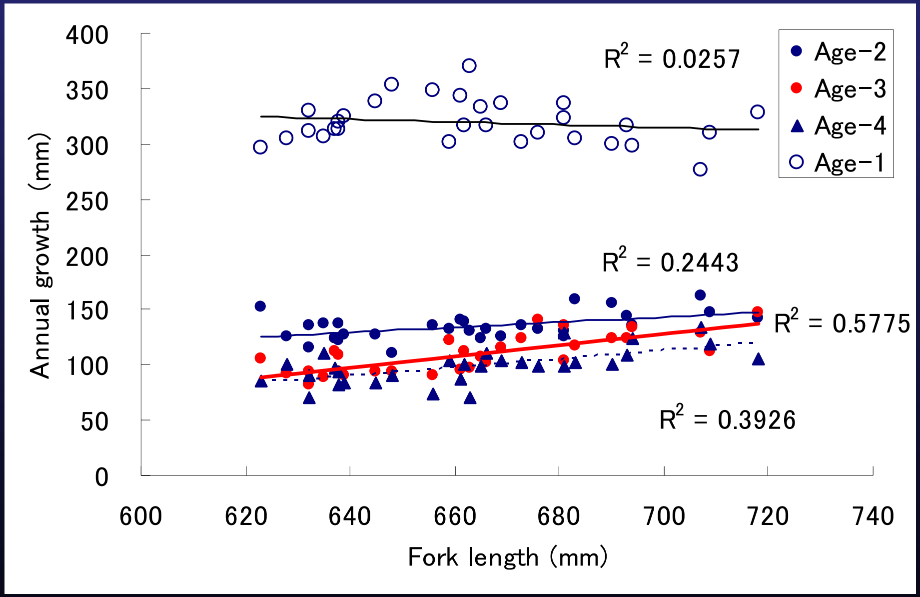


Changes in annual growth of age-4 female chum salmon returning to Ishikari River during 1970-2001. L_{cj}: growth at the coast of Japan, L_{os}: growth at the Okhotsk Sea.

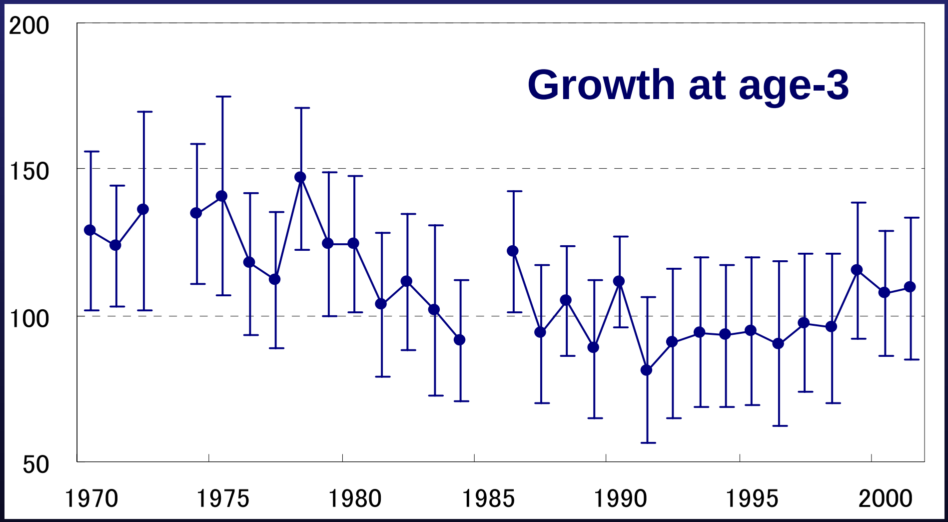
Growth of Ishikari River chum salmon in the Bering Sea (at age 2-4)



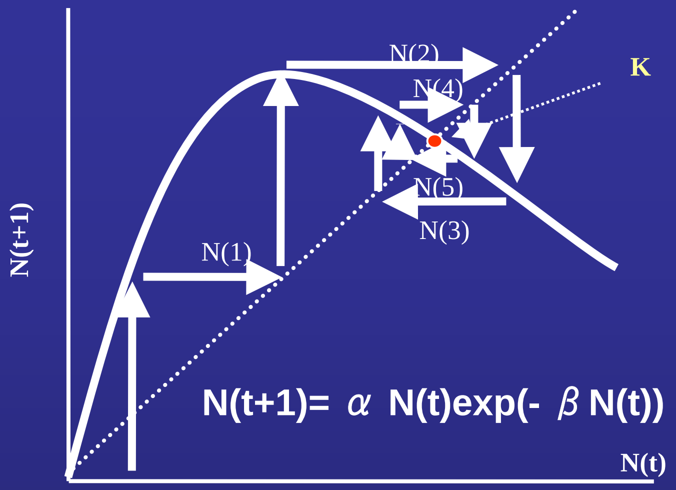
Change in anomaly in fork length of adult chum salmon returning to the Ishikari River during 1953-2004.



Relationship between fork length and annual growth of adult chum salmon by age in the Ishikari River during 1970 to 2001

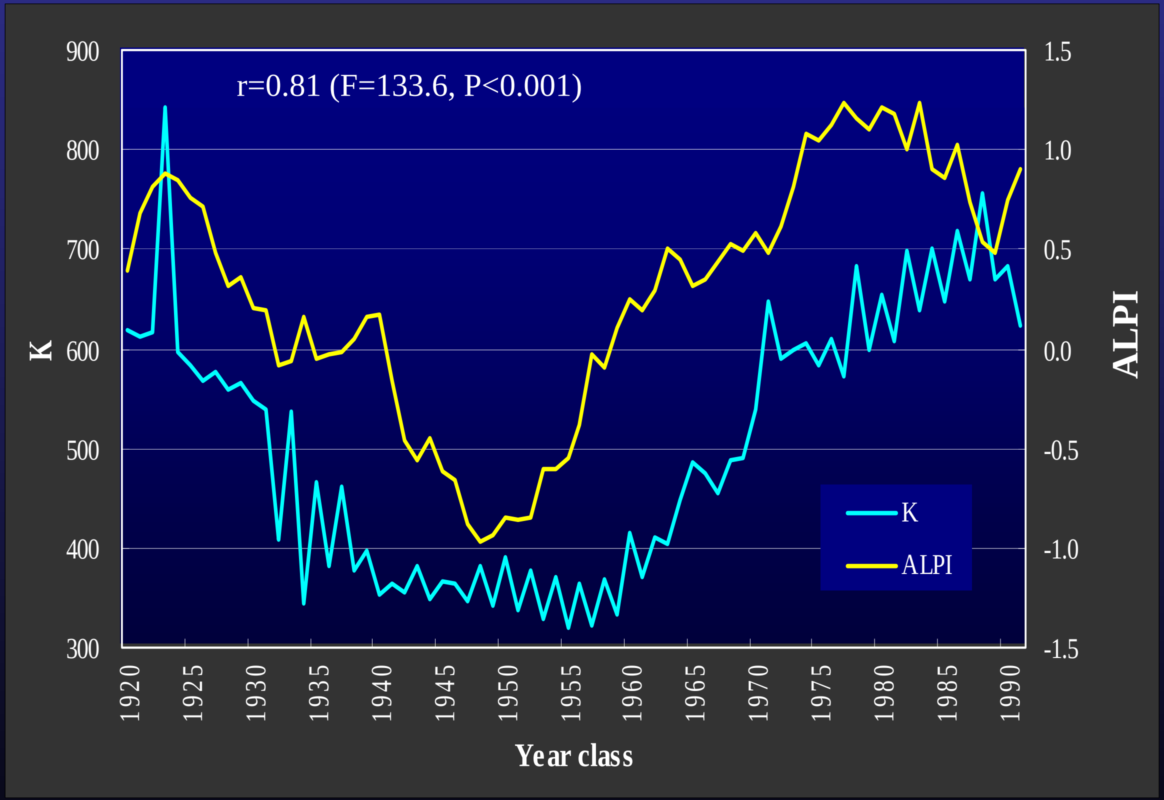


Change in growth at age-3 of Ishikari River chum salmon in the Bering Sea during 1970-2002.



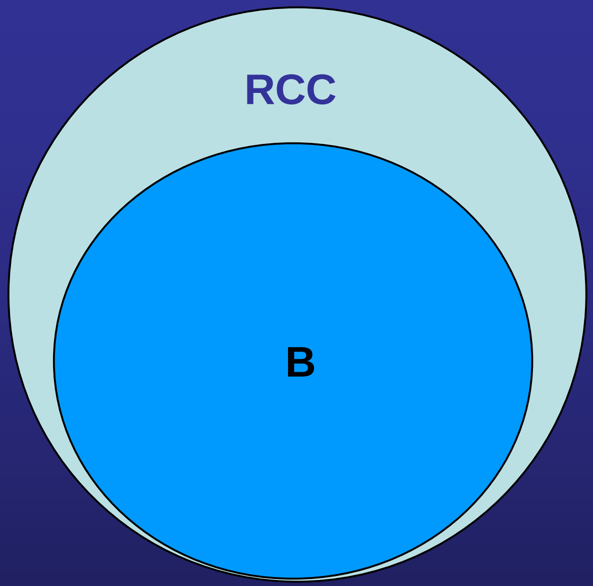
Carrying capacity **K**

= Replacement level **ln（α）/β**



Changes in carrying capacity (K) of three species of Pacific salmon and Aleutian Low Pressure Index (ALPI).

Relationship between carrying capacity and population density-dependent effect in Hokkaido chum salmon population



RCC=(CC-B)/CC × 100

RCC: Residual carrying capacity

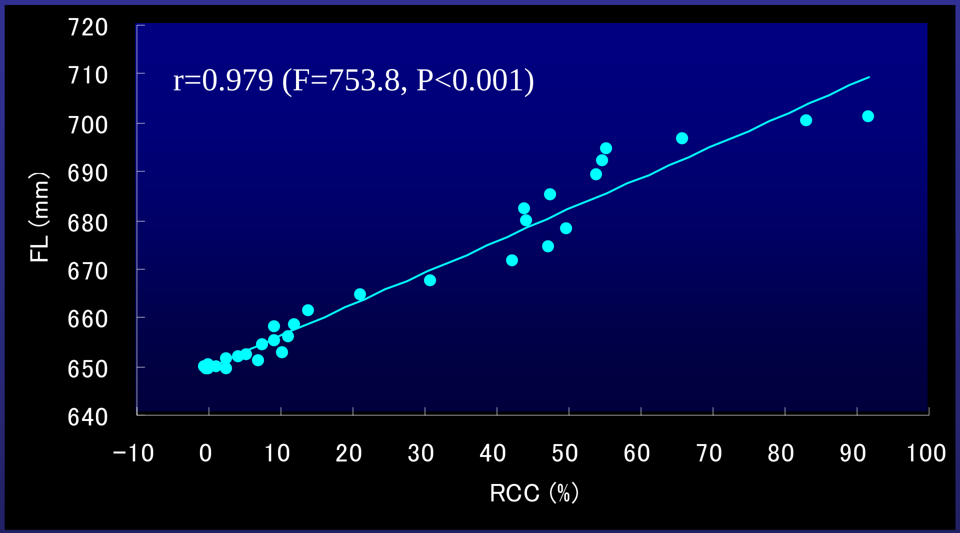
CC: Carrying capacity

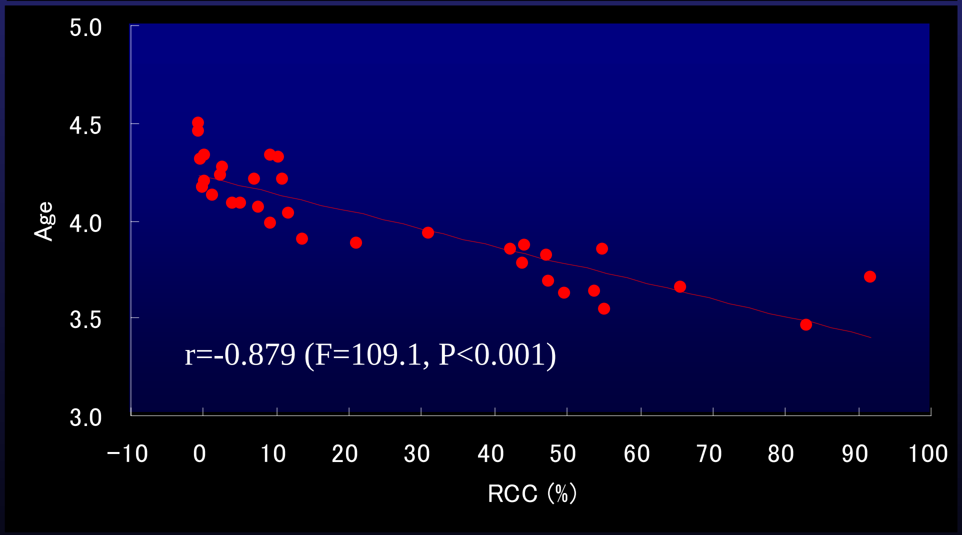
B: Biomass

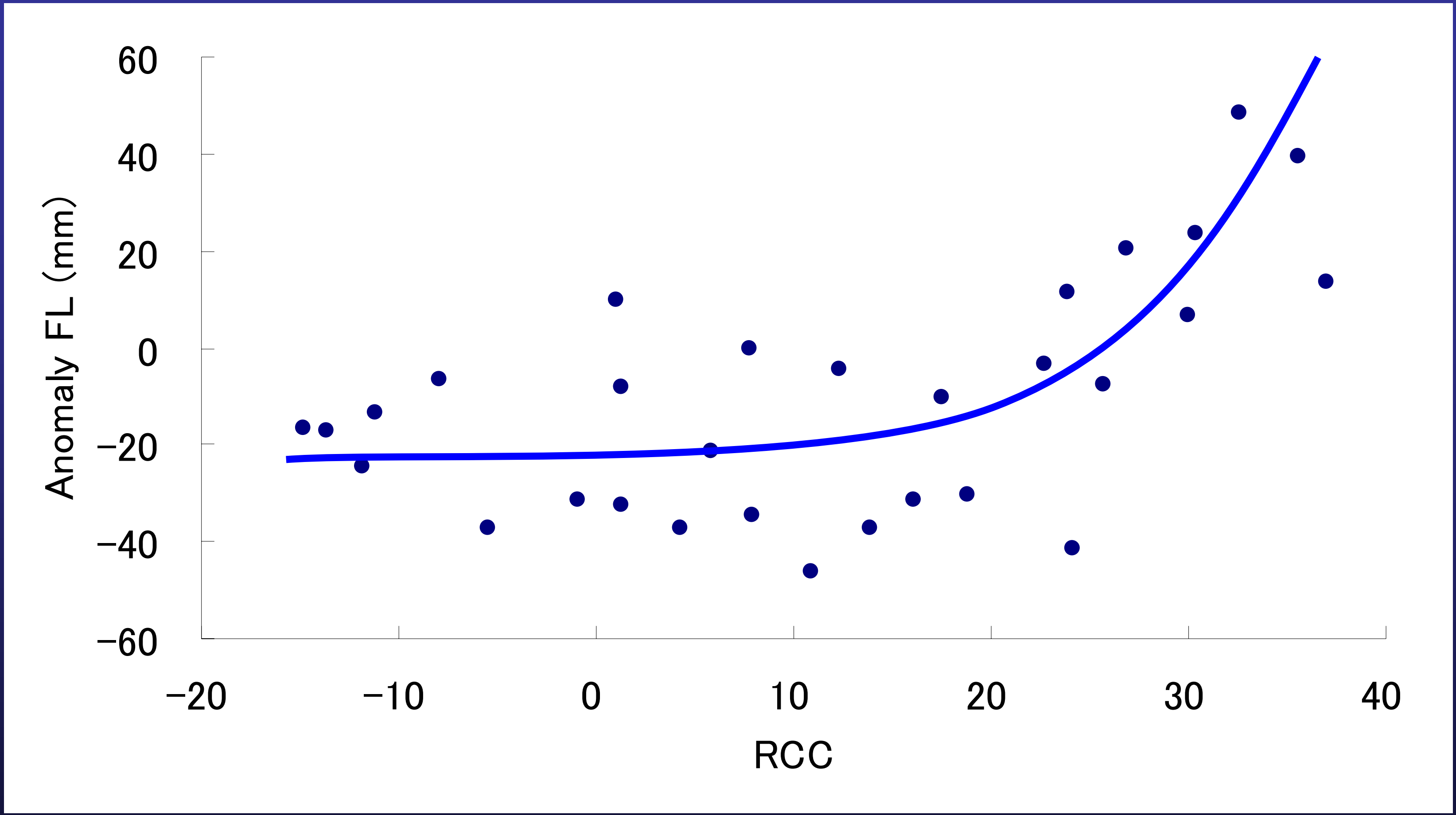
FL: Fork length (mm)

AGE: Mean age at maturity

Hokkaido

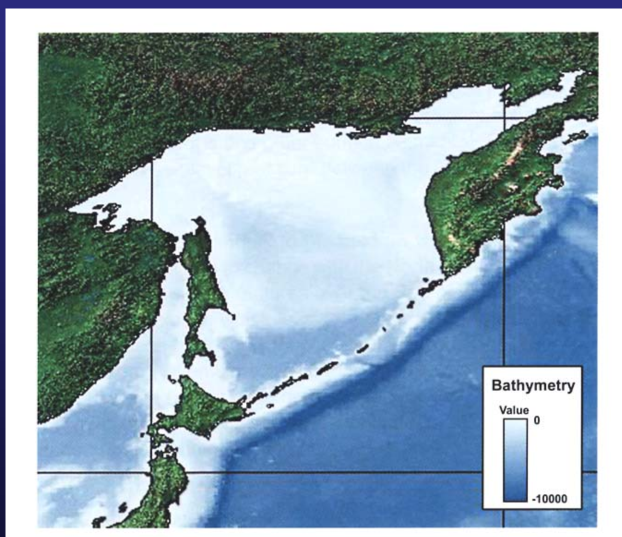


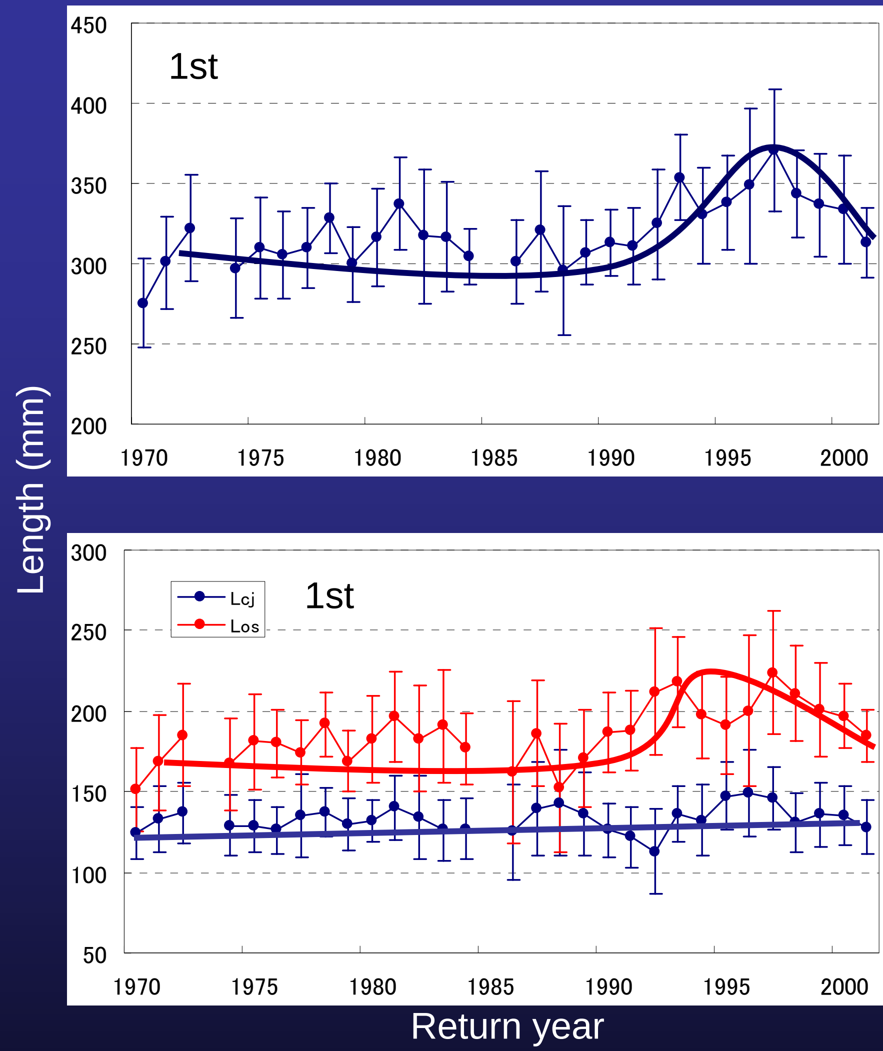




Relationship between anomaly of fork length and residual carrying capacity (RCC) in the Ishikari River population. RCC (%) =(Carrying capacity – Run) / Carrying capacity ×100.

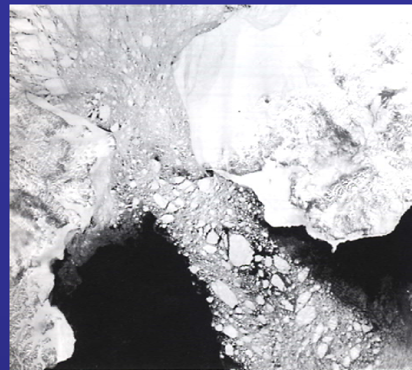
Growth of Ishikari River chum salmon in the Okhotsk Sea (at age 1)

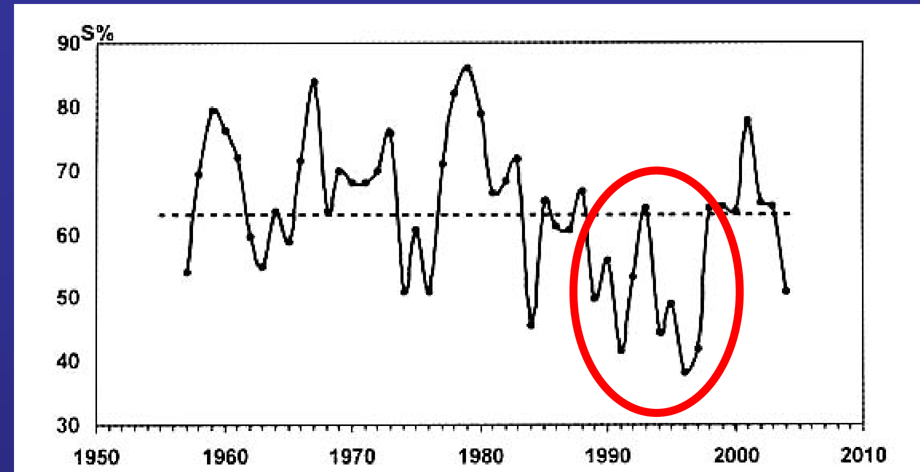




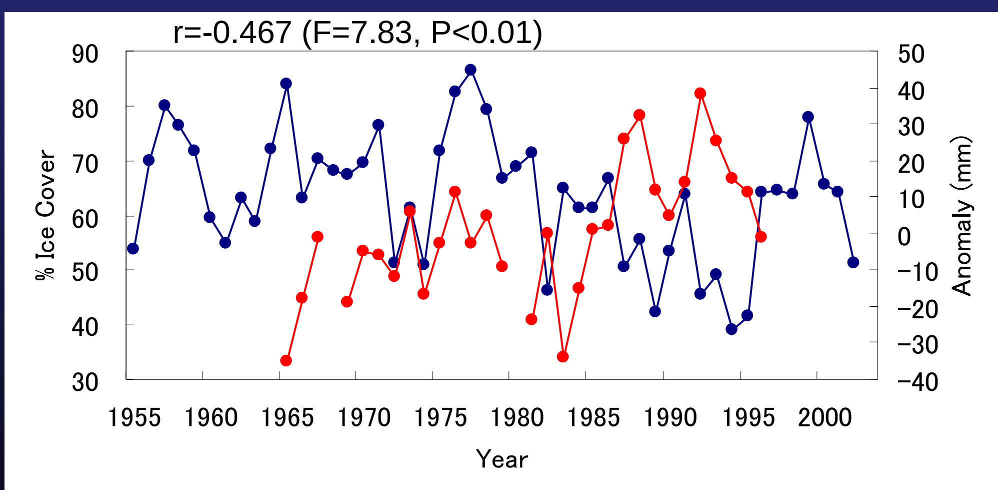
Changes in growth at age-1 of adult chum salmon returning to the Ishikari River during 1970-2001. L_{cj}: growth at the coast of Japan, L_{os}: growth at the Okhotsk Sea.

Ice cover in the Okhotsk Sea

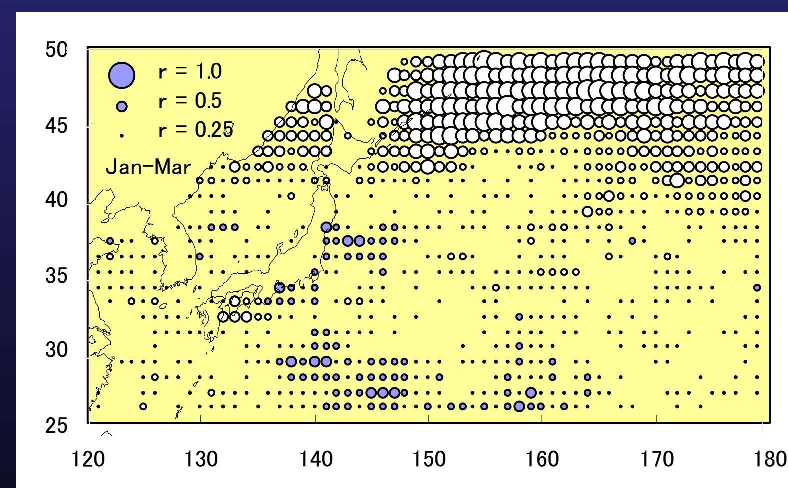




Changes in winter ice cover area (% from the total sea area) in the Okhotsk Sea (Ustinova et al. 2002)

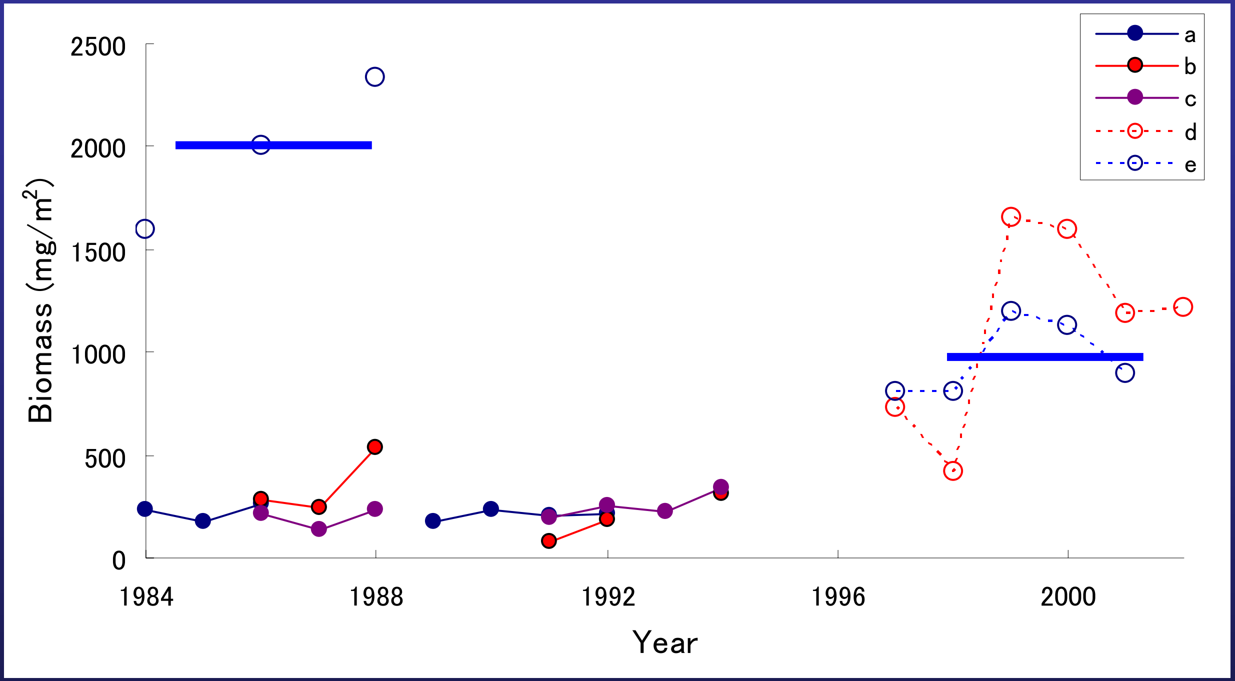


Changes in winter ice cover area in the Okhotsk Sea (blue) and anomaly of growth in the first year of age-4 female chum salmon returning to the Ishikari River (red).



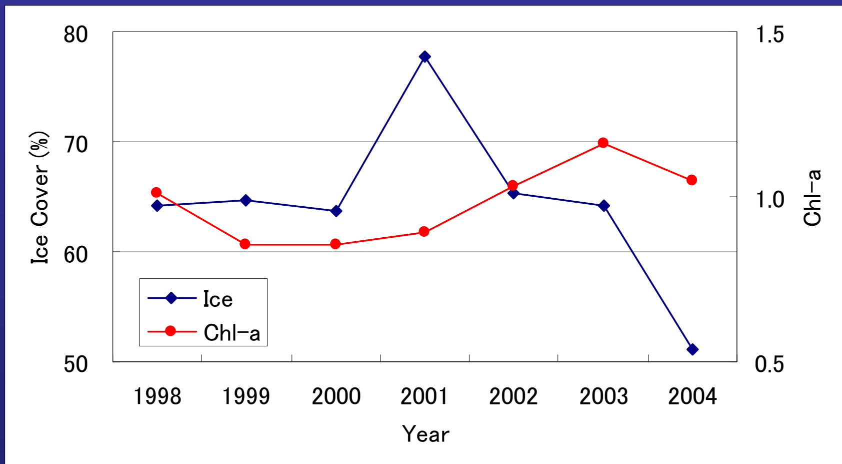
Correlation map between 1° gridded sea sea-surface temperature in winter (January-March) and ice cover area in the Okhotsk Sea during 1957-2004

Annual change in zooplankton biomass
- No relation



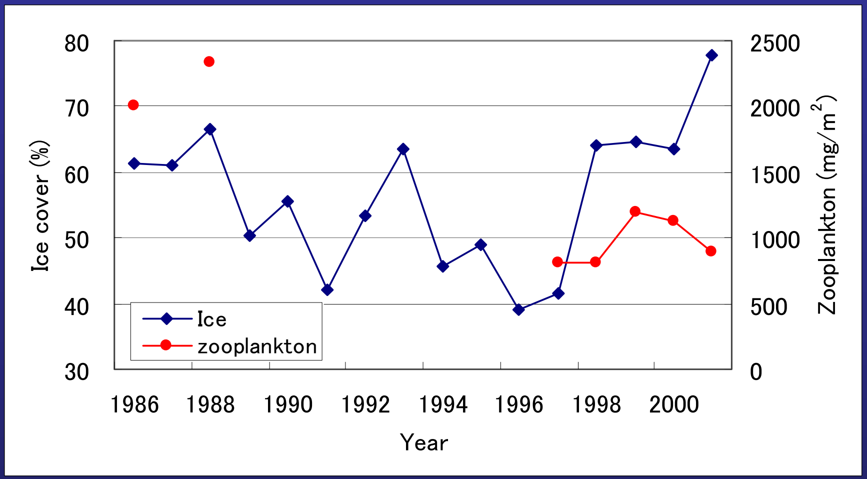
Annual change in zooplankton biomass in the Okhotsk Sea.
a) Southern part of the Okhotsk Sea (Shuntov and Dulepova 1996)
b) West Kamchatka Area: Northern 54°N (Shuntov and Dulepova 1996)
c) West Kamchatka Area: Southern 54°N (Shuntov and Dulepova 1996)
d) Northern Sea of Okhotsk: Spring (Kim et al. 2005)
e) Northern Sea of Okhotsk: Summer – Fall (Kim et al. 2005)

Chlorophyll-a



Changes in ice cover rate and chlorophyll-a in the Okhotsk Sea during 1998-2004.

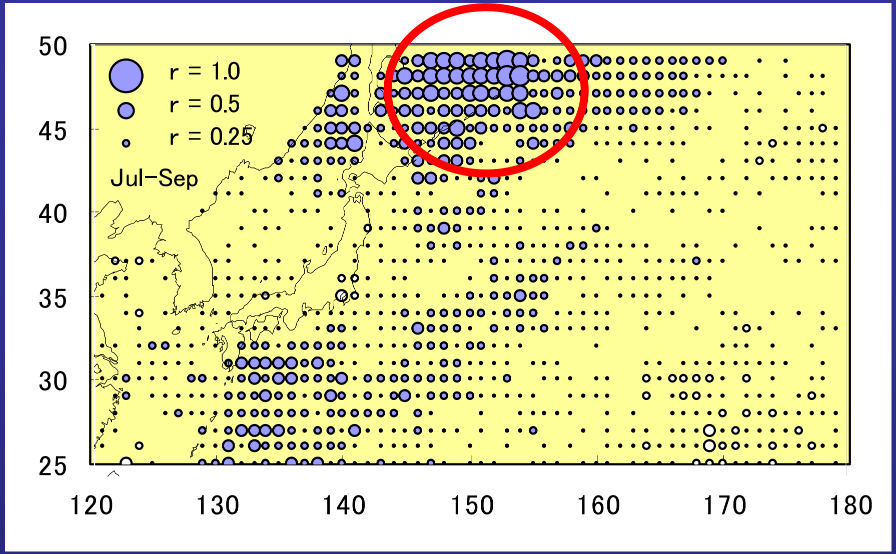
Zooplankton



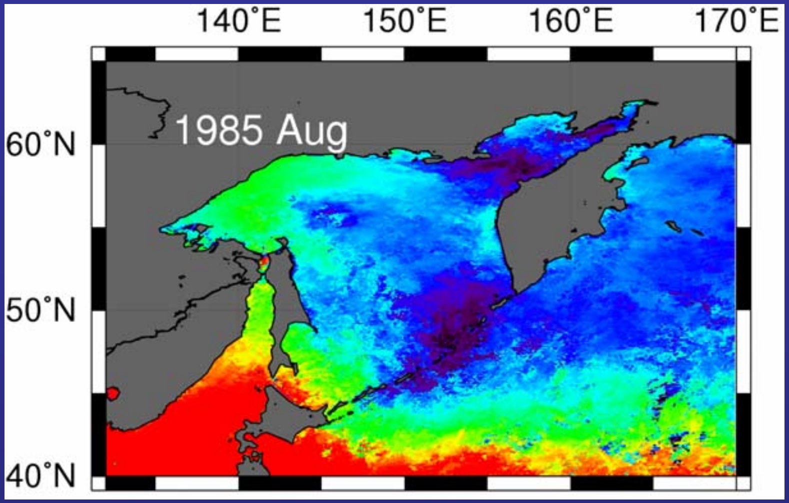
Changes in ice cover rate and zooplankton biomass in the Okhotsk Sea during 1986-2001.

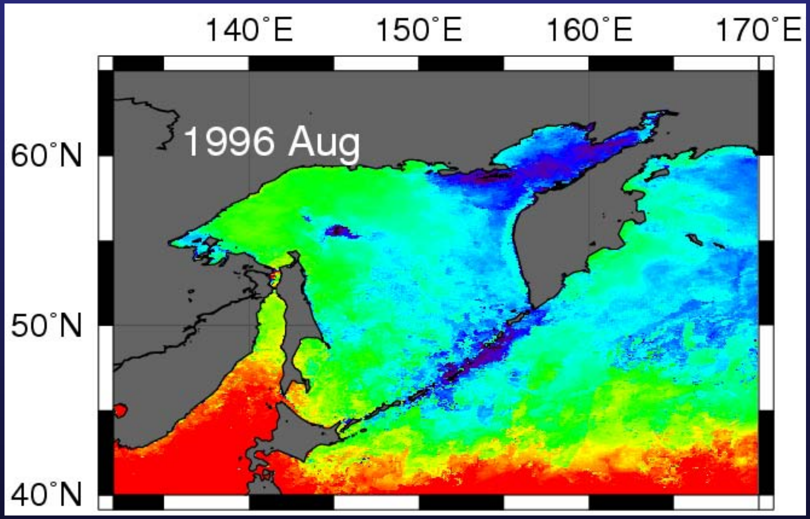
Correlation coefficient between Ice cover rate and productivity in the Okhotsk Sea

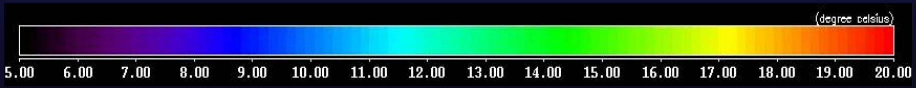
	Area	Years	n	r	F	*P*	References
Chlorophyll-a	50-56N, 145-155E	1998-2004	7	-0.373	0.807	0.410	Present data
Zooplankton	Northern Okhotsk Sea	1986, 88, 1997-200	7	0.164	0.138	0.726	Kim et al. (2005)
	Southern Okhotsk Sea	1986-88, 1991-94	14	0.282	0.138	0.726	Shuntov and
	West Kamchatk	1986-88, 1991-94	7	0.494	1.614	0.260	Dulepova (1996)



Correlation map between 1° gridded sea sea-surface temperature in July-September and growth anomaly of Ishikari River chum salmon.



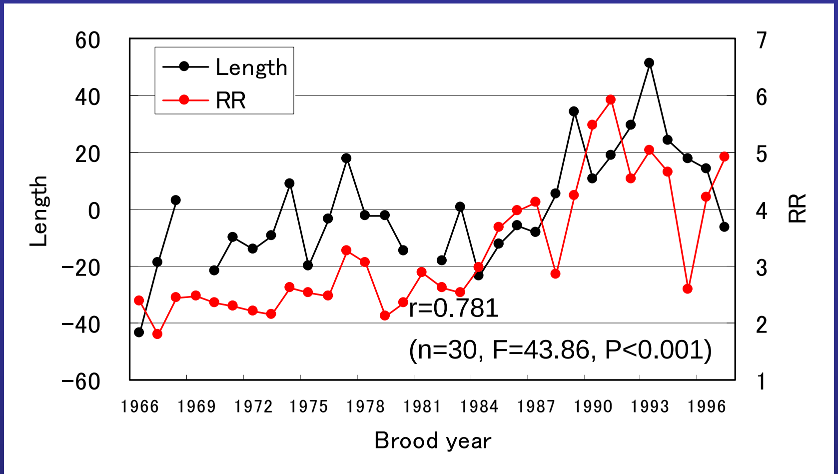




Growth at the Okhotsk Sea:

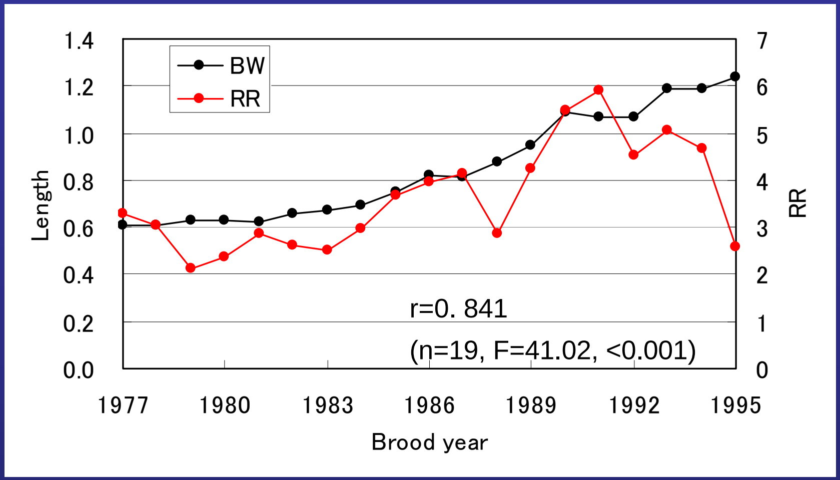
SST (=Ice Cover Rate) > Productivity trend

Growth in the Okhotsk Sea & return rate



Changes in anomaly of growth at age-1 (Length) and return rate (RR) of chum salmon in Hokkaido.

Body size of juvenile released & return rate



Changes in body weight (BW) of juvenile released and return rate (RR) of chum salmon in Hokkaido.

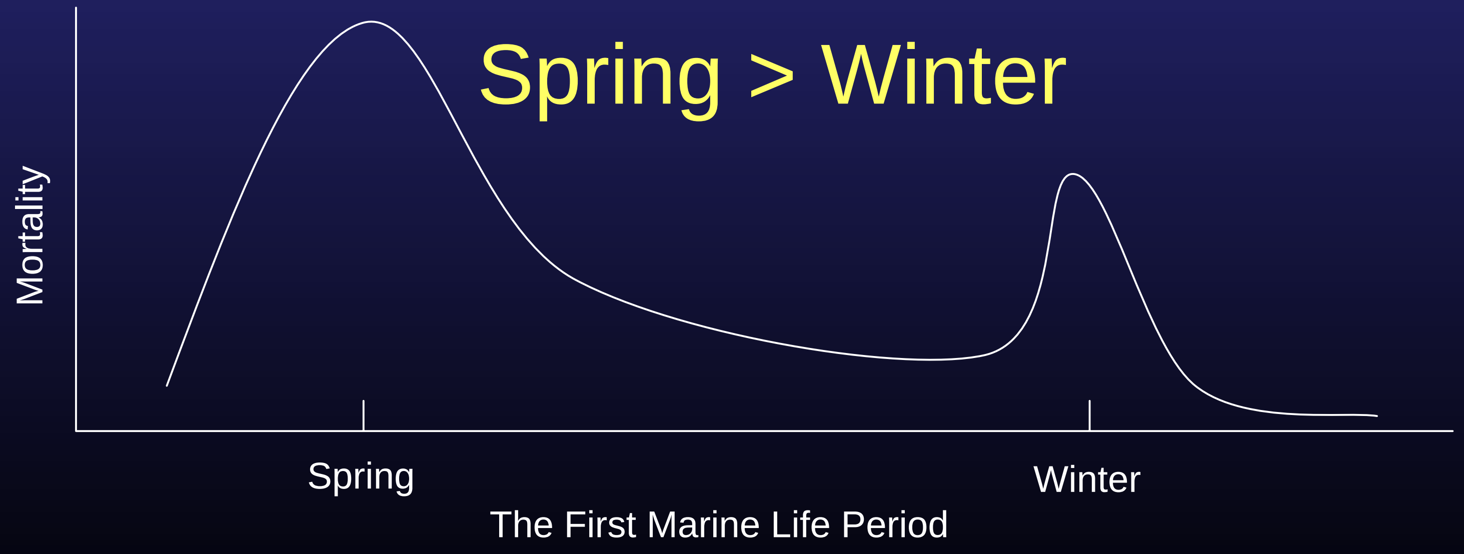
Result of multiple regression analysis in return rate of Hokkaido chum salmon population on average body size (g) at the release and average growth of the Ishikari River chum salmon at the age 1

Variable	Slope	Partial correlation	T	*P*
Body size of juvenile released	4.003	0.700	3.797	0.002
Growth of young at age-1	0.002	0.039	0.152	0.881
Constant	0.876		0.240	

r^2=0.685, df: n1=2, n2=15, F=16.32, P<0.001, AIC=41.404

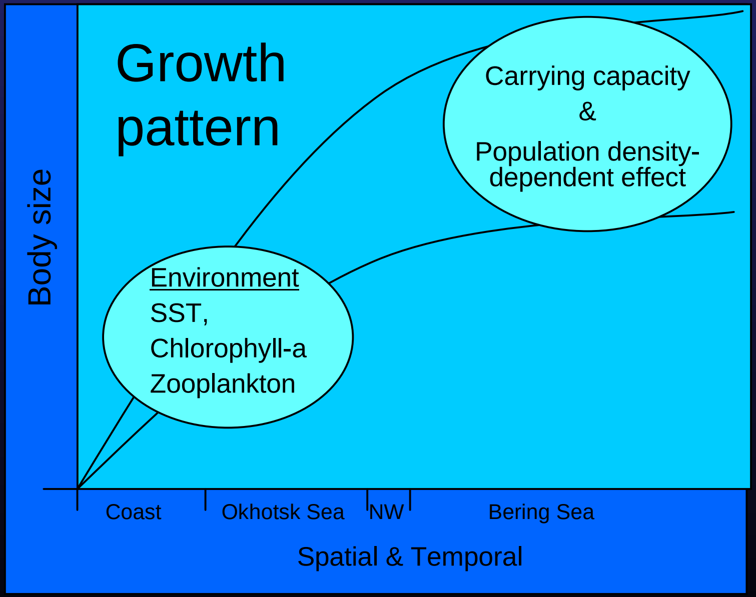
Period of Critical Mortality in the Pacific salmon

- Size-selective mortality immediately after the seaward migration (Healey 1982) ➡ Spring
- Size-related mortality over the first marine fall and winter (Beamish et al. 2004) ➡ Winter



Conclusion

The life history strategy of Pacific salmon offers a useful framework for evaluating not only inter- and intra-specific interactions but also climate-related risk factors around the North Pacific



e.g. Growth pattern of Japanese chum salmon:

- The Okhotsk Sea: Environmental factors (SST, Ice Cover, Zooplankton Community)
- The Bering Sea: Intra-specific interaction (Population density-dependent effect)

Comments to slides

Slide 1

Our human being has an impact on the earth, including the marine ecosystem. This figure shows changes in air temperature and sea ice concentration at the Okhotsk Sea Coast of Hokkaido. As you see, the long-term variation of the sea ice concentration is well correlated with the air temperature at Nemuro. This would be one of phenomena of the global warming.

We'd like to present the spatial and temporal pattern of growth for Japanese chum salmon relating to the climate change and the response of life history strategy, in order to discuss climate and human impacts on the life history strategy of chum salmon.

Slide 2

This figure shows the migration route of Japanese chum salmon based on Urawa (2000). After spending the eraly marine life in the coastal waters of northern Japan in spring, Japanese chum salmon spend their first summer in the Okhotsk Sea, and then move to the Western Subarctic Gyre for the first winter. Thereafter, these chum salmon migrate between their summer feeding grounds in the Bering Sea and their overvintering grounds in the Alaskan Gyre. After about four years, they return to their natal rivers for spawning.

Slide 3

I totally analyzed 817 scales of age-4 female chum salmon collected in the Ishikari River during 1970-2001 except for 1973 and 1985. Distances and number of circuli from the focus to the inner edges of check and annuli of scales were measured by a scale image processor (Ratoc System Engineering Co.) to the nearest one micrometer along the longest axis. The r_1 – r_4 indicates annual scale radius. R_{cj} and R_{os} also show scale radiuses at the coast of Japan and the Okhotsk Sea, respectively. Individual growth in fork length was back-calculated from this formula, where values "114" and "40" indicate focus radius and fork length at squamation.

Slide 4

These figures show annual changes in growth by age.
At the first year, growth increased in the 1990s. On the other hand, growth at the other years decreased since the 1980s. In particular, the growth reduction at the third year was considerably higher than those in the other years.
The growth increase at the first year occurred at the Okhotsk Sea, but not at the coast of Japan.

Therefore, these results suggest that chum salmon derived from the Ishikari River indicated the growth increase at the Okhotsk Sea in the 1990s and the growth reduction at the Bering Sea since the 1990.

Slide 5

These two figures demonstrate annual changes in anomaly of fork length and growth at the third year of age-4 female chum salmon returning to the Ishikari River, respectively. As you know well, both growth reductions were synchronized. The coefficient of determination between the fork length and growth at the third year was highest in the other years.

Slide 6

I already estimated the carrying capacity of three species (sockeye, chum, and pink salmon) in Pacific salmon, using the replacement level on the Ricker's recruitment curve.
Then, I showed that these carrying capacities are significantly synchronized with the long-term climate change.

Slide 7

I defined the residual carrying capacity (RCC) as “carrying capacity” minus “biomass”, divided by “carrying capacity.” And then, I evaluated the relationship between the RCC and body size and age at maturity of chum salmon returning to Hokkaido.
Relationship between the RCC and the fork length of Hokkaido chum salmon population indicated significant positive correlation.
And the mean age at maturity showed the negative correlation with the RCC.
These results also suggest that the carrying capacity of chum salmon would be closely related with the long-term climate change and the population density-dependent effect.

Slide 8

The similar result was observed the relationship between RCC (residual carrying capacity) and anomaly of fork length in the Ishikari River chum salmon population. At less than 10% of the RCC, mature size will attain the biological minimum size. In the Bering Sea, therefore, growth of Japanese chum salmon will be affected by the population density-dependent effect.

Slide 9

I'd like to shift to the change in growth of Ishikari River chum salmon in the Okhotsk Sea. I already talked that the growth increased at the Okhotsk Sea in the 1990s, despite no change in the growth at the coast of Japan.

Slide 10

In the Okhotsk Sea, the ice cover area extremely decreased in the 1990s. In this period, on the contrary, the growth of Hokkaido chum salmon juvenile increased in the Okhotsk Sea. The relationship between the rate of ice cover area in the Okhotsk Sea and the growth anomaly of chum salmon juvenile indicates the significant negative-correlation.

By the way, the correlation map of SST in winter and rate of ice cover area in the Okhotsk shows the negative correlation. Therefore, this decrease in the ice cover area will be a consequence of an increase in SST in winter.

Slide 11

There are no continuous long-term data on zooplankton biomass in the Okhotsk Sea. Based on Kim et al. (2005), the zooplankton biomass from end of 1990s to the early 2000s was reduced by half in the 1980s.

Slide 12

These figures show changes in the rate of ice cover area and chlorophyll-a or zooplankton biomass. The chlorophyll-a is represented as annual mean based on data of the satellite. This table indicates results of those correlation coefficients.

In general, it is believed that the timing and duration of ice cover and winter winds determines the onset of the spring net primary production.
In the Okhotsk Sea, however, chlorophyll-a and zooplankton biomass are not closely coupled to the ice cover rate.

Slide 13

Relation map between the summer SST and the growth anomaly of the Ishikari River chum salmon in the Okhotsk Sea represents the significant positive-correlation.

That is, results of our limited data suggest that the growth of Ishikari River chum salmon will be affected by not the productivity trends (such as chlorophyll-a and zooplankton biomass), but the SST, relating to the rate of ice cover area in the Okhotsk Sea.

Slide 14

By the way, these figures show changes in the anomaly of growth in the first year, the mean body weight of juvenile released, and return rate of Hokkaido chum salmon population. The return rate is defined as survival rate from lease to return. The return rate correlated with the growth in the first year and body size of juvenile released.

However, the result of multiple regression analysis on the return rate of Hokkaido chum salmon population showed that (1) the regression identified body size of juvenile at the release, (2) that relationship between the growth in the Okhotsk Sea did not indicate significant trend.

Slide 15

There are 2 hypotheses on the period of critical mortality in the Pacific salmon: (1) Size-selective mortality in the early marine life period and (2) Size-related mortality over the first marine fall and winter relating to the sufficient growth by the end of the first marine summer. As far as our results, mortality of Ishikari River chum salmon population will higher in the spring than in winter.

Slide 16

Needless to say, the life history strategy of Pacific salmon offers a useful framework for evaluating not only inter- and intra-specific interactions but also climate-related risk factors around the North Pacific.

The growth pattern of Japanese chum salmon will be controlled by the environmental condition such as SST and Ice cover relating to the climate change in the Okhotsk Sea, and by inter- and intra-specific interactions such as the carrying capacity and the population density-dependent effect in the Bering Sea.