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Temporal lags between changes of climatic indices and some components of the Japan/East Sea ecosystem

Goals:

- to find significant relations between the year-to-year changes of environmental parameters and components of the Japan/East Sea ecosystem

- to determine temporal lags of the strongest statistical relations

- to analyze the relations and suppose their mechanisms

- to trace a response of climate shift in late 1980s in different levels of the ecosystem

- to elaborate a conceptual model of climate changes influence on the ecosystem

Materials:

Climate indices:

- Siberian High index: atmospheric pressure in the center of the Siberian High, averaged for December-February (data of Russian Hydrometeorological Center)
- Siberian High index: mean atmospheric pressure in the region 40-65 N 80-120 E, averaged for December-February (*from Panagiotopoulos et al., 2005*);

- Pressure gradient between the Siberian High and Aleutian Low, by months (*from Vasilevskaya et al, 2003*);

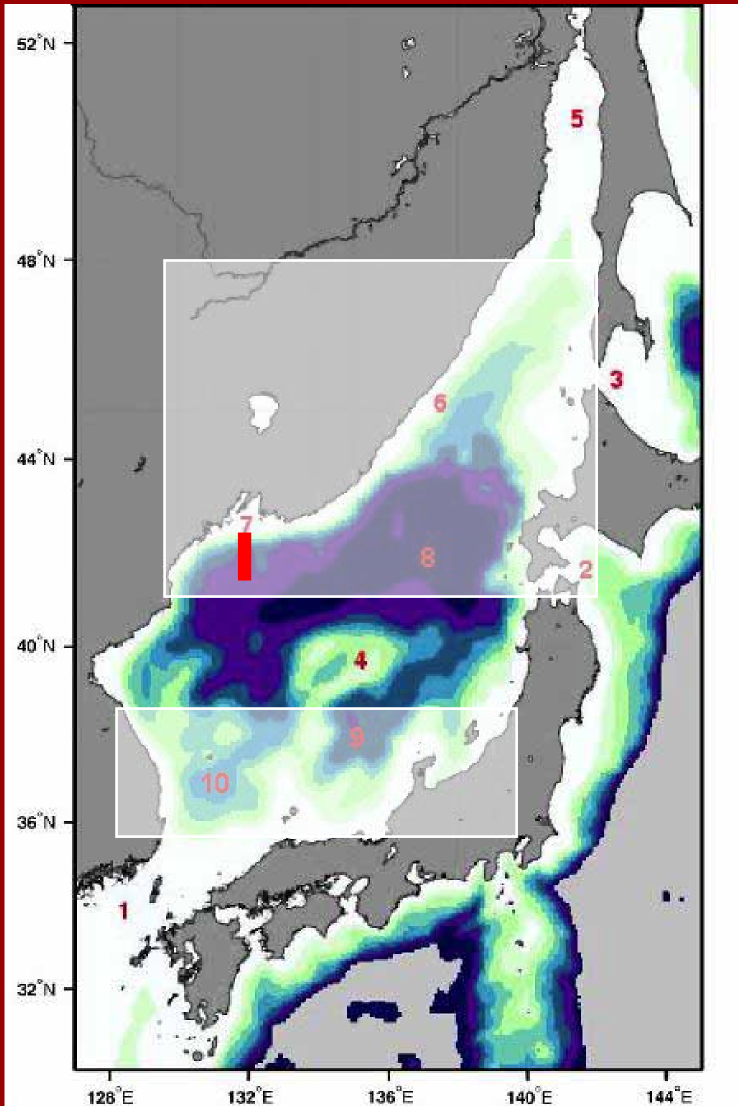
- Aleutian Low Pressure Index (ALPI),
- North Pacific Index (NPI),
- West Pacific Index (WP),
- Pacific Decadal Oscillation (PDO),
- Victoria winter Pattern (*Bond et al, 2003*),
- Arctic Oscillation Index (AO),
- ENSO Index
  (*from* http://www.cdc.noaa.gov/ClimateIndices/ ,
  http://www.beringclimate.noaa.gov/data/index.php ,
  http://www.cgd.ucar.edu/cas/catalog/climind/,
  http://www.cpc.ncep.noaa.gov/products/ ,
  http://jisao.washington.edu/ ,
  http://www.pac.dfo-mpo.gc.ca/sci/sa-mfpd/climate/clm_index.htm)

Materials:

Water temperature data:

- Japan Meteorological Agency SST monthly data averaged for two zones (35-38 N and 41-45 N) and by seasons (anomalies relative to 1970-2000)

- Temperature of the surface and subsurface layers at the standard section 41°30-42°30 N 132°00 E (southward from Vladivostok), averaged for winter and summer (anomalies relative to 1981-1991).
  Note: the Intermediate water mass is presented in the subsurface layer in this area.



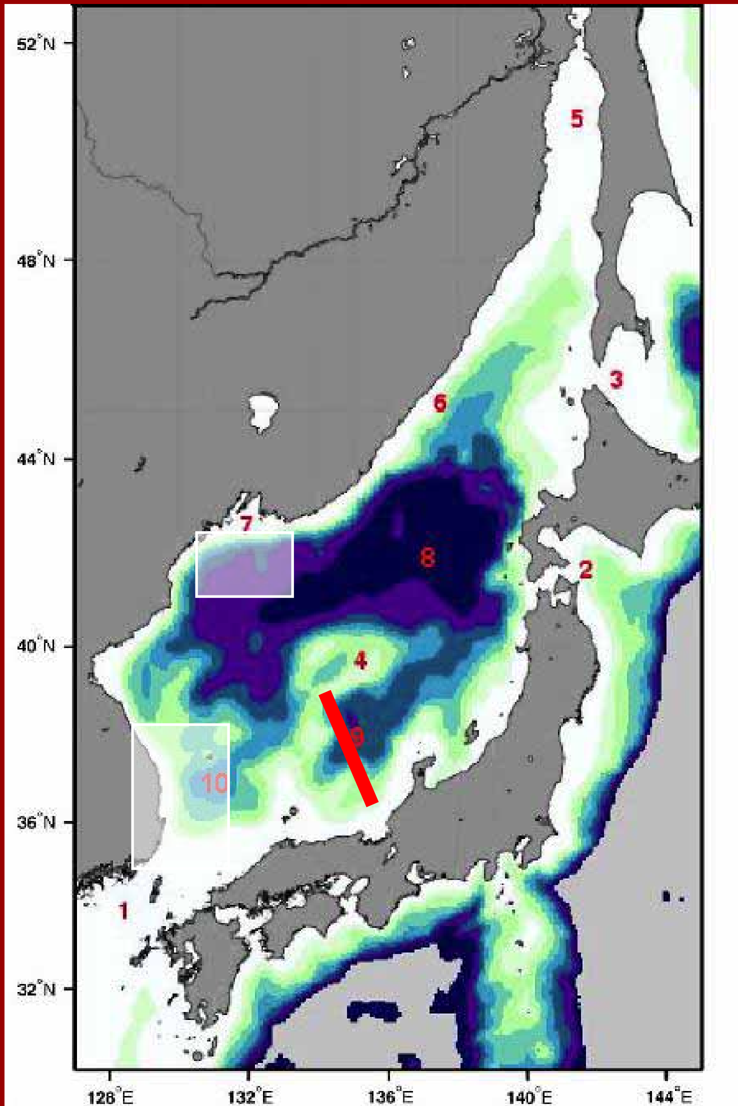
Materials:

Zooplankton data:

- Seasonal zooplankton biomass anomalies at six stations of PM-line (*from Minami, 1999 and Iguchi, 2004*) averaged by years

- Annual mean zooplankton biomass within the EEZ of Rep. Korea (*from S. Kang et al., 2000, with additions of Y.-S. Kang*)

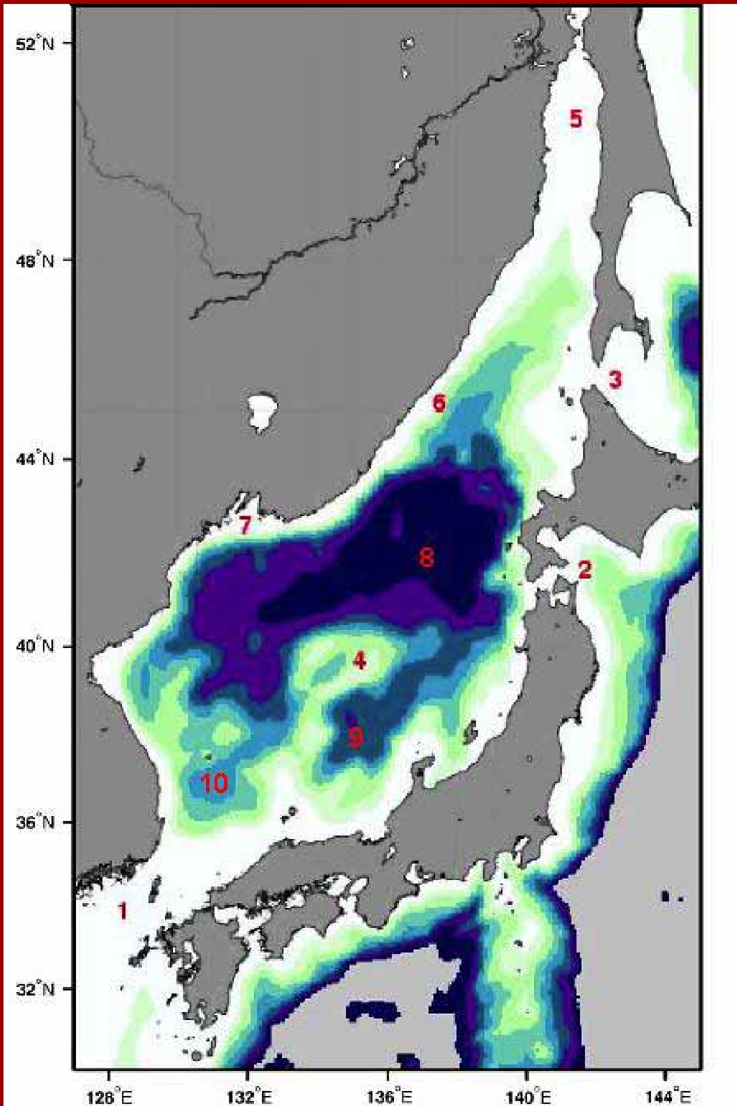
- Zooplankton biomass in May-June averaged for the area 41-42 N 131-133 E (southward from Vladivostok)



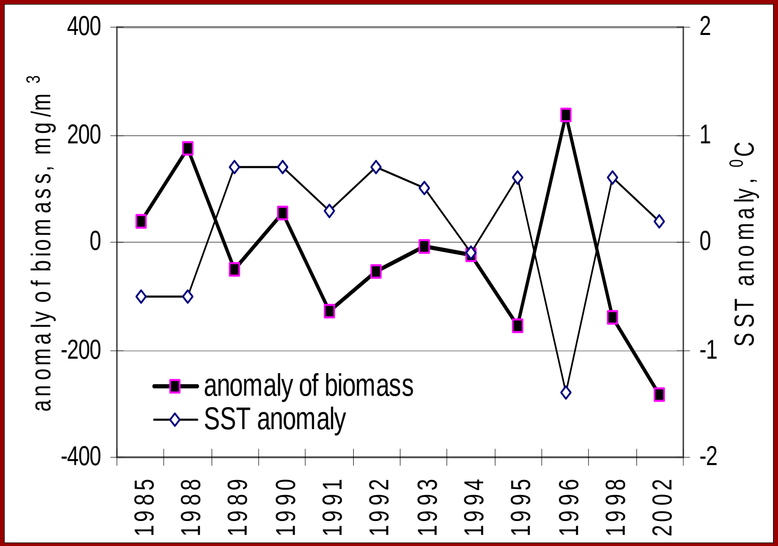
Materials:

Fish and squid data:

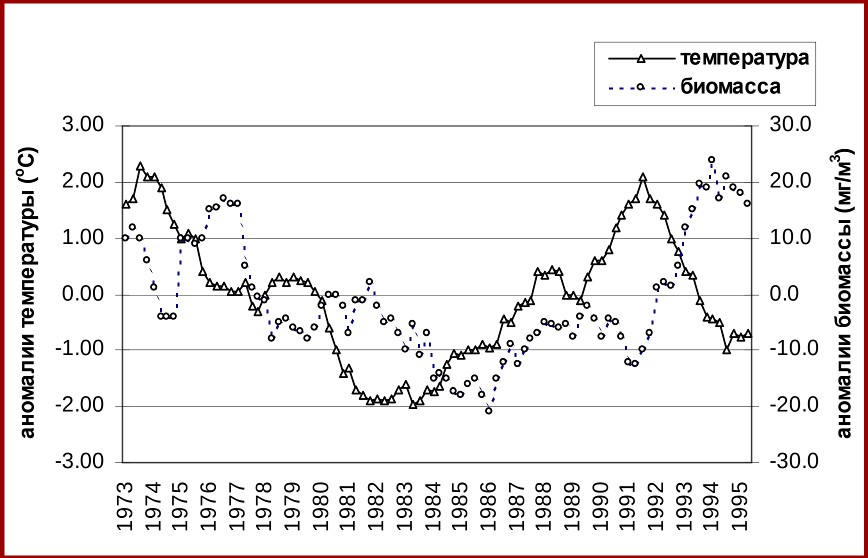
- Annual catch of sardine by Japan, South Korea, and Russia
- Annual catch of japanese common squid by Japan and South Korea
- Annual catch of jack mackerel by Japan, South Korea, and Russia
- Annual catch of saury by South Korea
- Annual catch of anchovy by Japan and South Korea
- Generations abundance for the pollock population in Peter the Great Bay
- Annual biomass of arabesque greenling in Russian EEZ
- Annual catch of saffron cod by Russia



Zooplankton dependence on SST:



Dolganova, Zuenko, 2004

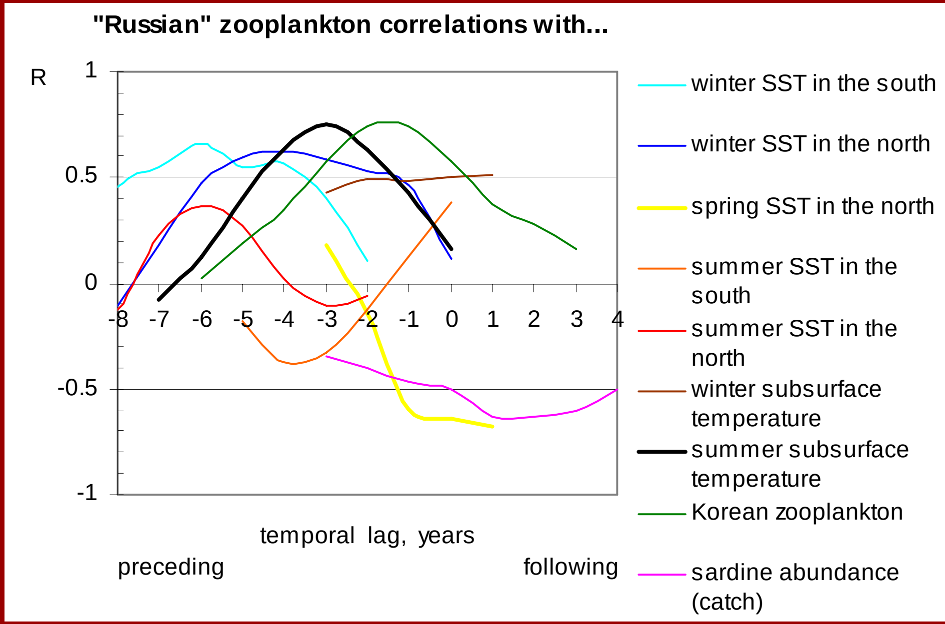


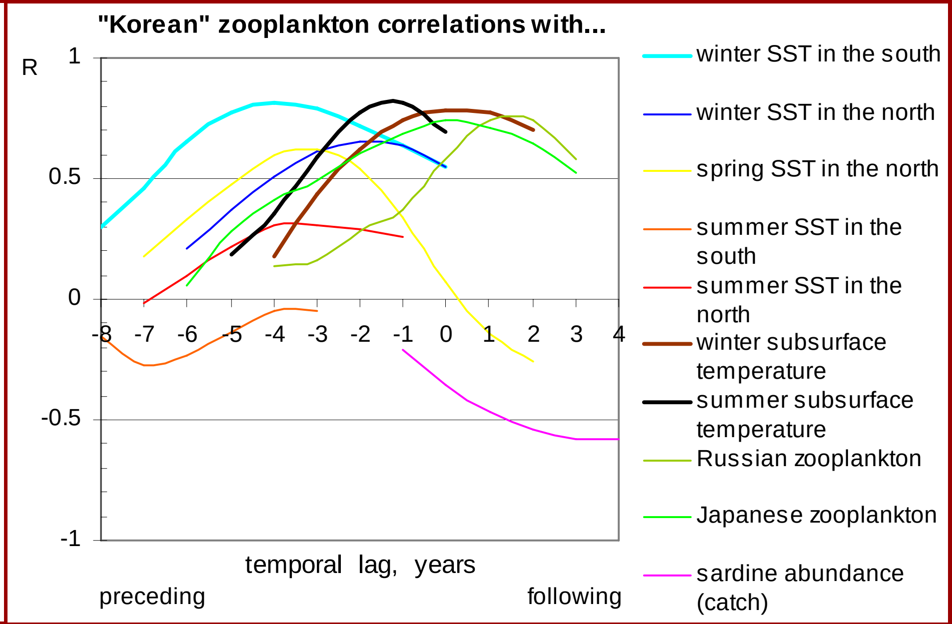
Minami, 1999; modified by Iguchi, 2004

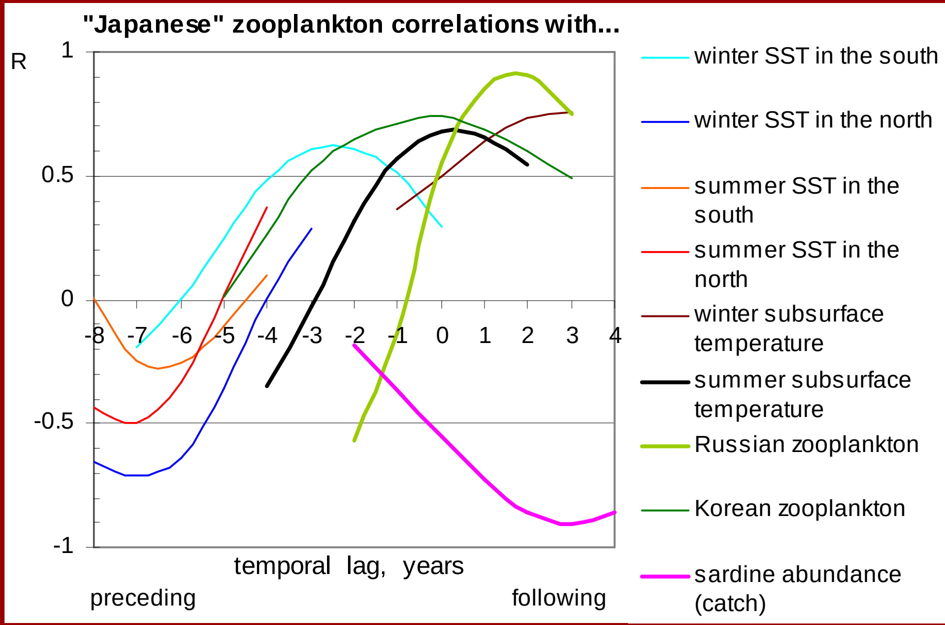
There are well-known negative dependence of zooplankton abundance on water temperature in spring-summer obviously caused by productivity increasing in conditions of better mixing or low productive subtropic community spreading with warm subtropic waters.

However, large-scale changes of zooplankton are positively dependent on the temperature that still has no reasonable explanation.

Zooplankton:



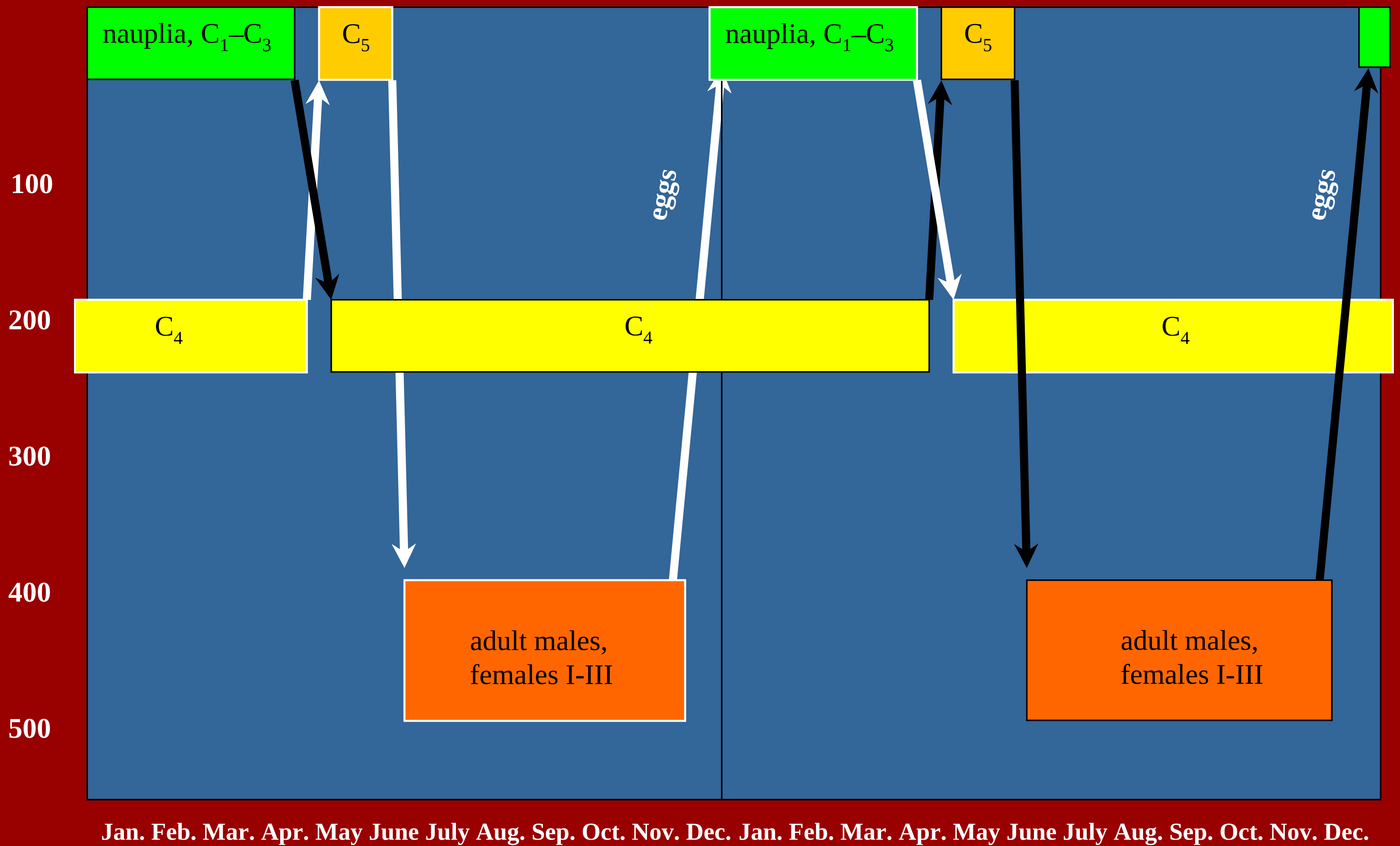




The highest correlations are:

- all 3 zooplankton series between each other with small (1 year) lags in succession: “Japan-Korea-Russia”
- between all 3 zooplankton series and subsurface temperature in summer with lag from 0 (Japan), 1 (Korea) to 2-3 years (Russia)
- between Japanese zooplankton and sardine abundance (negative) with positive lag 3-4 years

Scheme of *Neocalanus fremingery* life cycle:



after Miller, Terazaki, 1989

Zooplankton again

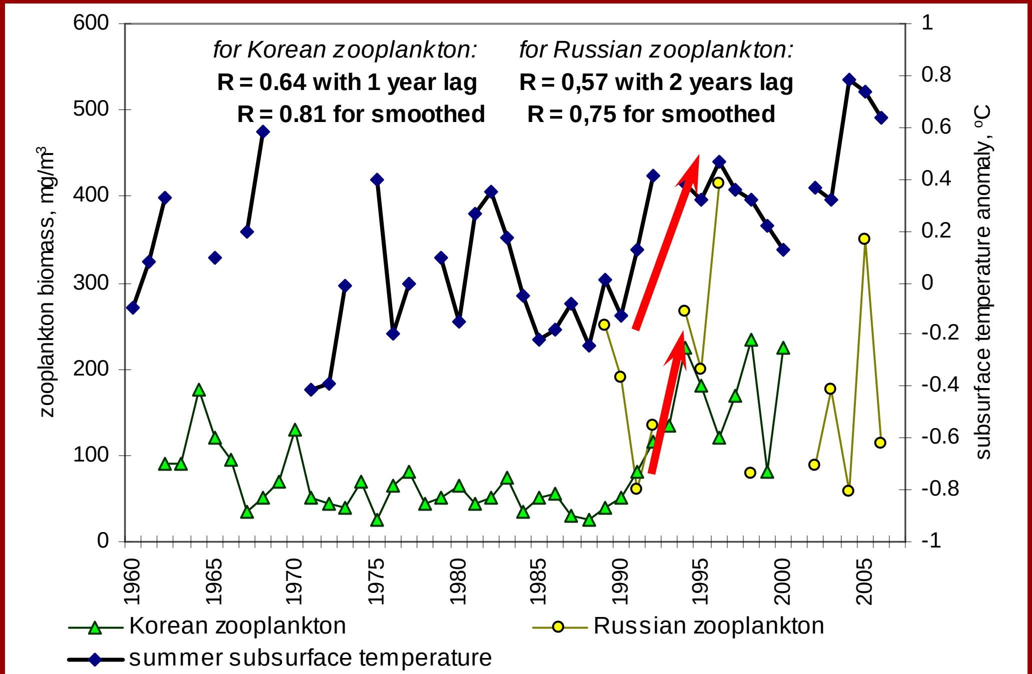
The upward shift of subsurface temperature in 1990-1993 caused the shifts of zooplankton abundance:

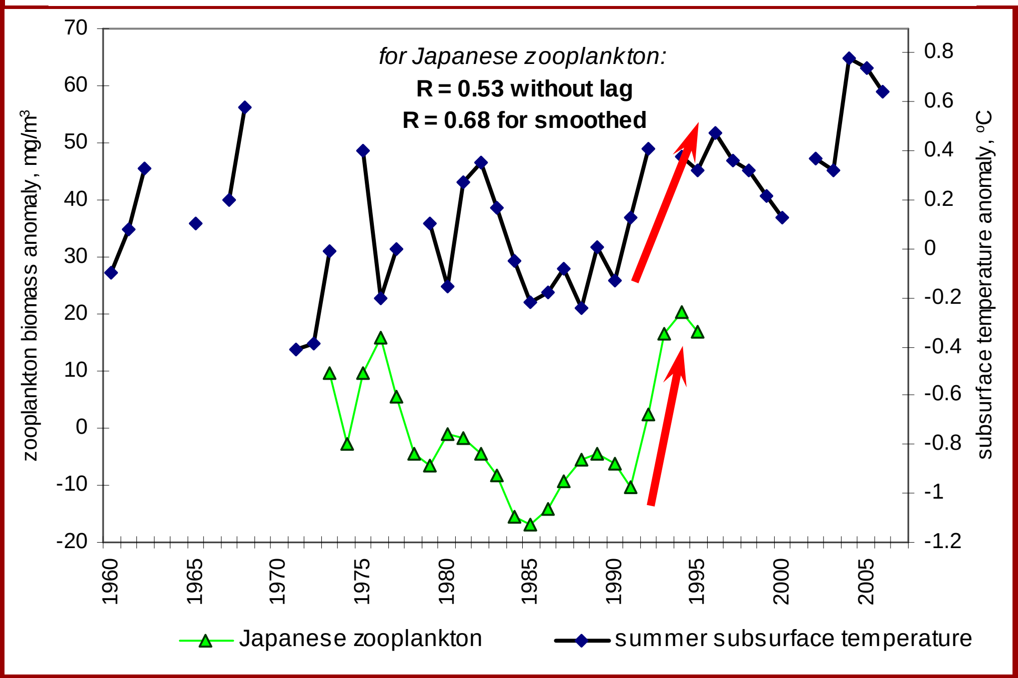
- in Japanese zone in 1991-1993;
- in Korean zone in 1992-1994;
- in Russian zone in 1993-1996.

Mechanism of the subsurface temperature influence on zooplankton abundance is concerned possibly with conditions of mass species maturation: the higher summer temperature provides successful spawning, so the generations following "warm" years have higher biomass in the second year of their life when they are sampled.

So, the lag between subsurface temperature and zooplankton biomass should be 2 years.
The shorter (0) lag between the temperature in Russian zone and Japanese plankton means that the temperature had changed there in 2 years earlier than in the area off Vladivostok.

Direct transport of some zooplankton species in the direction "Japan-Korea-Russia" is possible, as well





Subsurface temperature:

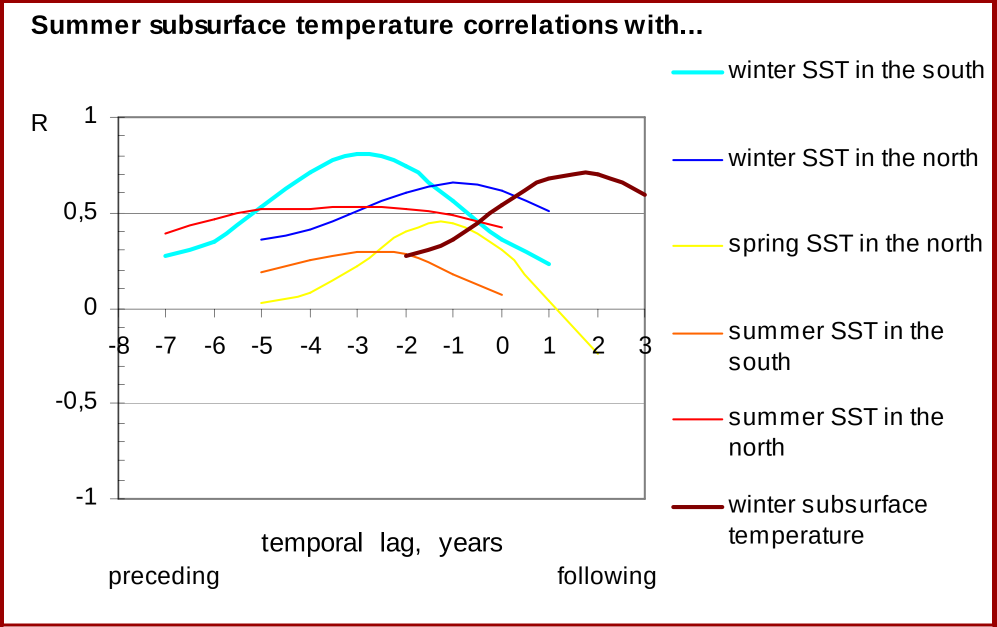
The highest correlations for the subsurface temperature in summer:

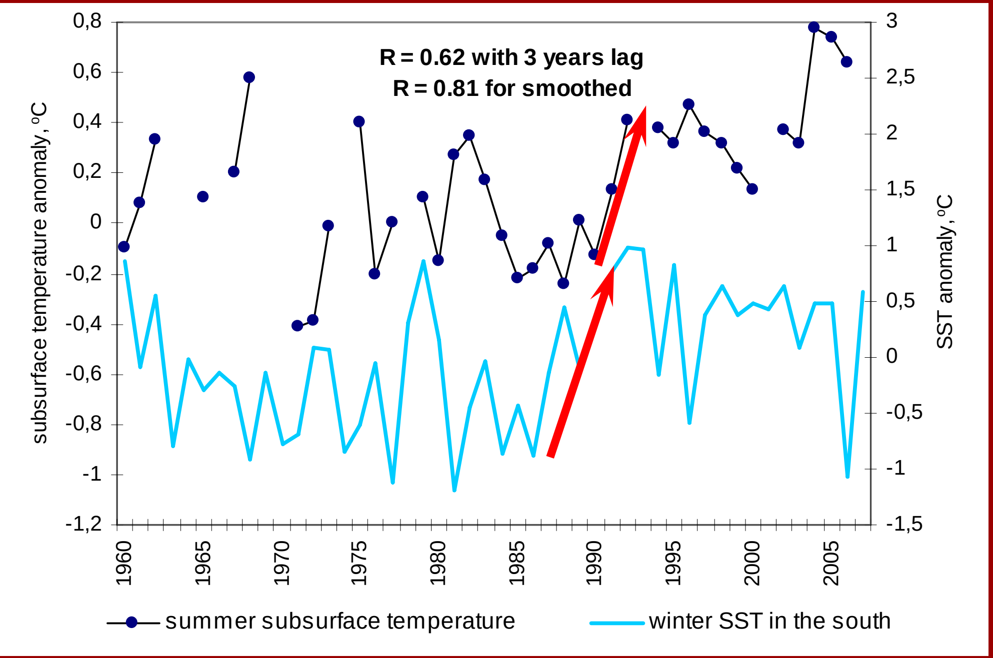
- with winter SST in the north with the lag 0-1 years. This is result of well-known mechanism of winter convection.

- with winter SST in the south with the lag 3 years. This is supposedly result of subduction in the Polar Front zone – another mechanism of the Intermediate water formation.
  In this case, the 3 years lag = the time of the new formed water transport to the area off Vladivostok.

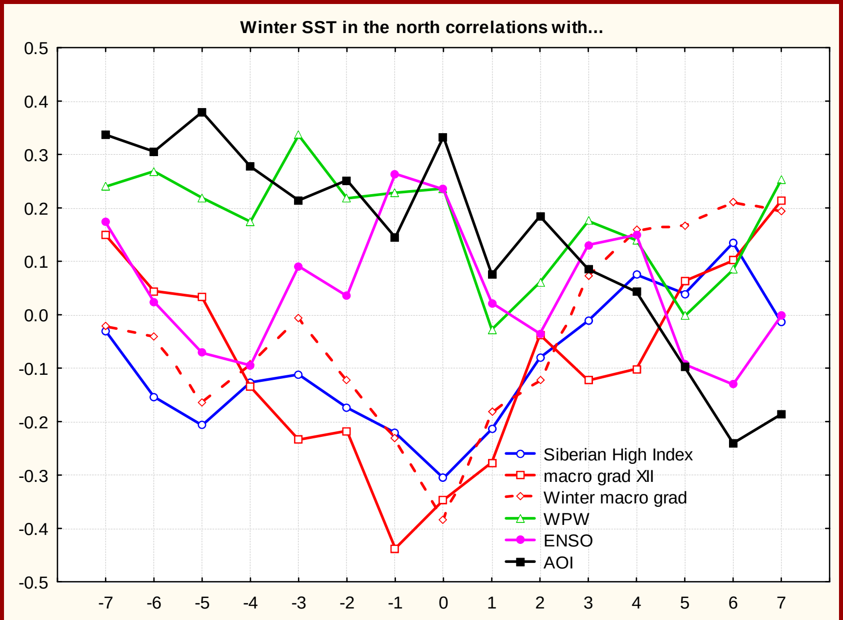
- with the subsurface temperature in winter with the lag –1-2 years, i.e. winter temperature changes follow to summer one.

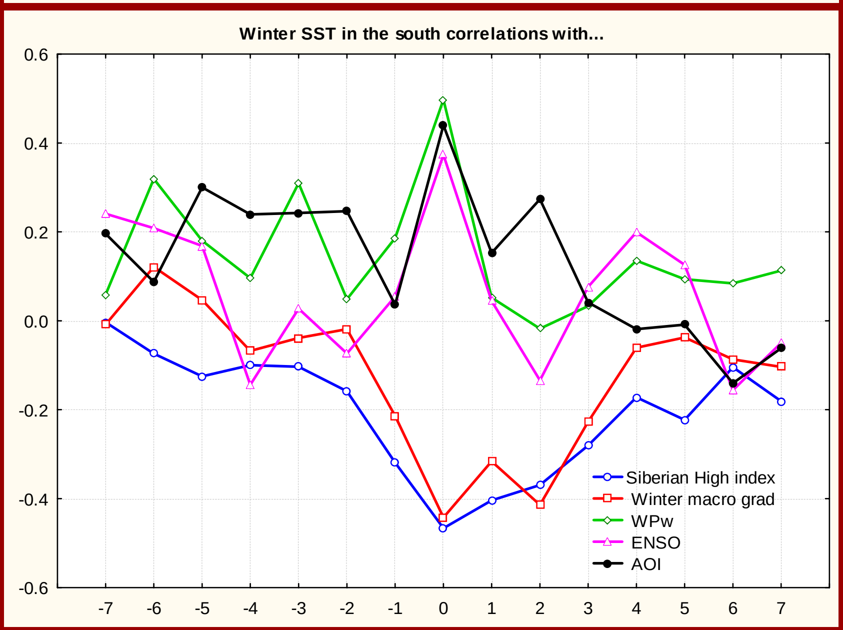
The upward shift of the SST in the southern JES in 1986-1991 caused the summer subsurface temperature rising in Vladivostok area in 1990-1993.





Sea surface temperature: winter



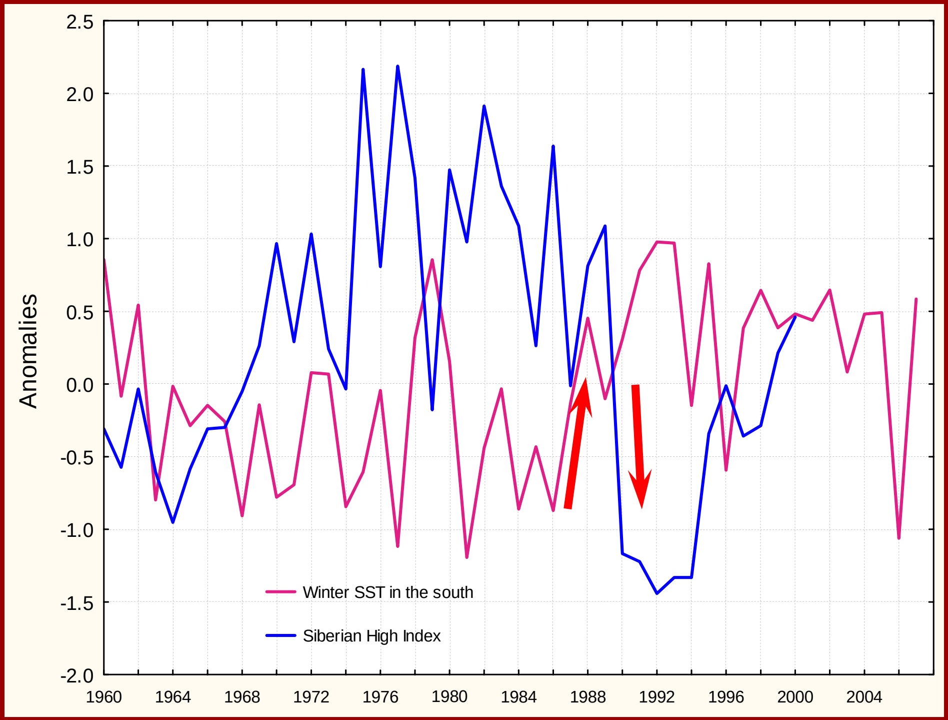


The highest correlations are:

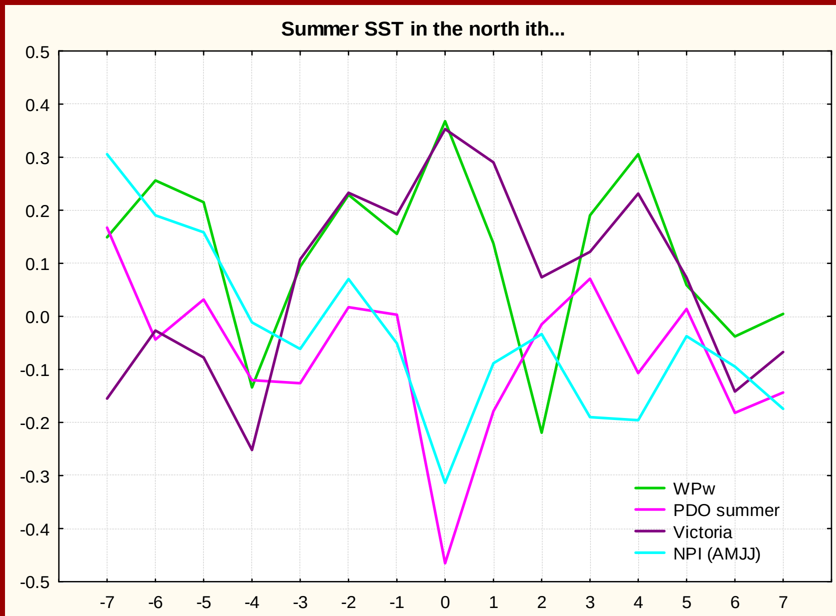
- between winter SST in the north and pressure gradient between Siberian High and Aleutian Low in December (negative, lag < 1 year: December gradient -> winter SST)

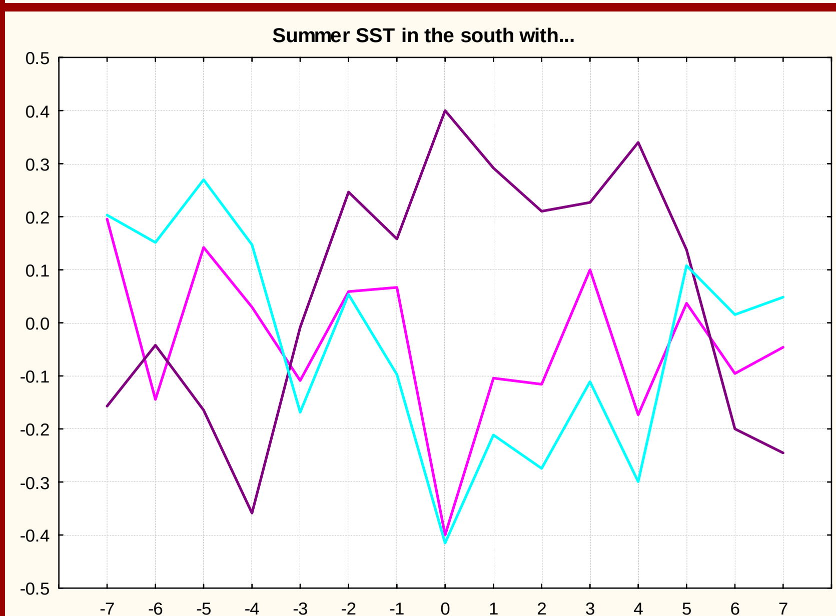
-between winter SST in the south and Siberian High Index (negative, synchronous)

The SST upward shift in 1986-1991 was caused by the Siberian High weakening and the pressure gradient SH/AL decreasing in 1986-1991



Sea surface temperature: summer



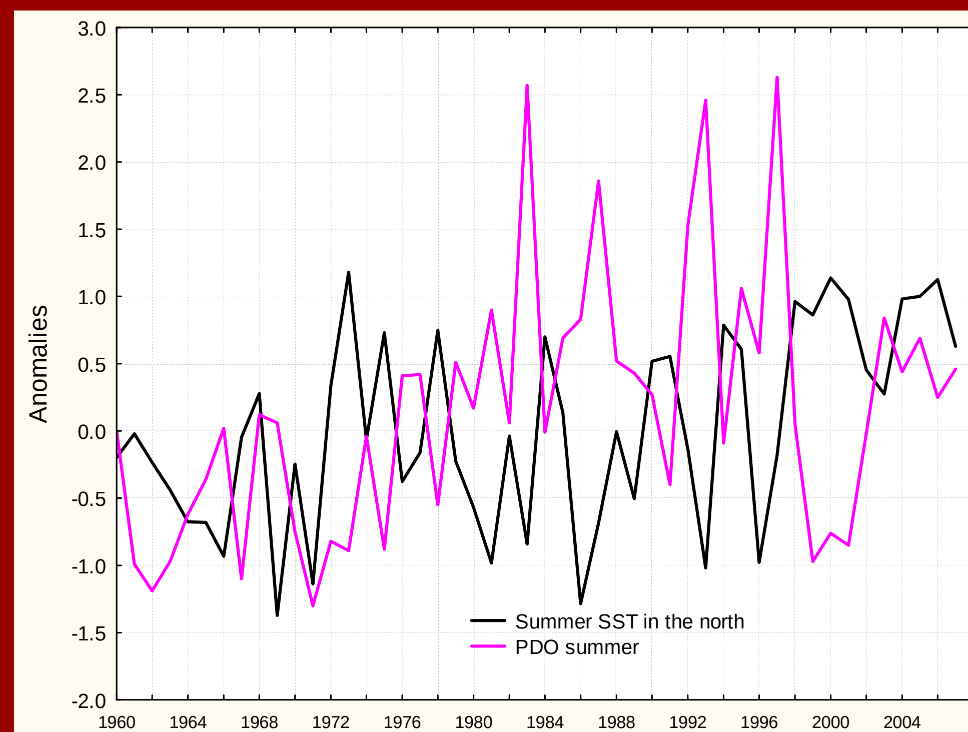


The highest correlations are:

- between summer SST in the north and summer PDO (negative, synchronous) or winter WP (positive, lag < 1 year)

- between summer SST in the south and summer PDO or spring-summer NPI (negative, synchronous)

The SST upward shift in 1986-1991 was not traced for summer



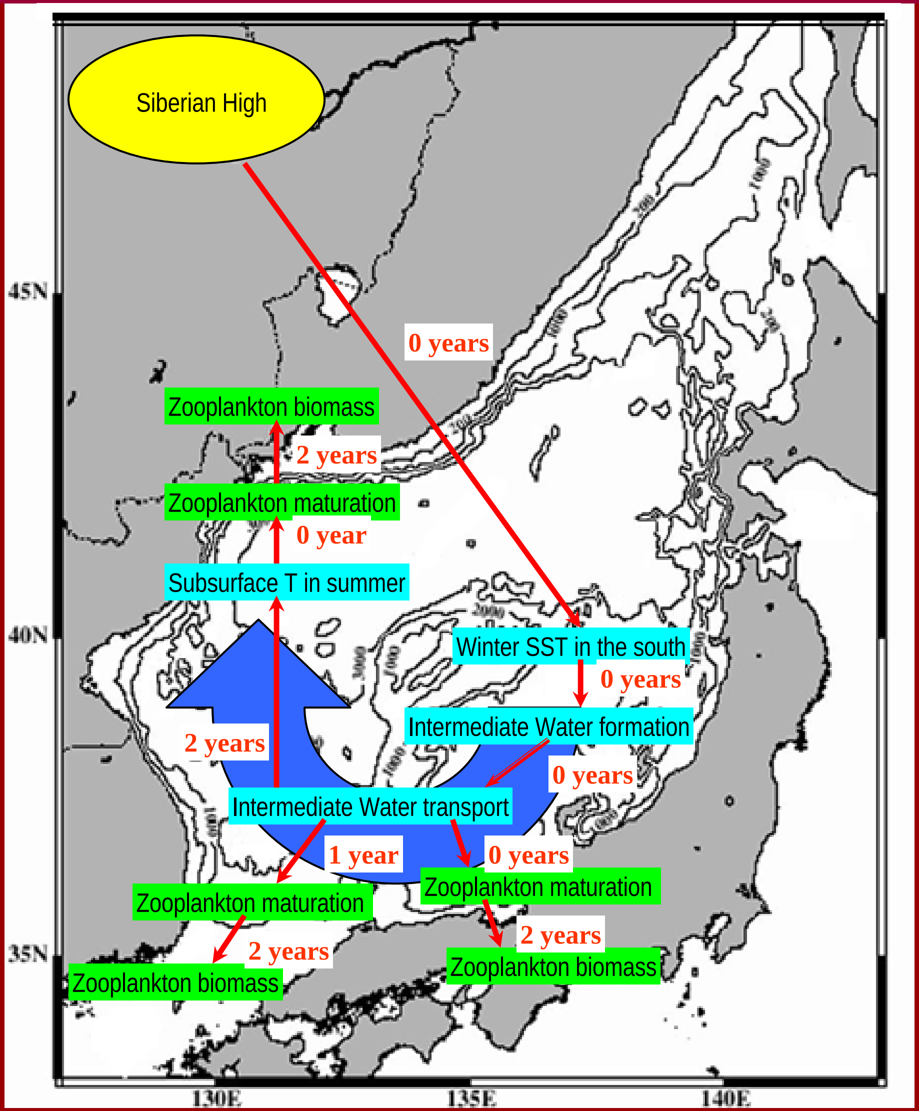
Scheme of climate influence on zooplankton:

As the result of summarized lags,

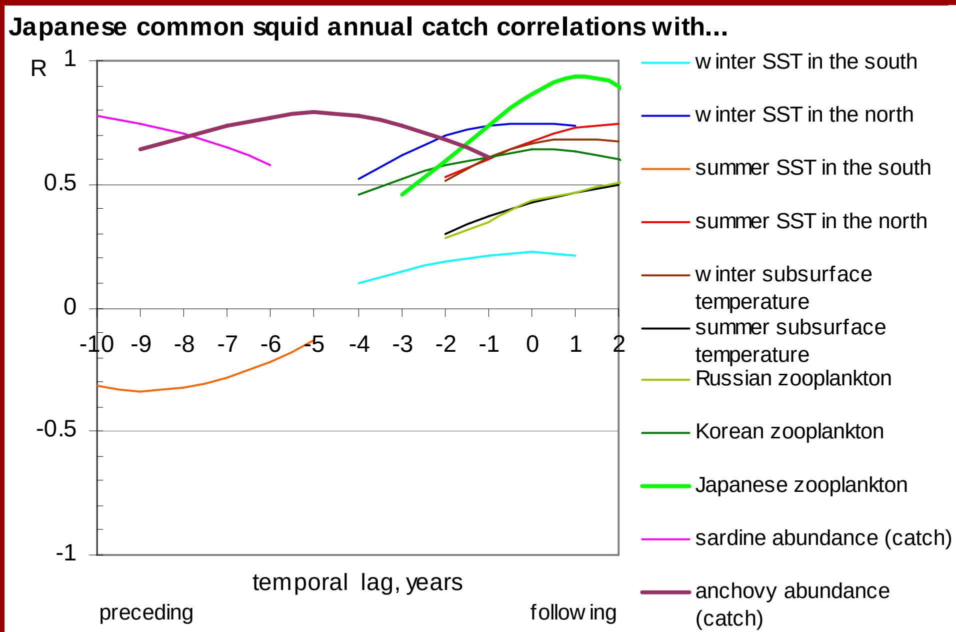
- changes of “Russian” zooplankton are in 3 years later than the changes in subsurface layer in the Russian zone and in 6 years later than the winter SST changes in the southern JES or Siberian High changes

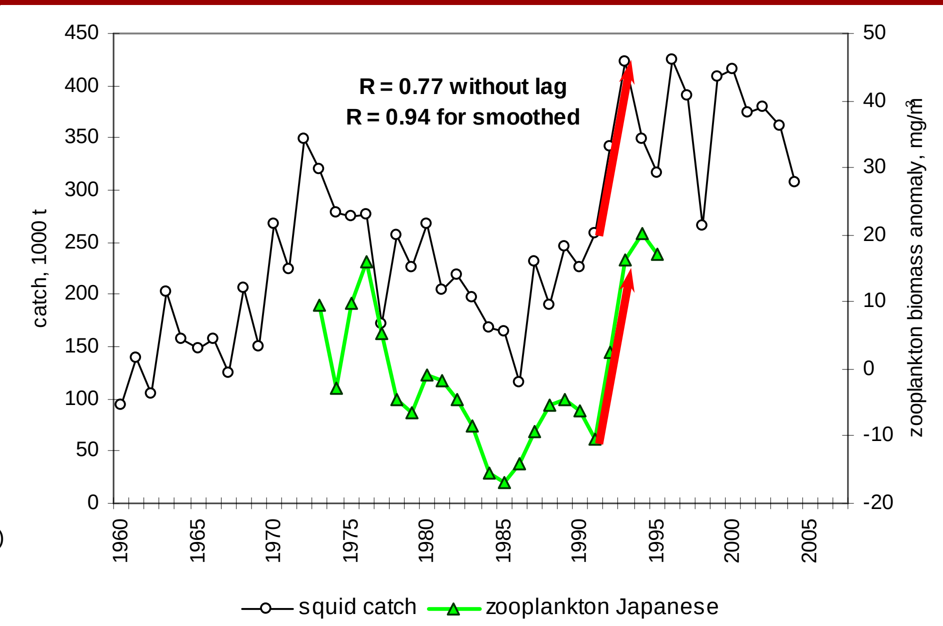
- changes of “Korean” zooplankton are in 1 year later than the changes in subsurface layer in the Russian zone and in 4 years later than the winter SST changes in the southern JES or Siberian High changes

- changes of “Japanese” zooplankton are synchronous with the changes in subsurface layer in the Russian zone and in 2 years later than the winter SST changes in the southern JES or Siberian High changes



Japanese common squid:





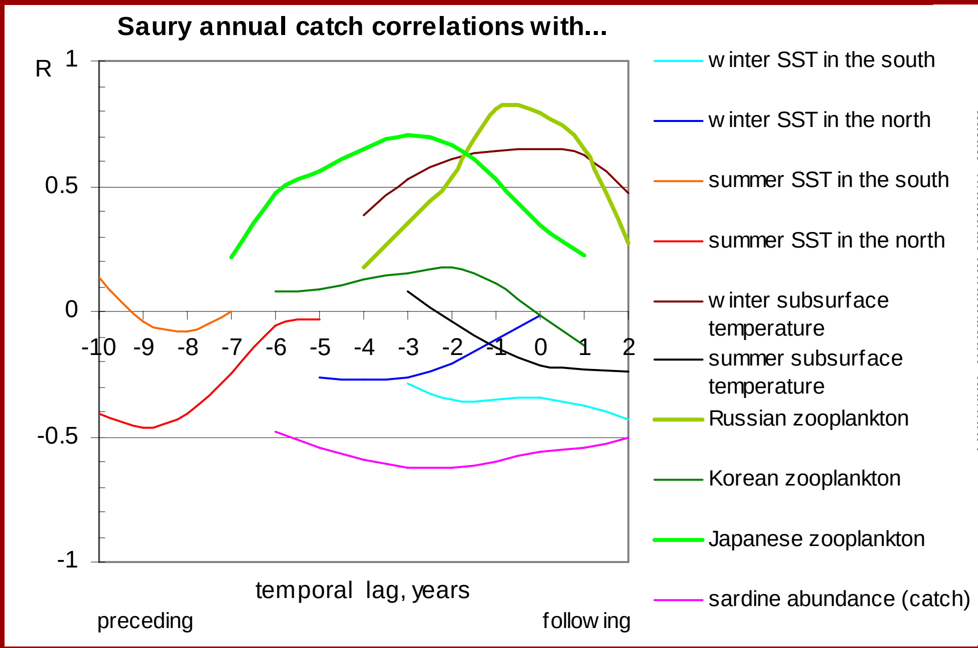
Strongly correlated with zooplankton biomass in the Japanese zone (positive, synchronous)

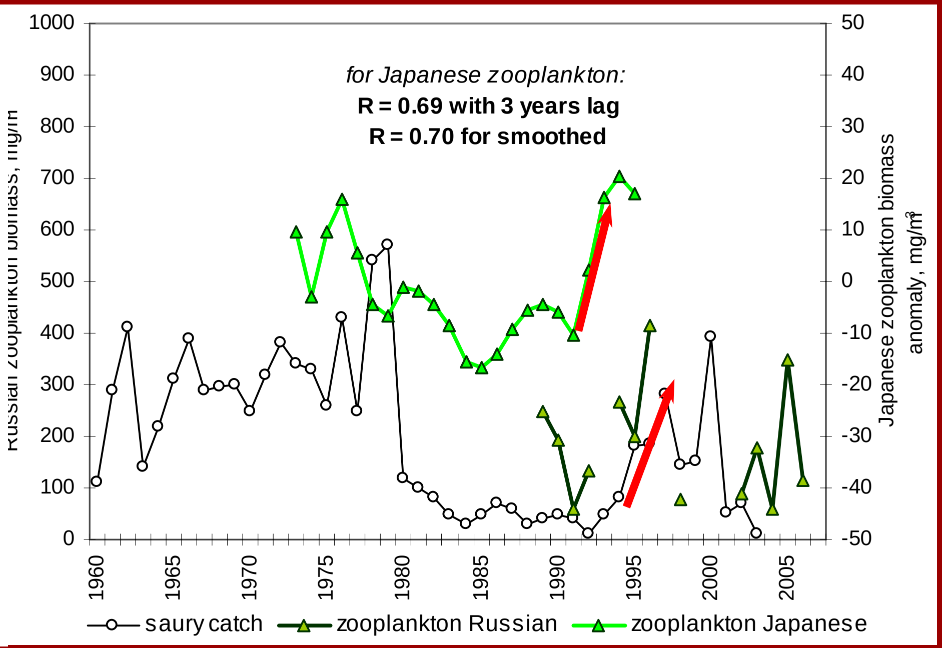
The zero lag is obviously related with 1-year life cycle of the squid

Another significant correlation is with anchovy abundance, as the squid's prey. Significance of sardine abundance is lower.

Zooplankton abundance shift in 1991-1993 (because of SST increasing in 1986-1991) caused the synchronic shift of the squid abundance in 1991-1993

Pacific saury:





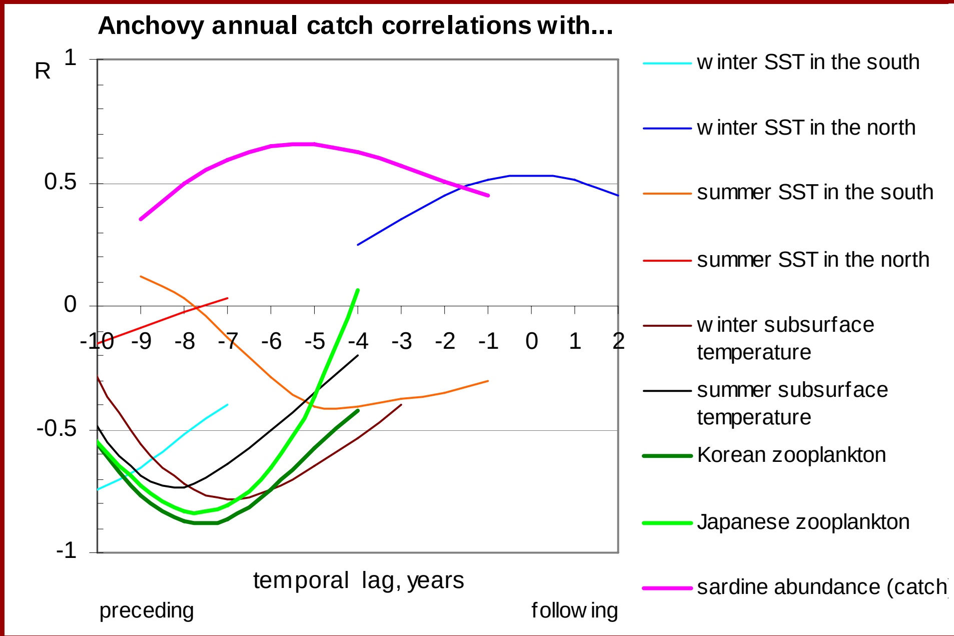
The strongest correlation with zooplankton biomass in the Japanese zone (positive, with 2-3 years lag). Strong correlation with Russian zooplankton is not trustworthy because of short overlapping of the rows. The correlation with Korean zooplankton is insignificant.

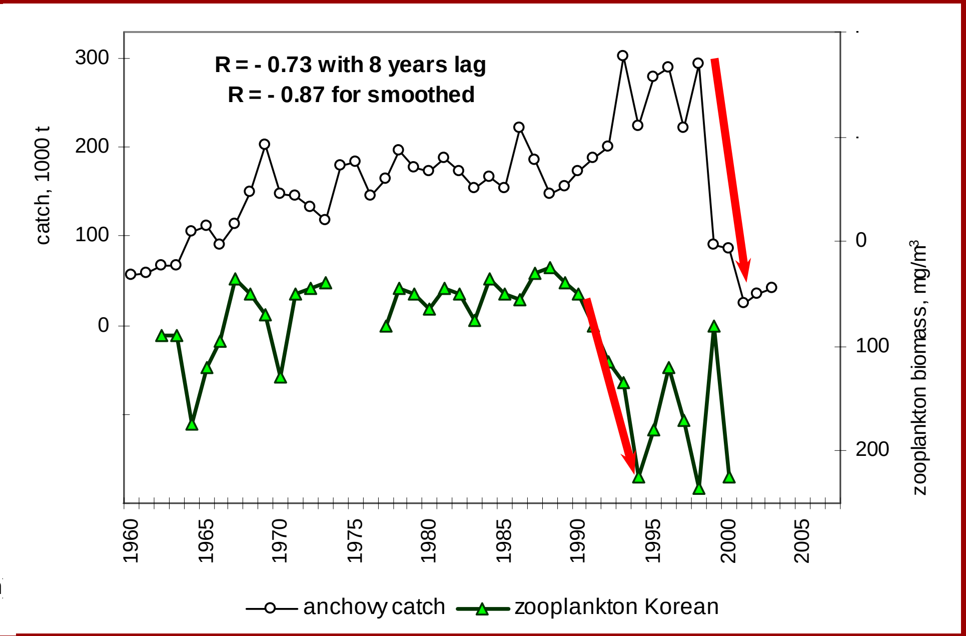
The lag is supposedly caused by 2-year life cycle of the saury and delayed reaction of fishery industry on the stock changes.

Negatively correlated with sardine abundance, obviously because of competition for food.

Zooplankton abundance shift in 1991-1993 (because of SST increasing in 1986-1991) caused the delayed shift of the saury abundance in 1994-1997

Japanese anchovy:



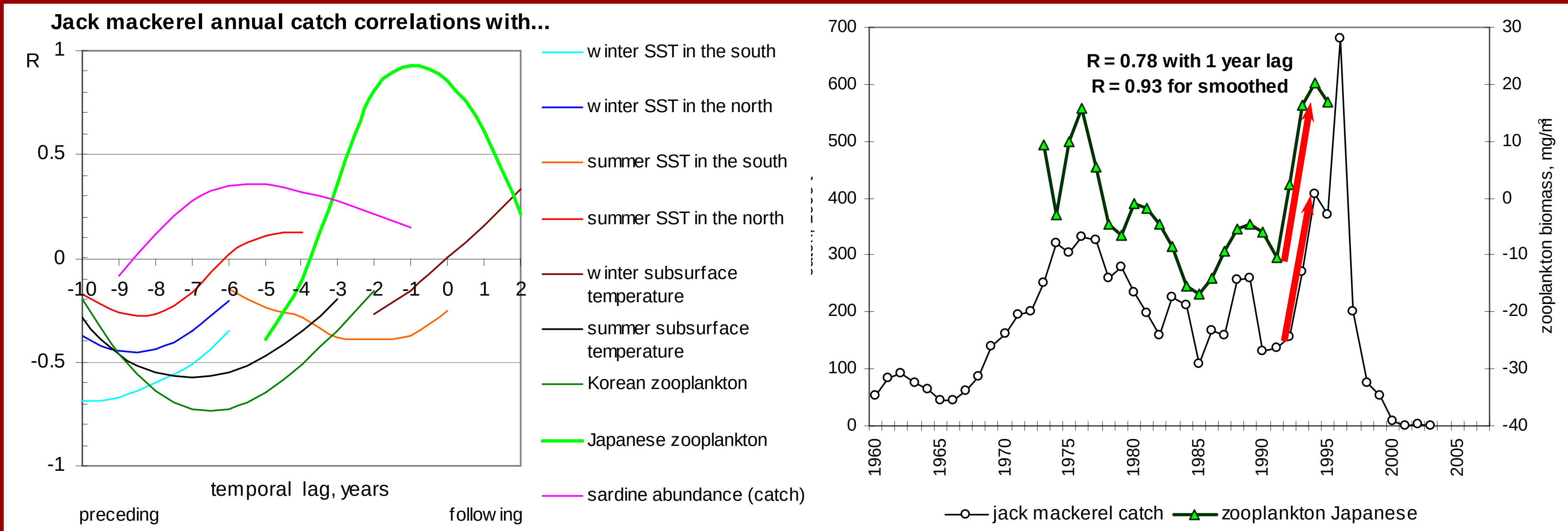


The strongest correlation with zooplankton biomass in the Korean zone (negative, with 7-8 years lag). Strong correlation with Japanese zooplankton, also negative.

Mechanism of these negative correlations with a long lag is unclear. However, strong positive correlation with sardine catch (high catch of anchovy after high catch of sardine) allows to suppose an associating of the anchovy fisheries with the sardine one. In this case, the catch of anchovy cannot be used as a measure of its abundance.

After zooplankton abundance shift in 1993-1994 (because of SST increasing in 1986-1991) the catch of anchovy had decreased in 1998-2001 but we are not sure that this was an ecological response.

Jack mackerel:

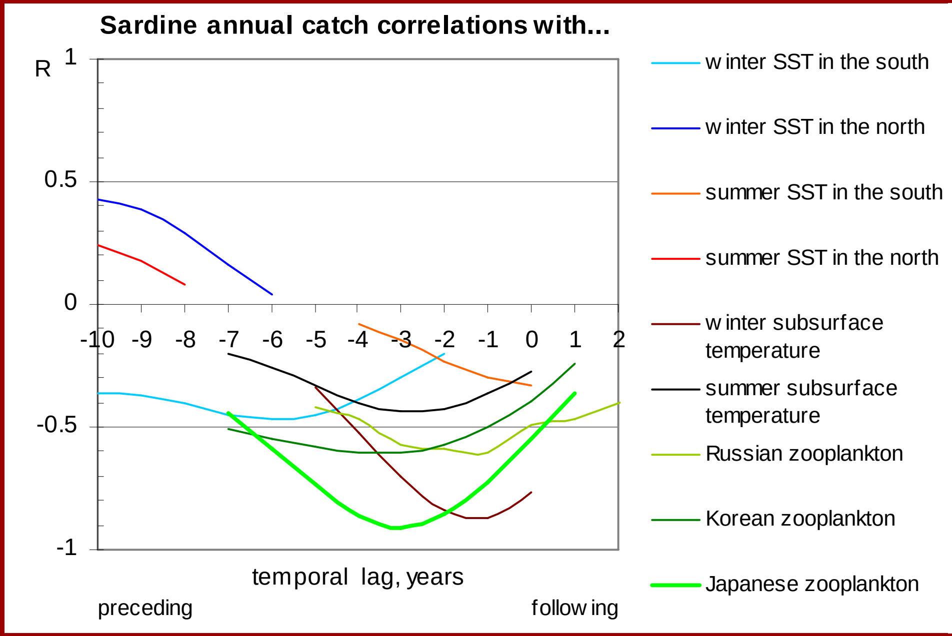


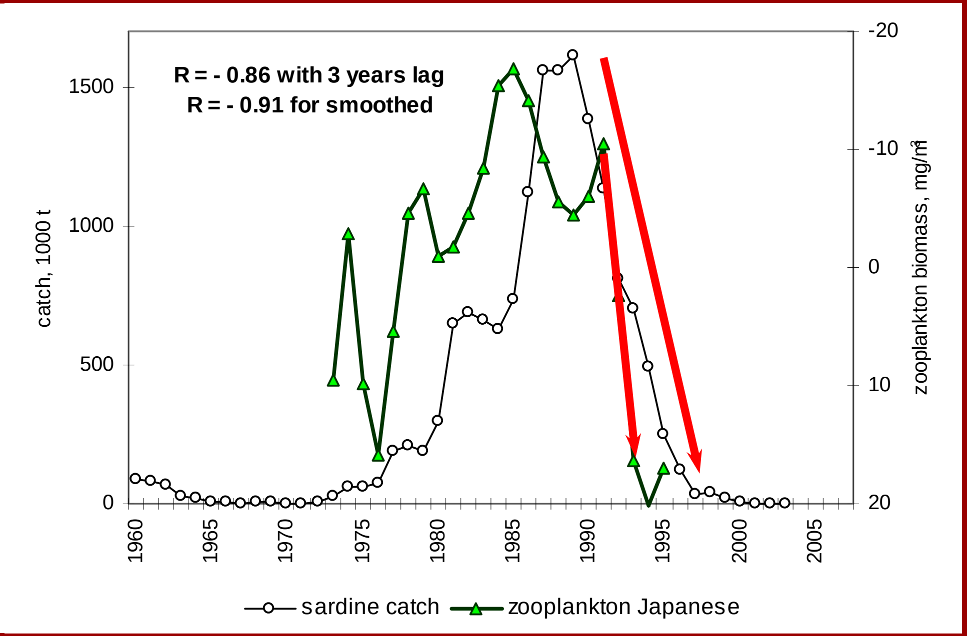
The strong correlation with zooplankton biomass in the Japanese zone (positive, with the lag 0-1 year).

This time is not enough for development of strong or weak generations of the mackerel. However, the mackerel fishery in the JES based on young fish of the age 0+ and 1+.

Zooplankton abundance shift in 1991-1993 (because of SST increasing in 1986-1991) caused the synchronous shift of the jack mackerel abundance

Japanese sardine:



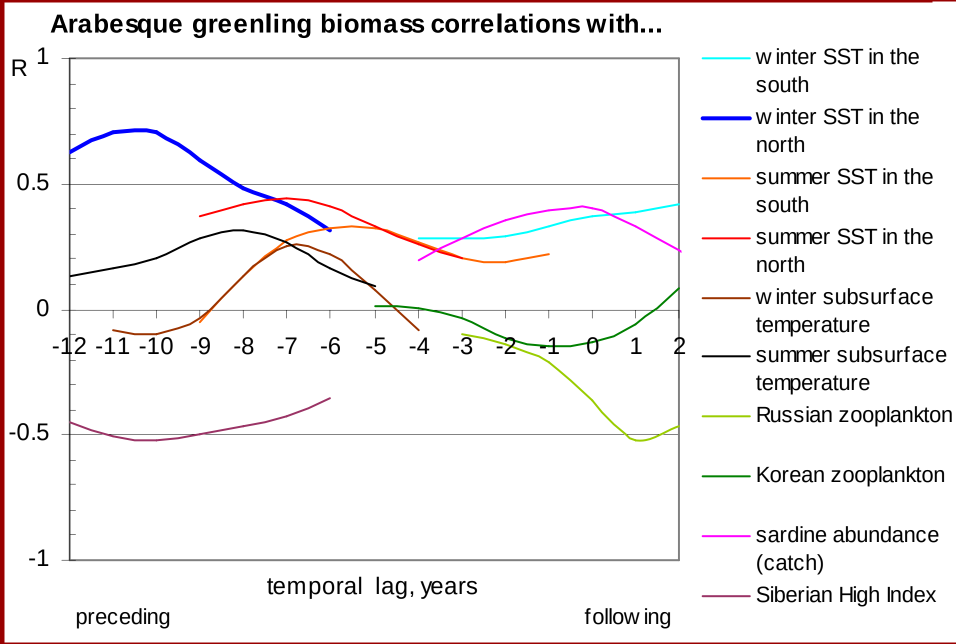


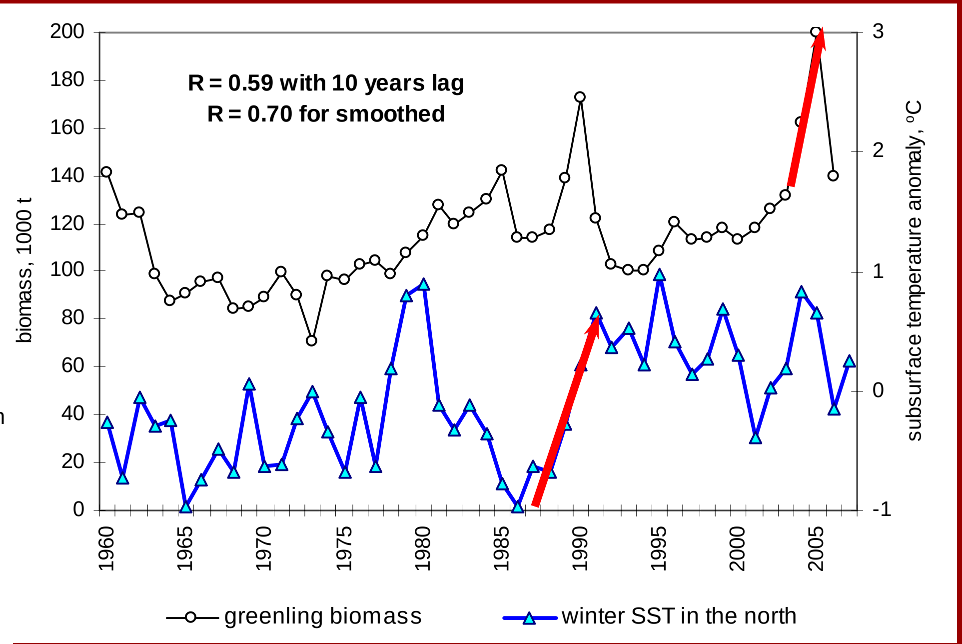
No significant correlation with any environmental parameters.
Strong negative correlation with zooplankton biomass in the Japanese zone with the lag 3 years.

The plankton abundance changes before the sardine catch changes. However, the plankton follows the sardine, because it is the prey for young fish, but adults mainly are subjected to fisheries. So, the 3 years lag is reasoned by the age of commercial stock of sardine.

Zooplankton abundance shift in 1991-1993 (because of SST increasing in 1986-1991) was strengthened (but not caused) by the sardine stock decreasing in 1989-1997

Arabesque greenling:



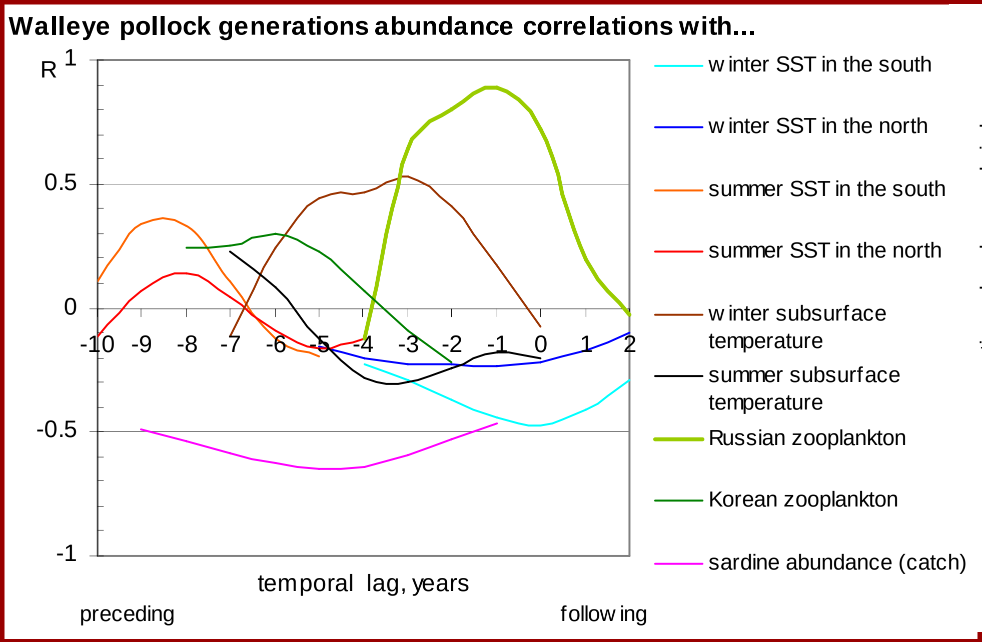


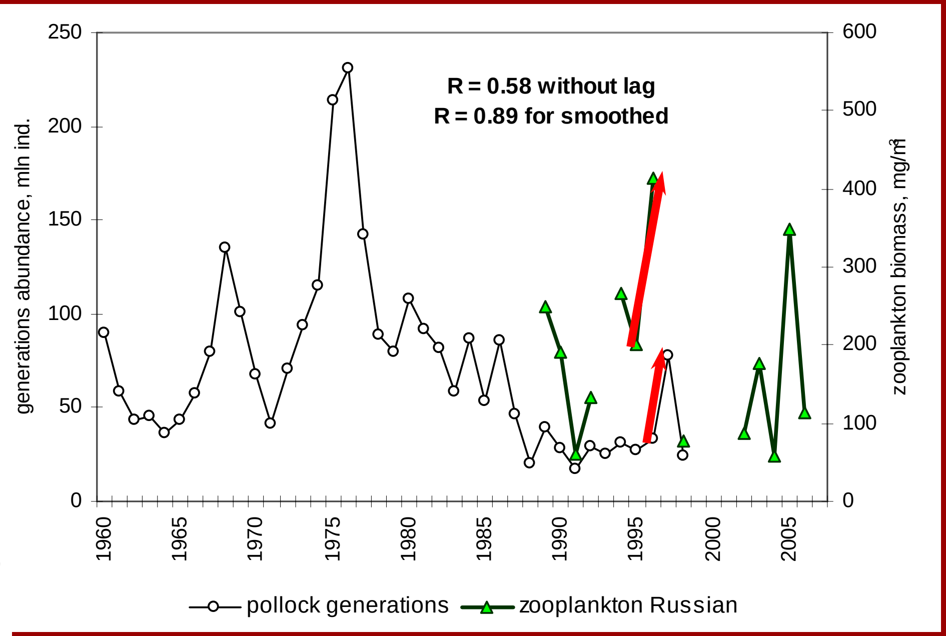
The strongest correlation is with winter SST in the northern Japan Sea (positive, with the lag 10-11).

This in not surprising for the species with larvae developing at sea surface in winter.
However, the lag cannot be explained by the life interval of greenling.
The correlation “works” better for smoothed rows: possibly, this lag is reasoned by “inertion” of the greenling stock because of low fecundity and high survival of its eggs and larvae.

Winter SST shift in 1986-1991 caused slowly increasing of the greenling stock until its upward shift in 2003-2005.

Walleye pollock (generations number):



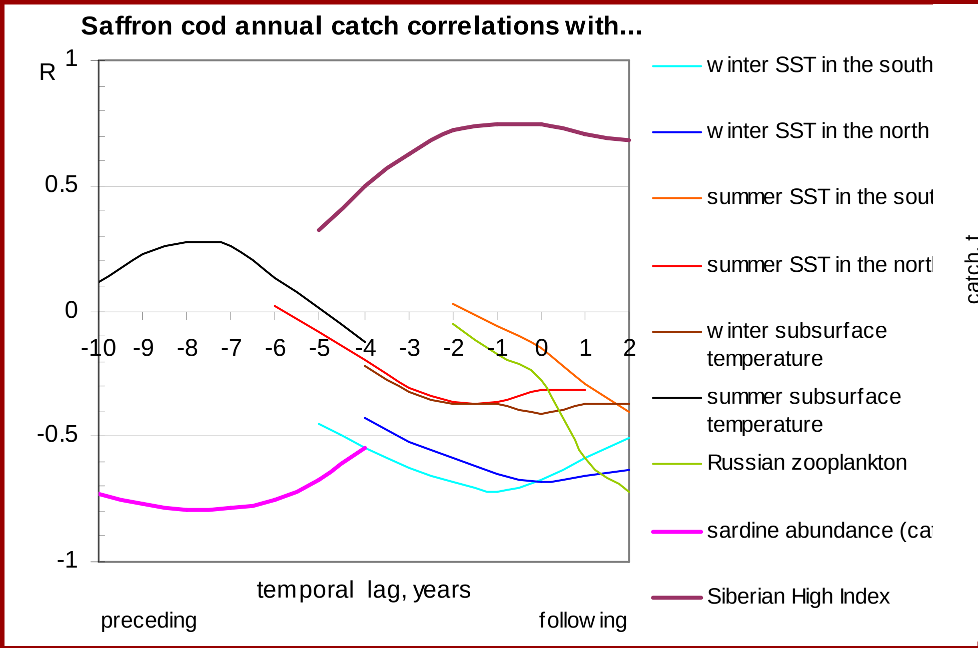


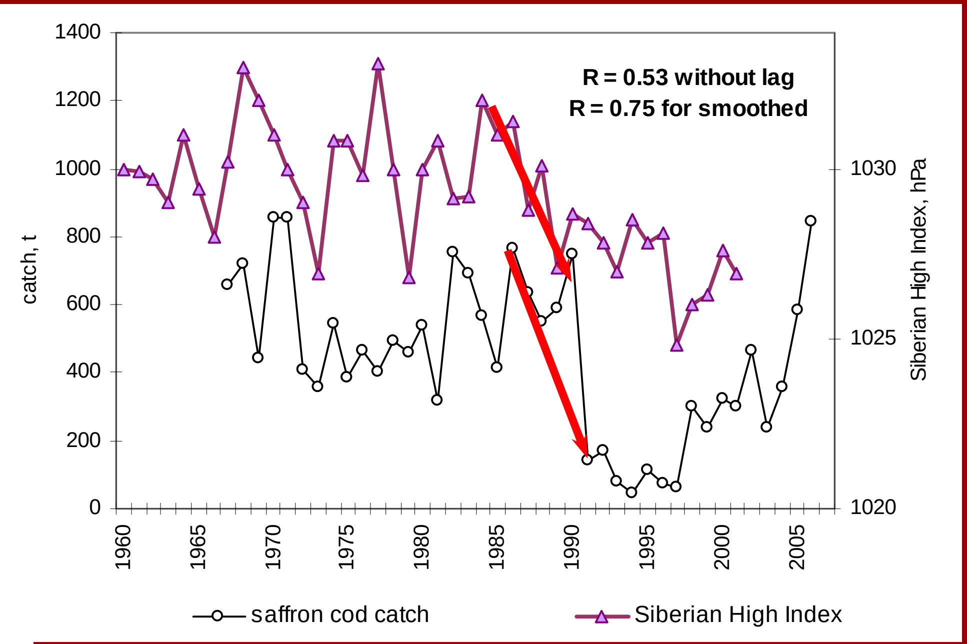
Strong positive correlation with zooplankton biomass in the Russian zone with lag 0-1 year. Unfortunately, it is not trustworthy because of short overlapping of the rows. Positive relation with winter subsurface temperature is weak, however, it became significant for strongly smoothed rows.

The synchronic relationship is obviously reasoned by mainly planktonic feeding of the pollock larvae and juveniles.

In conditions of zooplankton abundance increasing in 1996 (because of SST increasing in 1986-1991), strong generation of 1996 had formed. Recent increasing of the pollock biomass (not shown) is caused by strong generation of 2006 formed in conditions of high zooplankton biomass, as well.

Saffron cod:





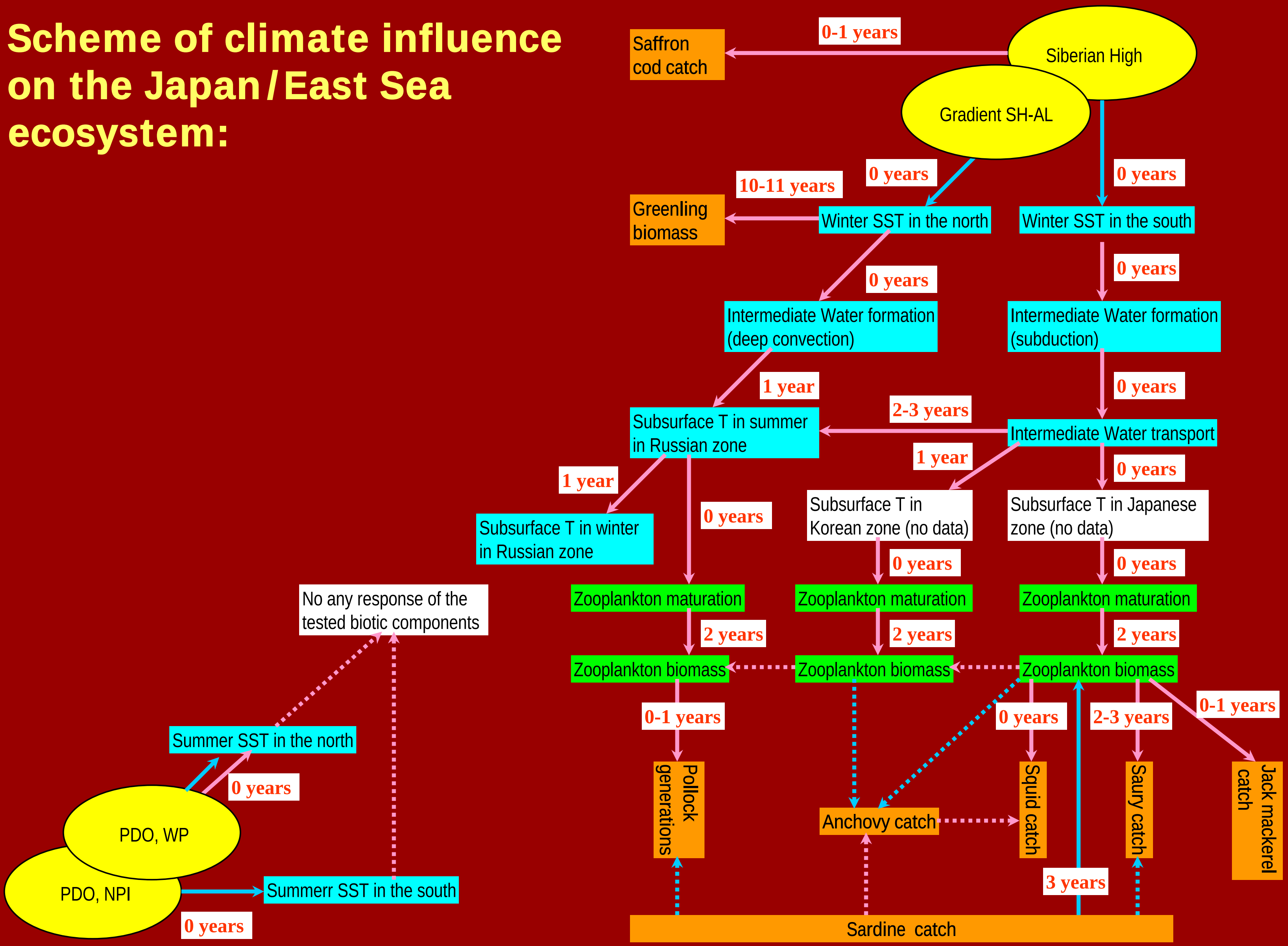
Strong synchronous positive correlation with Siberian High Index. This is a measure of winter severity, so: the colder winter, the higher catch.

This correlation has a simple nature: the saffron cod spawn when water temperature is below zero, so it has longer period of spawning in cold winters.

Besides, negative correlation with sardine abundance is revealed with the lag 7-8 years. Possibly, it is a result of competition for food between the sardine and plankton-eating juveniles of saffron cod?

The Siberian High weakening in late 1980s caused the reducing of saffron cod catch in 1986-1991.

Scheme of climate influence on the Japan/East Sea ecosystem:



Summary:

Surface layer. Atmosphere-Ocean interaction is synchronous or quasi-synchronous. So, SHI describes better atmospheric influence in winter, and the NPI – in summer.

Subsurface layer. Subsurface layer condition depends on winter processes at sea surface with a delay up to 4 years.

Zooplankton. Zooplankton abundance and composition depend on conditions in the subsurface layer with temporal lag 2 years.

Fish and squids. Abundance of mass fish and squid species depends mostly on feeding conditions in early ontogenesis, so the lags to their life interval (0-5 years).
Some species are influenced directly by physical factors (arabesque greenling and saffron cod).

Sardine and anchovy. Sardine and anchovy have no factors of influence among considered ones. In opposite, they influence on low levels of ecosystem. Obviously, other factors should be tested.

Regime shift. The regime shift in late 1980s cause water warming, zooplankton abundance increasing, and stocks increasing for majority of fish and squid species.

Application. Most of the correlations revealed can be used for forecasting of fish and squids stocks fluctuations.


The End