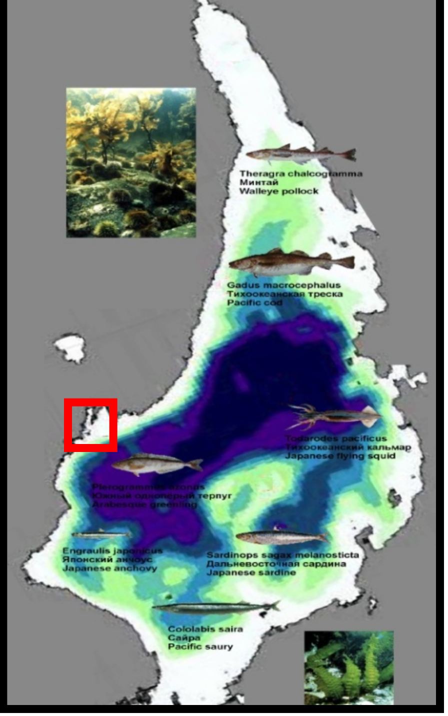
Cross-shelf advection as a mechanism of regional climate change influence on plankton community in the coastal waters

Yury Zuenko and Victoria Nadtochy

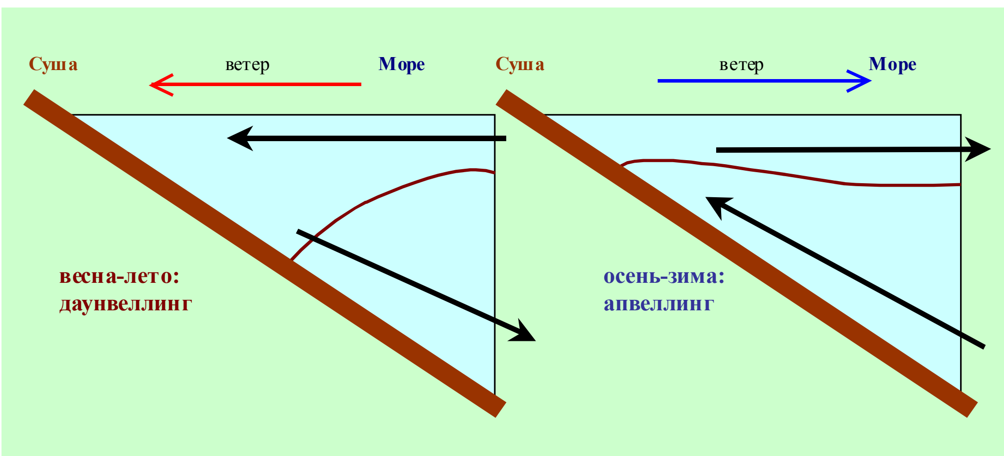
Pacific Fisheries Research Center (TINRO), Vladivostok, Russia



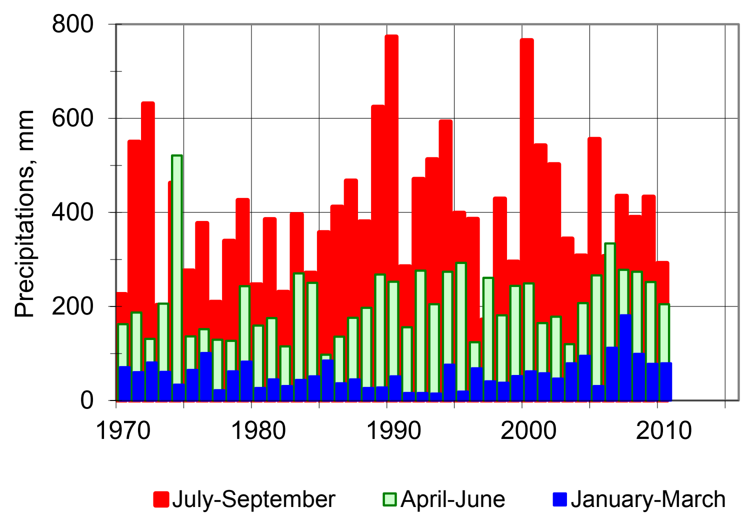
Goal: to understand the mechanism of climate change influence on plankton community of coastal zone in case of Peter the Great Bay, Japan/East Sea

The ecosystem of Peter the Great Bay is influenced by factors of both terrestrial and marine environments, as fresh water discharge and cross-shelf advection, and both these factors are subjected to changes of climate scale.

The Suyfen is one of the largest rivers of the Japan/East Sea basin with annual discharge about 2.2 km^3 *of fresh water*



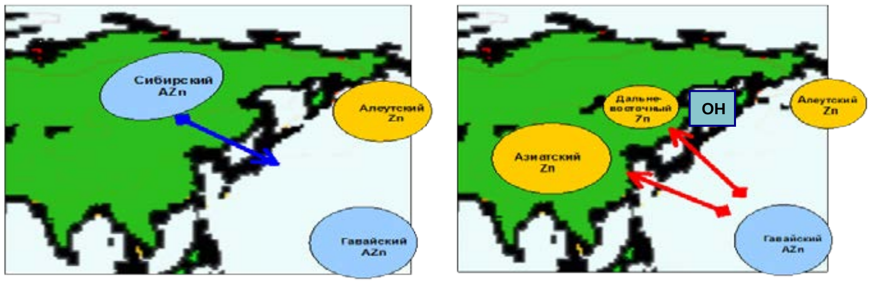
Scheme of on-shore and off-shore monsoon winds influence on cross-shelf water circulation and topography of pycnocline in the coastal zone of Primorye



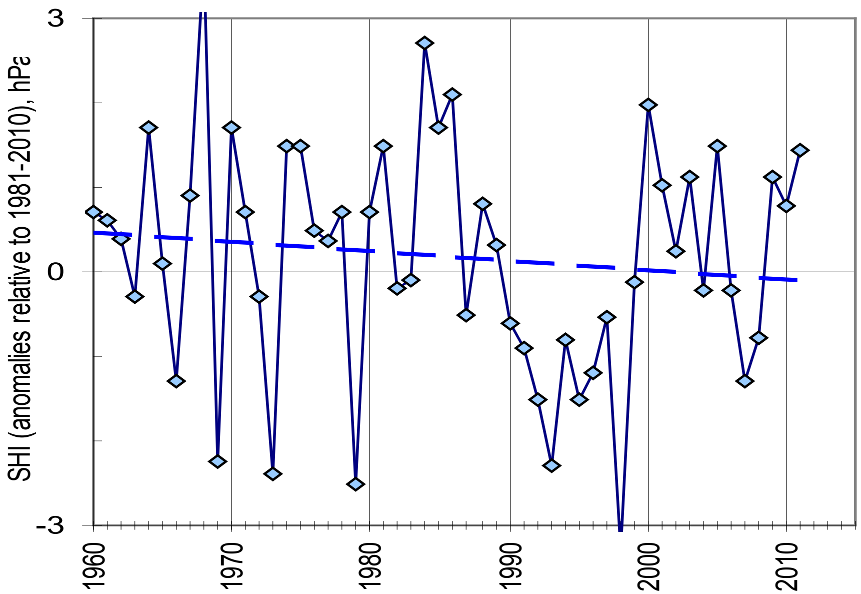
Dynamics of annual precipitation in Vladivostok: positive tendency is observed both for winter and summer

Climate change background

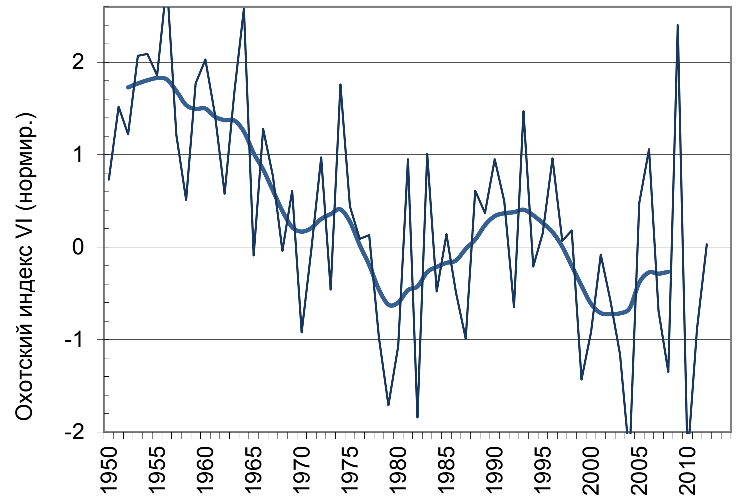
Large-scale climate changes in the Japan/East Sea area are conditioned by changes in Asia-Pacific monsoon system where trends to weakening of monsoon winds, in particular in winter, prevail in modern times. Inter-decadal fluctuations are observed on this background.

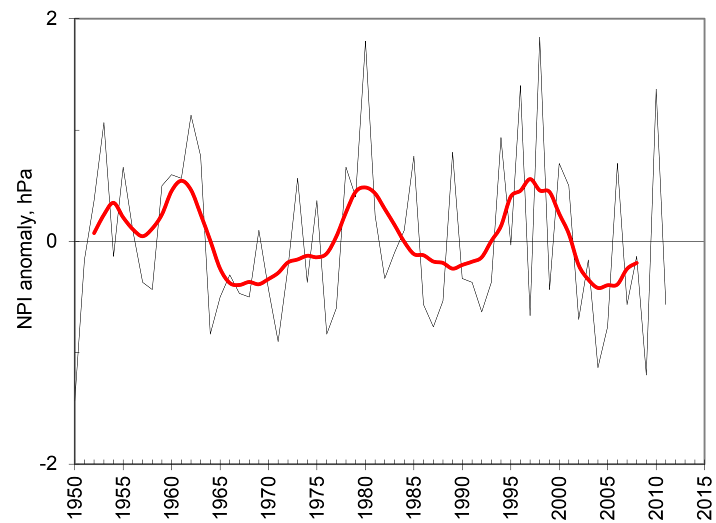


Schemes of winter and summer monsoon formation



Dynamics of winter monsoon intensity (Siberian High Index). Inter-decadal fluctuations are observed on the background of negative trend

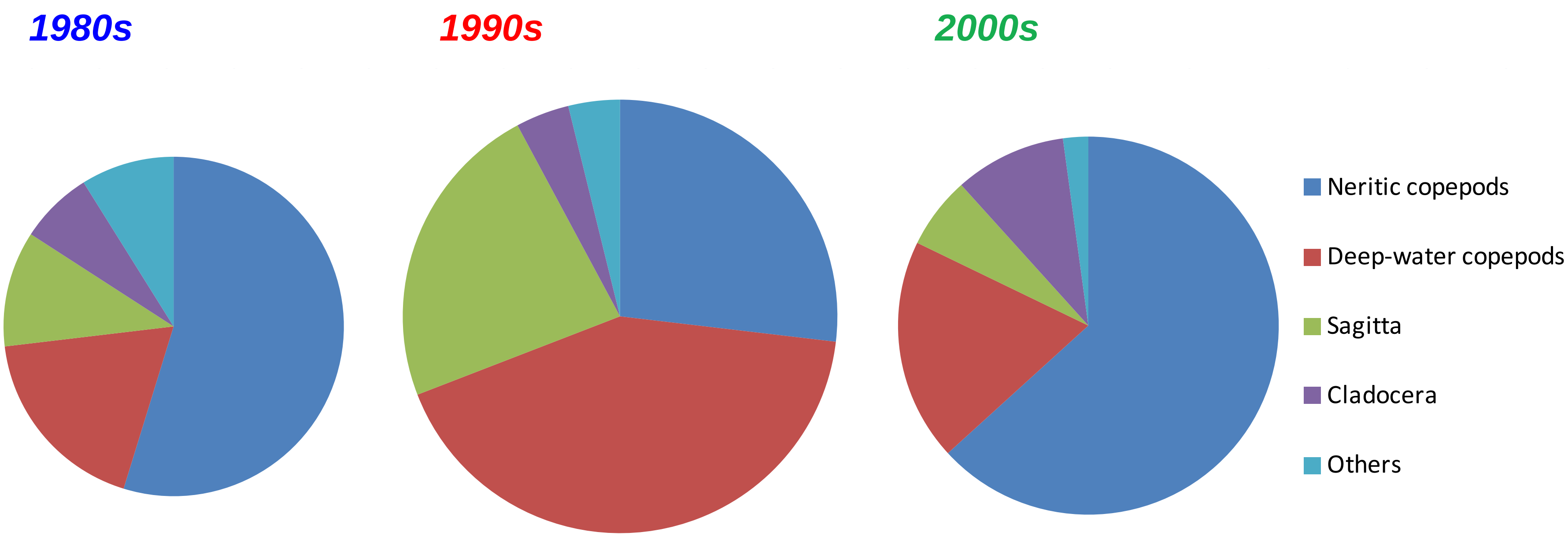




Dynamics of summer monsoon intensity in its first phase (Okhotsk Index) and second phase (North Pacific Index). Inter-decadal fluctuations are observed on the background of negative trends, but the trend is statistically insignificant for the 2nd phase

Change of zooplankton community

Large-scale climate changes in the Japan/East Sea area are conditioned by changes in Asia-Pacific monsoon system where trends to weakening of monsoon winds, in particular in winter, prevail in modern times. Inter-decadal fluctuations are observed on this background.

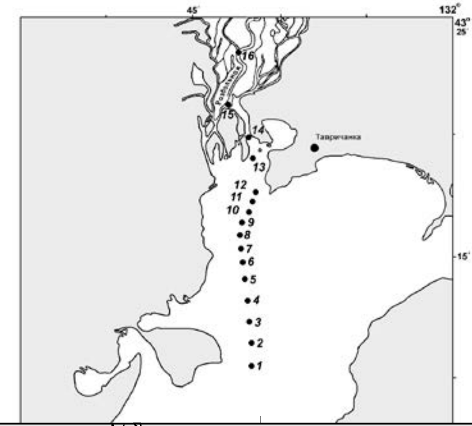


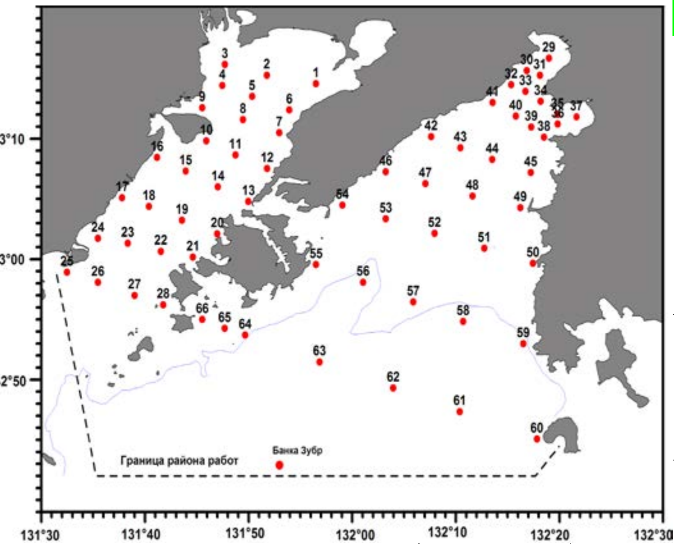
Total biomass: *1093 mg/m3* *2311 mg/m3* *1555 mg/m3*
Deep-water migrants: *29%* *65%* *25%*

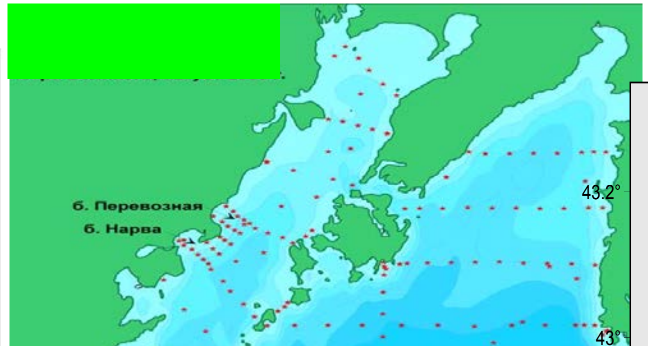
Species structure of early-summer zooplankton community in the coastal zone of Peter the Great Bay, by decades

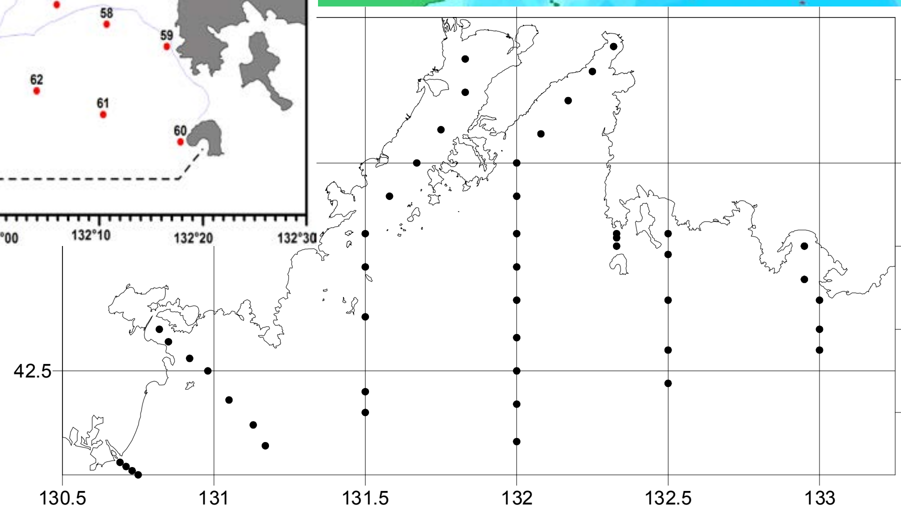
Data description

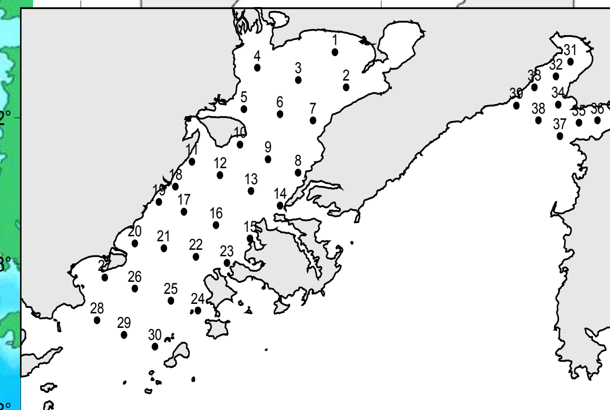
Several research programs were realized in the coastal zone of Peter the Great Bay, mostly in the Amur Bay, since 1980. The observations were the most frequent in the middle of 1980s, in the late 1990s, and in the 2007-2014, so now the series of irregular but frequent data exceeds 3 decades that means that they are enough long for evaluation of climate changes

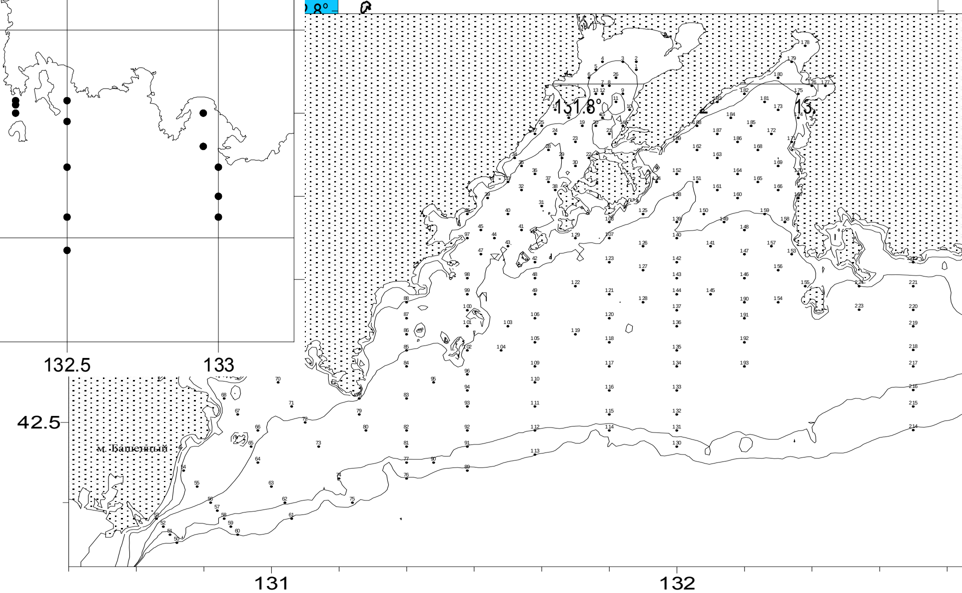








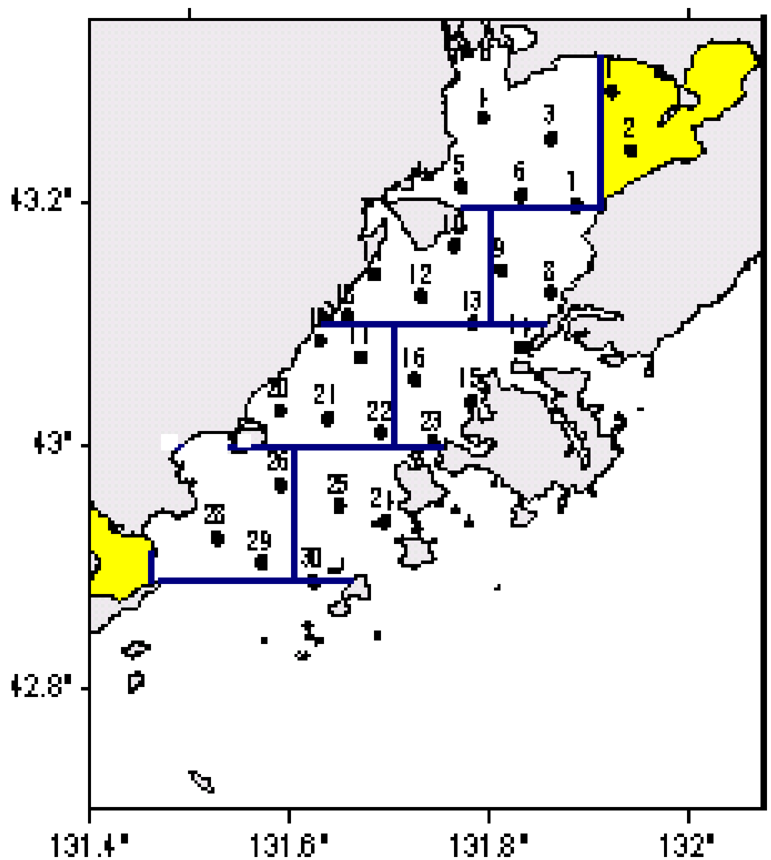




Some examples of the surveys in the coastal zone of Peter the Great Bay conducted with different research programs after 1980

Data processing

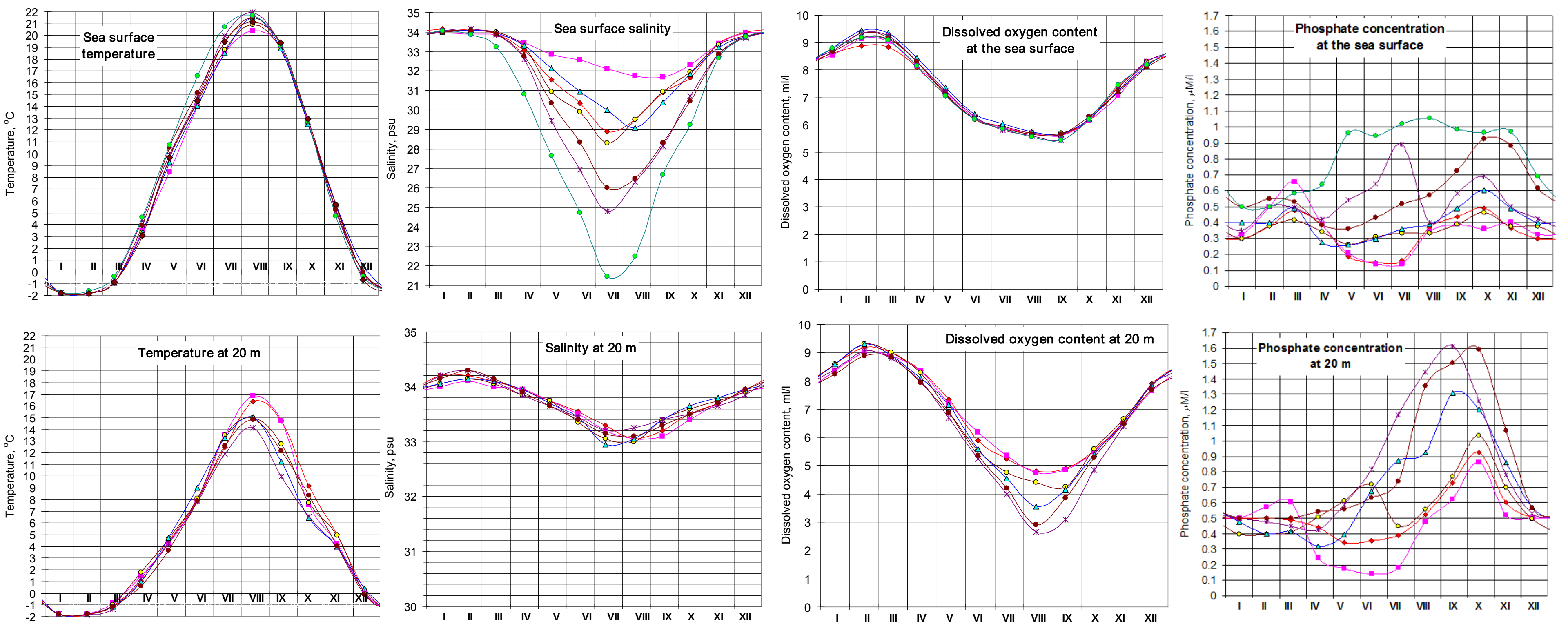
To avoid influence of spatial inhomogeneity, variations of zooplankton and oceanographic factors were averaged within small (6 x 6 miles) areas in the coastal zone and considered separately



Scheme of averaging within small areas of the coastal zone (a case of the Amur Bay).The data quantity in the yellow-colored areas is insufficient for he study

Data processing

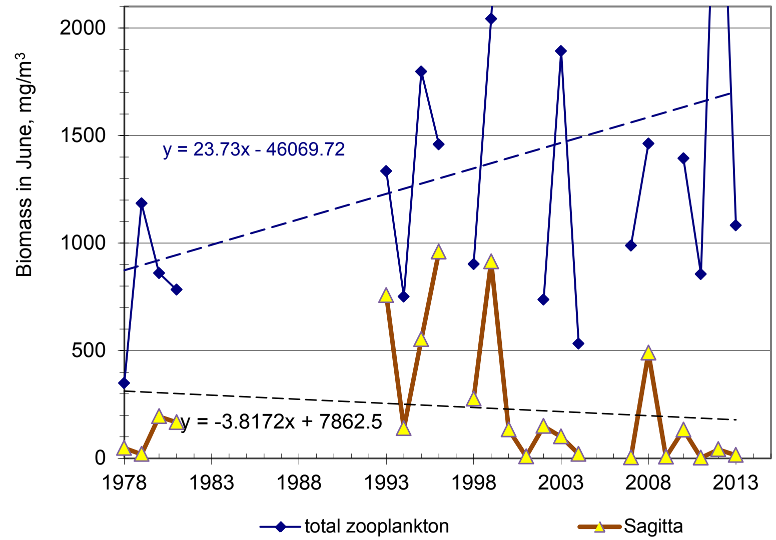
To exclude seasonal variations, seasonal decomposition was executed for all oceanographic data, and only one biological season was considered for zooplankton (early summer = June)

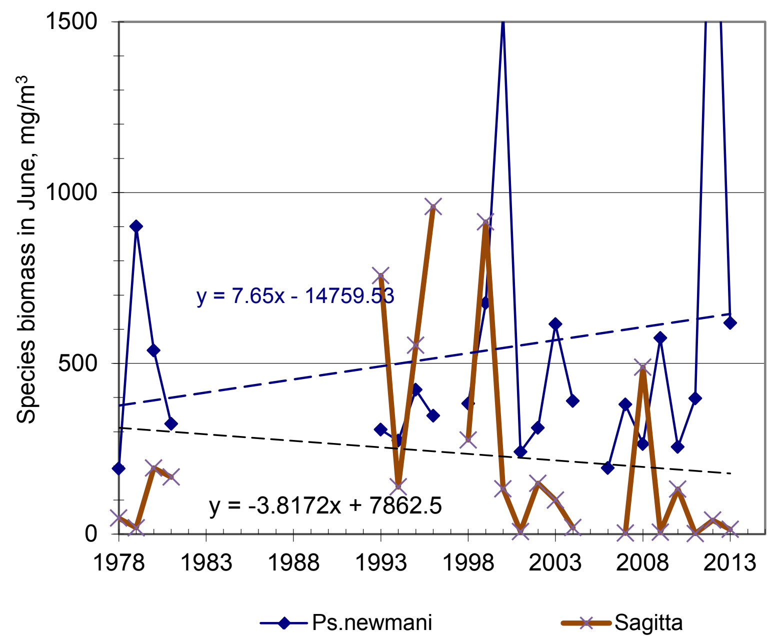


Examples of mean annual changes of water temperature, salinity, dissolved oxygen content, and phosphorus concentration at the sea surface (top panel) and at the sea bottom (20 m depth - bottom panel) in different small areas in the coastal zone of Peter the Great Bay

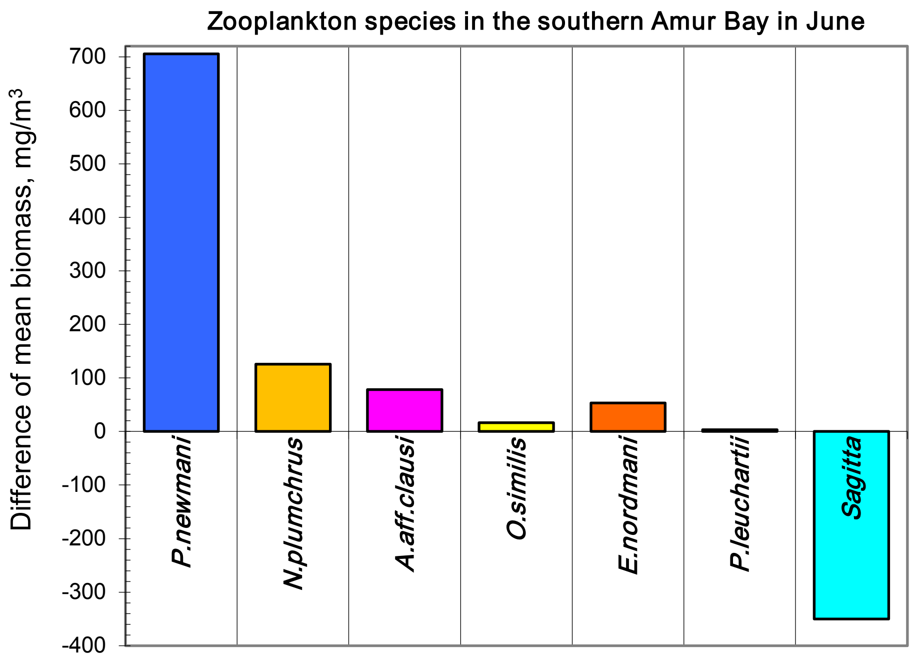
Zooplankton changes

Abundance and biomass of zooplankton species, as well as total abundance and biomass of zooplankton, have both year-to-year changes and certain tendencies in the climatic scale. The most of species have positive trend. The only exclusion among the mass groups of species are arrowworms, mainly *Sagitta elegans*, which become less abundant. They are allochtonous, so they spend winter and reproduce in the deep-water sea. Other mass species, which became more abundant, are neritic ones which reproduce in the coastal zone.



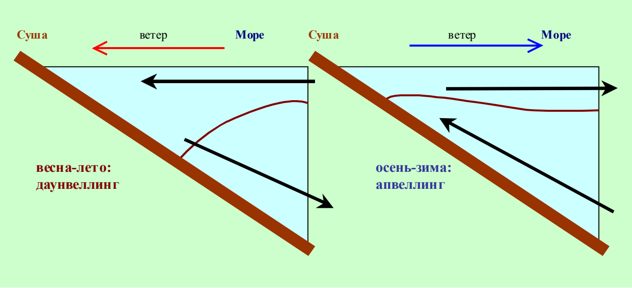


Year-to-year changes of the arrowwarms biomass in compare with the total biomass of zooplankton (upper panel) and the biomass of small-sized copepod Pseudocalanus newmani (bottom panel). The arrowwarms and other species have opposite trends of the biomass



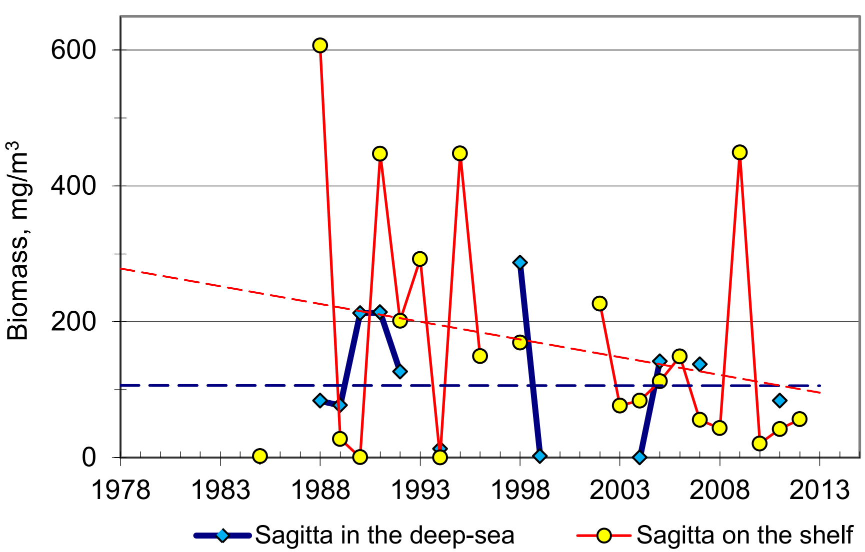
Biomass difference between 1980-1996 and 1998-2012 for mass species in the coastal zone of Peter the Great Bay

Zooplankton changes
vs summer monsoon changes

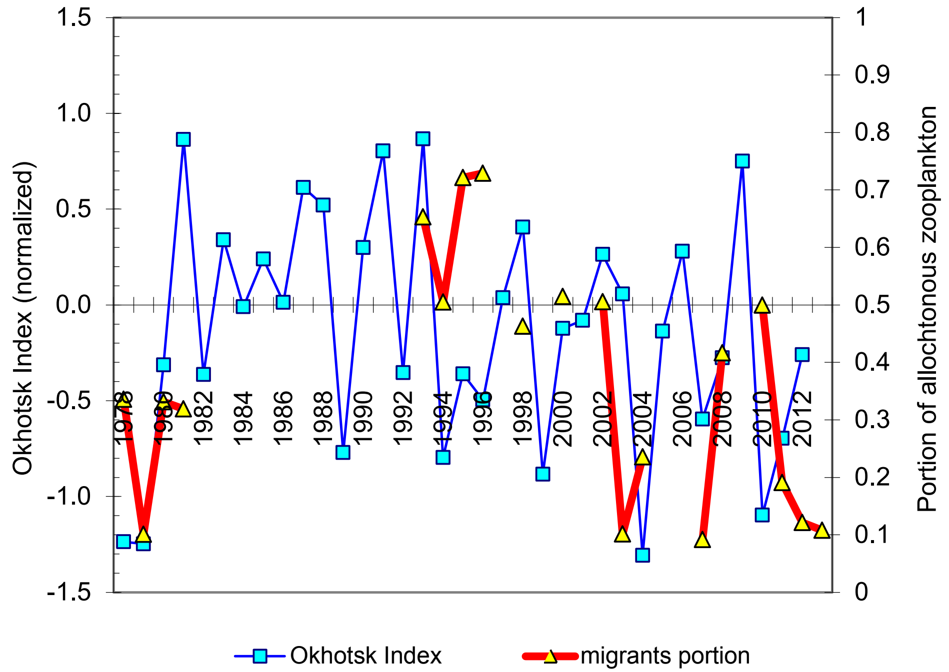


The negative tendency of arrowworms abundance is observed in the coastal and shelf zones only but is absent in the deep area of the Japan Sea. So, the state of the arrowworms population is stable, and recent decreasing of their abundance in the coastal zone is caused by weakening of their cross-shelf transport. These changes in zooplankton community coincides with weakening of summer monsoon that obviously drives the cross-shelf transport (r = 0.49).

So, decreasing of the migrants abundance could be reasoned by summer monsoon weakening. But what is the reason of local species blooming?



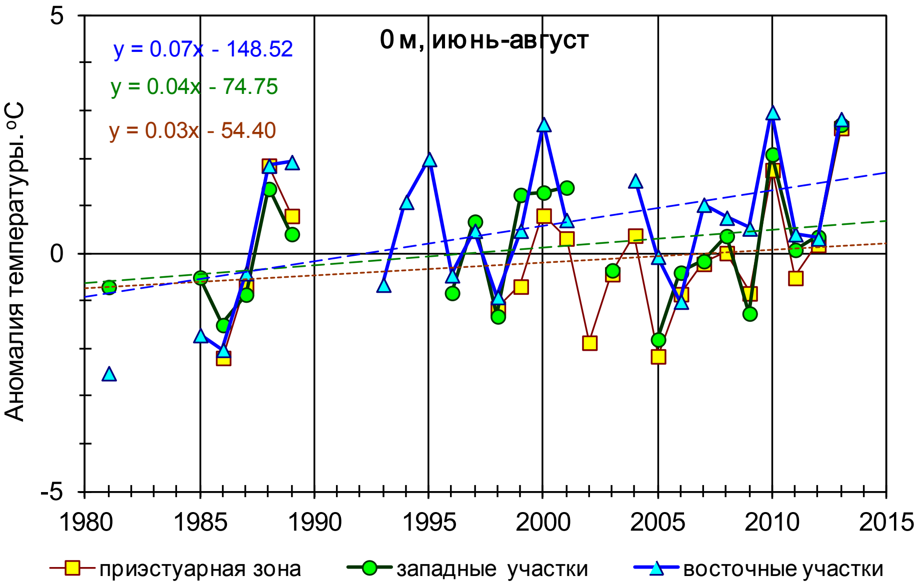
Year-to-year changes and trends of Sagitta biomass in the coastal zone of Peter the Great Bay and adjacent deep-water area of the Japan Sea in June

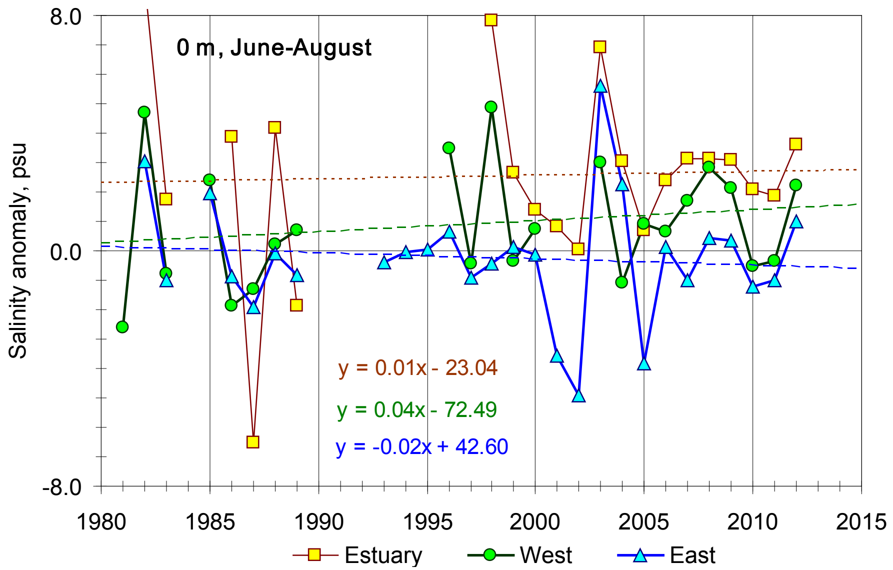


Year-to-year changes of the deep-water migrants portion in zooplankton of the coastal waters and the Okhotsk Index of summer monsoon intensity in June

Temperature and salinity

Temperature and salinity have similar year-to-year changes in different areas of the coastal zone in Peter the Great Bay and in different months within the seasons. The sea surface temperature has a tendency to increasing, and salinity doesn't have a statistically significant trend.



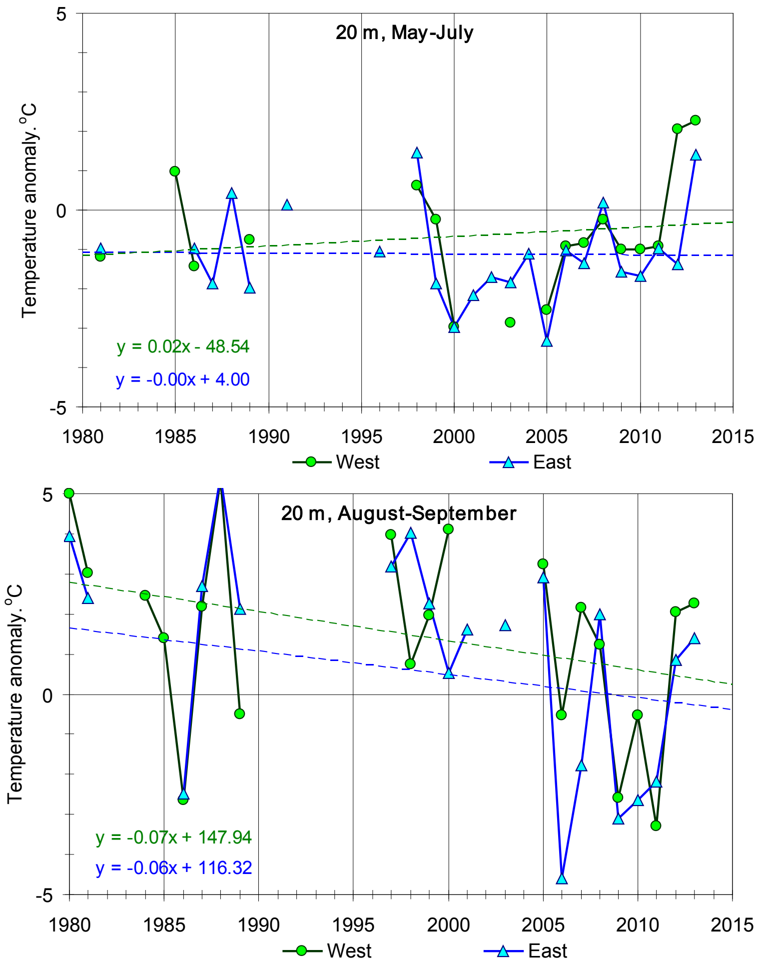


Year-to-year changes of mean summer SST anomaly in different areas of the coastal zone – positive trend is observed everywhere

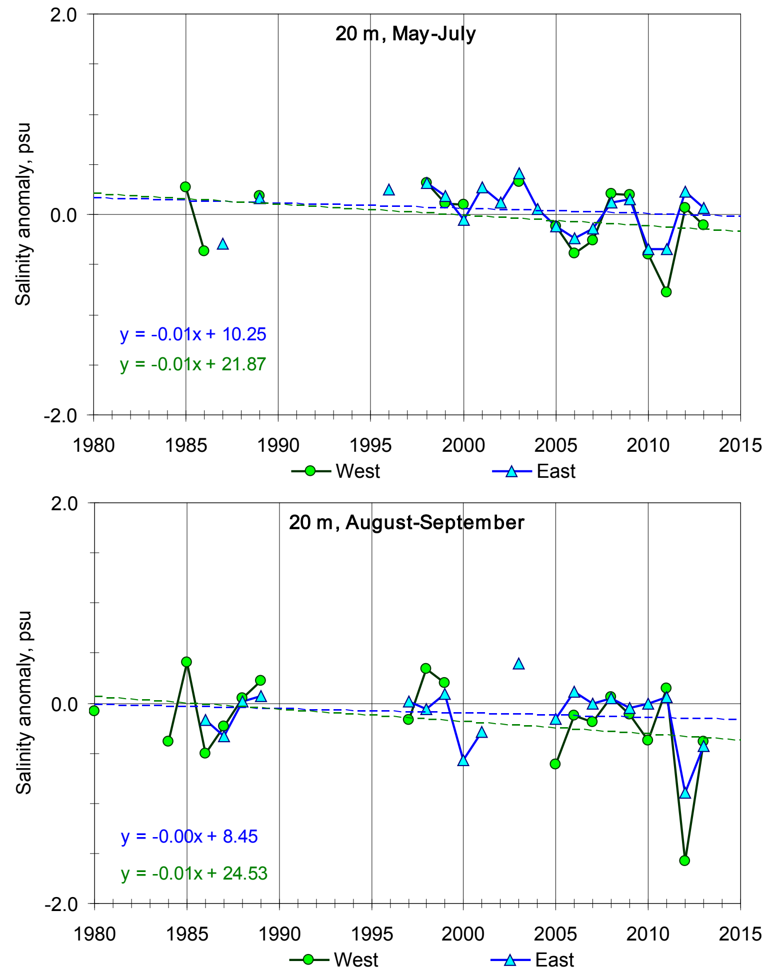
Year-to-year changes of mean summer salinity anomaly at the sea surface in different areas of the coastal zone – there are no statistically significant trends

Temperature and salinity

Temperature at the sea bottom has no trend in the early summer and ha negative trend in the late summer. Salinity at the sea bottom has no any statistically significant trend.



Year-to-year changes of temperature anomalies at the 20 m depth in the coastal zone (at the sea bottom)

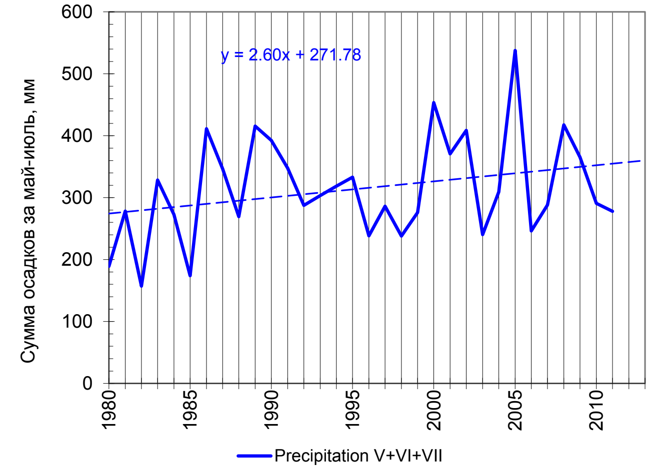


Year-to-year changes of salinity anomalies at the 20 m depth in the coastal zone (at the sea bottom)

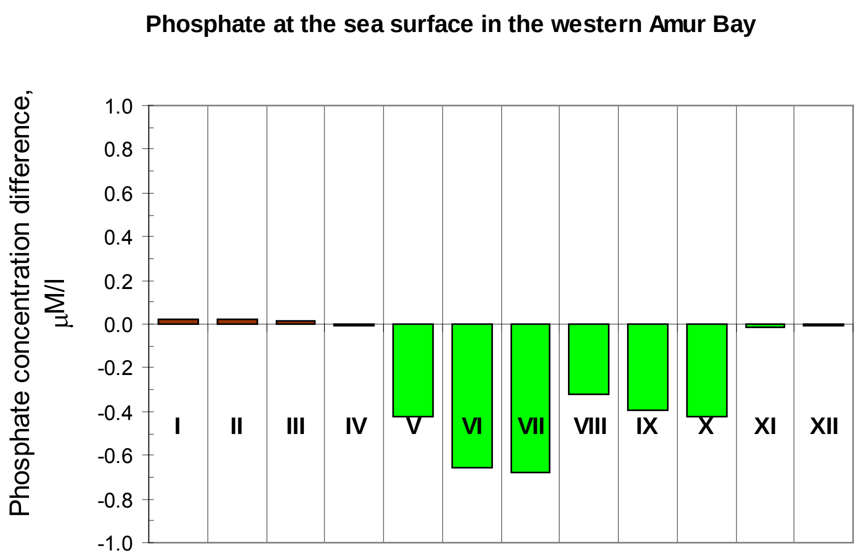
Nutrients

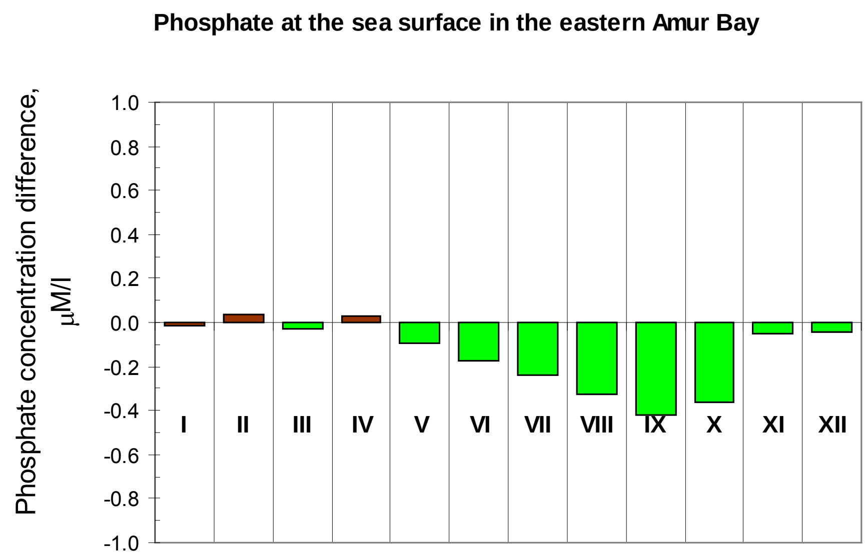
In spite of the river discharge increasing into the coastal zone of Peter the Great Bay (mainly from the Suyfen River), negative tendency of the nutrients concentration is observed for the coastal zone in summer. This tendency could be caused by strengthening of density stratification because of warming and freshening of the surface layer in the coastal zone.

So, potential productivity of the coastal waters is decreased.



Year-to-year changes and trend of summer precipitations in the Suyfen River valley

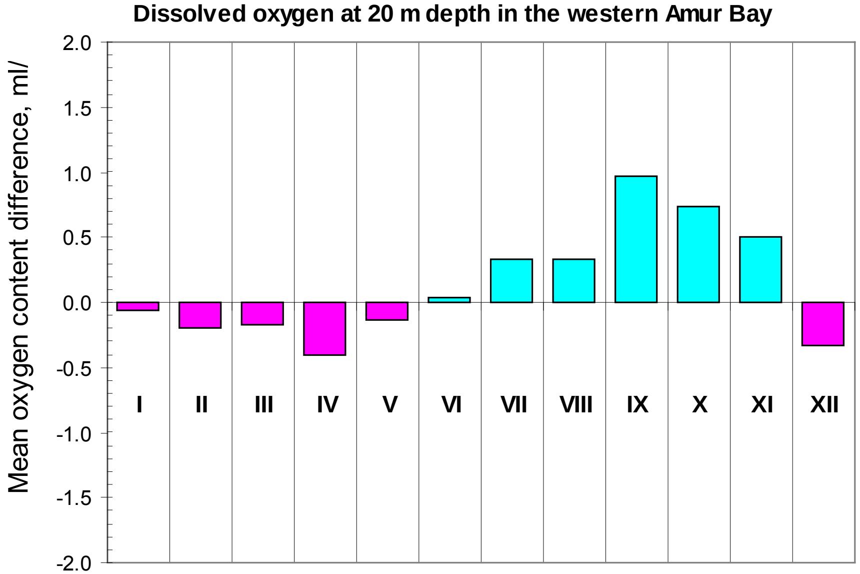


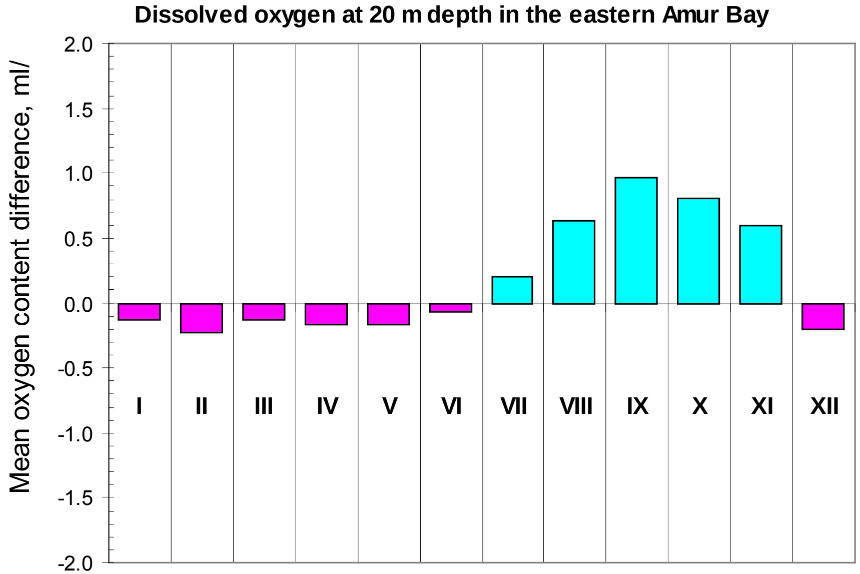


Difference of the mean concentrations of inorganic phosphorus at the sea surface in two areas of the coastal zone between 1980s and 2000s. The negative difference means a decreasing of concentration

Dissolved oxygen at the sea bottom

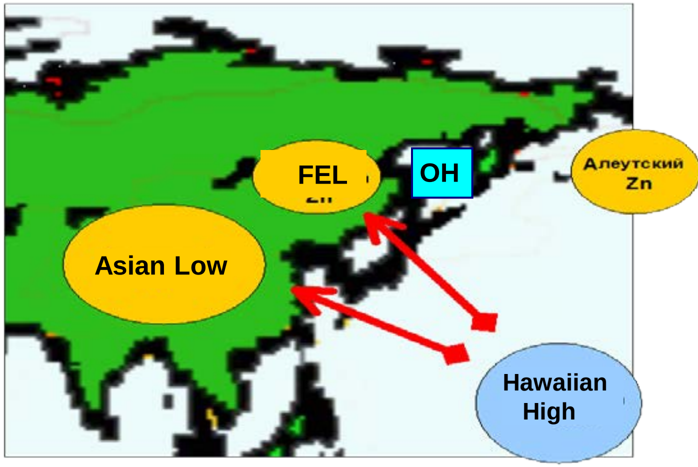
Hypoxia at the sea bottom in some areas of the coastal zone in Peter the Great Bay became easier in the 2000s, in compare with the 1980-1990s. It is another evidence of lowering productivity for the coastal waters.





Difference of the mean dissolved oxygen content at the sea bottom in two areas of the coastal zone between 1980-1990s and 2000s. The content has increased for the period of hypoxia (late summer)

Conclusion: mechanisms of climate changes downscaling to the ecosystem of coastal waters in Peter the Great Bay – 1) abiotic components



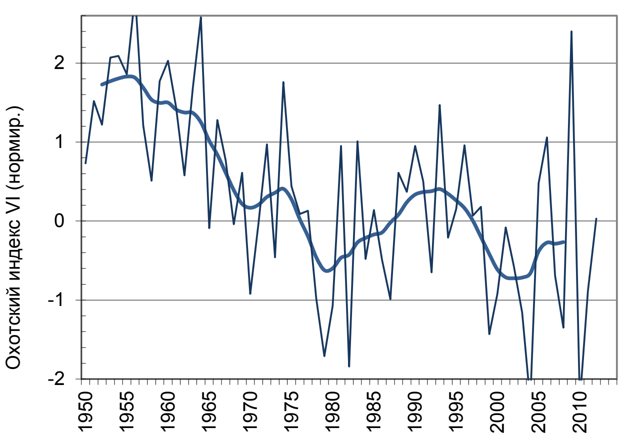
FEL = Far Eastern Low
OH = Okhotsk Sea High

Scheme of summer monsoon formation

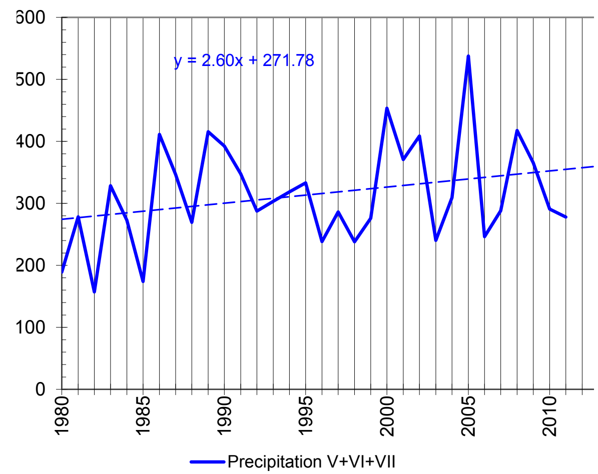
In conditions of recent weakening of high-pressure atmospheric centres, as the Okhotsk High, the summer monsoon is weakening that means for the coastal zone a lowering of atmospheric pressure, increasing of frontal rains, decreasing of cloudiness, weakening of stable monsoon winds, and as the result a warming of the sea surface. Secondary effect of the warming is a strengthening of density stratification and weakening of turbulent mixing in the period of the highest SST, that's why deep layers are cooling.

weaker monsoon → **warmer sea surface** → **stronger stratification**

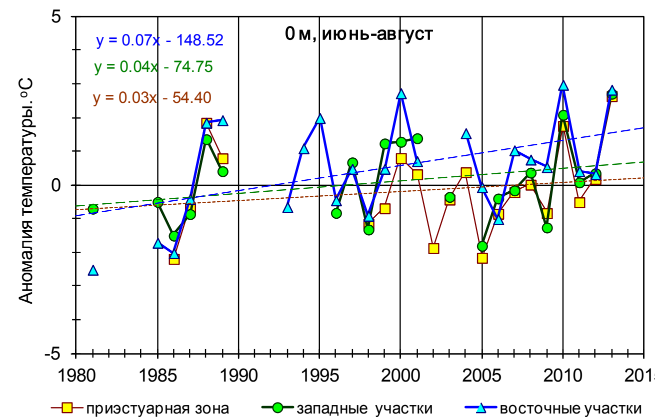
weaker monsoon → **weaker cross-shelf exchange**



Dynamics of summer monsoon intensity in its first phase (Okhotsk Index)

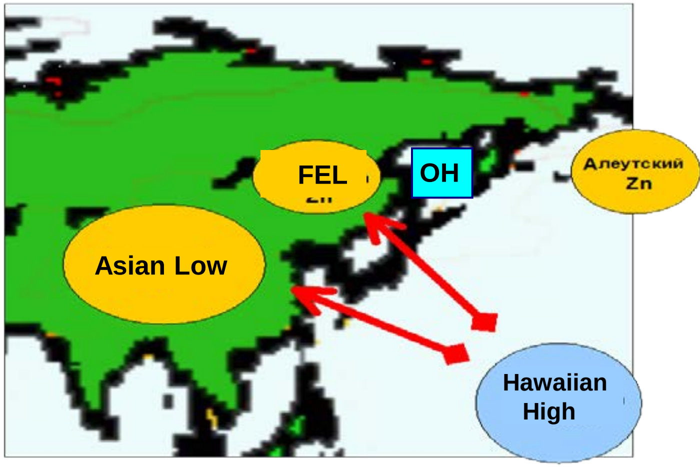


Summer precipitations in the Suyfen valley



Year-to-year changes of mean summer SST anomaly in different areas of the coastal zone

Conclusion: mechanisms of climate changes downscaling to the ecosystem of coastal waters in Peter the Great Bay – 1) bioproductivity



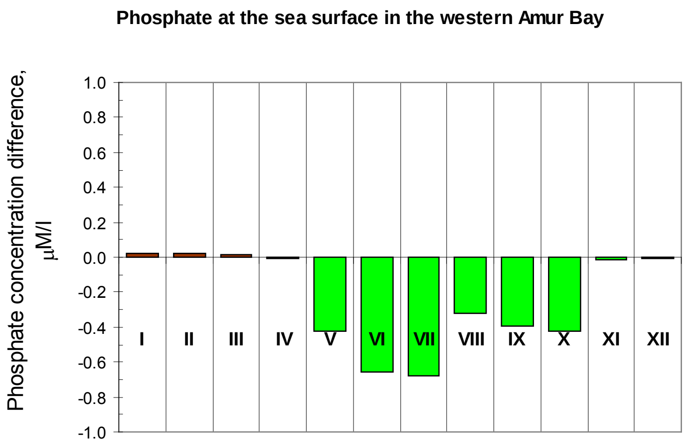
FEL = Far Eastern Low
OH = Okhotsk Sea High

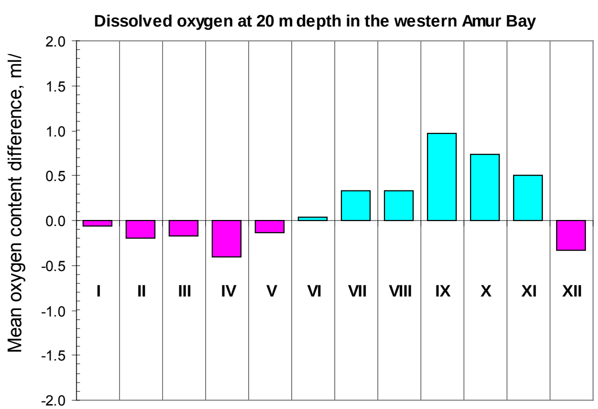
Scheme of summer monsoon formation

Another effect of the stratification strengthening is a weakening of nutrients upward influx to the photic layer that potentially prevents the primary producers growth.

As the result of supposed decreasing of phytoplankton concentration, summer hypoxia at the sea bottom became weaker

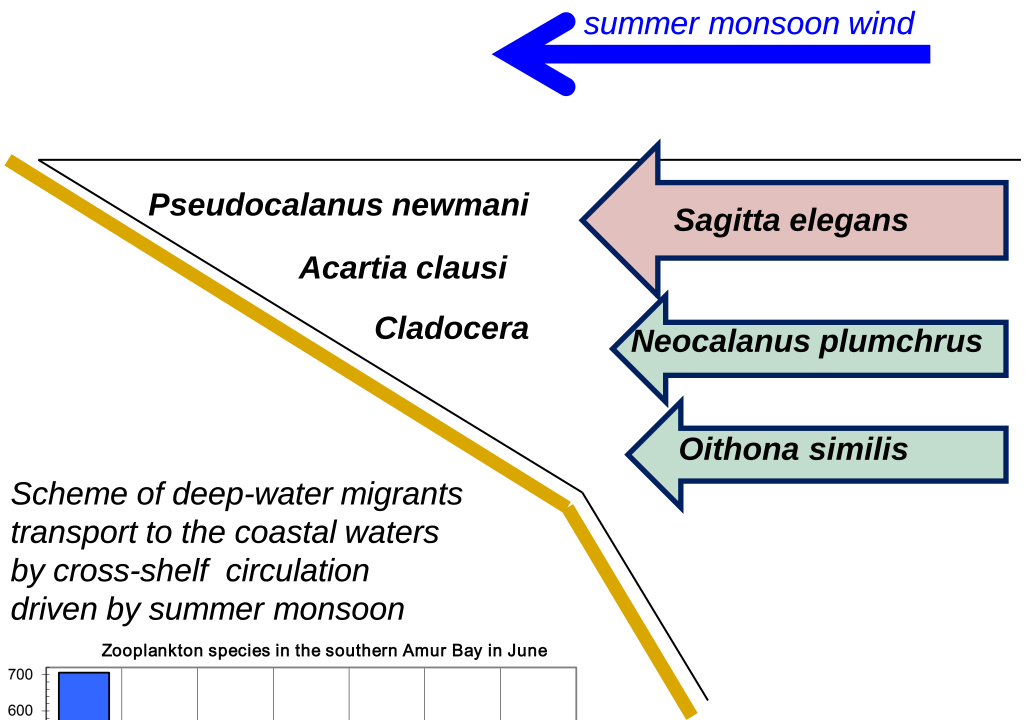
stronger stratification → lower nutrients → lower production



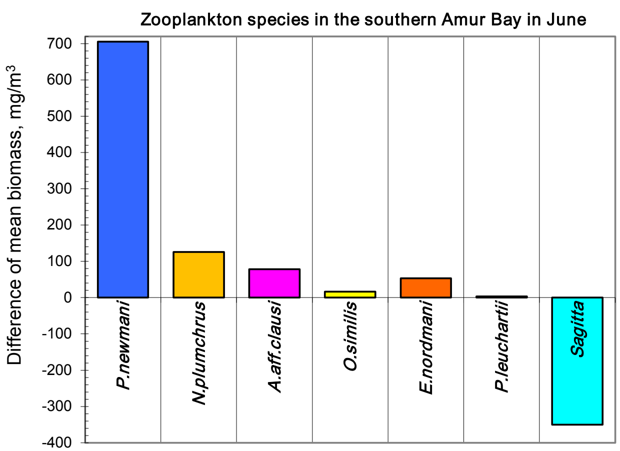


Difference of the mean concentrations of inorganic phosphorus at the sea surface in two areas of the coastal zone between 1980s and 2000s. The negative difference means a decreasing of concentration

Conclusion: mechanisms of climate changes downscaling to the ecosystem of coastal waters in Peter the Great Bay – 3) zooplankton



Scheme of deep-water migrants transport to the coastal waters by cross-shelf circulation driven by summer monsoon



Biomass difference between 1980-1996 and 1998-2012 for mass species in Peter the Great Bay

Decreasing of phytoplankton abundance in the coastal zone in summer obviously is not danger for the consumers because of surplus of its production – mass local species have enough food to maintain their populations.

Abundance of some allochtonous species, as the deep-water copepods *N.plumchrus* and *O.similis*, is decreasing in the coastal zone because of weakening of their cross-shelf wind-driven transport, but it is not essentially important for total biomass of zooplankton. Abundance of the most numerous allo-chtonous species, as the predatory *Sagitta elegance*, becomes lower, too, that has a positive effect on mass copepods in the coastal zone because of lower predatory.

lower production → no visible effect

weaker cross-shelf exchange → lower predatory → higher zooplankton abundance

Thus, climate changes cause lowering of productivity in coastal ecosystem of Peter the Great Bay, but zooplankton community of this area is top-controlled, and processes related to cross-shelf advection provide heightening of zooplankton abundance