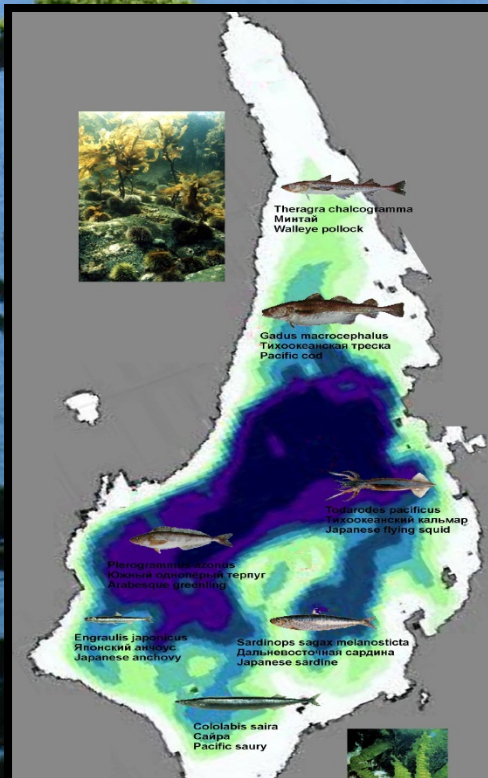
Conditions of phytoplankton blooms at Primorye coast (Japan/East Sea) and year-to-year change of their timing

Yury Zuenko
Pacific Fisheries Research Centre (TINRO), Vladivostok, Russia
zuenko_yury@hotmail.com



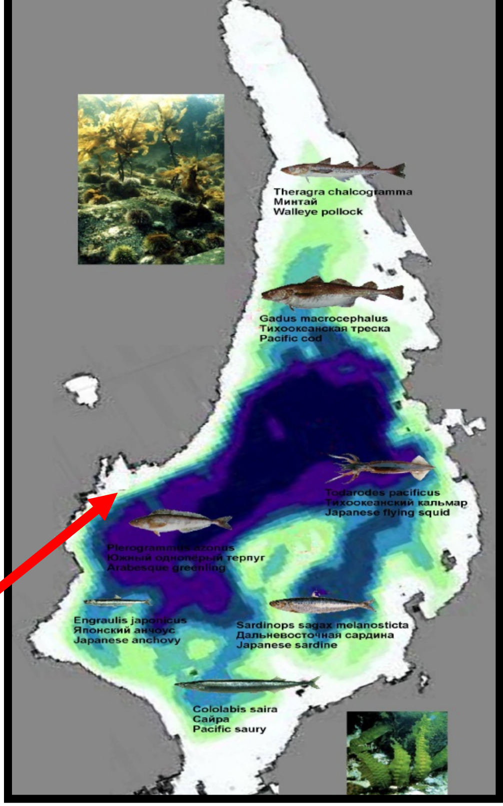
Data description: Chl *a*

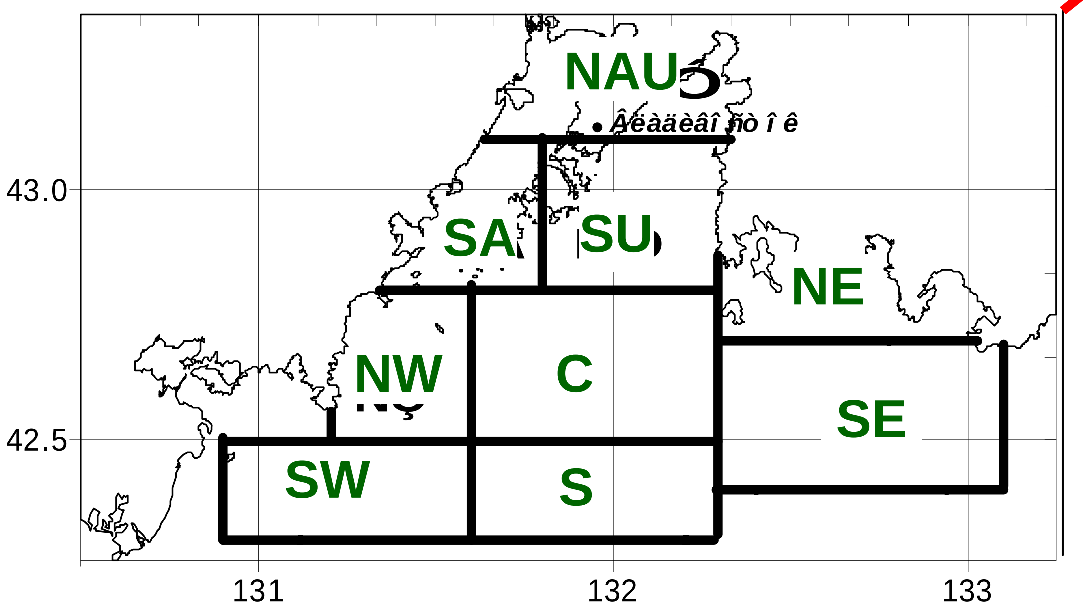
Blooming events are determined by analysis of seasonal variation of Chl a concentration at the sea surface in certain areas, calculated using standard algorithm from the data of 8-channel optical color scanner SeaWiFS mounted on SeaStar satellite (USA). The data are available at NASA website http://oceancolor.gsfc.nasa.gov/, from August 1997 to 2010.

Composite images for 8 days are used for the analysis. The data on absolute concentration are not used because of great errors of the standard algorithm for coastal zone. Relative concentration over the mean annual values for each area are considered as “blooms”.

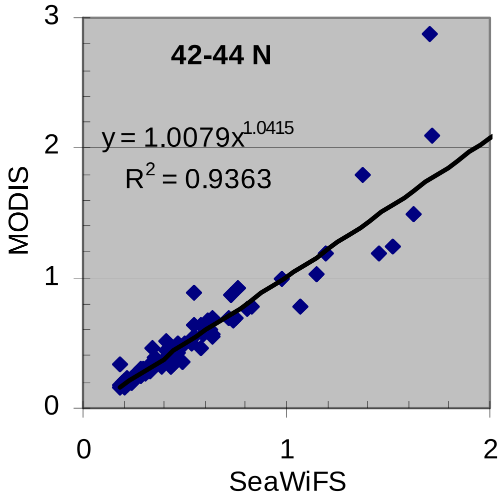
Analyses and visualizations used in this presentation were produced with the Giovanni online data system, developed and maintained by the NASA GES DISC

SeaWiFS data correlate well with MODIS (working since July 2002 until nowadays(, with excerption of high values, but MODIS data are not used in this analysis.



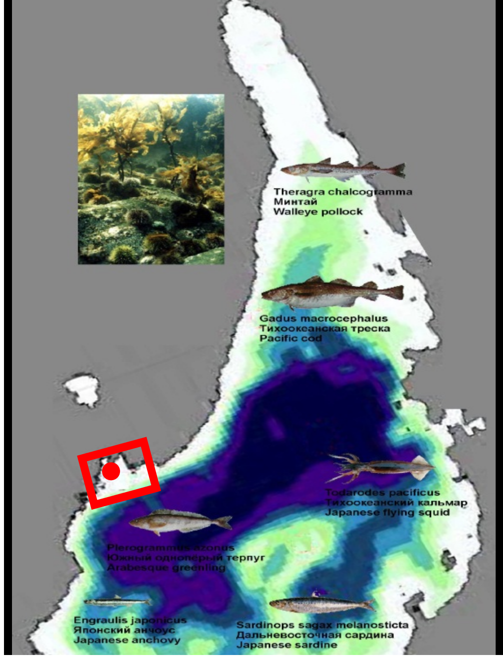


Scheme of the surveyed areas in Peter the Great Bay



Comparing of monthly averaged data between SeaWiFS and MODIS scanners

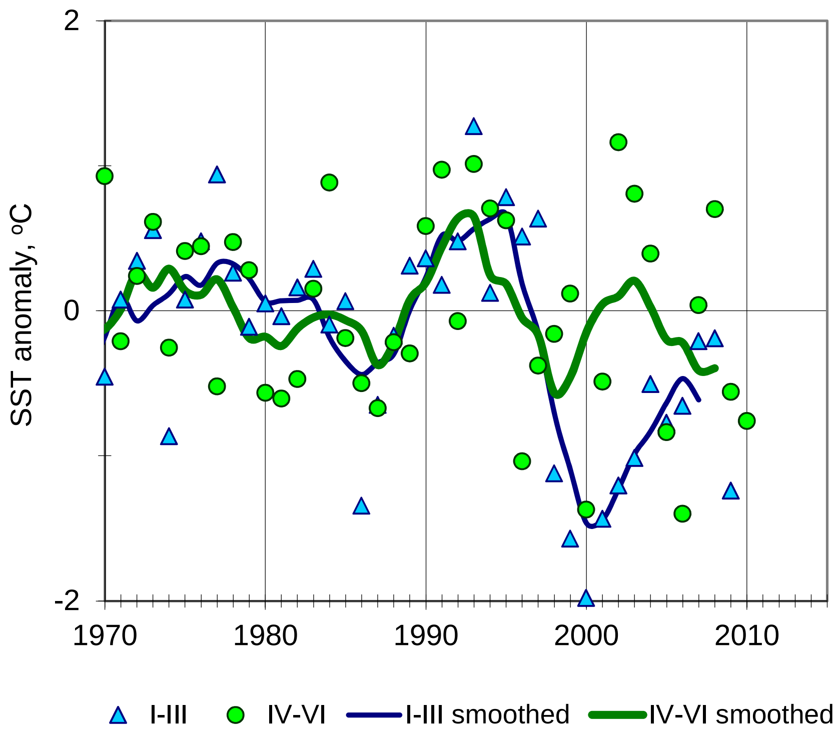
Data description: physical environments



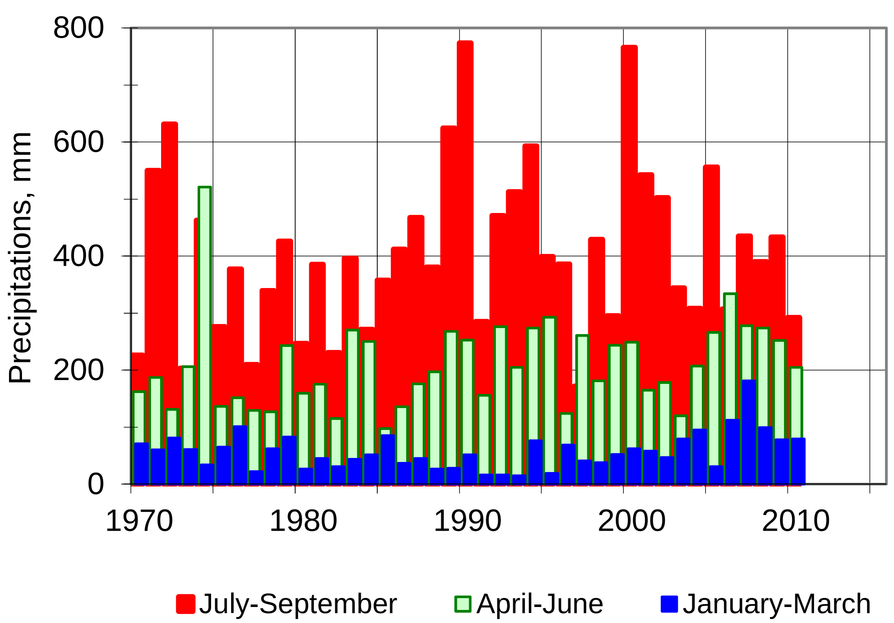
Monthly SST data from JMA data base averaged for 1x1-degree areas are used obtained in NEAR-GOOS.

In the Japan/East Sea, the SST is the main factor of water stratification. However, salinity of the surface layer is important in some coastal areas, that's why the data on precipitation for weather station Vladivostok are also used in the analysis.

SST has no significant tendencies, but interdecadal oscillations prevail with cool 1980s and 2000s and warm 1990s:Precipitations have positive trends in all seasons.



Winter and spring SST in Peter the Great Bay

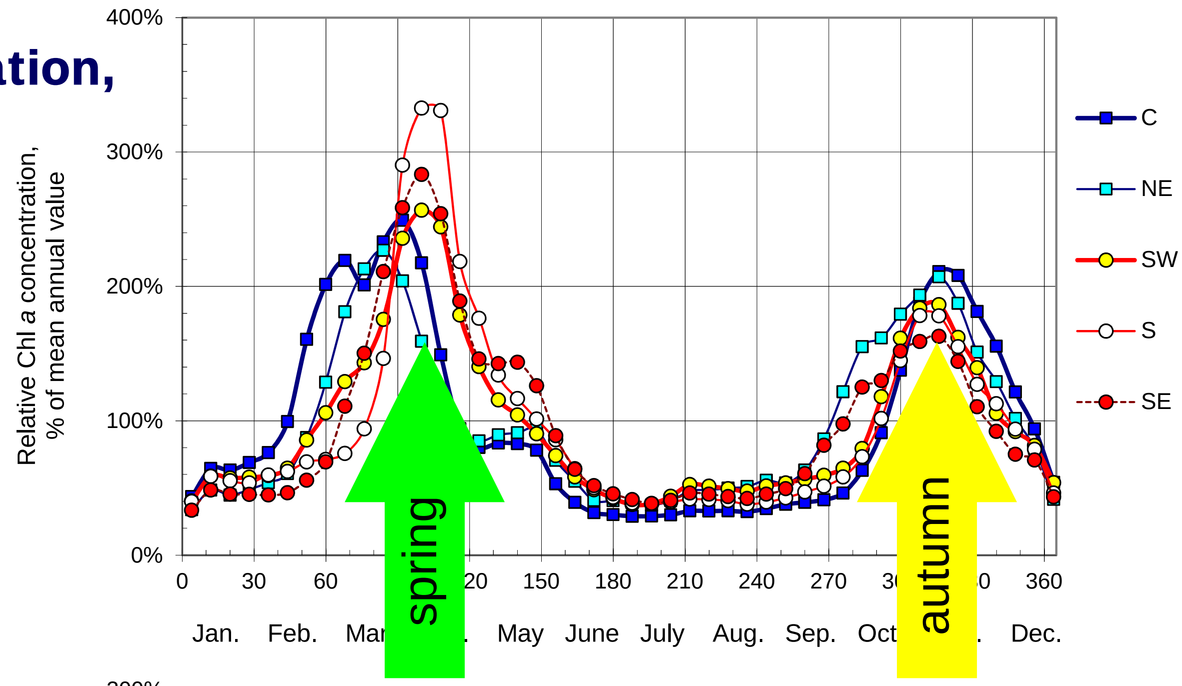


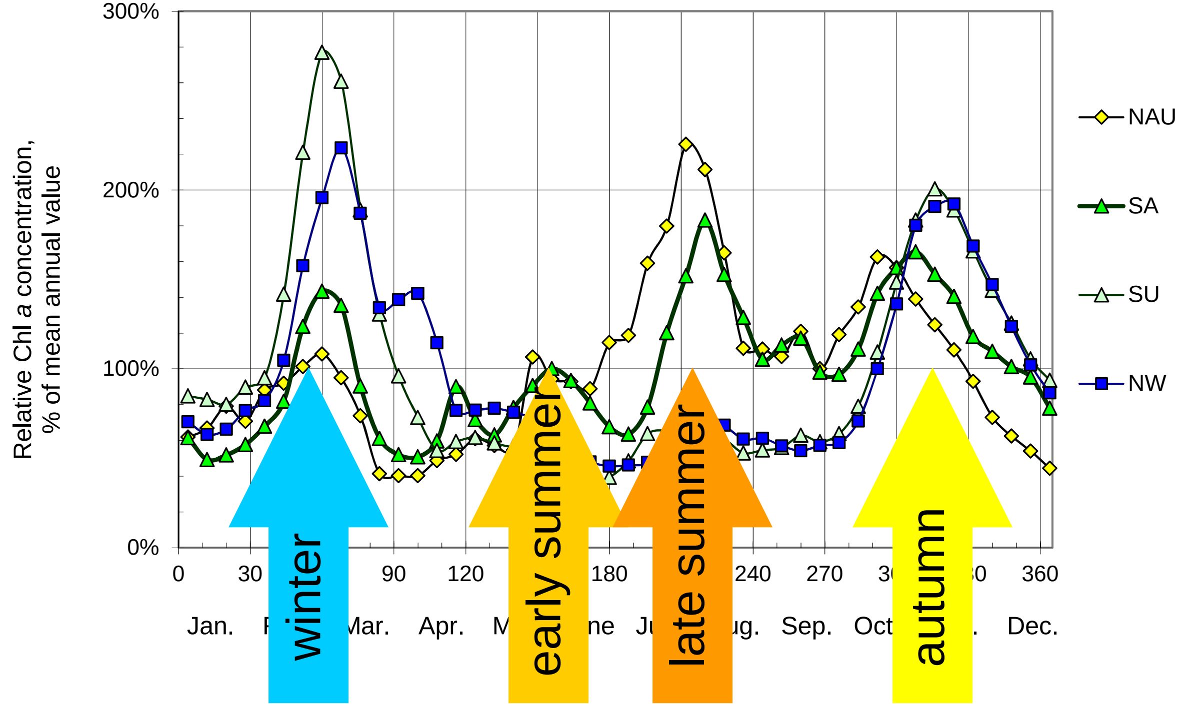
Winter, spring and summer precipitation in Vladivostok

Results: seasonal variation, blooms

Chl a concentration has regular seasonal variation with the peaks corresponded to blooms of phytoplankton.

In total, 5 peaks of Chl a concentration are observed in Peter the Great Bay annually. But only two booms are observed in the deep-water areas of the Bay – in spring and autumn, and 4 blooms are observed in its coastal waters – in winter, early summer, late summer, and autumn.



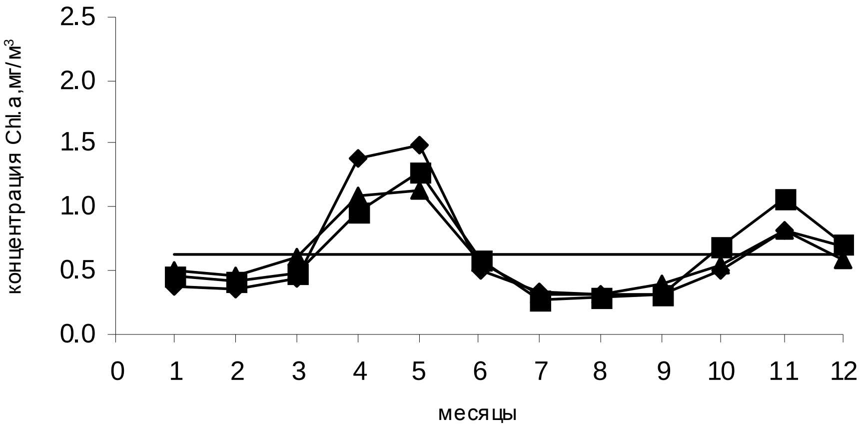


Mean seasonal variations of Chl a concentration (relative to the average) in certain areas of Peter the Great Bay

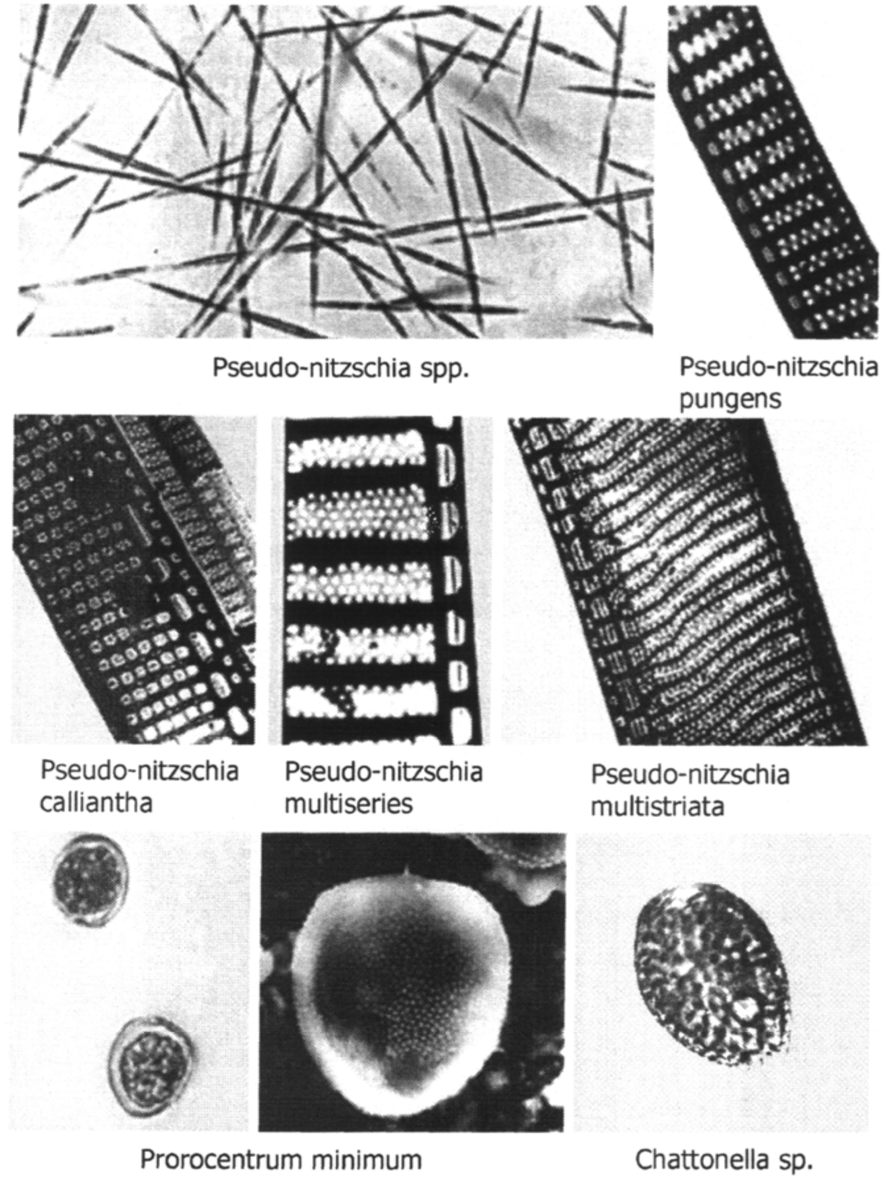
Results: seasonal variation, blooms

Maximal biomass (g/m^3) of phytoplankton in the northwestern Japan Sea in the periods of seasonal blooms (Zuenko, 2008, from the data for 1998-1999).

Season	Month of peak	Diatoms	Other groups	Dominant taxa
Spring	April	1.8	1.8	Chaetoceros, Thalassiosira
Summer (coastal zone only)	June, August	5.9	6.0	Thalassiothrix, Thalassionema
Autumn	September	4.9	5.0	Thalassiosira, Rhizosolenia

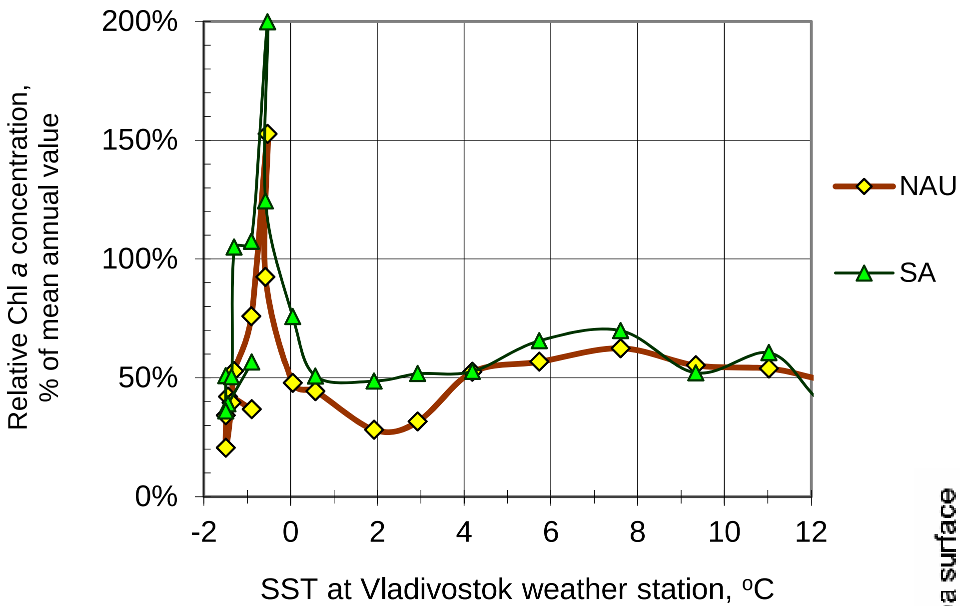


Seasonal changes of Chl a concentration on the surface of the northern Japan Sea in 1999, 2000, 2001, 2002 (shipboard sampling data) (Shtraikhert, Zakharkov, 2005)



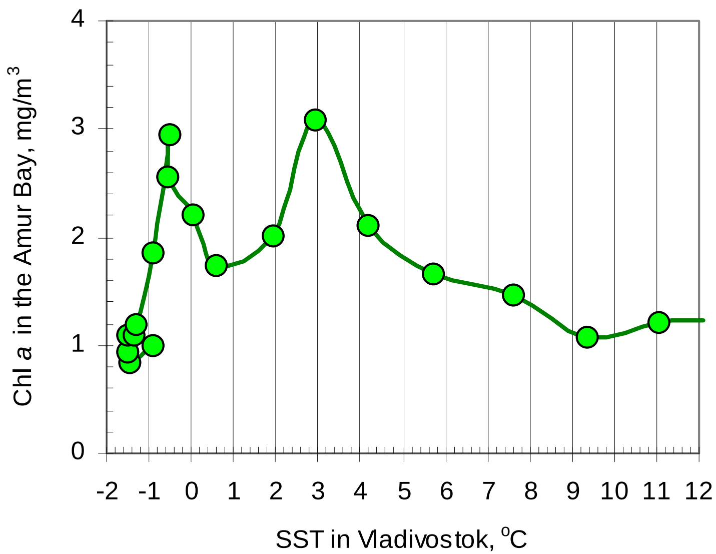
Toxic species of phytoplankton able to harmful blooming in Peter the Great Bay

Results: conditions of the blooms

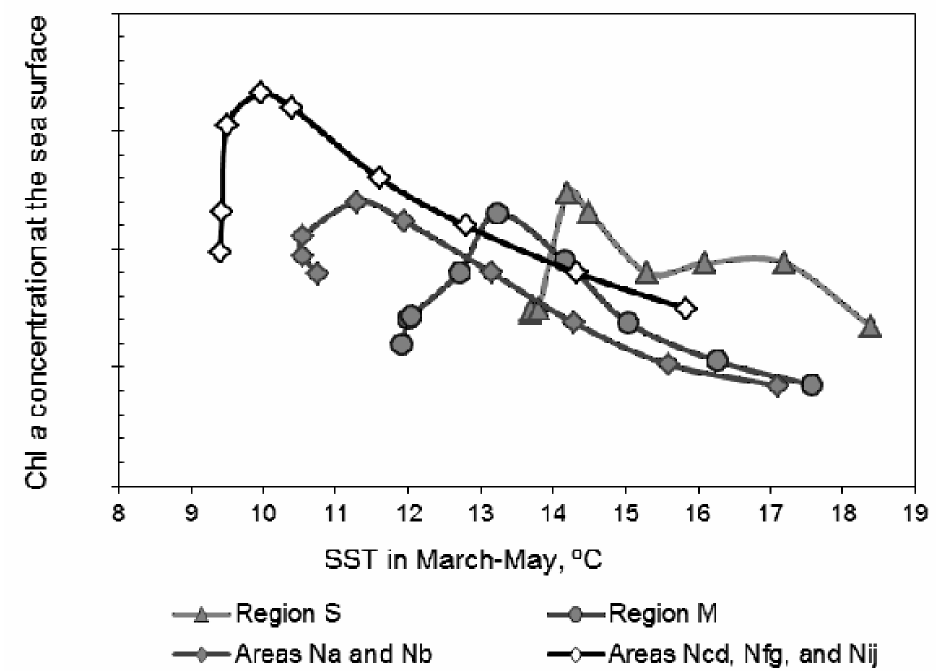


Winter bloom is observed in coastal waters only, usually in February-March when SST begins to rise from its minimal (negative) value..It is possibly initiated by ice melting in conditions of high nutrients.

Spring bloom does not occur in the areas of winter blooming, and in other areas it obviously is conditioned by stratification development. In Peter the Great Bay it occurs usually in April, when SST reaches the value 2-3°C, that is much lower than in the southern part of the Sea, where it happens under SST 10-15°, also in April .



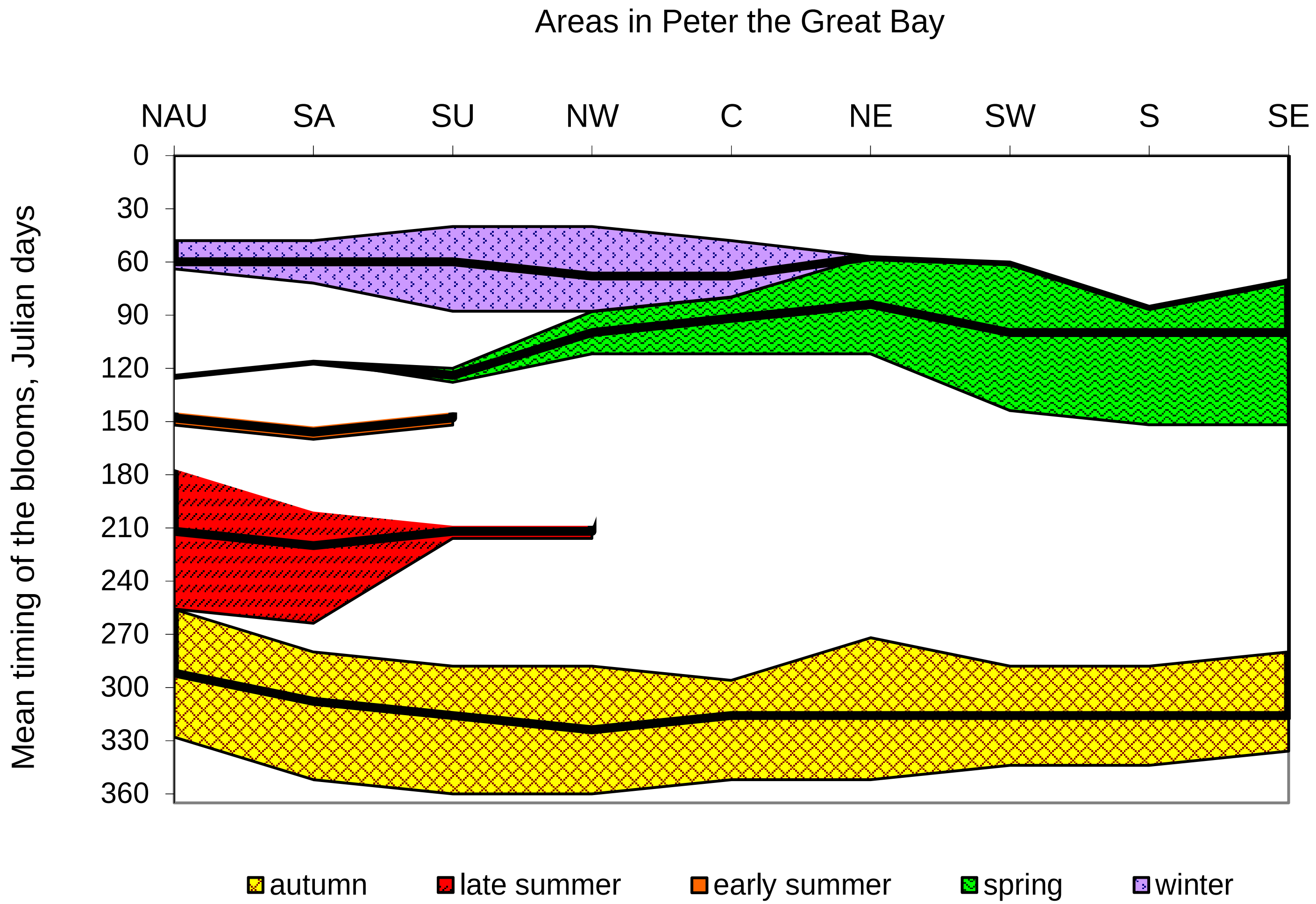
SST conditions of the winter bloom in the coastal waters and adjacent areas



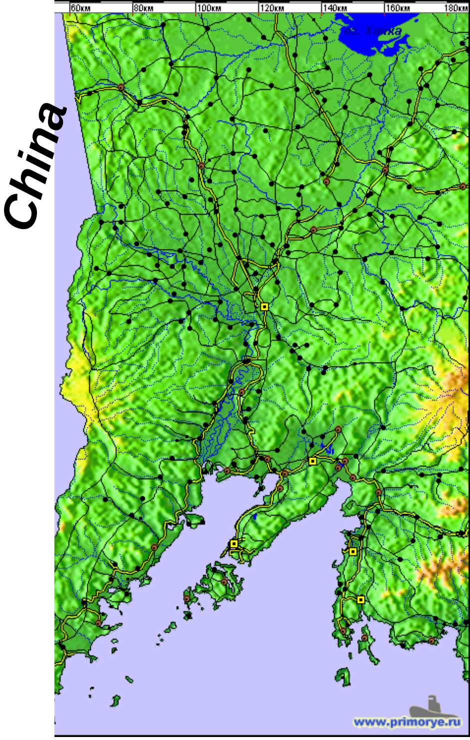
SST conditions of spring bloom is certain areas in the southern Japan/East Sea (from: Zuenko, Pershina, 2011)

Results: conditions of the blooms

Summer blooms occur in the coastal waters only, usually in June (small) and August (stronger and longer). These months are distinguished by floods on the rivers entering Peter the Great Bay the first is reasoned by snow melting in Manchuria mountains, and the second by heavy monsoon rains.



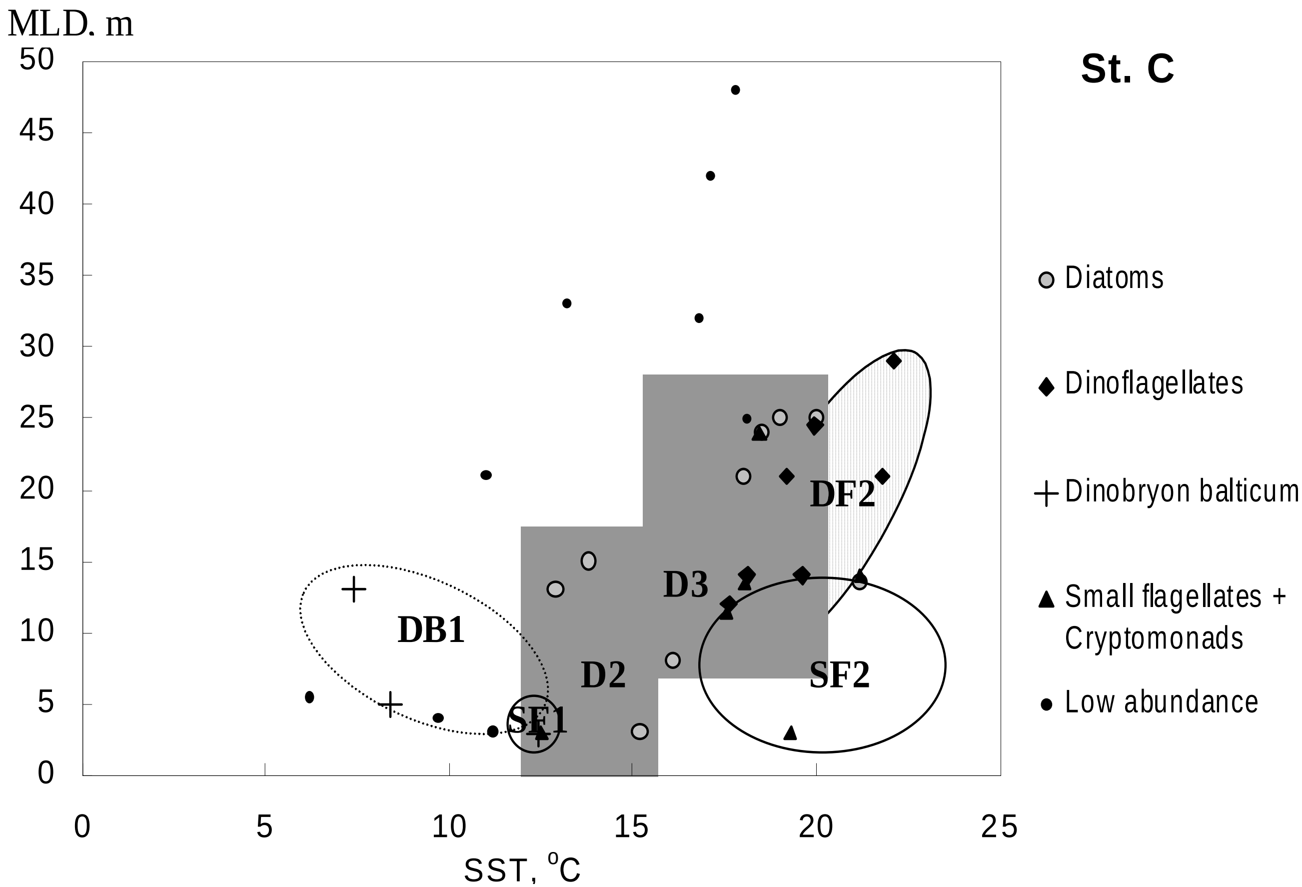
Mean timing (Julian days) of the peaks of Chl a, by areas of Peter the Great Bay



Results: conditions of the blooms

Actually, in this case SST is an indicator of water stratification, and for Diatomea blooms it should not be too high.

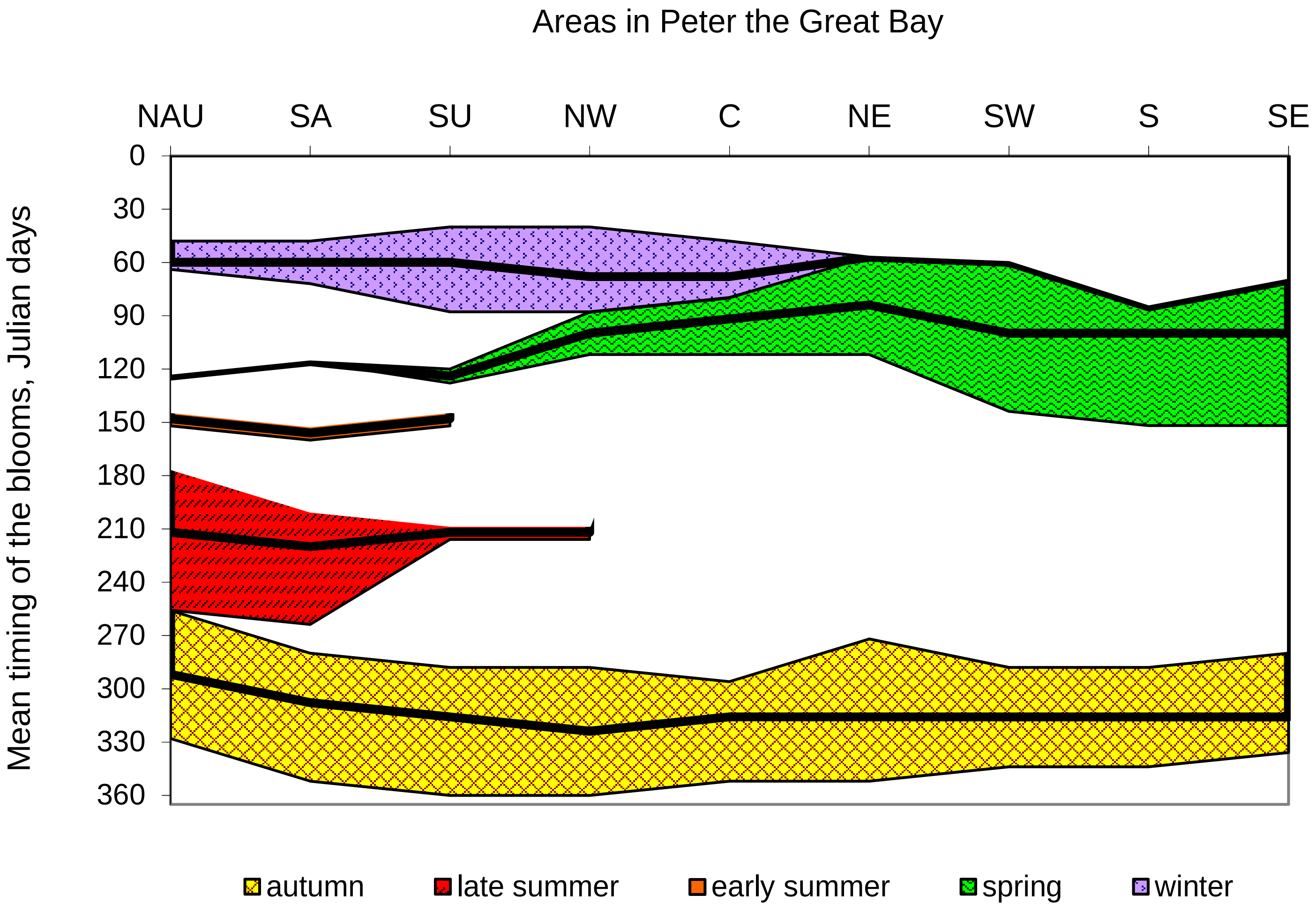
Another important factor is the mixed layer depth: if it is too high, blooms are not possiible because of photolimitation.



Conditions of early summer and late summer blooms in the coastal zone of Peter the Great Bay (from: Zuenko, Selina, Stonik, 2006)

Results: conditions of the blooms

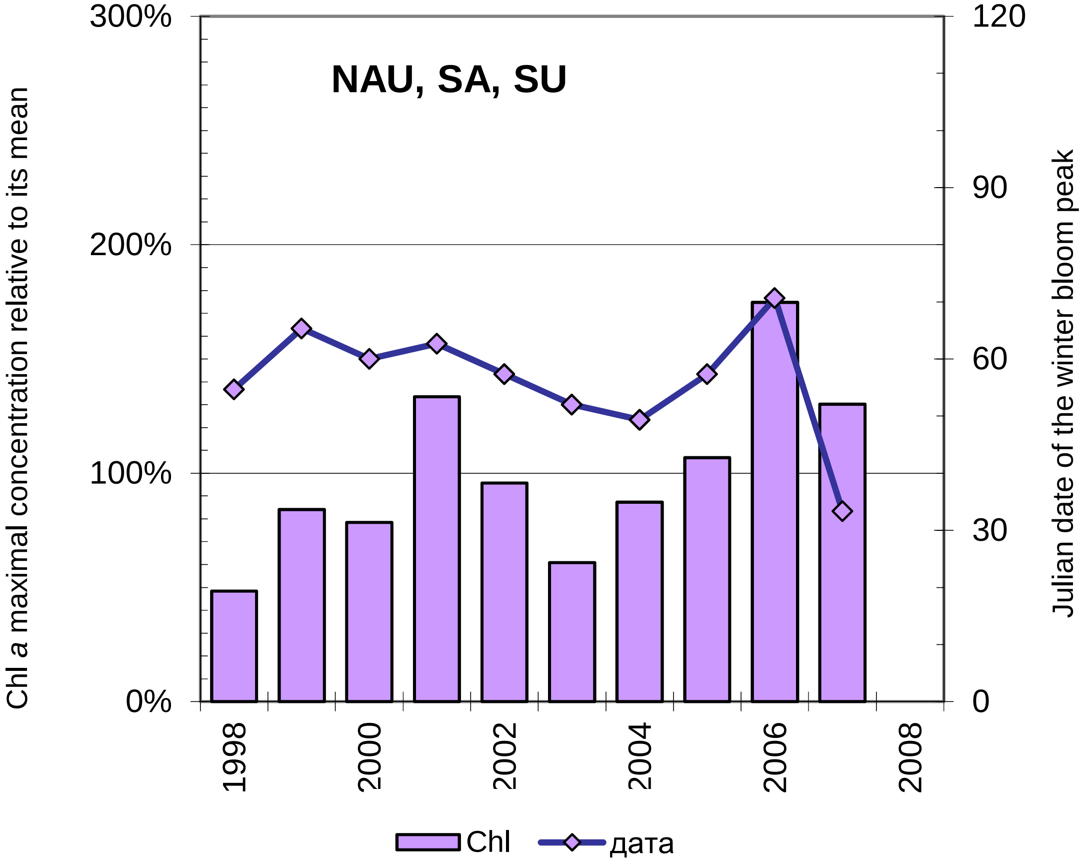
Fall bloom occupies the whole Peter the Great Bay in October-November. It was studied previously by Schtraikhert and Zakharkov (2005), who found that it was induced by storm mixing. It begins earlier in the coastal waters because of additional effect of upwelling, also caused by winter monsoon wind.



Mean timing (Julian days) of the peaks of Chl a, by areas of Peter the Great Bay

Results: year-to-year variation and its reasons: winter bloom

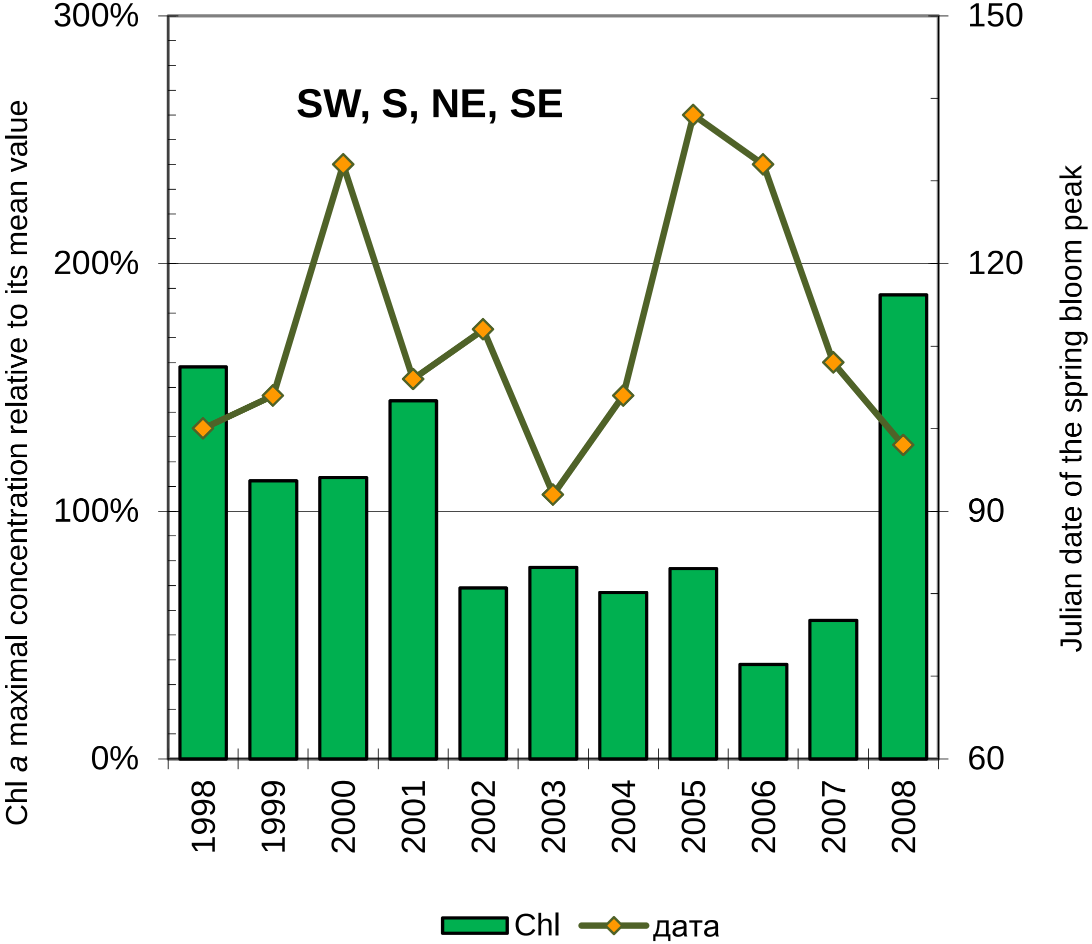
Timing of the winter bloom depends on winter severity: the colder, the later (r = -0.74). Usually the later blooms are stronger, possibly because of better illumination.



Year-to-year variations of the timing of winter bloom and its strength for the areas NAU, SA, SU (coastal waters)

Results: year-to-year variation and its reasons: spring bloom

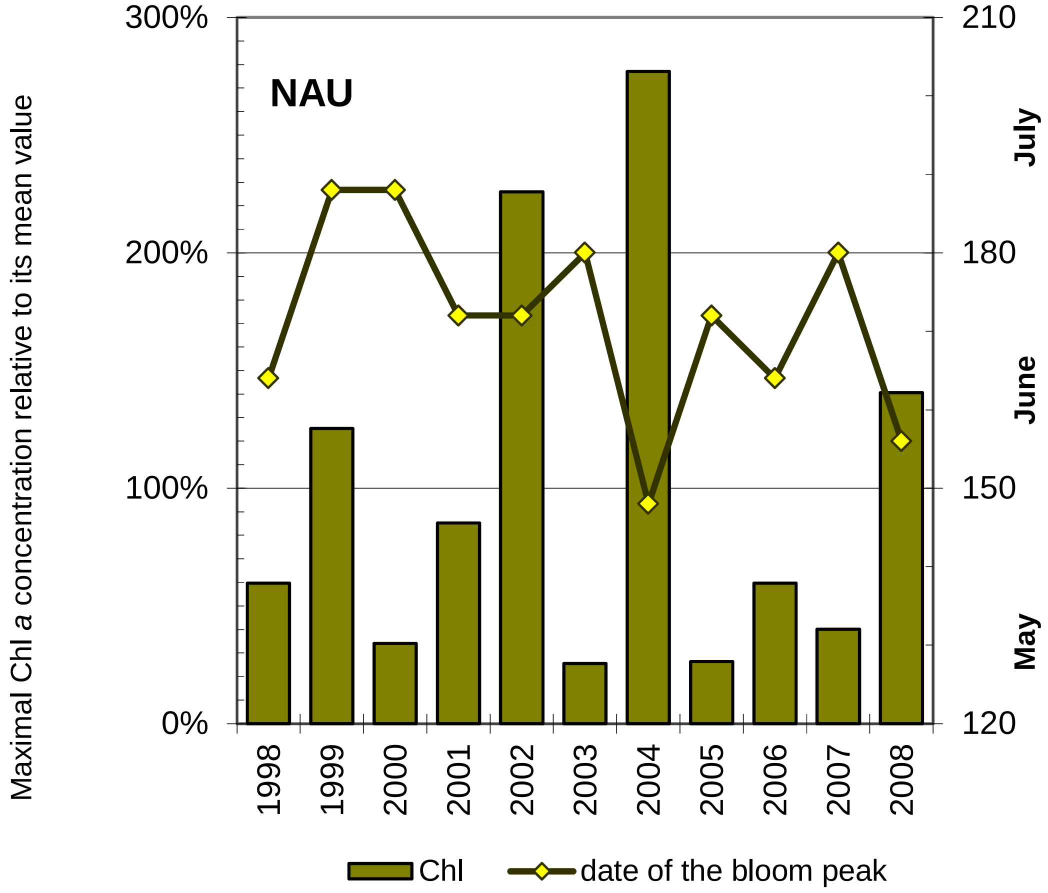
Timing of the spring bloom have strong negative dependence on April SST: the colder, the later (r = -0.78). There is no statistically significant dependence between the timing and the strength of the bloom.



Year-to-year variations of the timing of spring bloom and its strength for the areas SW, S, NE, SE (deep waters)

Results: year-to-year variation and its reasons: early summer bloom

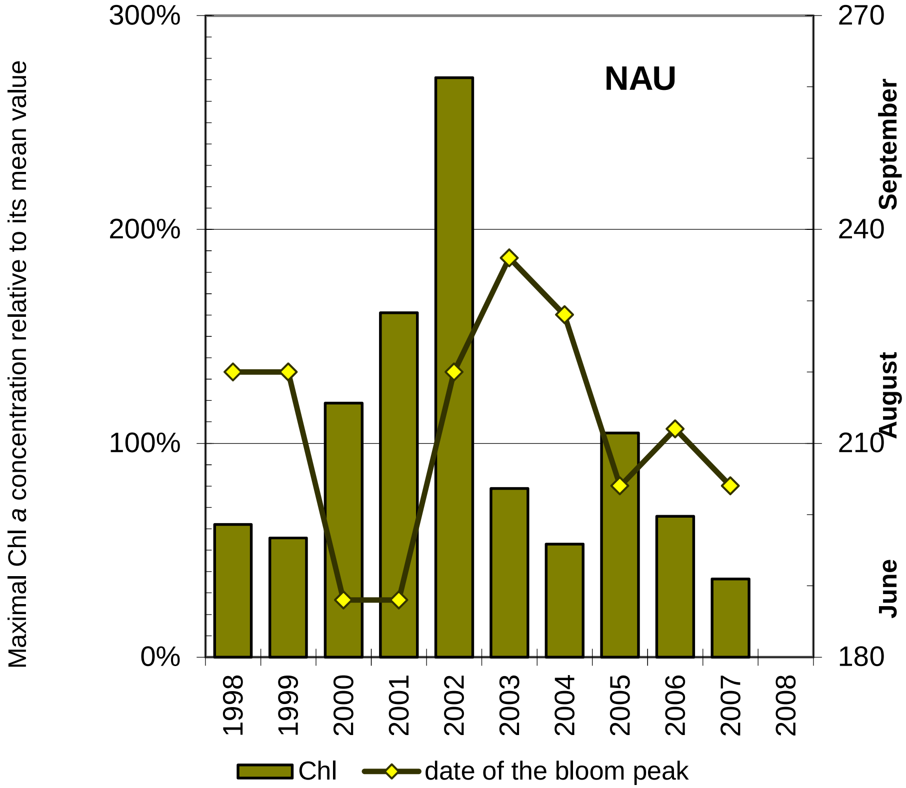
Timing of the early summer bloom within the estuarine zone of the largest river (Suyfun) has no any dependence on both SST and precipitation. In fact, blooming is permanent in this area, and its “waves” are reasoned by biological factors, as succession of phytoplankton community.

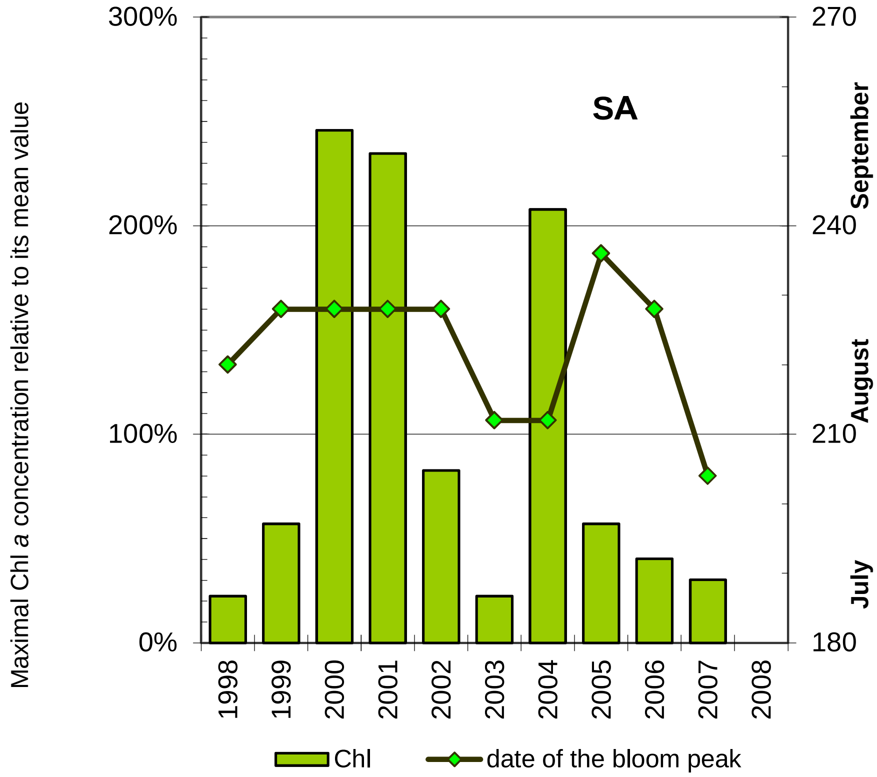


Year-to-year variations of the timing of early summer bloom and its strength for the area NAU (estuarine zone)

Results: year-to-year variation and its reasons: late summer bloom

Timing of the late summer bloom within the estuarine zone has no dependence on SST and precipitation, as well, but its timing outside the estuarine zone depends strongly on the time of maximal precipitation (r = 0,95). That means that the late summer bloom is possible in the areas outside the estuary immediately after the floods only.

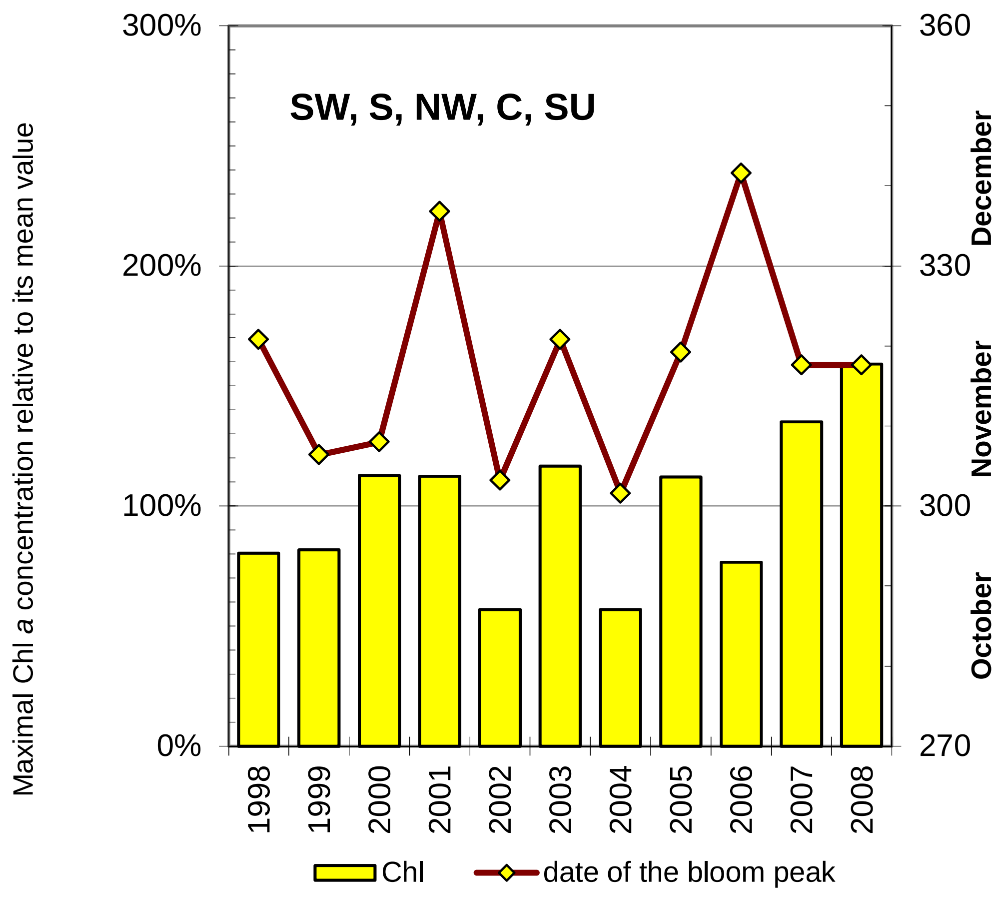




Year-to-year variations of the timing of late summer bloom and its strength for the areas NAU (estuarine zone) and SA (adjacent area)

Results: year-to-year variation and its reasons: fall bloom

Timing of the fall bloom is not very variable and doesn’t have significant correlation with both SST and precipitation (because it is conditioned by wind).

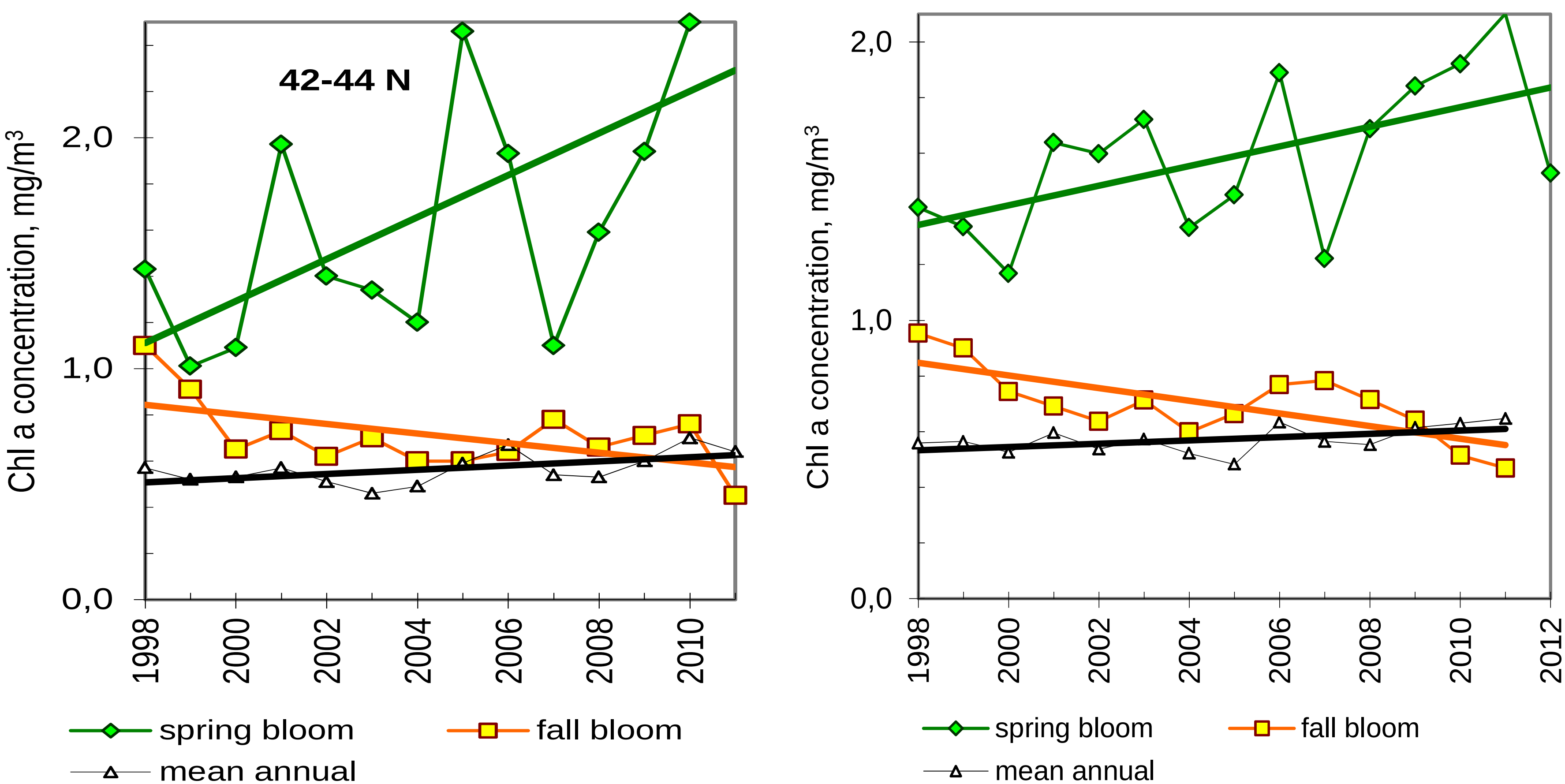


Year-to-year variations of the timing of fall bloom and its strength for the areas SW, S, NW, C, SU

Discussion: recent climate change influence on phytoplankton blooms

SST influences significantly on winter and spring blooms only, so cooling in the last decade caused a delay of both blooms (spring bloom – to late April – early May). Strength of the blooms has no any trend in Peter the Great Bay.

In adjacent deep-water area, spring bloom had a tendency to increase and fall bloom – a tendency to decrease in the last decade, so the mean annual biomass is rather stable.



Year-to-year variations of the strength of spring and fall blooms in the area adjacent to Peter the Great Bay and in the whole Japan/East Sea

Conclusions:

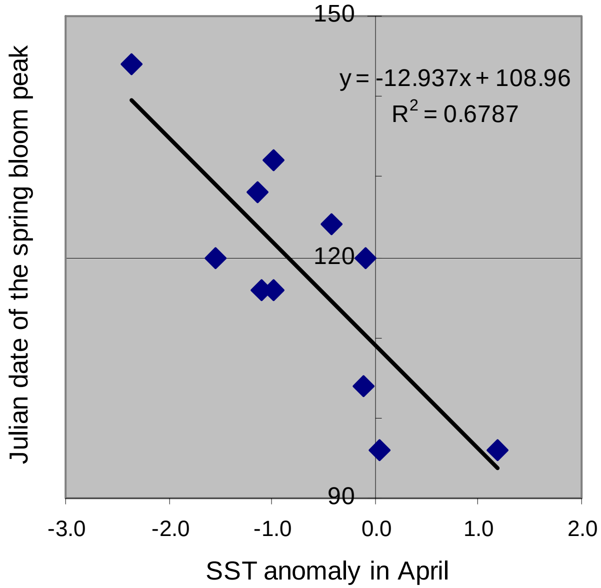
Deep-water and coastal parts of Peter the Great Bay have principally different regimes of phytoplankton succession: with 2 annual blooms in the deep-water areas and 4 annual blooms in the coastal waters.

Winter and spring blooms only are conditioned by the sea surface heating; summer blooms are conditioned by terrestrial water discharge, and autumn bloom – on winds.

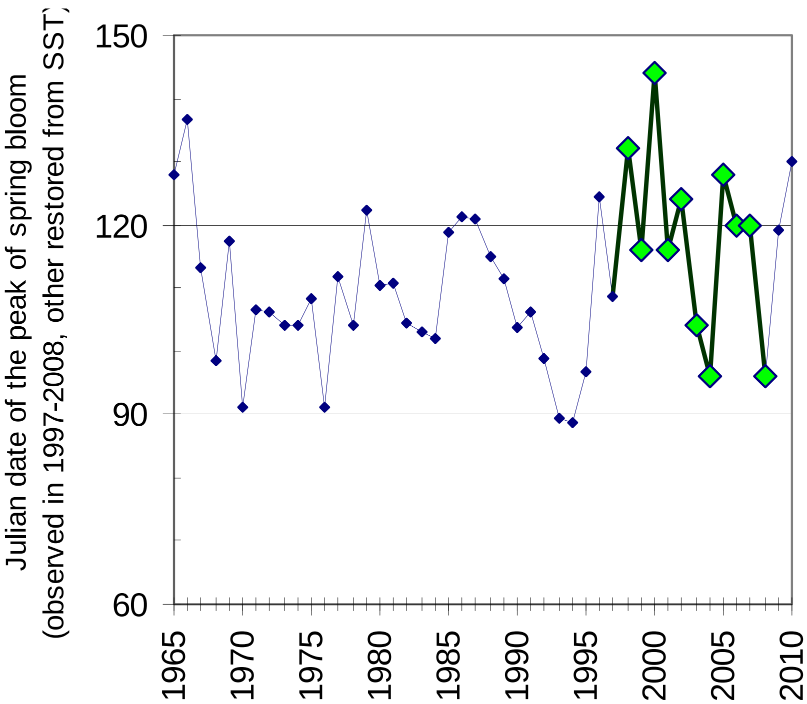
Timing of blooms in Peter the Great Bay depends significantly on SST or precipitation regime, except of the blooms in the estuarine zone, but strength of the blooms is weakly correlated with these environmental factors. In conditions of relatively low SST in winters and springs of the last decade, the timing of winter and spring blooms delayed to approximately a month, in compare with the 1990s. Timing of summer and fall blooms has no any significant tendencies.

Further goals:

Statistically significant dependence of the spring bloom timing on on SST in April (negative, r = 0.74) allows to reconstruct the dates of spring bloom for the years before SeaWiFS observations. This dates have a year-to-year variability with the range about 1.5 months determined by SST variations, but have no any significant trend.



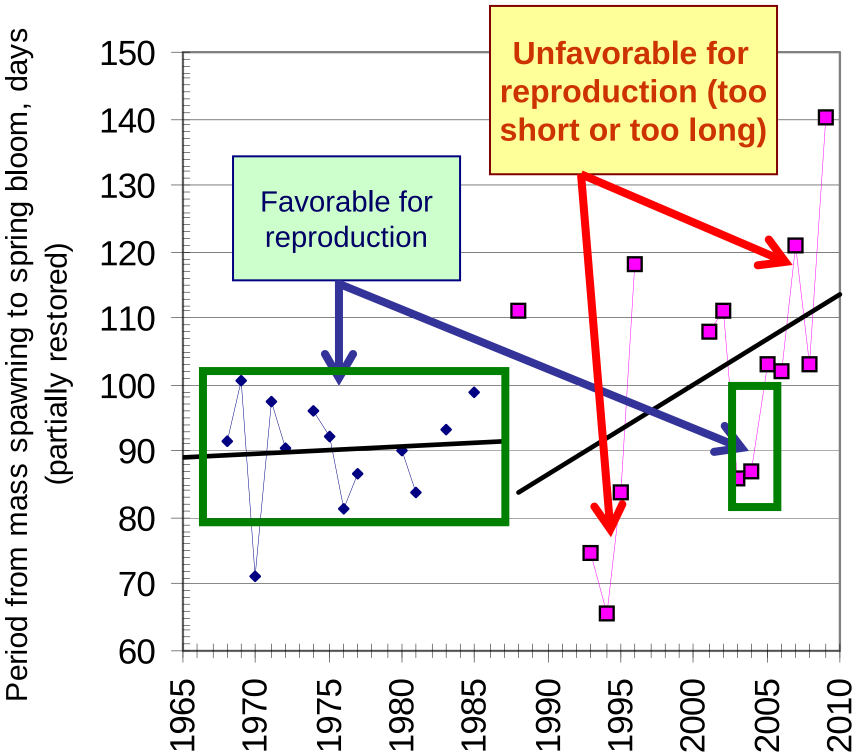
Dependence of the date of spring bloom peak in the coastal waters of Peter the Great Bay in 1998-2008 on SST anomaly



Year-to-year timing of Chl a concentration in the coastal waters of Peter the Great Bay (by SeaWiFS data and restored from SST)

Further goals:

Saffron cod *Eleginus gracilis* has successful reproduction in Peter the Great Bay in the years when the interval from its spawning to spring bloom is equal with the time of embryonal development (about 3 month in local temperature conditions). The match was observed in 1970-1980s, when the saffron cod reproduction was successful. When the interval became longer in 1990s (with exclusion of some years) – the reproduction became unsuccessful.

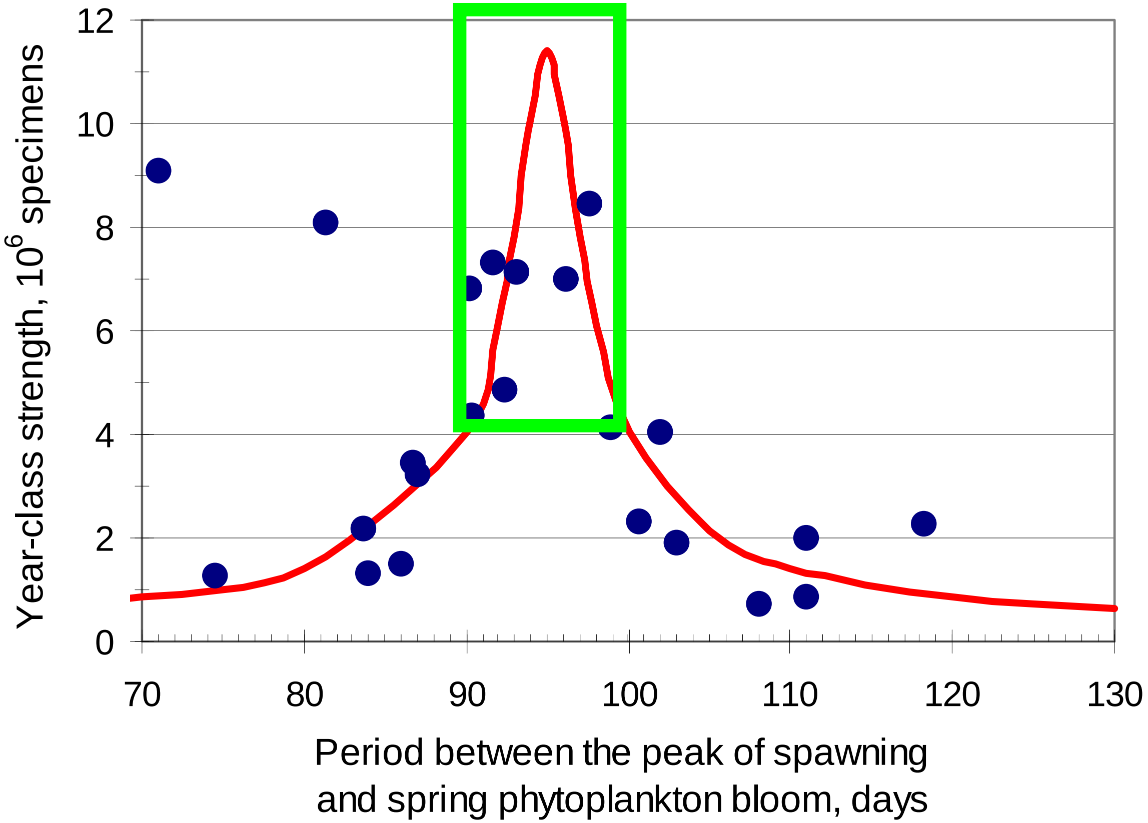


Year-to-year changes of the time interval between the peak of saffron cod spawning and the peak of spring bloom. Trends before and after 1988 are shown

Further goals:

Dependence of the year-class strength on the time between spawning and blooming of saffron cod could be approximated by a resonance function. After tuning, the optimal interval is determined as 95 days. Almost all (80%) of strong generations (>4 mln.ind.) were formed when the spawning was in 90-100 days before the bloom, and all (100%) weak generations were formed when the spawning was <90 or >100 days before the bloom.

So, the tipping of natural oscillating system “saffron cod + plankton” occurs when it goes out of resonance.



Dependence of the saffron cod year-class strength on the interval between its mass spawning and spring bloom

Resonance function:

$$N_i = \frac{a}{\sqrt{1+\left[Q\cdot\left(T_i - T_R\right)\right]^2}},$$

where
N_i – year-class strength for the year i;
T_i – time interval between the peak of spawning and the peak of spring bloom in the year i;
T_R – optimal (resonance) length of the interval;
Q – Q-factor of vibrating system;
a – empiric coefficient.

The saffron cod reproduction is successful and strong year-classes form in the years with T_i close to T_R that provides the best match of the larvae hatching with their prey abundance, but the years with extremely long and extremely short T_i are unfavorable for reproduction.

Parameters of this equation determined by its fitting to the data of observations:

T_R = 95 days;
Q = 0.53;
a = 11.4·10^6 specimens