Eco-hydrological mechanism of phytoplankton distribution in the reservoir

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or

Two paradoxes of phytoplankton distribution

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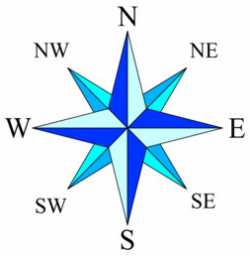
Novosibirsk city



The Novosibirsk reservoir

- Average depth is 8.2 m.
- The volume and water-surface area at the normal affluent level - 8.8 km3 and 1070 km2, respectively.
- The volume drawdown makes up 4.4 km3
- Annual water runoff is approx.5o km3

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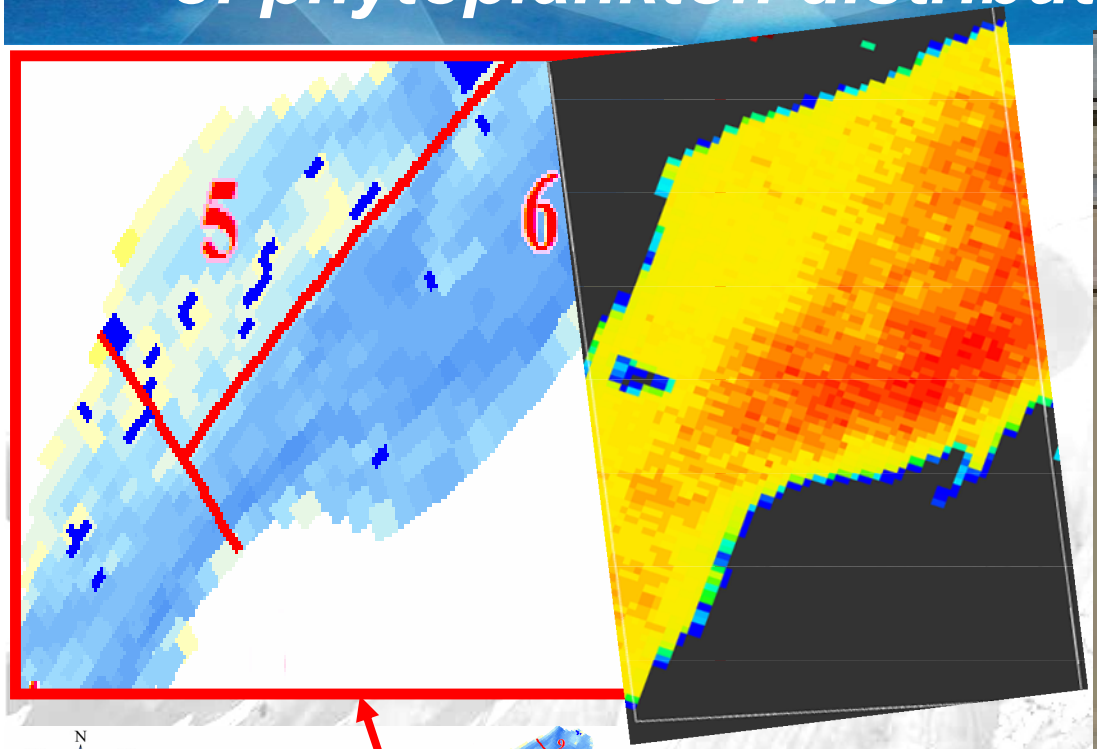

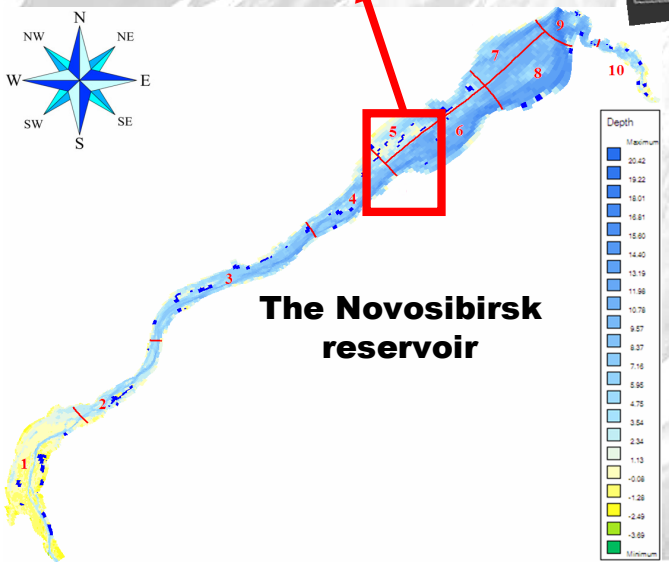

The Novosibirsk reservoir

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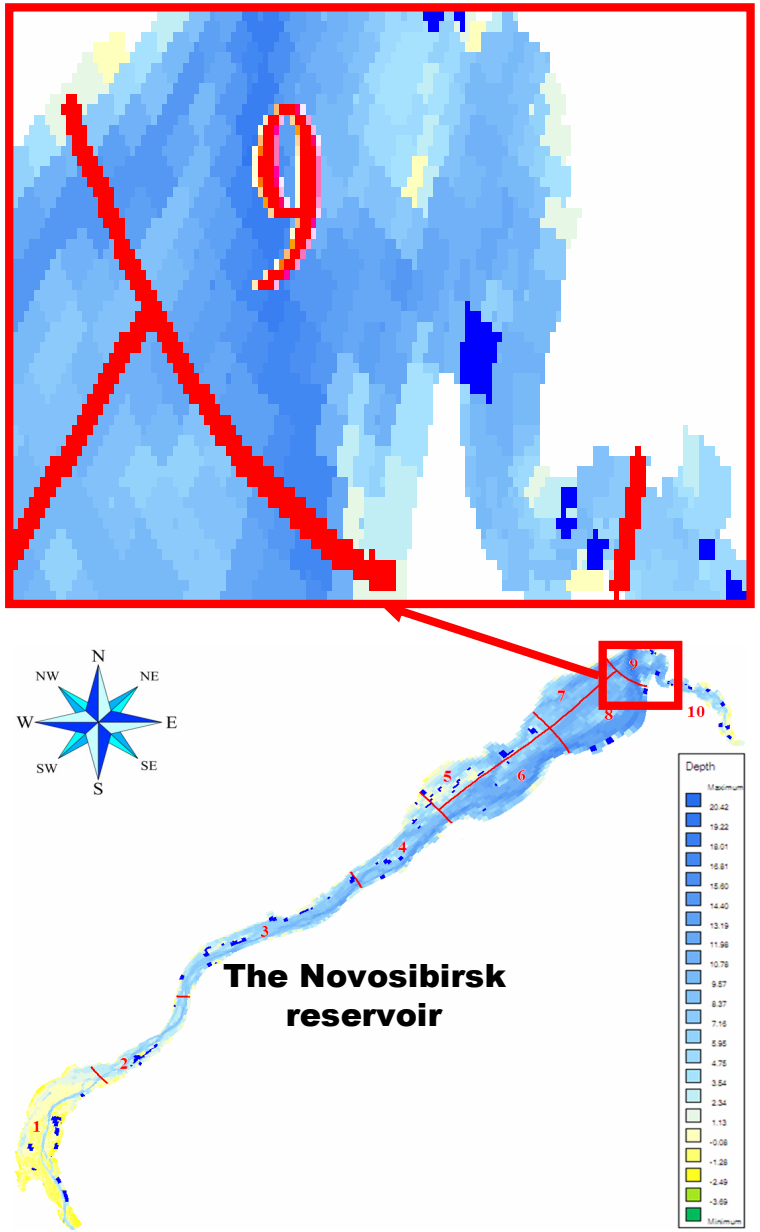
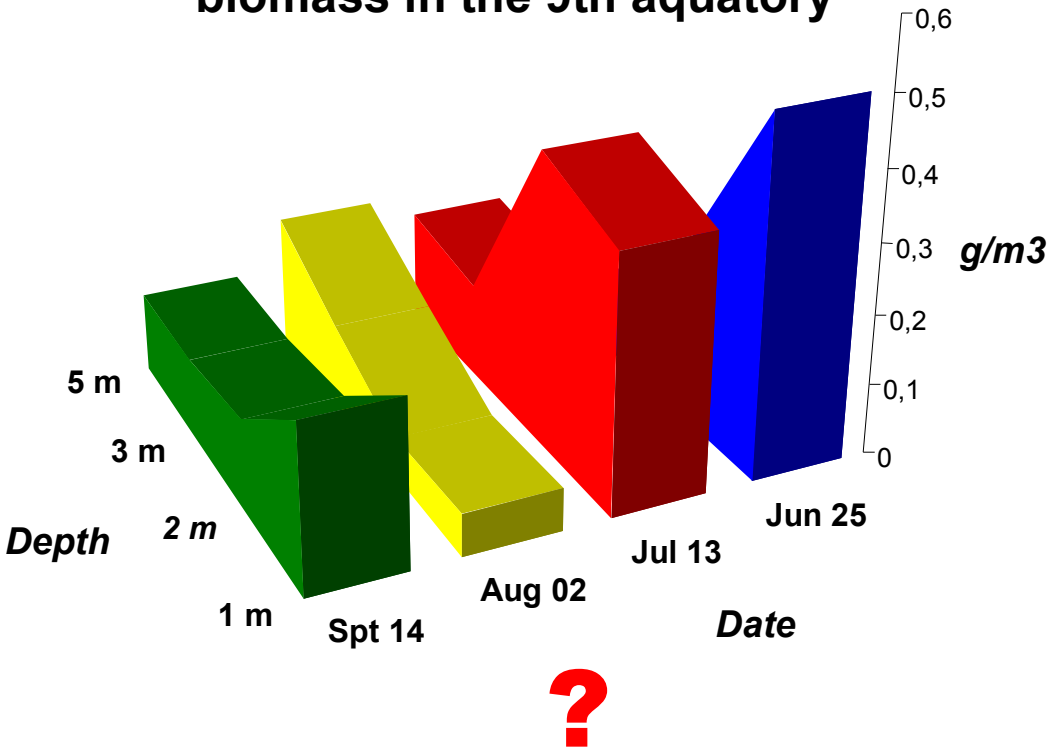


Observation data for phytoplankton biomass in the 9th aquatory



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Hydrothermal 3d-model:

$$\frac{\partial u_1}{\partial t}+u_\alpha\frac{\partial u_1}{\partial x_\alpha}-lu_2=-\frac{1}{\rho_0}\frac{\partial}{\partial x_1}\left(P_{atm}+g\int_{z_1}^{\zeta}\rho dz_3\right)+\frac{\partial}{\partial x_\alpha}K_\alpha\frac{\partial u_1}{\partial x_\alpha};$$

$$\frac{\partial u_2}{\partial t}+u_\alpha\frac{\partial u_2}{\partial x_\alpha}+lu_1=-\frac{1}{\rho_0}\frac{\partial}{\partial x_2}\left(P_{atm}+g\int_{z_1}^{\zeta}\rho dz_3\right)+\frac{\partial}{\partial x_\alpha}K_\alpha\frac{\partial u_2}{\partial x_\alpha};$$

$$\frac{\partial u_\alpha}{\partial x_\alpha}=0;$$

$$\frac{\partial T}{\partial t}+u_\alpha\frac{\partial T}{\partial x_\alpha}=\frac{\partial}{\partial x_\alpha}K_{T\alpha}\frac{\partial u_1}{\partial x_\alpha}+q_T;$$

$$u_\alpha=0\big|_{i\in\Sigma_0};\ u_\alpha=u_{i\alpha}(\vec{x},t)\big|_{i\in\Sigma_1};\ T=T_{in}(\vec{x},t)\big|_{i\in\Sigma_1};\ u_\alpha=u_{out}(\vec{x},t)\big|_{i\in\Sigma_2};$$

$$u_3=\frac{\partial\zeta}{\partial t}+u_1\frac{\partial\zeta}{\partial x_1}+u_2\frac{\partial\zeta}{\partial x_2}-P\Big|_{z_3=\zeta};\ K_3\frac{\partial u}{\partial z_3}=\frac{\tau}{\rho_0}\Big|_{z_3=\zeta};\ K_{T3}\frac{\partial T}{\partial z_3}=\frac{F}{c_p\rho_0}\Big|_{z_3=\zeta};$$

$$u_3=u_1\frac{\partial z_b}{\partial x_1}+u_2\frac{\partial z_b}{\partial x_2}\Big|_{z_3=z_b};\ K_3\frac{\partial u}{\partial z_3}=K_b|u|u\Big|_{z_3=z_b};\ \frac{\partial T}{\partial z_3}=0\Big|_{z_3=z_b}.$$

where $u_\alpha\ (\alpha=1,2,3)$ – components of water flow velocity;
T – water temperature

For the Novosibirsk reservoir (1981)

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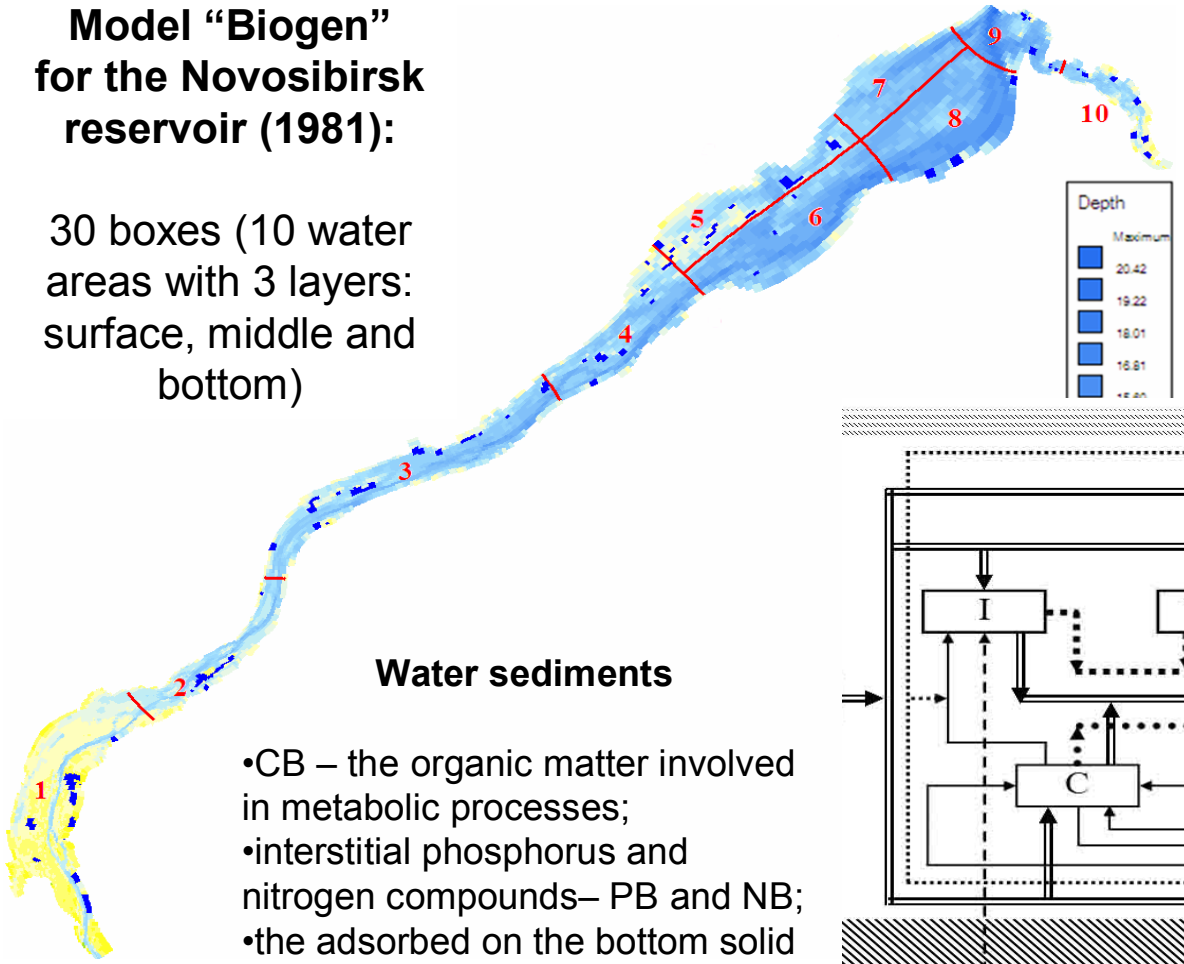
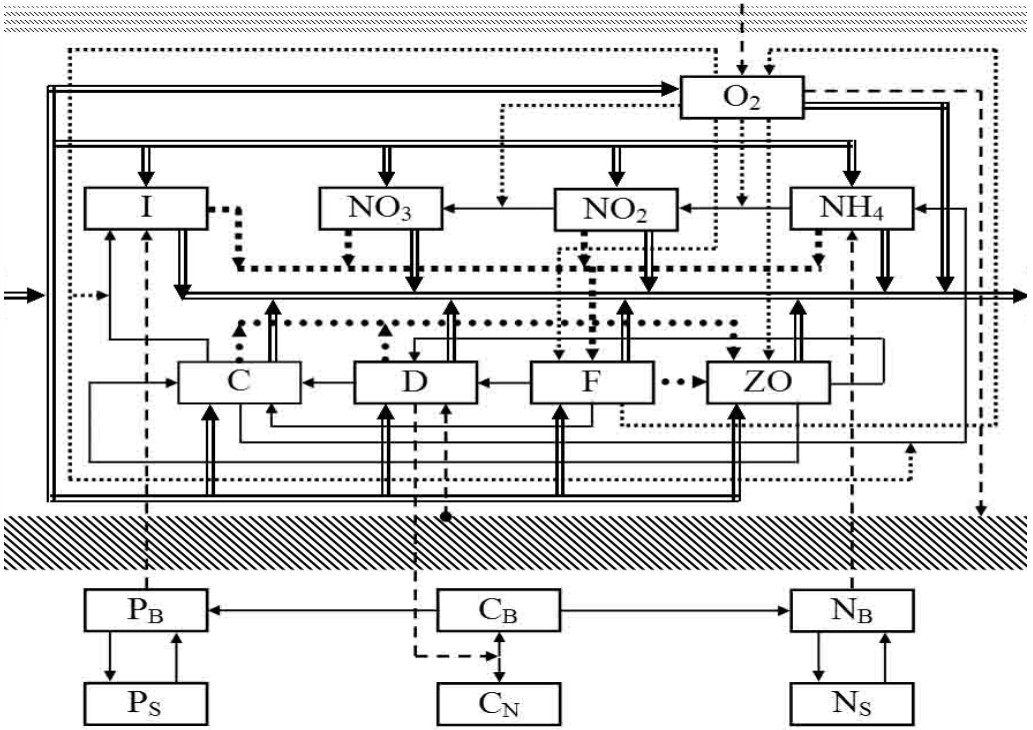
Aquatic Ecosystem Model "Biogen" for the Novosibirsk reservoir (1981):

30 boxes (10 water areas with 3 layers: surface, middle and bottom)



Water column

- ZO – the zooplankton biomass;
- F – the phytoplankton biomass;
- NH4, NO2, NO3 - the mineral forms of nitrogen;
- D – the detritus;
- C – the dissolved organic matter;
- I – the dissolved inorganic phosphorus;
- O2 – the oxygen.



Water sediments

- CB – the organic matter involved in metabolic processes;
- interstitial phosphorus and nitrogen compounds– PB and NB;
- the adsorbed on the bottom solid phase – PS and NS;
- CN - the passive organic matter in the bottom sediments (in nitrogen units).

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$$\frac{d(C_i \cdot W_j)}{dt} = W_j \cdot R_i + \sum_k Q^+_{k,j} C^+_{ki} - \sum_q Q^-_{j,q} C_i + J_{i,j} \cdot \Omega_j + G_{i,j} L_j, \quad (1)$$

where W_j – the j-th box volume; t – the time;

R_i – the rate of biochemical transformation of the corresponding compound C_i;

$Q^+_{k,j}$ and C^+_{ki} - the water input discharge from k-th box to j-th box and its i-th component concentration;

$Q^-_{j,q}$ - the water outlet discharge from j-th box to q-th box;

J_{ij} –mass flow in the interfacial surface of the j-th box;

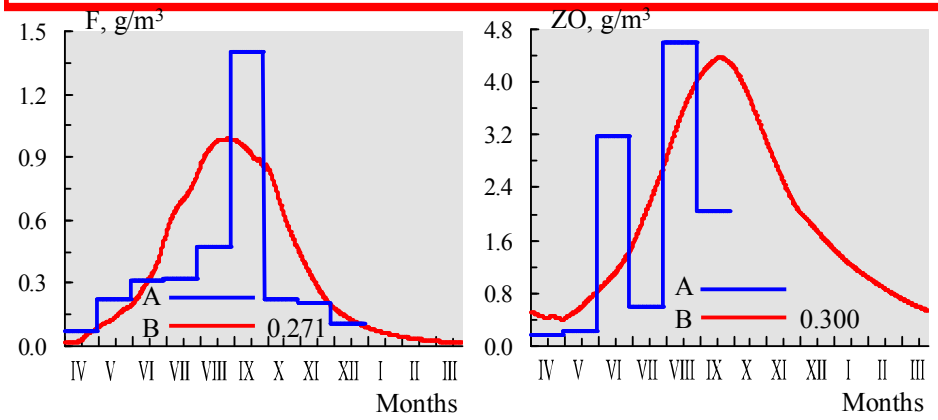
Ω_j - water-surface area of the j-th box;

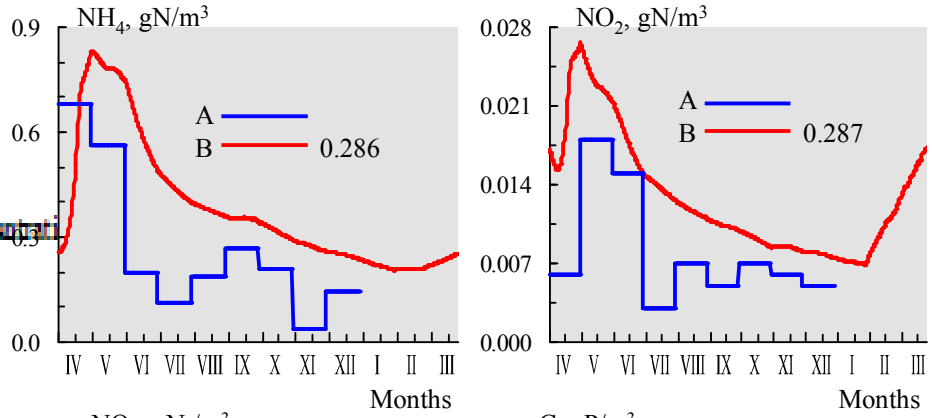
G_{ij} - lateral load characterizing the input from diffuse sources;

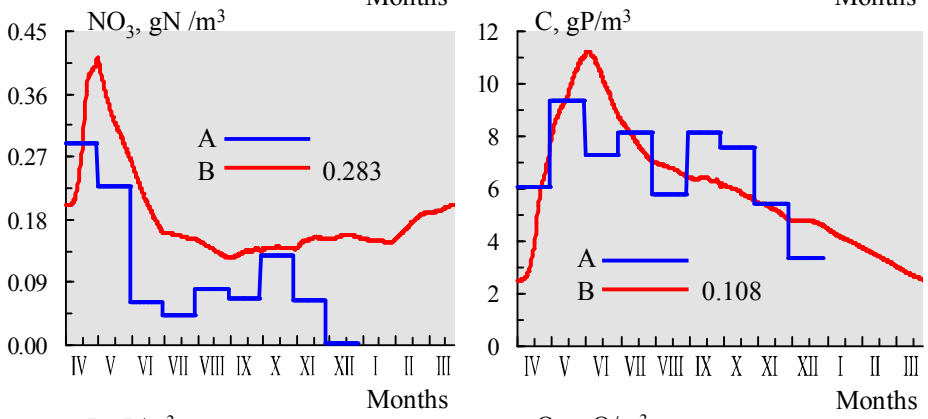
L_j –shoreline length of the j-th box.

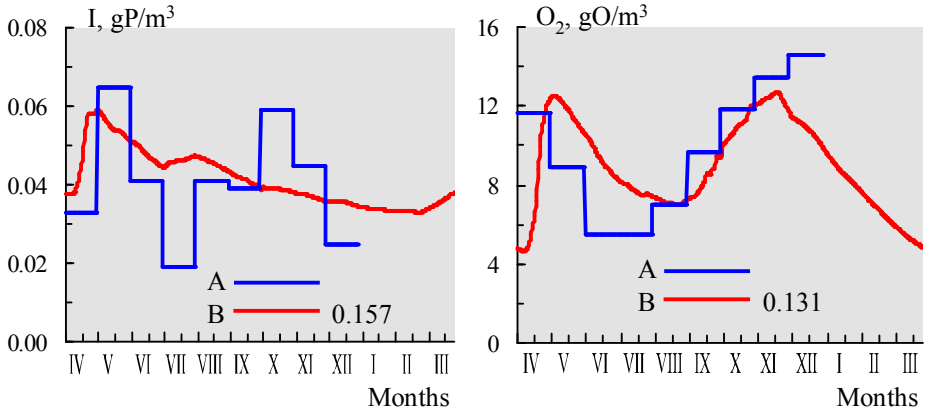
$$Cr = \frac{\sqrt{\sum_{i=1}^{n} (X_i - Y_i)^2}}{\sqrt{\sum_{i=1}^{n} X_i^2} + \sqrt{\sum_{i=1}^{n} Y_i^2}} \quad (2)$$

An aquatic Ecosystem Model "Biogen": calibration for Novosibirsk reservoir (1981)

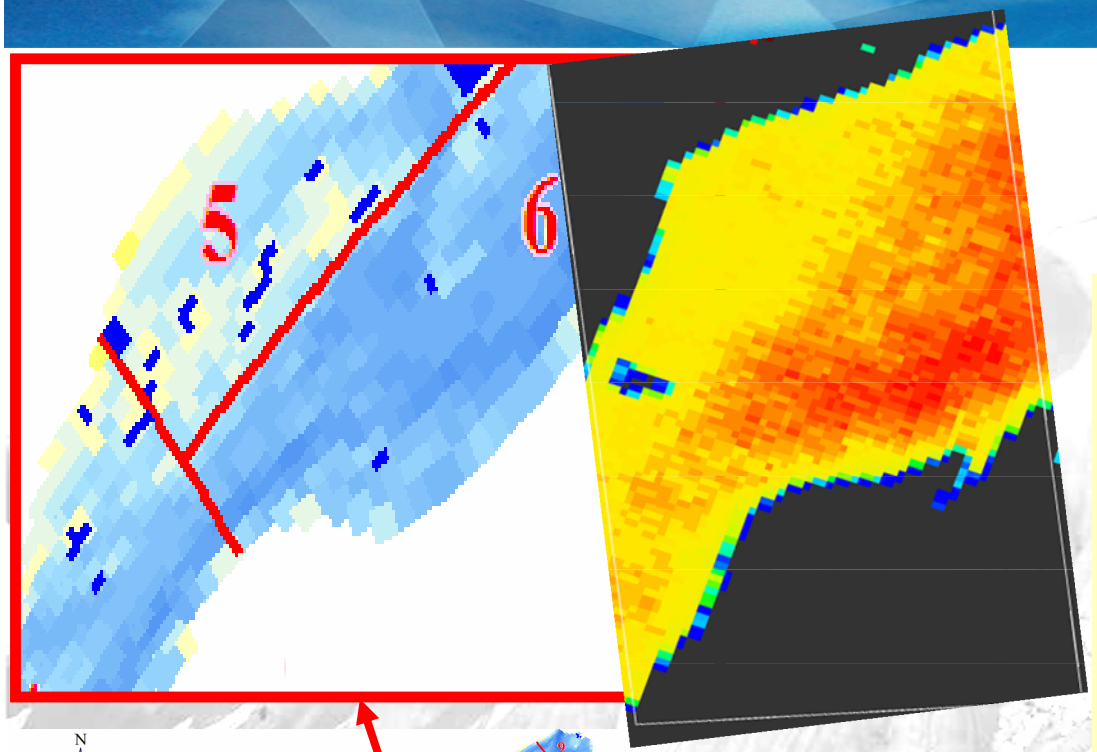


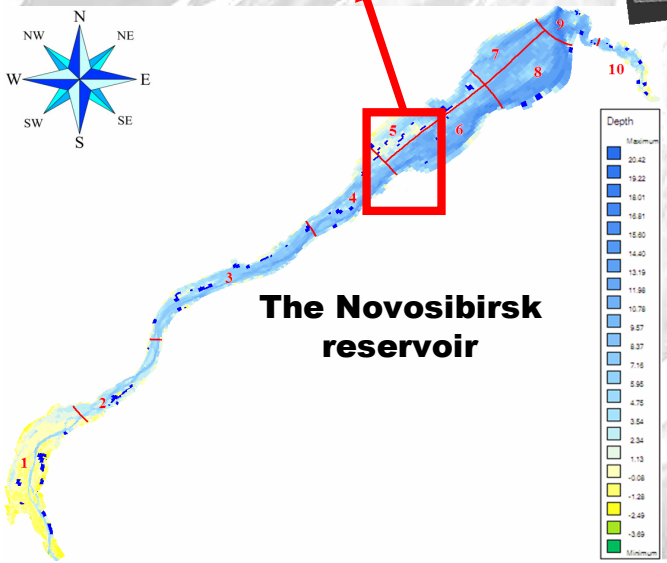




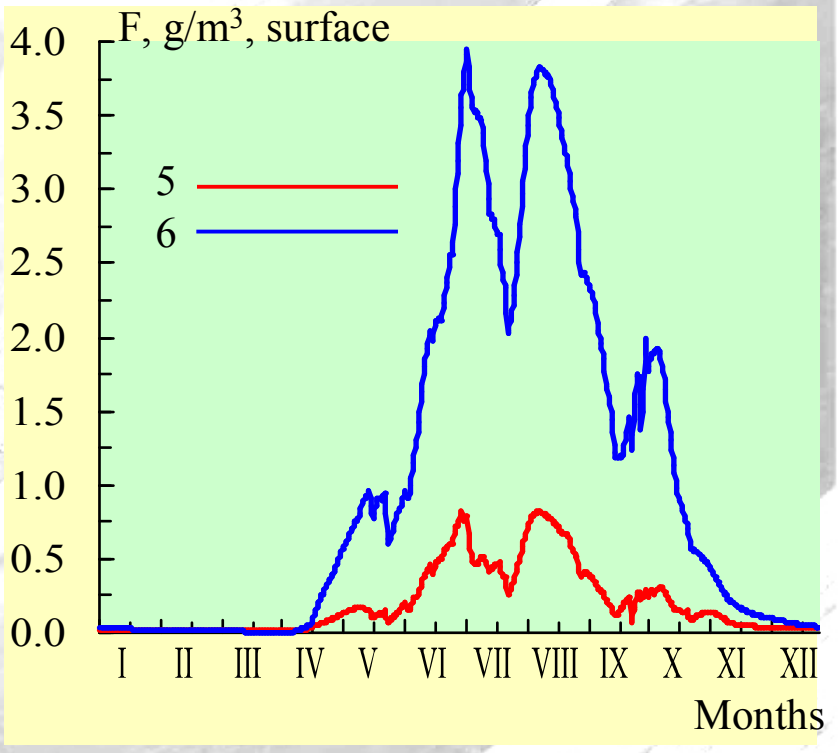


Result 1

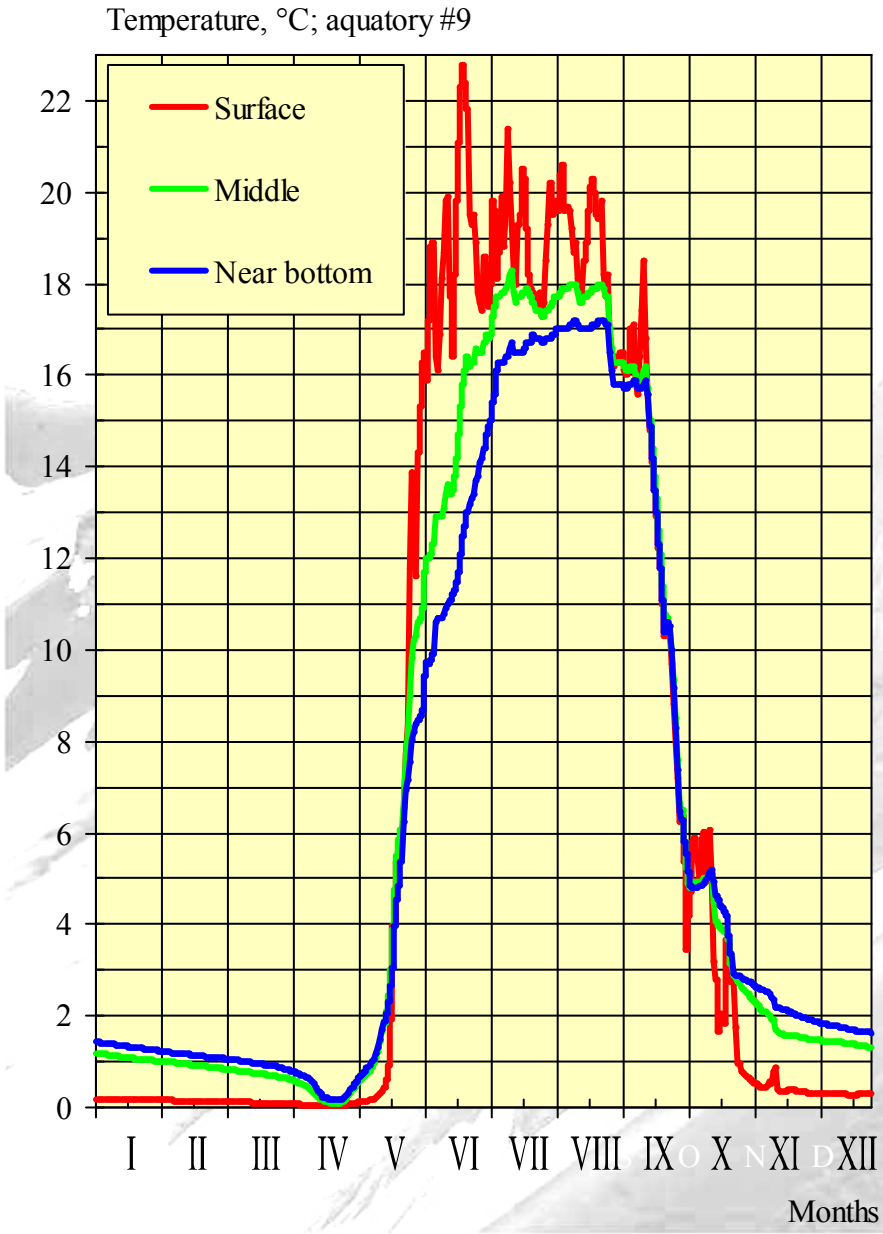


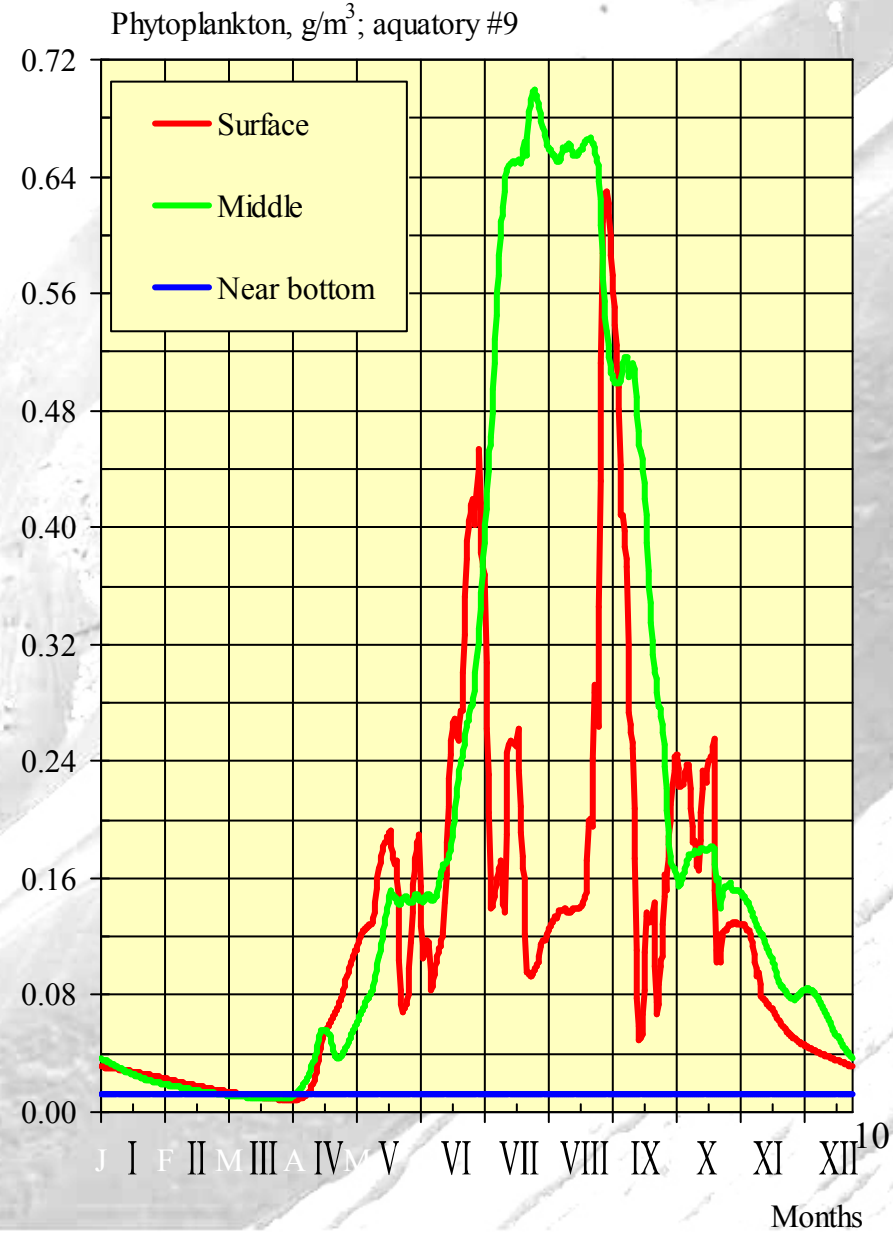


The Novosibirsk reservoir



Result 2


Temperature, °C; aquatory #9
Surface
Middle
Near bottom
22
20
18
16
14
12
10
8
6
4
2
0
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
Months


Phytoplankton, g/m3; aquatory #9
Surface
Middle
Near bottom
0.72
0.64
0.56
0.48
0.40
0.32
0.24
0.16
0.08
0.00
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
Months

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Conclusion:

1. Features of water exchange caused excessive development of phytoplankton biomass in the deep aquatory No. 6 of the Novosibirsk reservoir compared to the relatively shallow aquatory No. 5.

2. Thermocline "locking"and subsequent fluctuations in vertical water exchange induced excessively abundant phytoplankton in the water column compared to the surface layer in aquatory №9.

Eco-hydrological mechanism of phytoplankton distribution in the reservoir

Thank you for attention!