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ETEKOS EXPERIMENTAL ECOSYSTEM

V. V. Alekseyev and V. V. Sapozhnikov

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EXPERIMENTAL ECOSYSTEM "ETEKOS"

By

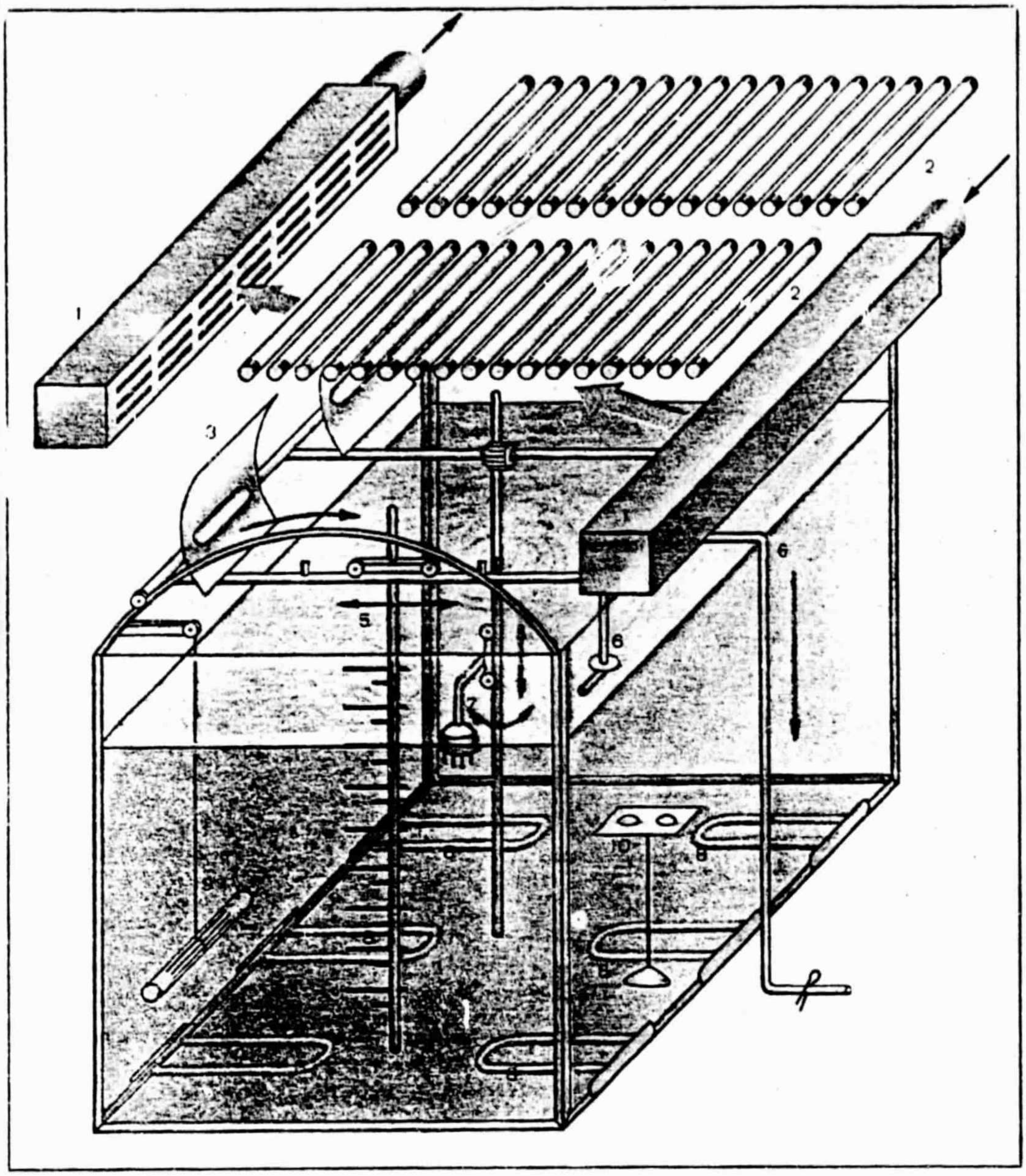
V. V. Alekseyev and V. V. Sapozhnikov

Vyacheslav Viktorovich Alekseyev, doctor of physical and mathematical sciences, senior scientist of physics department of M. V. Lomonosov Moscow State University, Biophysicist engaged in mathematical modeling of biogeocenoses. Author of a number of monographs, including Dinamicheskiye modeli vodnykh biogeotsenozov ["Dynamic Models of Aquatic Biogeocenoses"], Moscow, 1976. /70*

Viktor Vol'fovich Sapozhnikov, candidate of geographical sciences, senior scientist of geographical department of the same university. Specialist in hydrochemistry of reservoirs on dry land and oceans.

Disruption in the equilibrium in nature as a consequence of environmental pollution with industrial, agricultural and general wastes has induced enormous interest in the basic research of ecological problems, that can only be solved by the joint efforts of different specialties: physicists, chemists, biologists and so forth. The main information on the ecosystems has been obtained as a result of

*Numbers in margin indicate pagination in original foreign text.



Plan of Experimental Unit for Studying Ecosystems /71
1--system of air conditioning; 2--controllable system of illumination (soffit made of 56 fluorescent lamps); 3--xenon lamps moving over arches; 4--electric motors turning rod with probe and advancing it over the vertical; 5--movable post with oxygen sensors (oxymeters); 6--sampler; 7--probe to determine pH, dissolved oxygen and temperature; 8--electrical heaters; 9--instrument for determination of water transparency; 10--photoelements to determine light intensity.

observations in nature. However observations are the first, but far from the most effective method of study. The possibility of obtaining the maximum quantitative information and passing to construction of a mathematical model of the phenomenon is only provided by experiments.

The first experiments were made with ecosystems made of microscopic organisms. In 1912 L. L. Vudreff for the first time gave a quantitative description of the successive change in population of Protozoa in a hay extract under the influence of a change in the medium of the population and its organisms. He observed how numerous flagellates are replaced by varying types of colpodae, and then paramecia who are successively replaced by Hypotricha Infusoria, amoebae and Vorticellae.

A further stage in the development of this type of experiment was the study of closed micro-ecosystems (volume about 250 ml and more) that require for their development only light energy, as well as the study of the organisms developing in the chemostats and turbidostats of different types with controllable influx and efflux of nutrients.[1] A shortcoming of these systems--spatial heterogeneity of different physical and chemical properties of the medium. This shortcoming can be overcome only with the creation of basins of large capacity.

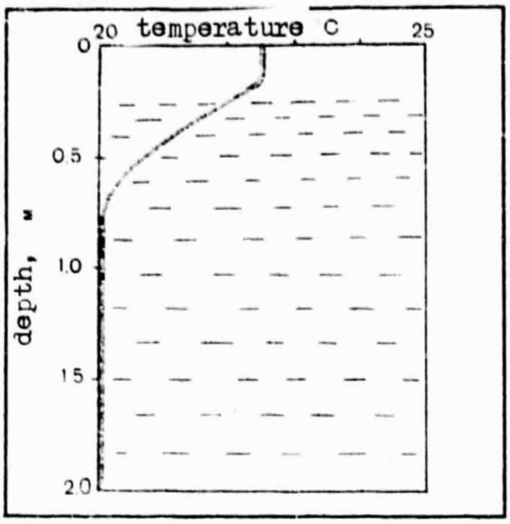
A study of the water biocenosis in a closed basin affords the possibility of /72
tracing the interaction between the components of the ecosystem under conditions close to the natural, but without any external interferences.

In the Moscow University in a special basin of the hydrophysics laboratory of the physics department the collective of authors (V. V. Alekseyev, Yu. I. Gorbatov, A. A. Georgiyev, M. Ya. Lyamin, V. N. Maksimov and V. V. Sapozhnikov) of the physics, biological and geographic departments have created a unit for study of ecosystems--the experimental ecosystem or Etekos.

In the formation of the structure of the aquatic ecosystem an important role is played by the vertical distribution of illumination intensity and temperature, and the intensity of turbulent exchange at different depths--factors that can be altered only in a basin of sufficiently large dimensions.

The working basin of Etekos is a reservoir of volume $3 x 4 x 3 = 36$ m^3. The basin itself and the air chamber above it are insulated from the environment. The water can be heated from below and cooled from above, so that in the system conditions can be created that are stable in time and uniform in space. However, this pattern, as a rule, rarely is realized in nature. It is much more interesting to have a medium in which the temperature, illumination intensity, and intensity of turbulent exchange are altered with depth. For this the illumination intensity and

[1] Pechurkin, N. N. Populyatsionnaya mikrobiologiya ["Population Microbiology"] Novosibirsk, 1978.



Vertical Distributions of Temperature in Three Days after Engagement of Fluorescent Lamps and with Engagement of Conditioner. Air temperature in chamber is lower than in upper layer of water. Due to cooling in the upper layer of water convective movement begins--an isothermic layer develops (shown by gray color).

temperature are regulated with the help of a soffit made of 56 fluorescent lamps of 40 w each. The light falling at an angle to the horizontal surface is created by lamps whose radiation spectrum can be regulated in certain limits. These lamps can be moved on the circumference.

The conditioner can maintain a certain temperature and humidity in the air chamber and at the same time alter the intensity of the convective exchange in the water that occurs with its cooling from above.

Nutrient salts can be added to the system, or by adding distilled water their concentration can be reduced, which is very convenient for studying the changes in the ecosystems that occur, for example, with eutrophication of reservoirs, i.e., with an increase in the concentration of nutrient salts in the water.

An important component of the unit is the original complex of measuring apparatus.

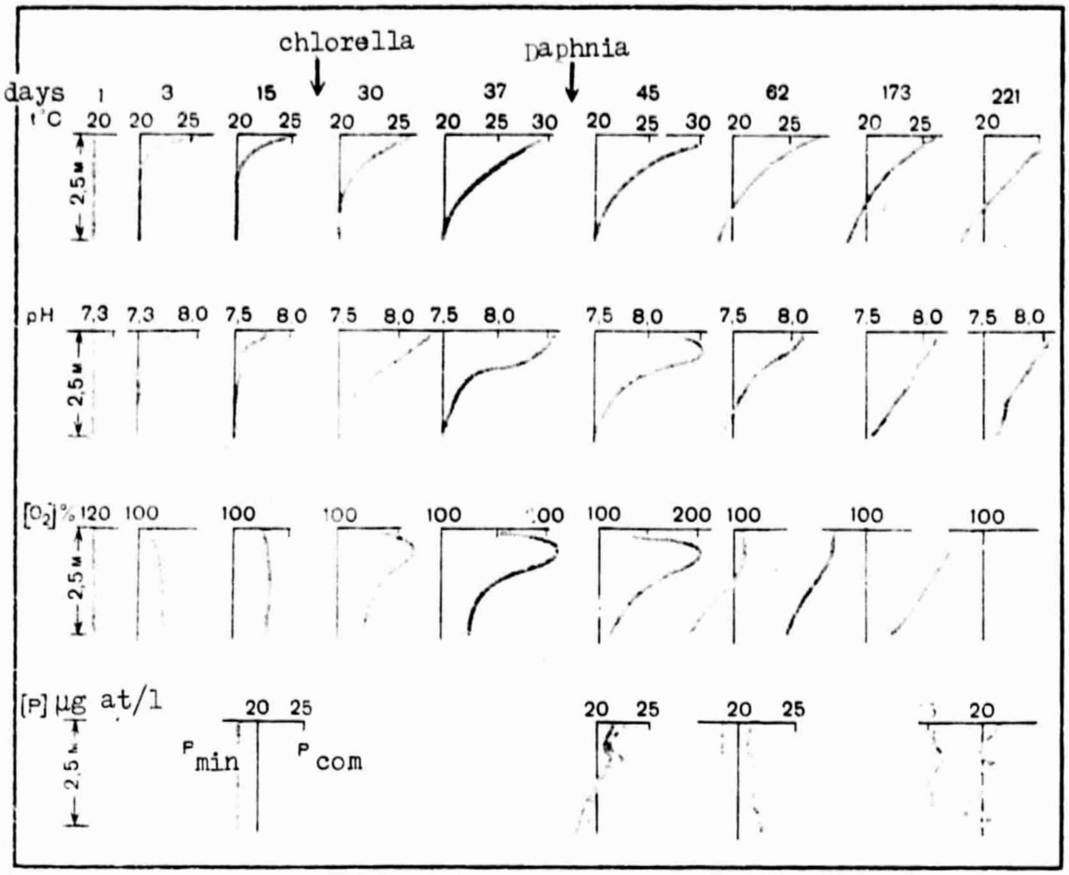
The first group includes physical and chemical parameters whose measurement is completely automated: temperature and illumination intensity at different depths, pH values and oxidation-reduction potential of the medium, concentration of dissolved oxygen. The measurement results are recorded by self-recorders.

The second group of parameters comprises concentrations of different biogenic elements. In principle their measurements are standard and can be automated. However, at the given stage the chemical analyses are made manually. With the help of the sampler, a polyethylene pipe 0.5 cm in diameter, the samples are taken from the necessary level and further are sent to the chemical laboratory. The hydrochemical analyses include determination of the organic and mineral forms of phosphorous and nitrogen, dissolved silicic acid, dissolved amino acids, etc.

Finally, the third group includes primarily the biological parameters--concentrations of different types of phyto- and zooplankton. Determination of these parameters is exceptionally difficult to automate. For example, the species composition of the phytoplankton can be determined only with the help of a micro- /73
scope. However, determination of the amount of primary product or the quantity of newly formed organic substance is successfully automated. To determine the primary product of photosynthesis in situ G. G. Shinkar and V. V. Sapozhnikov have suggested a special instrument--productiometer that is two glass tubes (dark and light) through which water is pumped. By knowing the concentration of oxygen at the inlet into the system (O_{in}) and the concentration of oxygen at the outlet from the dark (O_{dk}) and light tubes (O_{lt}) one can easily compute the complete product (O_{lt}-O_{dk}), the pure product (O_{lt}-O_{in}) and the destruction (O_{in}-O_{dk}). The use of this instrument makes it possible to conduct continuous recording of the product of the photosynthesizing algae and evaluate the rate of the destruction processes, or the amount of biochemical consumption of oxygen in the dark tube. By measuring at the inlet and outlet from the productiometer not only the concentration of oxygen but also phosphorous, nitrogen, as well as the pH of water, etc. one can evaluate /74
the effect of the processes of photosynthesis on the utilization and regeneration of the main biogenic components.

It is understandable that (O_{lt}-O_{in}) and (O_{in}-O_{dk}) will be determined by the time of stay of the water in the tubes. In order to determine more accurately the momentary value it is necessary to make this time (exposure) less. With large exposures we obtain the average values of the product for a long time and will not know the fine structure of the oscillations of the product in time.

A serious method problem in studying the ecosystem is the varying degree of accuracy of the obtained results and the varying degree of effect of the measurement process on the system. The sensors for temperature measurement can be made so small that they permit measurement of temperature gradients in a layer of



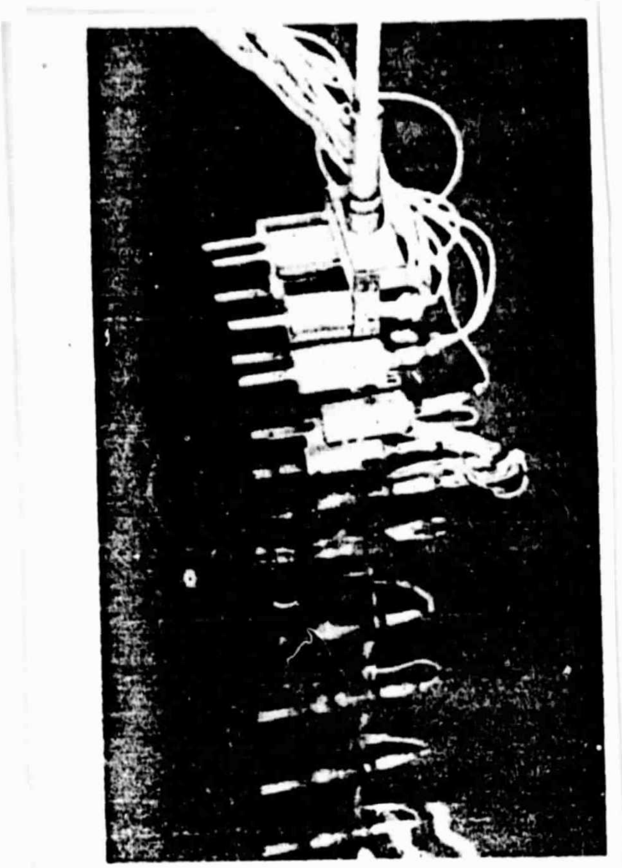
Course of Ecological Experiment

Vertical distribution of temperature, pH, concentration of dissolved oxygen $[O_2]$, mineral $[P_{min}]$ and complete phosphorous $[P_{com}]$. Due to the fact that nitrates were in the water in a surplus, their concentration during the experiment changed little, and therefore they are not shown on the figure. At the initial moment in time all the parameters were uniform.. On the first day of the experiment biogenic elements were added to the water (nitrate--KNO_3 and phosphate--KH_2PO_4) As a consequence of heating the reservoir in the upper layer of water (50 cm) a so-called thermocline was formed, the concentration of oxygen was reduced due to the reduction in its solubility with a rise in temperature; the pH rose since the content of carbon dioxide in the water was reduced.

In two weeks algae (chlorella) were added to the basin: intensive production of O_2 by the algae began.

In 1.5 months Daphnia were added to the system; they feed on chlorella. This led to a reduction in oxygen production, decrease in the pH maximum and gradual stabilization of the system.

water less than a millimeter thick (for example, with their help one can find a cold film on the surface induced by water evaporation). The oxygen sensors that are a galvanized cell made of two electrodes (silver--cathode and lead--anode) immersed in a solution of alkali cannot be made small enough. In addition, the oxygen near the sensor is rapidly consumed, and its constant influx is needed, therefore it is necessary to install the sensors on mobile poles. Thus, the



Pole with Thermal Sensors to Measure Temperature at Different Depths

area of disturbances created by the oxygen sensor is great as compared to the area of disturbances created by the temperature sensor. Although our sampler is significantly better than a bathometer, it also introduces strong disturbances since during the taking of samples 500-800 ml of water are suctioned off.

The ecological experiment we described lasted about a year. The lamps were turned on for the entire experiment. This made it possible to simplify the interpretation of the findings, since the question of diurnal changes in /75
the parameters was removed.

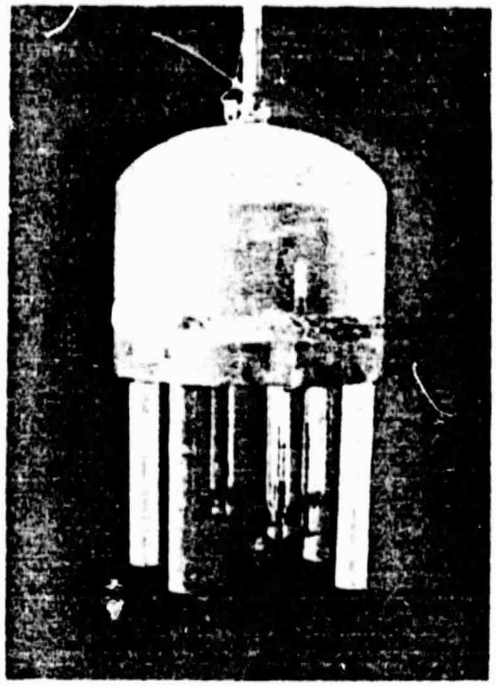
In the beginning of the experiment all the indices were uniform regardless of depth. The water was supersaturated with oxygen, its concentration reached 120% of the equilibrium value, with a temperature of 20° it was 11 mg/l. Nitrate (KNO_3) and potassium phosphate (KH_2PO_4) were added to the water. Heating by the lamps of the surface layer led fairly rapidly to formation of a stable stratification with respect to the vertical. The concentration of oxygen in the upper layer was reduced due to the fact that the solubility of the molecular oxygen drops with an increase in temperature.

Roughly in two weeks in the basin algae were added (chlorella). In a week after the entrance of the algae due to intensive photosynthesis at a depth of 40 cm the maximum content of oxygen was observed (up to 222%). The maximum pH (8.4) was located somewhat higher, at a depth of 20 cm. Evidently, this is a result of two processes: impoverishment of the upper layer of CO_2 due to reduction in its solubility with an increase in temperature and utilization of CO_2 in the process of photosynthesis. In nature, (for example, in the Mozhayskiy reservoir) the surface layer to a depth of 1-2 m is usually mixed, and there the maximums of oxygen and pH coincide with depth.

In 1.5 months after the start of the experiment Daphnia were placed into the basin; they feed on chlorella. The balance between the production of oxygen by photosynthesis and the consumption of oxygen for respiration of the Daphnia and oxidation of the organic substance was disrupted. The oxygen concentration in the upper layer began to drop drastically, and in 20 days oxygen supersaturation was no longer observed. The concentration of oxygen in the upper meter layer was just below 100%, which indicated the dominant role of the zooplankton.

In the last phase of the experiment such a production-destruction equilibrium was formed where an insignificant quantity of oxygen released during photosynthesis was immediately consumed for respiration and oxidation of organic residues falling out of all links in the food chain (bacteria, phyto- and zooplankton). Impoverishment was noted of the surface layer (0-60 cm) of all forms of nitrogen: there was a sharp reduction in the concentration of nitrates, nitrites appeared whose concentration was increased depending on depth.

Thus, the processes occurring in the basin simulated well the analogous processes in natural reservoirs. The studies conducted in the basin indicated the great potentialities of the Etekos unit: the experiment can be repeated, the conditions can be controlled, the measurements can be made in considerable more detail than in nature. In developing these studies one can obtain the necessary coefficients for compilation of a mathematical model of water biocenosis. Construction of such a model will permit control of the hydrochemical and hydrobiological pattern of reservoirs, and consequently, control and prediction of the water quality. This system can be useful for working out and comparing different types of techniques



Mobile Probe for Measuring Temperature, pH and O_2

proposed for monitoring the environment. Knowledge of the details of the production-destruction process is necessary in controlling synthesis of organic substances in the photosynthetic layer in order to more efficiently use solar energy. Acceleration of the turnover of organic substance in such an optimized ecosystem (due to reduction in the number of trophic levels) will make it possible to accumulate a considerable quantity of organic carbon in the bottom deposits. Thus, one can obtain a biochemical energy source in which the appropriate bottom microorganisms will break down the organic substance into methane and CO_2. As a result solar energy is transformed into a convenient fuel--methane. Nature provides us with finished samples of such a fuel element--this is release of methane from the bottom silts of eutrophic reservoirs and stagnant reservoirs. The deep-water lake Kivu in Central Africa is already being used as a source of gas. Its water contains 60 billion m^3 of methane in the dissolved form.

Recommended Literature

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