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DYNAMIC PARAMETERS OF ISSYK-KUL LAKE

Abstract. The results of experimental research of variable parameters of Issyk-Kul are presented in this paper. This paper presents the results of field studies and the results of numerical calculations of the changing biogenic parameters of lake Issyk-Kul. The developed mathematical model of the dynamics of the biomass of phytoplankton in built methods for evaluation of chlorophyll content, given its distribution and depth depending on the different cases of light penetration. Based on the processing of satellite images of lake Issyk Kul in different ranges, data on the increase in the area of biogenic materials on the surface of lake Issyk Kul were obtained for the first time.

Key word: Issyk-kul lake, phytoplankton, biogenic substance, GIS-technologies, chlorophyll, light absorption.

ИССЛЕДОВАНИЯ ДИНАМИЧЕСКИХ ПАРАМЕТРОВ ОЗЕРА ИССЫК-КУЛЬ

Аннотация. В данной работе представлены результаты натурных исследований и результаты численных расчетов, изменяющихся биогенных параметров озера Иссык-Куль. Разработанные математические модели динамики биомасс фитопланктона. Построены способы оценки содержания хлорофилла с учетом его распределения по глубине в зависимости от проникновения света. На основе обработки спутниковых снимков озера Иссык Куль в различных диапазонах впервые получены данные об увеличение площадей биогенных материалов на поверхности озера Иссык-Куль.

Ключевые слова: озеро Иссык-Куль, фитопланктон, биогенные вещества, ГИС-технологии, хлорофилл, абсорбция света.

ЫСЫК-КӨЛ КӨЛҮНҮН ДИНАМИКАЛЫК ПАРАМЕТРЛЕРИН ИЗИЛДӨӨ

Аннотация. Бул макалада Ысык-көл көлүнүн биогендик параметрлеринин өзгөрүшүндөгү сандык эсептөөлөрдүн жана натурдук изилдөөлөрдүн жыйынтыктары келтирилди. Фитопланктондун биомассасынын динамикасынын математикалык модели иштелип чыкты, хлорофиллдин маңызын баалоо ыкмасы, анын жарыктын кирүү тереңдигине жараша таралышы келтирилди. Ар кандай диапазондордо Ысык-көлдүн спутниктен алынган сүрөттөрдү карап чыгуунун негизинде биринчи жолу көл бетиндеги биогендик материалдардын аянты чоңоюшу алынды.

Негизги сөздөр. Ысык-көл көлү, фитопланктон, биогендик заттар, ГИС-технология, хлорофилл, жарыктын абсорбциясы.

Issyk-Kul lake is one of the largest mountain lakes in the world. It is located in the Issyk-Kul hollow in the Northern Tien Shan between 76°05 and 79°12 east longitude and 41°51 and 42°56 north latitude. The level of the lake lies at an altitude of 1606.9 m above sea level. The length of the lake is 178 km, the maximum width is 60.1 km, the area is 6236 km^2, the maximum depth is 668 m, the average depth is 278.4 m [1], and the volume of water is 1738 km^3. The lake is elongated in the latitudinal direction and is surrounded on all sides by high mountain ranges: from the south Terskey Ala-Too (maximum height 5,280 m, average – 4,290 m), from the north – Kungei Ala-Too (maximum height 4,770 m, average – 4,200 m) .

The lake is non-freezing, the temperature of the upper layers of water in January is 4–6°, February is 3–5°, in March it is 4–5°, in April it is 7.5–8.5°, in May it is 9–11°, in June – 14–17°, in July – 18–22° (up to 24°), in August – 17–19°, in September – 13–15°, in October – 11–13°, in November – 7–9°, December – 6–8° [2]. At a depth of 25 meters in August, the water temperature in the central (deepest part of the lake) is about +8o, closer to the coast – 12–14 o. At depths above 500 meters, the water temperature throughout the year is kept within 3.6–4.2°C

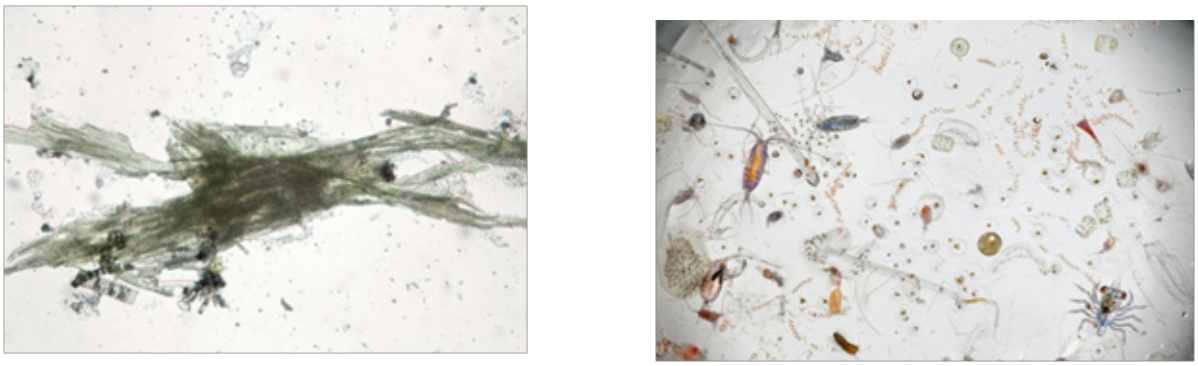


Fig.1. Different types of phytoplankton/2/.

Experimental studies of the state of phytoplankton of Issyk Kul lake have been carried out since 1996 and the results of studies have been published in various publications, for example in /2–7/.

More than 100 species of algae were found in the phytoplankton of the lake, among which the greatest species diversity falls within the group of blue-green (Cyanophyta), diatom (Bacillariophyta) and green (Chlorophyta) algae. Among the blue-green algae mass species are Merismopedia punetata Megen, M.tenuissima Lemm., Yloecapsa varia (A.Br.) Hollerb., Y. Minor (Kötz.) Hollerb., Microcystis pulverea (Wood.) Forti. et al. (Table 1), among diatoms Cyclotella meneghiniana Kütz., C. caspia Yrun., C. ocellata Pant. et al., among greens representatives of protococcal algae predominate (Oocystis issykkulica Kulumb,O. Borgei Snow., O. Pelgica Lemm., O. Solitaria wittarock, O. Parva W.et.W., Dictiosphaerium pulchellum Wood. var pulchellum, etc. These groups of algae make up over 95% of the species composition and phytoplankton biomass. The presence of phytoplankton at great depths is associated with the active circulation of the water masses of Issyk-Kul.

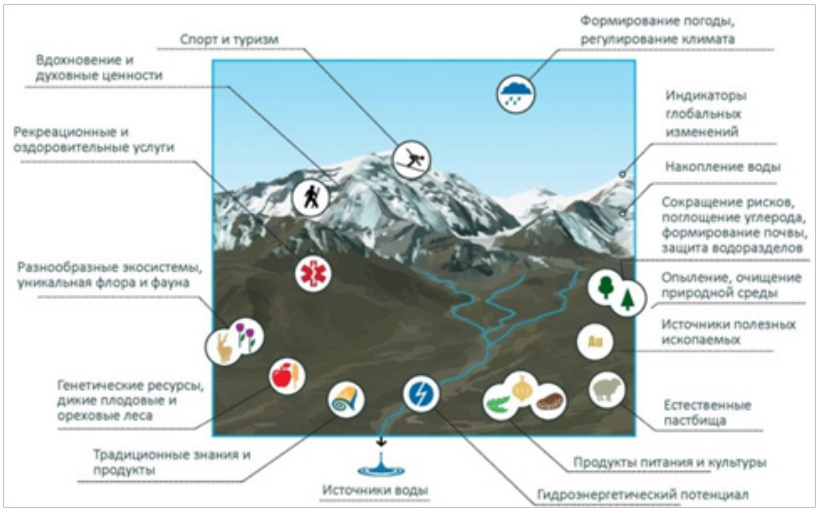


Fig.2. Scheme of natural, environmental and man-made risks /1,2 /

Transparency in the central part of the lake in winter is on average 24–25 m, in the summer 14–16 m; in the coastal zone, respectively, 11–18 m and 3–8 m. The maximum transparency of water up to 40–45 meters is observed in the winter in the center of the lake. In bays and shallows, it decreases due to phytoplankton and zooplankton and mineral particles, especially in the mouths of large rivers to 0.5–1 meters. Issyk-Kul water is slightly saline, the total water salinity is about 5.97 mg / l, which is 5.5 times less than the salinity of sea water. In the zone of the confluence of large rivers, water salinity decreases to 2–2.5 mg / l. Issyk-Kul has a chloride-sulphate-sodium-magnesium type of mineralization: Cl content 0.63–1.60 g / l, Ca – 0.08–0.12 g / l, N (+ K) – 0.65 – 1.54 g / l, Mg – 0.11–0.29 g / l, $SO4^{--}$ 0.83–2.10 g / l [1–5]. Despite the great depths, the mineralization of water vertically and horizontally is very heterogeneous, which is explained by water currents and the good miscibility of the water mass. Issyk-Kul water has an alkaline reaction – pH – 8.0–8.6. The oxygen content in the upper layers of water is 6-6.5 ml / l, at a depth of 50 meters – up to 7 ml/l, in calm backwaters and inlets the oxygen content can reach 10–14 ml/l. Biogenic elements necessary for the development of phytoplankton aquatic vegetation in the water of Issyk-Kul is very small. More of them are contained in the surface waters of bays and backwaters: phosphorus up to 2–5 mg / m3, nitrates 0.5–1.6 mg / m3, ammonium nitrogen – 4.8–7.8 mg / m3. The content of trace elements in water mg / l: Fe-11.00; Br-1.74; J-0.04; Mo-0.05; Ag-0,002; Cu-0.0023; Zn-0.0475; Ni-0.001 [1,2].

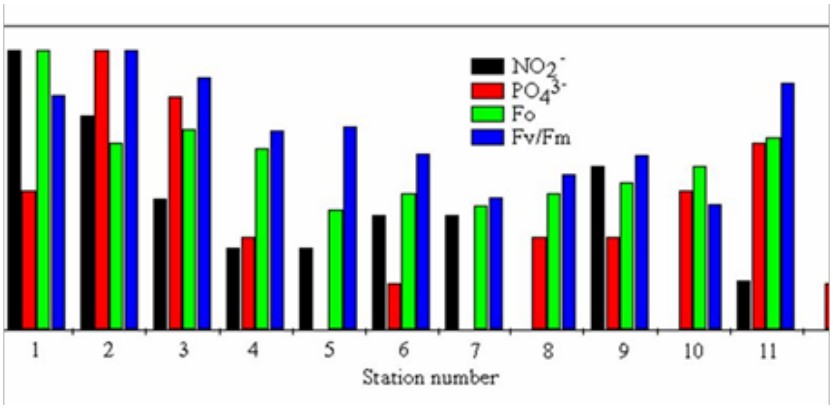
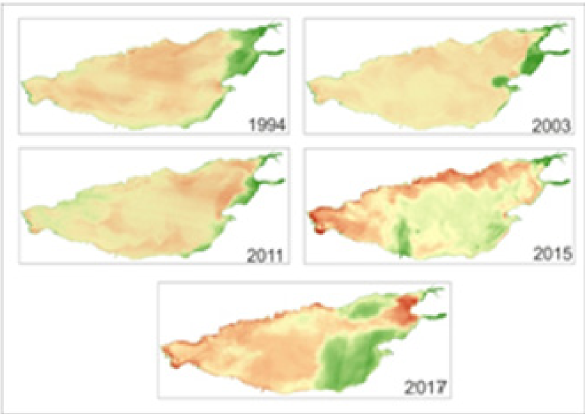
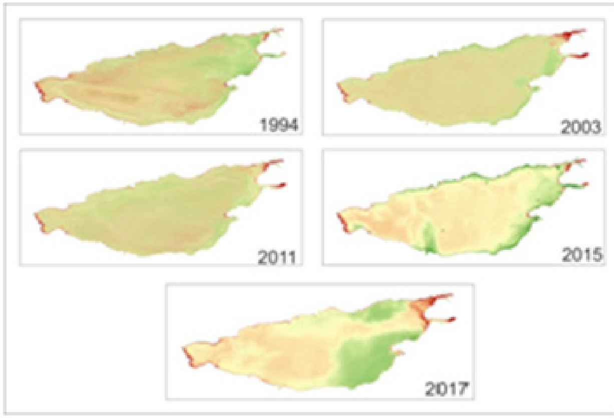


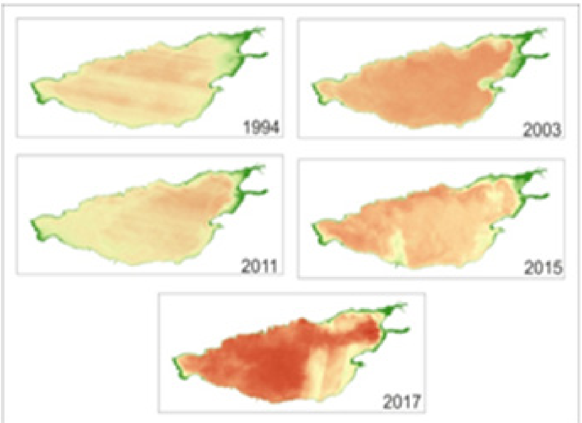
Fig.3. Distribution of parameters of the fluorescence Fo (Chl *) and Fv / Fm, and the concentration of inorganic nitrogen and phosphate along the coast of Karakol-Tamga Issyk Kul lake

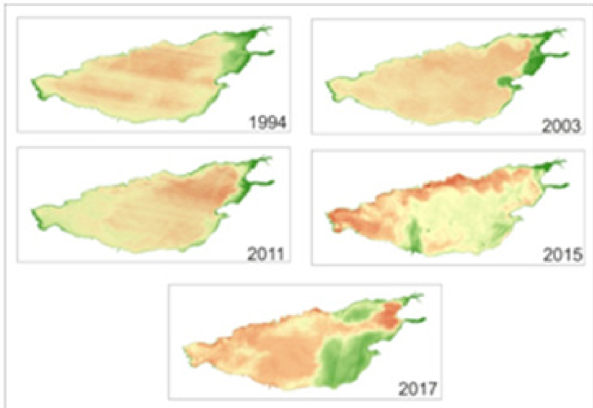
Due to the lack of biogenic elements, the phytoplankton of Issyk-Kul lake is developed much weaker than, for example, in such large lakes as Ladoga, Onega, Baikal, etc.

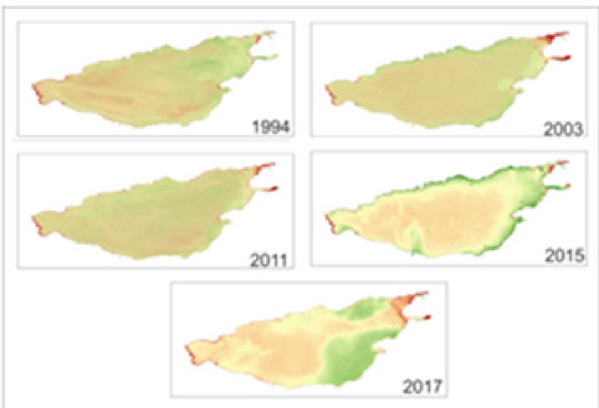
Despite the relatively high abundance of phytoplankton, its biomass is relatively small, which is explained by the small size of algae. The highest phytoplankton biomass in the water layer up to 50 m is observed in January-February (16–33 mg / m^3) and the greatest in May-June (273–284 mg / m^3), followed by its decrease [2.5].

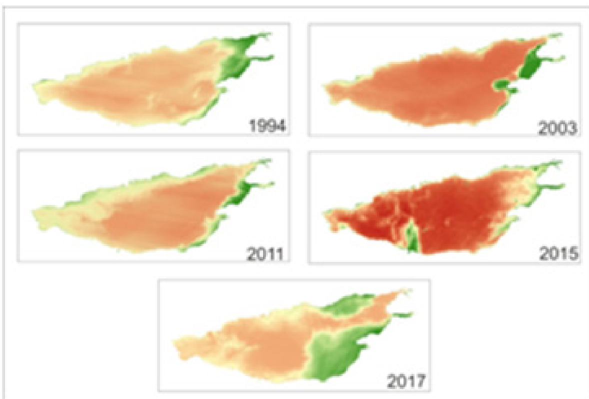












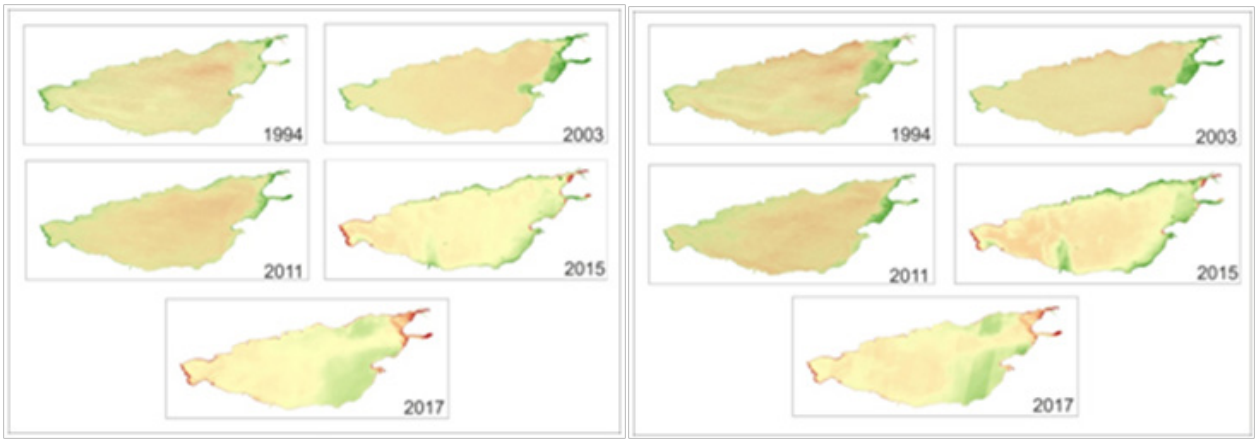


Fig. 4. Satellite images of Issyk Kul lake in various ranges /5 /.

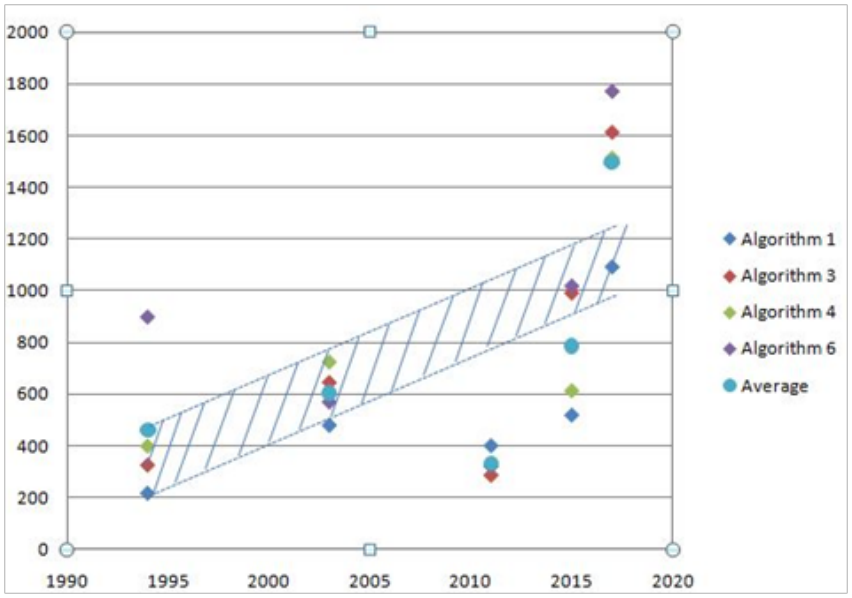


Fig. 5. Increase in nutrient areas /4/.

On the basis of the considered images, it can be concluded that the main processes of transfer of suspended material and its maximum concentrations to the coastal part of the lake, the central part of the lake is slightly affected by these processes. For the first time, data were obtained on the increase with time of the value of occupied areas of biogenic materials.

The use of mathematical models allows us to make the most of the available information on phytoplankton. We restore the distribution of chlorophyll using a mathematical model of phytoplankton functioning in the vertical column of water in a reservoir. Chlorophyll contained in phytoplankton, provides the processes of photosynthesis and the production of biomass.

The obtained estimates of the chlorophyll content in the reservoir can be used to assess the primary production of the aquatic ecosystem, which determines the biological productivity of the entire ecosystem, as well as for solving other problems.

The properties of the model of a system of mathematical equations on the functioning of phytoplankton in a vertical column of water were investigated in the work [4].

The concentration of chlorophyll generally decreases in the direction from the coast. This happens synchronously with the change in surface temperature. These data were used to analyze the dynamics of chlorophyll content. The numerical values used for most of the parameters of the model from the literature. The adjustment of the model [2,5] was made on the basis of experimental data [2–3].

To work with the model, tests of the mathematical method, namely the two-stage Runge-Kutta method, were initially carried out. The solution of the Kolmogorov-Petrovsky-Piskunov equation was tested, which is similar to the equation of the model under consideration. It was concluded that in this case the two-step Runge-Kutta method gives a better approximation compared to the explicit scheme. This method was used in the algorithm for solving the system of equations of the model under consideration. To obtain preliminary numerical calculations, program code was written. An increase in the areas of biogenic substances leads to a change in the state of phytoplankton and chlorophyll, as shown by the preliminary results of numerical calculations (Fig. 5.6).

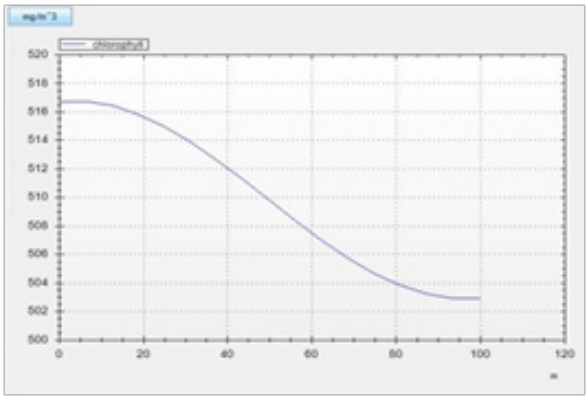


Fig.5. Calculated chlorophyll values (without the influence of biogenic materials).

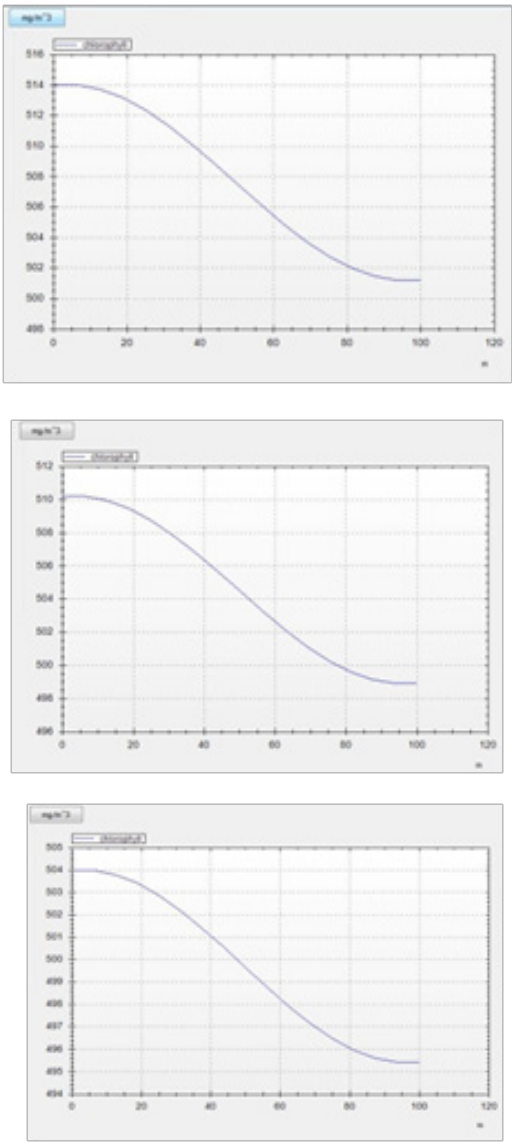


Fig.6. Estimated values of chlorophile at illumination 75%, 50% and 25%

Thus, the analysis of satellite images taken in certain years makes it possible to identify such features of the processes of circulation of lake water and the transfer of suspended and, accordingly, solute, which cannot be established by other methods with a sufficiently high accuracy. Obviously, based on the analysis of satellite images for different periods of time, it is possible to construct an objective model of circulation and transport, taking into account the probabilistic nature of these processes on a local scale against the background of a regional deterministic process. It also makes it possible to more accurately

predict the possible trajectories of the transfer of suspended and dissolved substances in lake waters and areas of accumulation of pollutants in the lake.

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