

MORPHOMETRIC PARAMETER FOR AN ESTIMATION OF A TROPHIC
STATUS OF LAKES

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A b s t r a c t. The ratio of lake perimeter to lake area is proposed for the estimation of a trophic status of lakes as an integral parameter. A trophic status of lakes located on territory of the Shatsk National Park is being analyzed. Advantages of this parameter are confirmed by comparison with other parameters (Carlson index, chlorophyll index, oxygen concentration). They are the following: simplicity of determination (from the mapping documents), stability to short-term changes of meteorological conditions, possibility of application at the development of a strategy of lake treatment.

K e y w o r d s: ecosystem, lake, trophic status, morphometric parameter, Carlson's indexes

INTRODUCTION

For an estimation of a trophic status of a water ecosystem the Carlsons indexes on a transparency, chlorophyll "a", phosphorus, the measurement of oxygen concentration and so forth are usually used [3,7]. These parameters depend essentially on short-term meteorological and other spatial-temporary changes in lake systems, techniques and conditions of their measurement (for example, the measurement of a transparency is influenced by light exposure). They do not always completely, comprehensively and authentically display a trophic status of a water ecosystem. In addition for an estimation of a trophic status of lakes the various parameters should be frequently and repeatedly measured and statistically processed. That is not practical, long-term and is also an expensive process. Besides, each of the listed parameters displays the influence only of one or several partial factors, which result to eutrophication. Together with it, an eutrophication is a many-sided process, which depends on the cumulative action of many factors and, accordingly, is

not shown equally through the change of various observable parameters. Therefore, the problem of the development of an integral criterion for the estimation of a trophic status of water ecosystems is very urgent [1,5].

INTEGRAL MORPHOMETRIC PARAMETER

In this connection, in the present work a new integrated parameter for an estimation of a trophic status of lakes and their classification – relation of perimeter to the area of lake is offered:

$$\rho = \frac{L}{S} \quad (1)$$

where L – perimeter of a lake, which area of water mirror depends from “irregularity” of a coastal line, S – the area of water mirror.

The given parameter well displays the cumulative influence of the various factors on eutrophication of a lake. It is known, that for classification of lakes for trophic status the intensity of formation of primary production is usually used. This parameter is determined by the intensity of photosynthesis and depends on the concentration of biogenic substances (compounds of phosphorus and nitrogen). The concentration of biogenic substances depends on many factors, basic among which is an intensity of inflow of these substances from a coastal zone and volume of water weight, in which these substances are dissolved. And with an increase of the perimeter of a lake the quantity of biogenic substances, which acts in this process, grows.

On the other hand, the concentration of biogenic substances decreases with increase of volume of water weight, in which biogenic substances are dissolved. This volume of water weight is proportional to the product of the area of water mirror of the lake on the depth of hashing. Thus, concentration of biogenic substances is reciprocally proportional to the area of water mirror. Therefore use of the relation of perimeter of a lake to its area, as an integral parameter, for an estimation of a trophic status of a lake is natural. For the benefit of it that fact also testifies, that eutrophication begins with the occurrence of gulfs, and it, in turn, results in an increase of a coastal line, which is shown in the change of the offered integral parameter and testifies that this parameter displays clearly the dynamics of the eutrophication process.

The quantity of biogenic substances, which acts in a lake as a result of drains, depends on the loading of coast (industrial infrastructure, agricultural grounds and

so forth). This fact is possible to take into account, having presented the factor of the form as:

$$\rho = \frac{\int \omega(x) dx}{S^{(L)}}, \quad (2)$$

where $\omega(x)$ – weight factor of inflow of biogenic substances, which takes into account the presence of objects of pollution on the coast. At $\omega(x) = 1$ (the identical influence of all coastal lines) from the relation (2) follows the relation (1).

For determination of regions of lake, which are subject strengthened to eutrophication, it is possible to use local values of the factor of the form (2), which correspond to the certain region of the perimeter. The increased values of the factor of the form testify to a menacing influence on the appropriate region and about the necessity of the acceptance of the safety decisions.

Let us note, that, a coastal line – typical example of fractal structures [4,8]. It is known [4], that the parameter of fractal dimension of a coastal line can be the characteristic of a region. Ratios of perimeter and area such as:

$$\rho_D = \frac{[L(\delta)]^{1/D}}{[S(\delta)]^{1/2}}, \quad (3)$$

(δ – length of the standard of measurement, L – perimeter, S – area, D – fractal dimension) were investigated by Maldebrot [4] at a choice of parameters, which would characterize similarity of islands and clouds.

DISCUSSION

Use of parameter ρ is of interest also at a mathematical modeling of a lake ecosystem. Such modeling is usually carried out with the purpose of studying and forecasting of the dynamics of processes which occur in these ecosystems. For this purpose the equation of balance for biogenic substances, phytoplankton and animal plankton are being formed in the form of system of the differential equations in a normal form [2]. These equations can be generated so that they contain two types components: components, which are proportional to length L of a coastal line, and components, which are proportional to area of water mirror.

These components in the equations of balance, as a rule, will display actions of opposite directions and will have opposite signs (for example, components, which

are proportional to L – positive, and components, which are proportional to S – negative). Their joint action will result in the balance of a system.

The algebraic equations, which one can receive from the differential equations that have been written down in a normal form, by equating the right parts with zero will determine the situation of balance [6]. These situations of balance will be functions of parameter ρ . Thus, the structure of mathematical model as the differential equations with the right parts, which are the sum of two sets of components, proportional to L and S , results that dynamics of processes, conditions of balance and the equilibrium statuses are functions of parameter ρ (1). Such presentation of variables of status and equilibrium statuses, as functions of parameter ρ , can be useful for research and forecasting of processes of dynamics of lake systems on the basis of the integral characteristics, if the detailed information is not completely known.

As an example of the use of the offered criterion we shall consider some results of the analysis of long-term supervisions of a status of lakes of the Shatsk National Natural Park (ShNNP) [3]. In Table I, the Carlson's indexes on chlorophyll "*Chl*" and on transparency *ISD*, and also the offered form factor for some lakes on territory of the ShNNP are given. They demonstrate the application of different parameters, including parameter ρ , for an estimation of a trophic status of lakes.

Table I. The Carlson's indexes and the form factor for the Shatsk lakes

Lake	Carlson's indexes		Form factor
	<i>Ichl</i>	<i>ISD</i>	
Svityaz	30	39	1.1
Pulemecke	48	62	1.0
Lyucimer	54	60	1.9
Luki	38	63	3.1
Pisochne	35	39	2.9
Ostriv'yanske	53	56	3.7
Krymno	41	54	4.2
Peremut	36	39	3.3
Chorne	55	73	4.6
Sominec	45	54	7.5
Linovec	59	-	16.7

The data given in Table I, allow classifying of lakes on a trophic status on the basis of different parameters. On the basis of only one of the characteristics of lake system the classification presentations will be different. Therefore determination of a trophic status on the basis of separate parameters is not always correct. The

trophic status of a lake is formed as a result of the influence of many various processes on a physical nature. Therefore for determination of a trophic status the set of many characteristics is necessary to consider which display different processes.

On the other hand, the trophic status is shown in a final case in the attributes of the ageing of a lake, one of which is the formation of gulfs, which increases the length of a coastal line. Therefore use of those attributes, which display the cumulative influence of different processes, is natural for an estimation of a trophic status of a lake. One of such parameters also is the factor of the form $\rho(1)$. The deviation of parameter ρ for the lake Pulemecke is explained by intensive anthropogenic loading on this lake in the given time and the late process of aging (in virtue of inertia).

The analysis and comparison of the basic characteristics of the Shatsk lakes allows one to classify the Shack National Park lakes on a degree of increasing of degradation on a number of groups [3]:

- the 1st group – lake Svityaz;
- the 2nd group – lakes PISOCHNE, PEREMUT, PULEMECKE, LYUCIMER;
- the 3rd group – lakes Krymno, Luki, Ostrivvanske;
- the 4th group – lakes Dovege, Plotychchya, Chorne;
- the 5th group – lake Linovec, Sominec, Klymivske.

The researchers carried out such classification on the basis of sufficient complete and many-sided limnological information on the status of lakes and its complex rating. It displays similar processes in lakes, which are included into the given group and, obviously, testifies that for their improvement it is necessary to take identical measures. On the basis of separate parameters (for example, the Carlson's indexes on chlorophyll "a" or transparency) the classification of lakes will be another, and, it is possible, unilateral (incomplete). At the same time the given classification is well coordinated with values of the form factor ρ (see for comparison last column of the table), that testifies to sufficient completeness of display of the information about the status of lakes on the basis of the offered parameter $\rho(1)$.

Advantages of the use of the offered integral parameter are the following: simplicity of determination (from cartographical materials – topographical maps, plans, aerial photographs), information density, and stability to short-term changes of meteorological and other spatial-temporary conditions. The practical value of the offered parameter entails that this parameter focuses on concrete practical actions on the improvement of lakes (for example, reduction of length of a coastal line by overlapping of gulfs) etc.

CONCLUSION

Analysis of a trophic status of the Shatsk lakes and comparison of various parameters, which are used for an estimation of a trophic status (Carlson's indexes on a transparency, chlorophyll "a", the concentration of oxygen etc.) confirmed that new offered parameter clearly displays the trophic status of lakes. Use of the offered integral parameter for an estimation of a trophic status of lakes does not exclude an opportunity of further (if it is necessary) specifications of a status of water ecosystems by other methods.

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MORFOMETRYCZNY PARAMETR DO OCENY STANU TROFICZNEGO JEZIOR

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S t r e s z c z e n i e. Zaproponowano zintegrowany parametr do oceny stanu troficzności jezior. Tym parametrem jest stosunek obwodu do powierzchni lustra wody jeziora. Analiza troficzności jezior na terenie Szackiego Parku Narodowego wykazała przydatność proponowanego parametru.

S ł o w a k l u c z o w e: ekosystem, jezioro, parametr morfometryczny, indeksy Carlsona