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DEPARTMENT OF CLIMATOLOGY, HYDROLOGY AND GEOMORPHOLOGY

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HYDRO-GEOGRAPHIC CHARACTERISTICS OF THE LAKES IN RILA MOUNTAIN

ABSTRACT

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The dissertation consists of 163 pages of main text, divided into an Introduction and three chapters, including: 54 tables, 63 figures, a bibliography of 132 titles - 45 in Cyrillic and 87 titles in English. An appendix is included at the end.

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The public defense of the dissertation work will take place at a meeting of the scientific jury on _____ 2023 at ___ o'clock in Sofia University "St. Kliment Ohridski".

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INTRODUCTION

Relevance of the topic

Lakes - natural reservoirs with slow water exchange and without direct connection to the sea (ocean), are an element of the hydrographic network and the global hydrological system with participation in the global and local water cycle and water balance. The first morphometric analyzes of lakes began in 1787 with determining the depths of some lakes in England. Over the past century, a number of studies have been based on data from purposefully conducted expeditions.

Modern scientific research examines lakes as geosystems – a component of natural landscapes, which, together with lake watersheds, form a complex limnosystem with interaction of hydrological, hydrophysical, hydrochemical, hydrobiological and other processes. Among the lakes, an important place is occupied by high-mountain reservoirs, and especially glacial lakes - part of the cryosphere and natural landscapes in large areas of the northern parts of Europe, Asia, and North America.

The interest in studying lakes globally and regionally is as a result of the fresh water they contain (Haeberli et al., 2016), because of their influence on the balance of the ice mass (Benn et al., 2007, Röhl, 2008, Loriaux & Casassa , 2013 , Carrivick et al., 2016, Miles et al., 2016) , because of the possible occurrence of catastrophic floods (Haeberli et al., 1989 , Reynolds, 1992, Clague & Evans, 2000, Breien et al., 2008, Westoby et al., 2014, Carrivick & Tweed, 2016), which is considered the largest and most extensive glacial hazard in terms of a possible disaster and damage (UNEP, 2007).

Research studies of glacial lakes have also been linked to long-term climate change (Richardson & Reynolds, 2000, Gardelle et al., 2011, Emmer et al., 2016, etc.) and global warming in recent decades (Smol, 2012, Nie et al., 2013, Carrivick & Quincey, 2014, Wang et al., 2014, O'Reilly et al., 2015, Zhang et al., 2015, etc.). A number of studies have found increases in lake area and volume, for example in Alaska (Pelto et al., 2013), West Greenland (Carrivick & Quincey, 2014), Central Asia and other parts of the world. Magnusson et al. (1990) note that there has been an increase in research on lakes on a regional scale in the last few decades.

One of the subjects of regional research is the morphometric characteristics of lakes (Buckel et al., 2018). The morphometric indicators - length, width, length of the shoreline (lake perimeter), area of the water mirror, maximum and average depth) are used for balance assessments, for dynamic, thermal, hydrochemical and biochemical processes in water bodies. The morphological characteristics of the origin of lake reservoirs, together with their shape and size, largely determine their further evolution and duration of existence.

The first official data on some morphometric parameters of lakes in the Rila Mountains were given by J. Tsviich (1897) and Zh. Radev (1920). Siniovski (2015) and Tsvetkova (2019) illustrate the early study of the lakes (specifically (the Musalensky Lakes group) through the map of J. Tsviych (1897) and a scheme drawn on a Russian topographical map. Information about the lakes in the first decades of the 20th century . was given by Deliradev (1928, 1932). Valuable morphometric data for the lakes in Rila are contained in the studies in the 1930s and 1940s by Vulkanov (1932a, 1932b, 1938).

In the 1940s and 1950s, field measurements of the Seven Rila Lakes were carried out by Paunov (1940), and later by the alpine expeditions of the "Akademik" DSO (cited in the Lakes of Bulgaria, 1964). The limnosystems in Rila were also studied by Vodenicharov (1960, 1962). The above-mentioned studies, as well as purposefully carried out measurements in the 60s and 70s of the 20th century, were summarized in "The Lakes of Bulgaria" (1964).

The book describes in varying degrees of detail the morphometric indicators, as well as the thermal stratification, the hydrochemical features and the biological specificity of the lake reservoirs. In "The Lakes of Bulgaria" (1964), for 140 lakes in Rila, data is published about the height above sea level, the area of the lake catchments and the water mirror, for 89 lake reservoirs information about the lake water volume is presented, and for 54 lakes - the maximum depth .

The published data provide a basis for comparison with some of the results in the present study, which in turn is a prerequisite for tracking the evolution of the lakes on the one hand and for the analysis of climate changes in the high mountain hypsometric belts over the last 60 years.

The most recent morphometric data for lakes in Rila were published in 2014 for the group of Musala Lakes (Aleksandrov and Stoyanova, 2014). A digital model and bathymetric map of Karakashevo Lake was obtained based on field measurements with an echolot (on a special boat) and GIS (Aleksandrov and Stoyanova, 2014).

The lakes in Rila have been studied in different contexts: as geotopes by Tsvetkova (2016, 2019), in the studies of glacial forms by Jovan Tsvijch in (cited by Siniovski, 2015, Tsvetkova, 2019), Radev (1920), Ivanov (1954) , Glovnya (1956, 1962, 1968), Velchev (1999), on soil-geomorphological studies (Yanakiev, 1956), on geological studies (Petrusenko et al., 1966, Arnaudov, 2001), on hydrochemical (Botev, 2000) and hydrobiological analysis (Beshkova, 2000, Hristozova et al., 2004, Kalchev et al., 2004, Ognianova-Rumenova et al. 2017, etc.).

The object of research of the present work are the high mountain lakes, lake groups and lake systems in Rila mountain, and the **subject of research** - the geographical and hydrographic characteristics of the lake reservoirs in Rila.

Purpose and tasks
The aim of the dissertation is a morphometric description of the lakes and establishment of dependencies between morphometric indicators, identification of lake systems.

To achieve the set goal, the following tasks are **performed**:

- Analytical overview of the geographical characteristics, of the absolute and relative morphometric indicators, of the hydrophysical and hydrochemical characteristics of the lake reservoirs applied in the research studies
- Field observations, measurements of the morphometric parameters of lakes based on satellite images and calculation of the relative morphometric characteristics of the lakes.

- Establishing and analyzing statistically significant relationships between individual morphometric indicators

- Description of the lakes within the borders of Rila, by mountain divisions and river basins.

Territorial scope of the study This part of the dissertation presents brief information about the glaciation in Rila, about the climate, hydrographic structure and hydrological processes.

Limitations of the study
Limitations in the development of the present dissertation work are set by:

a) the possibility of direct observations and measurements to be carried out only in the summer months, because in the winter the lakes freeze and the ice and snow remain for a long time, and do not allow field measurements; b) the purchase of a sonar in the second year of the three-year period for the development of the dissertation topic; c) the location of some lakes in hard-to-reach places, which is why the description of many high-mountain lakes includes only basic characteristics

related to the area, length and width of the water mirror; the lack of hydrometric monitoring does not allow for the accurate calculation of the water balance elements and tracking the hydrological regime in an annual and multi-year aspect.

CHAPTER ONE: THEORETICAL BASIS AND RESEARCH METHODS

1.1. Theoretical basis of the study

The theoretical basis of the present dissertation research is the description of the lakes according to various characteristics - morphogenetic (origin of the lake basins), hydrographic, hydrological, hydrophysical, hydrochemical, hydrodynamic and hydrobiological, that are adopted in the scientific limnological literature. The review of scientific research shows that in most of the studies done, the measured and calculated characteristics for lakes are used to classify lake water bodies by one or more characteristics or to systematize knowledge on the one hand, and to reveal the diversity and uniqueness of lakes, on the other hand. The morphometric characteristics of the lakes are divided into two groups: data obtained from field measurements; data calculated from field survey data (Welch, 1948, Hutchinson 1957, Olson, 1960, Wetzel & Likens, 2000). From the first group are area, volume, maximum depth, length and width of the water mirror, length of the coastline. In the second group, the relative depth, the average width, the development of the coastline are the most important.

1.2. Research methods

Field observations and measurements, classification method and statistical methods (descriptive statistics, frequency and correlation analysis) are used in the present study.

1.2.1. Field observations and measurements. The own observations and measurements were made during the summer and autumn months of 2019–2022, when the lakes were not frozen and had a free water surface. The geographical characteristics were made through field observations with the watches: Suunto ambit 3 and Polar V800 Javier Gomez Noya, the technology of which allows precise description of the route, drawing polygons, measuring latitude and longitude, altitude. The depth of the lakes was determined using Trilachev Sonar Deeper (Fig. 1). The device has a measurement range of up to 90 m via GPS, can measure the temperature of lakes, as well as scan and create bathymetric maps, i.e. to show the topography of the lake bed. A specially adapted D11 RC Boat Fish Finder boat was used in part of the lake bottom measurement procedures, with the help of which even the most inaccessible points of the lakes are reached (Fig. 2). In 2021, filming was also done with a drone.

Фиг. 1. Deeper Smart Sonar Chirp+

F. 2. Boat D11 RC Boat Fish Finder

Of essential importance in the present work are the measurements with the tools of the Google Earth program (Google Earth Pro) on satellite images purchased by them.

A classification method was applied to determine classes (the accepted taxonomic unit) according to individual morphometric indicators.

The statistical methods in the present study were used in the general characterization of the lakes in Rila, as well as in the description of the lake groups. These include descriptive statistics, correlation analysis and cluster analysis. In the course of the work on the dissertation, the correlation analysis was applied to study the relationships and dependencies between some of the measured and calculated morphometric parameters. Pearson's simple linear correlation was used because the relationship between two quantities was being investigated.

In the present work, the following approach is adopted for the description of lakes in lake systems. A lake system is a group of lake bodies that are connected to each other by water streams. The basis for such a distinction is given by the essence (definition) of the concept of system - elements that connect with each other and form a certain whole. In the specific case, the lakes, connected to each other by watercourses, function hydrologically in accordance with the degree of dependence on each other. A lake group is a collection of lakes developed in close proximity to each other, but without direct connection between them. All lake systems have been assigned names: for example "Dolna Vodnichalska", "Golsko Bachiiska" lake system, "Golemi Rybni" lake system, "Teodosievo Jendemska" lake system, etc., described in the second chapter of this dissertation work.

CHAPTER TWO: GENERAL CHARACTERISTICS OF THE LAKES IN RILLA MOUNTAIN

The present work describes geographically and morphometrically 173 lakes on the territory of the Rila Mountains. Most of the lake reservoirs, object of the present study, refer to the circus glacial lakes and are located in trough valleys individually, in lake systems or lake groups. The remaining lakes occupy depressions in tectonic disturbances (Lakes in Bulgaria, 1964).

2.1. Geographical description of the lakes in the Rila Mountains

Geographical coordinates. The lakes in Rila are located from north to south between 42.262º N. (Panicishte village) and 42.019º N. (Ez. Plitkoto), and from west to east - between 22.226º E. (Malko Gradinsko ez.) and 23.749º east. (Ez. Ravnichalsko). The largest number of lakes (73.2% of all investigated lakes in Rila) are concentrated between 42.119º N and 42.219 N.
Name of the lakes. From the conducted studies, it was established that a number of lakes in Rila do not have their own names, but are called First..., Second.... and so on (Lakes in Bulgaria, 1964). The name of some lakes reflects the hydrological and morphometric characteristics of the reservoir, other lakes bear the name of a neighboring peak, a third group of lakes reflects their attachment to the river basin in which they are located.In the present study, names of the following lakes are proposed: ez. Dodovo (from the Urdini lakes group) - after the village of Dodov; Visoko Urdino, due to its highest location in the Urdini Lakes group; the lakes Golyamo Karaomerichko, Sredno Karaomerichko, Malko Karaomerichko and Najme Karaomerichko from the group of Karaomerichki (Karaomerishki) lakes, named after the place in the lake group and the occupied area.
Lake groups, lake systems, single lakes. The present study identified 41 lake groups, 22 lake systems and 20 single lakes. The lake groups are composed of two to ten lake reservoirs, with a predominance of the lake groups, which include three lakes each (13 lake groups) and two lakes each (11 lake groups), or a total of 58.5% of all lake groups. Eight lake groups include four lakes, three lake groups – five lakes, one lake group – six lakes, three lake groups – seven lakes, one lake group – eight lakes and one lake group (Gornoprekorechki) – 10 lakes. The number of lake groups is relatively evenly distributed over the mountainous parts of Rila, with the largest number in Central Rila. The largest lake groups in terms of number of lakes are in Northwest Rila (Table 1).

Table 1
Number of lake groups and individual lakes by division in Rila mountain

Range	Single lakes	Number of lakes in a group							Total lake groups	
		2	3	4	5	6	7	8	Total	%
Northwest	6	2	6			1	1	2	12	29,3
Central	4	7	3	4	2		1		17	41,5
East	7	3	4	3	5		1		12	29,3
Souuthwes	3	–	–	–	–	–	–	–	–	–

In the Rila Mountains, 22 lake systems with a different number of lakes are identified - between two and seven lake reservoirs, connected to each other by water streams. Lakes from the Seven Rila Lakes, Popovokapski, Malomalovishki, Vodenicharski, Marichini, etc. lake groups are connected in a lake system. The most numerous are the lake systems composed of two lakes - e.g. the lake systems "Vodenicharska", "Golemi Ribni", "Golyamo Banenska", "Golsko Bachiiska", "Teodosievo Jendemska" and others. The most numerous are the lake systems composed of two lakes - e.g. the lake systems "Vodenicharska", "Golemi Ribni", "Golyamo Banenska", "Golsko Bachiiska", "Teodosievo Jendemska" and others. The distribution of the lake systems is relatively even across mountain divisions: in Northwestern Rila – 11 lake systems, in Central (Middle) Rila – eight lake systems, composed of two lake reservoirs; in Eastern Rila – three lake systems. Single lakes in Rila – 20. Most single lakes are located in the northwestern and eastern mountain divisions (table 1). Studies of the geographical distribution of lakes in Rila show an almost equal number of lakes in the North-Western part - 60 and in the Central part - 61 lakes, which makes up a total of 69.9% of all natural water bodies in the studied mountain (35.3% and 34 .7%, respectively in each of the two mountain sections). In Eastern Rila, 49 lakes have been developed (28.3% of all lakes), and in Southwestern Rila – three lakes (1.7% of the total number of lakes in Rila).

Elevation of lakes. The studies in the present work show that the lakes in Rila are located between 1381.0 m (Panichishte lake) and 2713.0 m (Ledeno Musalensko lake) with a concentration of almost half (41.7%) of them between 2300.0 and 2400.0 m. The altitude location of the lakes above 2000 m gives reason to designate them as the high mountain type of lakes (Aleksandrov & Stoyanova, 2014). The research shows that the largest number of lakes - 68 in number, representing 42.0% of all lake reservoirs in Rila, are located between 2300 and 2400 m, and the least in the hypsometric belts with a height of up to 2000 m (lakes Panichishte and Suhoto near Rila Monastery) and above 2700 m (Ledeno Musalensko).The number of lakes in the 2,200–2,300 m and 2,400–2,500 m altitude zones has the same relative share – 37 lake reservoirs. While the total area of the mountain continuously decreases with increasing altitude, the number of lakes and the area peak around 2400 m, which is related to the control of glacial dynamics on the occurrence of high mountain lakes and hypsometry, not area. The distribution of the number of lakes in Rila by altitudinal zones is also preserved in the separate parts of the mountain, with a higher relative share in Northwestern Rila (45.6% of all studied lakes), and a smaller one in Central Rila (41.7 %) and Eastern Rila (36.9% of all studied lakes).A similar distribution to that throughout the mountain shows the number of lakes in the altitude zones 2200–2300 m and 2400–2500 m in the North-Western and Central parts, but different in Eastern Rila, where 23.9% of all lakes are concentrated between 2200 and 2300 m, and between 2400 and 2500 m – 17.4% (Fig. 3).

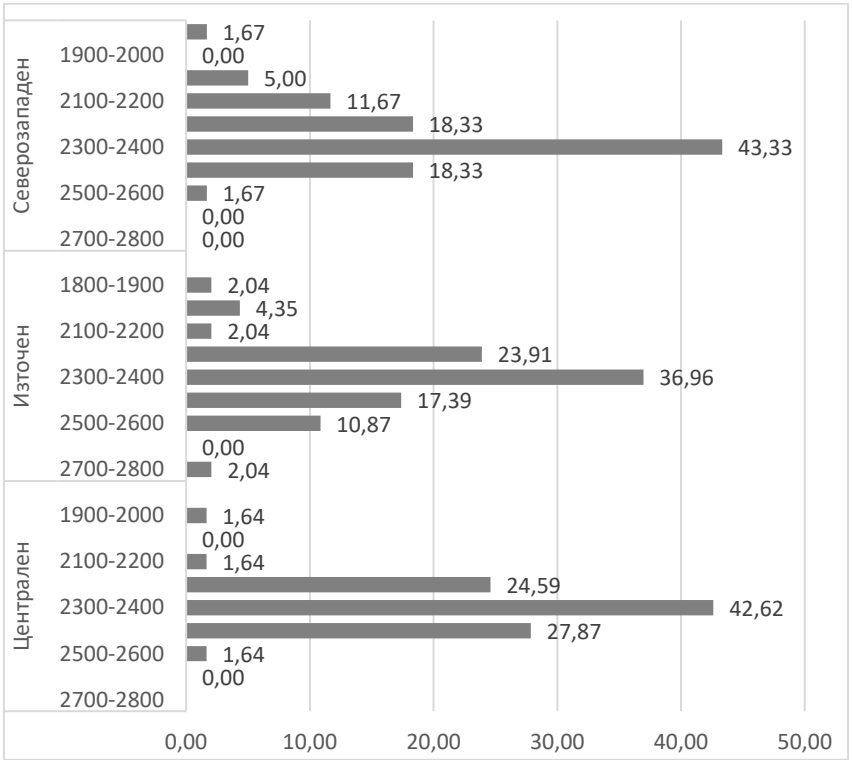


Fig. 3. Distribution of lakes by altitude and mountain shares

2.2. Morphometric description of the lakes

Area of the lakes. Lake reservoirs in the Rila Mountains have an area (F) of the water mirror between 0.05 ha (0.478 m2) - ez. at least Karaomerichko, and 25.7 ha (257,723 m2) – ez. Stinky -2 located in the central mountain section. The average area of the lakes in Rila is 1.53 ha, with square deviation (σ) – 2.93 and coefficient of variation (Cv) – 1.91 (table 2).

Table 2 Descriptive statistics of the area of lakes in Rila by area and shares

Area (km^2)	**Rila**	**Range**			
		NW	**Central**	**East**	**SW**
Mean	1.53	1.59	1.86	1.14	0.39
Median	0.53	0.69	0.50	0.43	0.42
Σ	2.93	2.39	4.03	1.78	0.18
A_s	4.95	5.15	4.67	3.47	-0.94
F_{max}	22.7	9.49	25.77	10.25	0.55
F_{min}	0.05	0.07	0.059	0.12	0.18
C_v	1.91	1.50	2.18	1.55	0.38

The analysis of the data from the descriptive statistics on the area of lakes by mountain divisions shows the smallest average area for lake reservoirs in Eastern Rila, and the largest average area of the lakes in Central Rila. The smallest fluctuations are between the areas of the largest and smallest area in the northwestern part of Rila. The distribution of lakes in Rila by area shows that 113 or 65.3% of all lakes have a surface of the water mirror up to 1.0 ha. The smallest is the group of lakes with an area of more than 9.0 ha, to which belong Smradlivo-2, Gorno Ribno, Ribno Yakorudsko, Babreka, Kalin-1 and Kalin-2 lakes. The distribution of the lakes by area up to 1.0 ha is approximately preserved also by mountain divisions. An exception is the central part of Rila, where among the smallest lakes, those with an area between 0.2 and 0.3 ha predominate, as well as the larger number of lakes in the northwestern and eastern parts with an area of 0.3 and 0.4 ha (Table 3).

Table 3. Distribution (%) of lakes with an area of up to 1.0 ha in Rila and its mountain divisions by area

Area (ha)	Rila	Rnage			
		NW	Central	East	SW
0-0.1	6.2	8.3	10.0		33
0.1-0.2	24.7	27.8	20.0	28.6	
0.2-0.3	15.9	8.3	25.0	14.3	
0.3-0.4	20.35	22.2	17.5	22.9	
0.4-0.5	7.1	2.8	7.5	11.4	33
0.5-0.6	5.3	5.6	5.0	2.9	33
0.6-0.7	4.4	11.1	2.5	2.9	
0.7-0.8	4.4	2.8	5.0	8.6	
0.8-0.9	7.1	8.3	7.5	5.7	
0.9-1.0	4.4	2.8	10.0	2.9	

The total lake area of the lakes by lake groups is between 0.25 ha for the Leevstanski lake group and 36.33 ha for the Seven Rila Lakes lake group. With the largest share - 23.8% in the total lake area (237.82 ha) of the lakes in Rila are the lake groups composed of three lakes, which are also the most numerous part compared to the other lake groups. With a similar relative share - 22.6% in the total lake area are the lake groups made up of seven lakes (Jendemski, Musalenski and Seven Rilski), as well as the lake groups made up of four lakes - 20.7%. The largest lake group - Gorno Prekorechki, consisting of 10 lake reservoirs, has a total area of 4.7 ha.

The distribution of non-lakes by area and altitude shows that the smallest lake reservoirs with an area of up to 1.0 ha are predominantly developed between 2200 and 2500 m and with the greatest concentration between 2300–2400 m (45 lake reservoirs out of a total of 109 or 41.3% of the lakes in this class) and less at altitudes between 2400 and 2500 m (30 lake bodies) and between 2200 and 2300 m (22 lake bodies out of a total of 109). A similar concentration of a large number of lakes of the same area in one altitudinal zone 2300–2400 m is observed for lakes with an area between 1.0 and 2.0 ha (Fig. 4).There is no regularity in the distribution of lakes in Rila by area and altitude - lakes with an area of , more than 2.0 ha are developed between 2100 and 2600 m. The distribution of the lakes by area (up to 1.0 ha) and altitude in the separate mountain parts is preserved as that for the reservoirs in the entire mountain, with the exception of Central Rila, in which the largest number of lake reservoirs with this area are evenly distributed between 2300– 2400 m and 2400–2500 m.

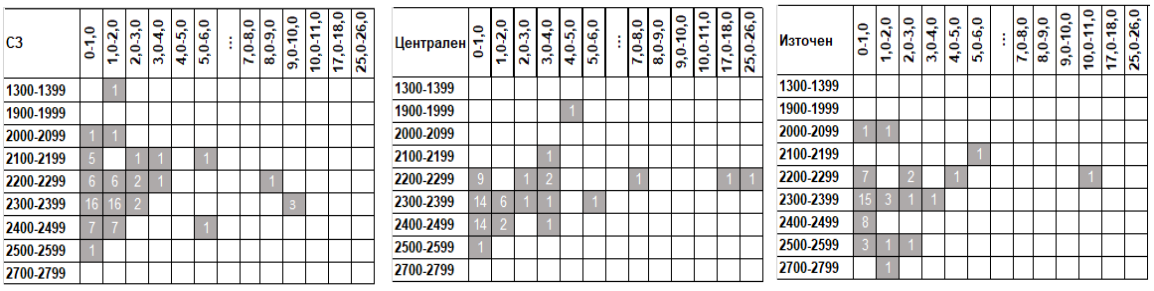


Fig. 4. Distribution (number) of lakes in Rila by area and altitude by mountain sections

The maximum depth. The maximum depth of the lakes in the Rila Mountains according to the data from "Lakes in Bulgaria" (1964) is within the limits of 1.0 m (Vtoro Malko Banensko lake and Smradlivo-3 lake) and 37.5 m (Okoto lake). The group of lake reservoirs with a maximum depth of up to 7.0 m is large, to which 72.7% of the lakes are included.

The smallest (10.9%) is the relative share of very shallow lakes; medium deep (29.2%), deep (21.8%) and very deep lakes (23.6%) have almost the same relative share. The relative share of the very deep lakes is higher than the relative share for the whole mountain in Eastern Rila and in the Central Mountain Division. All very shallow and shallow lakes are up to 2.0 ha in area, with the exception of ez. Potter (Big), which has an area of 5.6 ha. Medium deep lakes are included in all gradations in area up to 4.0 ha. Deep lakes are predominantly 2.0 to 4.0 ha in area.

Length of the lakes. The length of the water table (L) of the lakes in Rila is between 36.0 m (Malko Chervivo lake) and 876 m (Smradlivo lake 2) with an average value of 155.6 m (Table 4). Only the lakes in Central Rila have an average length greater than the average for the entire studied territory. The variations between the maximum and minimum values of the length of the water mirror are the largest at the lakes in the Central Mountain Division, and the smallest difference between the limit values of this morphometric indicator is in Southwestern Rila.

Table 4. Descriptive statistics of the length of lakes in Rila and by divisions

Length (m)	Rila	Range			
		NW	Central	East	SW
Mean	155.6	154.5	170.7	141.3	101.7
Median	113	123	115	104	112
σ	124.5	113.9	156.4	90.9	18.8
A_s	2.76	1.93	2.83	1.93	-1.73
L_{max}	876	611	876	486	113
L_{min}	36	37	36	50	80
C_v	0.80	0.73	0.91	0.64	0.15

Data on the simultaneous distribution of lakes by length class and area reveal an increase in their length with an increase in their area. All lakes with a very small length (up to 80 m), with a small length (between 80 and 113 m) and most lakes (59.0%) with an average length are included in the class of very small lakes (up to 1.0 ha). Less than (38.6%) refer to lakes with an area between 1.0 and 2.0 ha. Among the long lakes (between 187 and 398 m) with the largest share are those with an area between 2.0 and 3.0 ha. The very long lakes have an area of more than 7.0 ha (Table 5).

Table 5. Distribution of lakes (number) in Rila by length and area

Class	Area (ha)												
	0-1,0	1,0-2,0	2,0-3,0	3,0-4,0	4,0-5,0	5,0-6,0	…	7,0-8,0	8,0-9,0	9,0-10,0	10,0-11,0	17,0-18,0	25,0-26,0
Very small – under 80 m	44	–	–	–	–	–	–	–	–	–	–	–	–
Small – 80.1–113.0 m	43	–	–	–	–	–	–	–	–	–	–	–	–
Average – 113.1-187 m	26	17	1	–	–	–	–	–	–	–	–	–	–
Large – 187.1–398 m		8	12	8	2	4							
Very large – over 398,1 m							–	1	1	3	1	1	1

Width of lakes. The width of the water mirror (B) of the lakes in Rila is between 17.0 m (Malko Rezhepsko reservoir) and 390 m (Smradlivo-2 reservoir) with an average value of 95.9 m. The width has smaller fluctuations between the maximum and minimum value, which also shows the coefficient of variation of 0.71. Another difference compared to the length of the water mirror is a larger average value of the width of the lakes in the North-West Division than the average for Rila, and the smaller coefficients of variation compared to the length of the lakes (Table 6).

Table 6 Descriptive statistics of lakes by latitude in Rila and by mountain divisions

Width - (m)	Rila	Range			
		NW	Central	East	SW
Mean	95.9	103.0	94.9	89.6	54.3
Median	72.0	80.0	68.0	70.0	55.0
σ	68.8	73.4	73.3	57.8	14.0
A_s	1.63	1.45	1.87	1.21	-0.21
B_{max}	390.0	346.0	390.0	273.0	68.0
B_{min}	17.0	26.0	17.0	23.0	40,0
C_v	0.71	0.71	0.77	0.64	0.21

The distribution of lakes by width and area shows a concentration of very small (with a width of up to 45 m) and small lake reservoirs (with a width of 45.1 to 72.0 m) in the group of lakes with an area of up to 1.0 ha (Table 7).

Table 7
Distribution (number) of lakes in Rila by width and area

Classification by Width	Area (ha)												
	0-1,0	1,0-2,0	2,0-3,0	3,0-4,0	4,0-5,0	5,0-6,0	…	7,0-8,0	8,0-9,0	9,0-10,0	10,0-11,0	17,0-18,0	25,0-26,0
Very Small – to 45 m	46												
Small – 45.1–72.0 m	41												
Avarage – 72.1–129 m	26	16		1									
Big – 129.1–242 m		9	13	7	2	3			1				
Very Big – over 242 m						1		1		3	1	1	1

Most lakes (60.5% of the whole group) with an average width also have an area of up to 1.0 ha, fewer are those (37.2%) with an area between 1.0 and 2.0 ha. Large lakes are predominantly in the group with an area between 2.0 and 3.0 ha (38.2%) and less with an area between 1.0 and 2.0 ha (26.5%).

The distribution of lakes by width and length shows the largest number of lake reservoirs in the very small class according to both morphometric indicators. Very small lakes in width are predominantly (71.7% of the lakes in this group) in the very small in length class, and have a lower relative share (26.1%) in the small in length class. Only one lake (Smadlivo-4) of the very small ones in width has an average length between 113 and 187 m. The very large lakes in width are included in the classes large and very large in length and form a group of seven lakes, very large in both studied morphometric characteristics. The exception is only one lake (Okoto lake), which is very large in width and long in length.

Elongation of lakes. Longitude of the water mirror - Kprod.. (the ratio between the length and the average width of the flooded mirror) shows the average value for the lakes in Rila 2.59 and varies between 1.54 (Parvo Kovachko lake) and 5.89 m (Malko Mertvo Yakorudsko lake) . The obtained results testify to the oval or round shape of most lakes - 134 out of a total of 173 or 77.5%. Lakes with a predominantly oval or round shape are included in all classes of lakes along the length of the water table. This result can be explained by the irregular shape of a number of lakes.

Length of coastline. The length of the shoreline (S) of the lakes in Rila is within the limits of 110 m (Least Karaomerichko lake) and 2933 m (Smradlivo-2 lake) with an average value of 503.8 m (Table 8). The studied morphometric indicator has large variations between the maximum and minimum value of the lake shoreline – Cv = 0.78.

Table 8. Descriptive statistics of lakes in Rila along the coastline

Length of the shoreline- (*S*) **(m)**	**Rila**	**Mountain range**			
		NW	**Central**	**East**	**SW**
Average value	504.6	524.4	530.6	456.5	367.0
Median	392.0	414.0	388.0	350.0	336.0
σ	394.2	386.5	467.0	309.0	86.8
A_S	2.80	2.15	3.11	2.06	1.40
S_{max}	2933.0	2215.0	2933.0	1569.0	465
$13S_{min}$	110.0	155.0	110.0	164.0	300
C_V	0.78	0.74	0.87	0.67	0.19

The distribution of lakes by shoreline length and area shows a concentration of very small (with a shoreline length of up to 256 m), small (with a shoreline length of 256 to 391 m) and medium lake reservoirs of the studied morphometric characteristic in the group of lakes with an area of up to 1.0 ha. Fewer than the group of medium lake reservoirs (34.9%) are between 1.0 and 2.0 ha in area. About one-third (34.1%) of the lakes are large in shoreline length (between 608 and 1240 m) are concentrated in the group with an area between 2.0 and 3.0 ha (Table 9).

Table 9. Distribution (number) of lakes in Rila by length of coastline and area

Classes of the lenaght of shore line		**Area (ha)**											
		0-1,0	**1,0-2,0**	**2,0-3,0**	**3,0-4,0**	**4,0-5,0**	**5,0-6,0**	**…**	**7,0-8,0**	**8,0-9,0**	**9,0-10,0**	**10,0-11,0**	**17,0-18,0**	**25,0-26,0**
Very Small	under 256	44												
Small	256.1–391	42												
Acergae	391.1–608	27	15	1										
Large	608.1–1240	1	8	12	8	2	3		1					
Very large	over 1240						1			1	3	1	1	1

Coefficient of shoreline development. The coefficient of shoreline development (Ks) of the lakes in Rila has an average value of 1.48, between 1.07 (Malkata Panitsa lake) and 2.44 (Vtoro Kalinsko lake) (Fig. 5). In the class of lakes with slightly fragmented shores are one fifth of the lakes both in the entire mountain and in mountain divisions, with the exception of the South-Western division, where there is not a single lake with slightly fragmented shores.

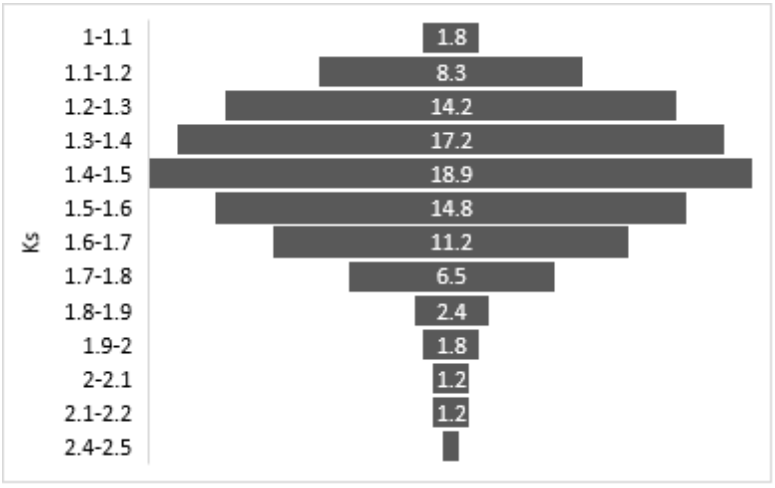


Fig. 5. Distribution (%) of lakes by shoreline development factor

2.3. Empirical dependencies between morphometric indicators

Empirical relationships between morphometric parameters are adequately described by linear and non-linear regression models and confirm identical studies. The distribution of lakes in the plain regions according to Seekell et al. (2013) is carried out according to their level, and this rule does not apply to lakes in mountainous regions, since the size of lake reservoirs is influenced by the

topography.The Kaiser-Meyer-Olkin (KMO) statistical test is 0.72 (>0.50) proves the adequacy of the initial data, and the Bartlett's Test is 0.00 (<0.001), i.e. morphometric indicators are sufficiently highly correlated. The two statistical tests provide grounds for applying factor analysis. The subsequent statistical procedures show that the distribution of the variance between the studied morphometric indicators highlights the area of the lake water surface as the main, main factor for the rest of the measured and calculated indicators (the eigenvalue is 4.743, greater than 1.00) . The adequacy test - the Kaiser-Meyer-Olkin (KMO) test has a value of 0.86, i.e. greater than 0.05. The results of the factor analysis for one main factor that affects the morphometric parameters is confirmed by the screen plot – a graph that shows the number of factors that influence the studied morphometric indicators of the lakes in Rila (Fig. 6).

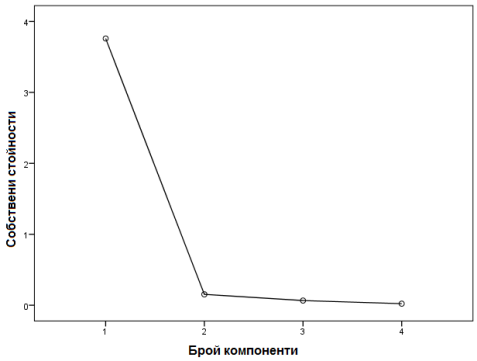


Fig. 6. Screen plot of the factor analysis

The statistical significance of the correlation between the studied parameters due to the large number of variables was tested at $\alpha = 0.01$ (two-sided criterion), denoted in table 10 by the abbreviation sig. from significant.

Table 10
Correlation matrix of some morphometric indicators

Indicators		***L***	***B***	***L*** *бр.л.*	***F***	***H***
R	***L***	1,00	0,905	0,977	0,938	-0,191
	B	0,905	1,00	0,914	0,851	-0,190
	L *бр.л.*	0,977	0,914	1,00	0,931	-0,204
	F	0,938	0,851	0,931	1,00	-0,157
	H	-0,191	-0,190	-0,204	-0,157	1,00
Sig.*	***L***		,000	,000	,000	,007
	B	,000		,000	,000	,008
	L *бр.л.*	,000	,000		,000	,005
	F	,000	,000	,000		,023
	H	,007	,008	,005	,023	

The relationships between the studied statistical parameters are initially presented graphically by non-linear regression, after which linear regression models are made with confidence limits drawn in red and with gray limits of the validated model.

The relationship between the area and the length of the lakes in non-linear regression has a curvilinear form and shows an increase in the length of the water mirror with the increase of the area in the form of a power function and with a correlation coefficient of 0.938. Deviations from the leveling line are shown by the data of lakes Smradlivo-2, Bliznaka, suhoto (at Rila monastery), Golyamo Manastirsko (Black gyolche) and Jozola (Fig. 7). The linear regression model has the form presented in Fig. 8 the data for the morphometric parameters of Smradlivoto-2, Bliznaka, Granchar (Golamoto), Ravnichalsko (Belmekensko) and Golyamo Kalinsko lakes remain outside the confidence limits. The reason for the indicated deviations, regardless of the fact that they are not statistically significant, must again be sought in the anthropogenic intervention and more specifically in the construction of a gathering derivation (1995) and an increase in the area of the lake Potter and on the retaining wall of the Ravnichalsko dam (Belmekensko).

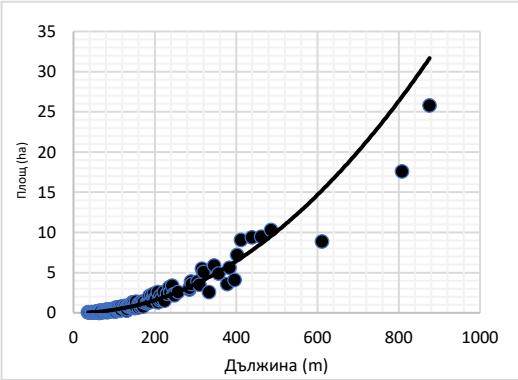
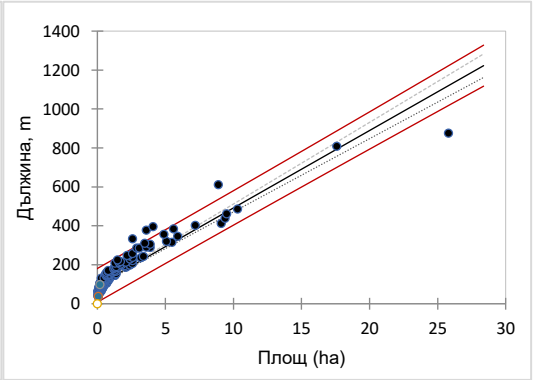


Fig. 7. Nonlinear regression between the area and the length of the lakes in RIla



Фиг. 8. Regressional model of the correlation between the area and the length of the lakes in Rila

The correlation between the length and width of the lakes has a correlation coefficient of 0.91 and shows that as the length increases, the width of the lake water surface also increases with a faster increase in length compared to width.
The relation between water table length and shoreline length is the strongest in comparison to the others, with a correlation coefficient of 0.98 and a coefficient of determination of 0.95 and a linear regression model.

Conclusions
1. The geographical characteristics of the lakes in Rila show:
- The difference in the geographical coordinates of the studied lake reservoirs is 0.243º in terms of latitude and smaller – 0.10º in terms of longitude;

- The limnonyms in Rila have different etymologies, but with differences in individual scientific and popular science sources, as well as the repetition of some names (e.g. Suhoto), which requires additional explanations for each of them

- Lakes in Rila form lake groups and lake systems as a result of their origin and, more specifically, the occupation of cirques, as well as independent lakes; lake groups are made up of two to ten lake reservoirs, and lake systems, or lakes linked together by water streams, made up of two to seven lakes; the number of lake groups has a relatively even distribution in the separate mountain parts, except for the southwestern part, in contrast to the lake systems, almost all of which are developed in the northwestern and central parts of Rila; single lakes are found mostly in the northwestern and eastern mountain divisions.

- The lakes in Rila are mostly located above 2000 m, a fact that places them in the group of high mountain lakes, and some of them also in so-called remote lakes due to the difficult accessibility to them; the concentration of almost half of the lake reservoirs between 2300.0 and 2400.0 m suggests the places of the most intense exaggeration in terms of height, at the same time in all mountain parts except the southwest; the altitude of the lakes is an indirect indicator of their young age, as well as of the thermal features of these reservoirs.

2. The morphometric characteristics of the lakes in Rila reveal:
- The lakes in Rila are predominantly with an area of up to 1.0 ha (65.3% of the studied 173 lake reservoirs) or close to the average value (1.54 ha) of this indicator for the entire mountain, with large differences between the smallest and the largest water mirror; with an area of more than 7.0 ha in Rila there are eight lakes; the size of the water mirrors is closely related to the type of lacustrine basin, which includes most lacustrine reservoirs to the type of circus glacial lakes; the results highlighted the importance of regional hypsometry for the distribution of lake area.

- The lakes in Rila have an average length of the water mirror of 155 m with a large difference between the measured final values; all lake reservoirs with a very small and small length are also characterized by a very small area; the concentration of a large number of lakes in the specified category is again linked to the location of most of them in cirques.

- The width of the lakes in Rila fluctuates in narrower limits around the average value of 95.9 m relative to the length; lakes of very small and small width predominate, with a very small group of lakes of very large width, which is in accordance with the relief form they occupy.

- The lakes in Rila, in terms of the length of the water mirror, for the most part approach a round or slightly oblong shape, which can be explained by the armchair-like depressions that occupy most of them.

- The length of the coastline of the lakes in Rila varies widely, similarly to the morphometric indicators characterized above, but in most cases it suggests weakly dissected shores, which is explained by the stability of the rocks, small water masses and poorly manifested hydrodynamics.

- The coastline development coefficient is the only morphometric indicator with the smallest variations between its largest and smallest value.

- Through statistical tests and non-linear and linear regression, it is proven that the area of the lake water surface is a main, main factor for the rest of the measured and calculated morphometric indicators; the statistical parameters, and more precisely the coefficient of variation, of the measured morphometric characteristics also show that the differentiation found is more closely related to the size of the lake reservoirs than to the depth.

CHAPTER THREE: HYDROGRAPHIC DESCRIPTION OF LAKES IN RILLA BY MOUNTAIN DISTRICTS AND RIVER BACHINS

3.1. THE LAKES IN RILLA ON MOUNTAIN PARTS

3.1.1. NORTHWEST RILLA

Overall Characteristics

Northwestern Rila is divided in its highland part into the Malovishki, Damgski, Kalinski, Otovishki and Kabulski mountain divisions, and in the low part, the so-called Lakatnishka Rila – in two parts (northern and southern). In the studied area, 60 lakes are described, organized into 12 lake groups, which include 10 lake systems and 20 lakes, as well as six lakes outside the lake groups.

Geographical description of the lakes

Geographical coordinates. Among the investigated lakes in Northwestern Rila, the southernmost is lake Dodovo (42.1691° N), the northernmost – ez. Panichishte (42.2626° N), the westernmost – ez. Malko Gradinsko (23.2263° E.), the easternmost location – ez. Yellow Gol (23.2263° E).

Geographical description of the lakes

Lake groups, lake systems, single lakes. The lakes in Northwestern Rila are unevenly distributed along mountain sections. There are 27 lakes (45% of all lakes) in the Malovishki part of Northwest Rila, 10 lakes in the Damgsky part (17%), nine lakes in the Kabul part (15%), eight lakes in the Otovishki part (13%) , in the Kalinsky district - six lakes (10% of all lakes. The lakes in Northwestern Rila form 12 lake groups, consisting of two to ten lakes and 11 lake systems, which include between two and seven lakes. Geographical description of the lakesThe lake groups The seven Rila lakes, Popovokapski, Malomalovishki and Malovishki are lake systems at the same time,

because the lakes are connected to each other by water streams. The largest number of lake systems can be found in the Malovishki part of Northwestern Rila.

Within the boundaries of Northwest Rila, names have been assigned to the following lake reservoirs: ez. Dodovo (after the village of Dodov) and ez. Visoko Urdino (according to its location in relation to the other lakes) from the Urdini lake group; ez. Malko Elensko from the Elenski lake group; ez. Prekoretsko (after the village of Prekorets) and ez. Malko Svinsko (by the size of the area compared to Svinsko Lake) from the Gornoprekorechki lake group.

Elevation of lakes. All the lakes in Northwest Rila are located above 2000 m, with the exception of lake Panichishte (1380 m). The lowest of the other lakes, at 2080 m, is the lake. Svinsko from the group Svinski Ezera, and the highest located - 2533 m, ez. The tear from the Seven Rila Lakes. The average altitude of the lakes in Northwest Rila is 2304m. The distribution of the lakes by altitude is similar to that throughout Rila.

Morphometric characteristics of lakes

Area of lakes (F). The lakes in Northwestern Rila have an average water surface area of 1.59 ha, between 0.073 ha - ez. Fourth Upper Prekorechko, and 9.49 ha - lake Kidney (table 11). Their total area is 95.22 ha.

Table 11

Descriptive statistics of lakes in Northwest Rila

Imdoicatore	Morphometric indicator					
	***F* (ha)**	***L* (m)**	***B***		**Shoreline**	
			***B* (m)**	**B_{cp}**	***S***	**K_s**
$\overline{x}$	1,59	154,6	103,0	68,9	524,4	1,49
M_e	0,69	123,0	80,0	52,9	414,0	1,44
σ	2,39	114,0	73,4	51,1	386,5	0,27
A_s	2,41	1,93	1,45	1,45	2,15	1,16
E_x	5,15	35	1,98	1,63	5,96	2,16
C_v	1,50	0,73	0,71	0,74	073	0,18

The area of the lakes in Northwest Rila has the greatest differences (dispersion) compared to the other morphometric indicators - the coefficient of variation (Cv) is 1.50. The largest number of lakes – 16 (26.6% of all lakes) with an area of less than 1.0 ha are concentrated in the altitude zone 2300–2399 m and about twice as many lakes in the altitude zones 2200–2299 m and 2400–2499 m. Lakes with an area of less than 1.0 ha prevail in all mountain divisions, with the largest number of them in the Musalensky division. The largest lakes in area are developed in the Kabul and Kalinsky mountain divisions.

Length of lakes. The length of the water table (L) of the lakes in Northwestern Rila is between 37.0 m (the Chetvryto Gorno Prekorechko lake) and 611.0 m (the Bliznaka lake) with an average value of 154 m.

Width of lakes. The lakes in Northwest Rila have an average value of the width (B) of the lake water surface of 103 m, varying between 26 m (Sedmo Gorno Prekorechko lake) and 250.0 m (Babreka lake), excluding the two dams from the analysis (dam . "Kalin-1" and "Kalin-2"). The concentration of the lakes in the "very small", "medium" and "large" groups according to the two morphometric indicators is established.

Maximum depth. The maximum depth of the lakes in Northwestern Rila according to the data from "Lakes in Bulgaria" (1964) has an average value of 7.88 m and varies between 1.1 m (Sredno Malovishko lake) and 37.5 m (Okoto lake). , among 25 lakes with data for this morphometric indicator. The deepest lakes from direct measurements and published in "Lakes in Bulgaria" (1964) are located in the Kabul part of Northwestern Rila and include four of the Seven Rila Lakes (Dolno (Black), Bliznaka, Babreka and Okoto) and Lake Malka Panitsa from the Urdini group.

Elongation of lakes. The coefficient of elongation of the water mirror (Kprod..) has an average value of 2.37 and varies between 1.52 (Yonchevo lake) and 4.47 (Sedmo Gorno Prekorechko lake from the Gorno Prekorechki lake group) with a coefficient of variation of 0. 27. A coefficient of elongation above 3.0 is established for the Salzata and Bliznaka lakes from the Seven Rila lakes, the Strashno and Sedmo Gorno Prekorechko lakes from the Gorno Prekorechki lake group and others.
The shoreline length (S) of the lakes in Northwest Rila varies between 155 m (Viso Urdino lake) and 2215 m (Bliznaka lake) with a mean value of 524.4 m and a coefficient of variation of 0.78. The frequency distribution shows a concentration of the largest number of lakes in the intervals 100–299 m and 300–499 m.

Coefficient of shoreline development The coefficient of shoreline development (Ks) of the Northwestern Rila lakes is between 1.07 (Malkata Panitsa) and 2.44 (Golyamo Kalinsko) with an average value of 1.49. The largest number of lakes is 25 (41.7%), with a coastline development factor between 1.25 and 1.50. Irregularly shaped and usually with an uneven coastline in Northwestern Rila are the lakes Bliznaka (Ks = 2.08), Treto Sredno Vodenicharsko (Ks = 2.19) and Golyamo Kalinsko (Ks = 2.44). In the data published in "Lakes in Bulgaria" (1964) no information is found for Ks above 2.00. A possible reason is the difference in measurements of the area and length of the lake water mirror of the above three lakes.

Empirical relationships between morphometric indicators

The analysis of the investigated dependencies is presented in table. 12. The graph of the relation between the area and the length of the water mirror, as well as between the area and the width of the lakes, shows deviations from the line leveling the points for lake Bliznaka, the "Kalin 1" and "Kalin 2" dams (Fig. 9).

Table 12
Correlation between the morphometric indicators

Indicators	*F*	*L*	*B*	*S*	*Ks*	B_{cp}
F	1,00	0,952	0,917	0,930	-0,150	0,934
L	0,952	1,00	0,905	0,976	-0,121	0,908
B	0,917	,905	1,00	0,895	-0,233	0,970
S	0,930	0,976**	0,895*	1,00	0,046	0,880
Ks	-0,150	-0,121	-0,233	0,046	1,00	1,00
B_{cp}	0,934	0,908	0,970	0,880	-0,311	1,00

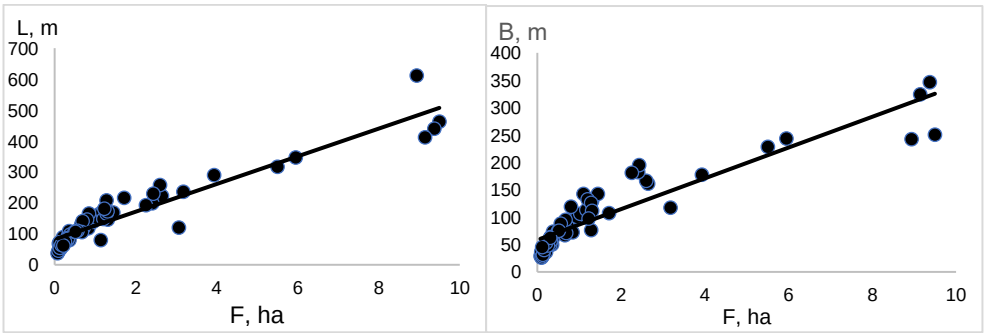


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Fig. 9. Relationship between: a) area (F) and length (L); b) area (F) and width (B) of the lakes in Northwest Rila

Because of the reasons stated above, deviations from the leveling line are also observed in the dependencies between area (F) and circumference of lakes (S) and between length and width of lakes (Fig. 9). The closest relationship is found between perimeter (S) and length (L) and area and length of lakes, and to a lesser extent between perimeter (S) and maximum width (B).

3.1.2 CENTRAL RILA

Overall Characteristics

Central Rila is separated by the valleys of the rivers Rilska and Levi Iskar (from the west), Cherni Iskar (from the north), Beli Iskar (from the east), Iliina (from the south). Within these boundaries, six mountain divisions are distinguished - Skakavishki, Marinkovishki, Shishkovishki, Kanarski (Kanarata village, located on the main watershed), Riletski and Briceborski.

Geographical description

Geographical coordinates. Among the studied 61 lakes in Central Rila, the southernmost is lake Great Rezhepsko Lake (42.079502°N), the northernmost – lake Jozola (42.181100° N), the westernmost – lake Plitko Manastirsko (Non-permanent) (23.410014° east), the easternmost location – ez. Fourth Kovacko lake (23.574785° east).

Distribution of lakes by lake groups and lake systems. The lakes in Central Rila are unevenly distributed along the mountain sections.There are five lakes (8.20% of all lakes) in the Bricheborski district of Central Rila, 18 lakes (29.51%) in the Kanarski district, 16 lakes (26.23%) in the Marinkivska district, and 16 lakes (26.23%) in the Rile district 12 lakes (19.67%), in Skakavishki division - five lakes (8.20% of all lakes) and in Shishkovishki division - 4 lakes (6.56% of all lakes). Lake reservoirs in Central Rila form 17 lake groups, consisting of two to seven lakes. The largest number of lake groups – six, are located in the Kanarski part of the Central Rila. In Skakviški part and Shishkoviški part, the lakes are independent and do not form lake systems.Eight lake systems are identified in Central Rila, which include two lakes each. The largest number of lake systems can be found in the Riletsky part of Central Rila - "Teodosievo Jendemska", "Riletsko Jendemska" and "Severno Jendemska". In the Kanarski and Marinkoviški parts, two lake systems are distinguished, respectively: "Zelenovrashka" and "Sino Karaomerichka" and "Dolna Vodnichalska" and "Golemi Rybni". One lake system, the "Golsko Bachiiska" lake system, has been identified in the Bricebor district. In Skakavishki division and Shishkovishki division, the lakes are not interconnected and do not form lake systems. Within the borders of Central Rila, the name of a lake has been assigned: Shallow Monastery Lake (Non-permanent).

Elevation of lakes. All lakes in Sredna Rila are located above 2000 m, with the exception of lake Dry Lake (Rila Monastery) (1912 m). The lowest located, at 2132 m, is the mountain. Jozola, and the highest – 2501 m, lake The first Vodnichal lake from the Vodnichal lake group. аъ large number of lakes in Central Rila – 26 (42.6% of all lake reservoirs) is concentrated between 2300 and 2400 m. The average altitude of the lakes in Central Rila is 2348.4 m. The concentration of the largest number of lakes in the altitude zone 2300–2400 m, as well as the distribution of lakes by altitude zones in the entire studied territory, is preserved along the mountain sections of the Central Rila. The largest hypsometric differences in the location of the lakes - between the lowest and the highest located, are settled in the Briceborsky part of the Central Rila, and the smallest - in the Shishkovski part.

Morphometric characteristics of lakes

Area of the lakes. Lakes in Central Rila have an area (F) of the water mirror between 0.0478 ha - lake At least Karaomerichko lake and 25.7 ha – ez. Stink Lake 2, at an average of 1.86 ha. All lakes, according to the threshold values for the classification of lakes by area, belong to the group of "very small in area" (0.1 - 1.0 km2).The largest differences (dispersion) of the area compared to the other morphometric indicators - coefficient of variation (Cv is 1.50) is an indirect evidence of the geomorphological processes that configure the lakes. The largest number of lakes (65.57% of all lakes) with an area of less than 1.0 ha are concentrated in the 2300–2399 m elevation zones and fewer in the 2200–2299 m and 2500–2600 m elevation zones.

Length of lakes. The length of the water table (L) of the lakes in Central Rila is between 36.0 m (Malko Chervivo lake) and 876.0 m (Smradlivo lake 2) with an average value of 170 m. Lakes between 36.0 m and 99.0 m in length (40.98% of lakes) and 100.0 m and 199.0 m (32.79 % of all lakes)predominated.
Width of lakes. The width of the lakes (B) varies between 17 m (Malko Rezhepsko lake) and 390 m (Smradlivo lake 2) with an average value of 95 m. The frequency distribution according to this morphometric indicator shows a grouping of lake reservoirs in the first two classes. No regularity is established in the change of the width (B) and average width (B average) of the lakes with the increase of altitude, as well as in the distribution by mountain sections of the Central Rila.
Length of coastline. The length of the shoreline (S) of the lakes in Central Rila is within the limits of 110 m (Lake Karaomerichko) and 2933 m (Lake Smradlivo 2) with an average value of 530.2 m. The largest number of lakes are located in the intervals 100–299 m (21 lake bodies – 34.4%) and 300–499 m (16 lake bodies – 26.2%) or slightly more than half of all studied lakes.
Coefficient of shoreline development. The coefficient of shoreline development (Ks) is between 1.12 (First Kovachko Lake) and 2.14 (Second Upper Levorechko Lake) with an average value of 1.46 (Fig. 10). With the lowest Ks values, or with an almost round shape, are the lakes Parvo Kovachko Lake (Ks = 1.12), 4th Jendemsko Lake (Lake Jendema) (Ks =1.13) and Parvo Dolno Levorechko Lake (Ks = 1.14). With a shape close to circular (Ks between 1.0 and 1.25) and a slightly indented shoreline are nine lakes.

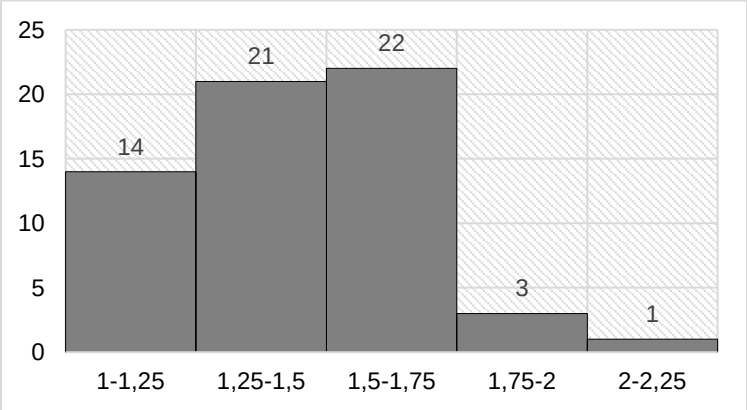

Fig. 10. Distribution of lakes in Central Rila by coefficient of shoreline development (Ks)

Empirical relationships between morphometric indicators. The correlation analysis between the measured and calculated morphometric parameters of the Central Rila lake reservoirs shows the closest relationship between the area of water mirrors and the length of the coastline and the area and width, similar to the relationships between the morphometric parameters studied so far (Fig. 11). The correlation coefficient for both dependencies is over 0.70, statistically significant, and the coefficient of determination reaches 0.88.

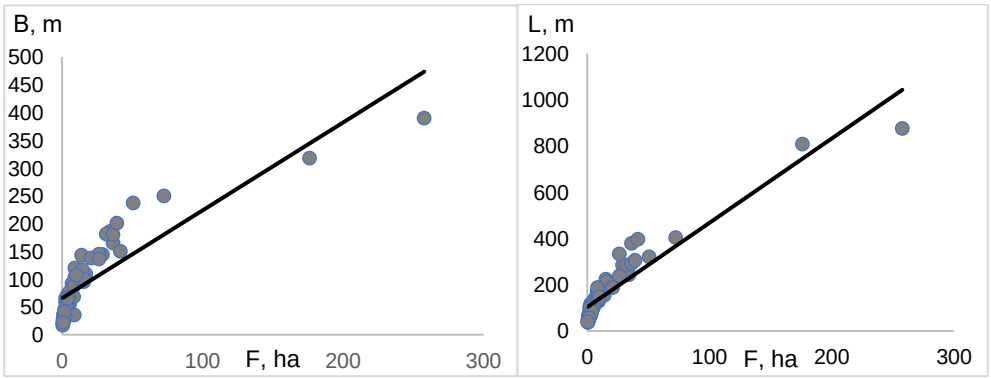

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Fig. 11. Relationship between: a) the area and the length of the coastline; b) the area and width of the water mirror

Urdini lakes

General hydrographic characteristics of the lake group. Urdini Lakes are a group of lakes in the northwestern part of the Rila mountain, east of the village of Damga (2670 m) and north of the village of Dodov (2661 m), in the source part of the river valley of the river Urdina. They occupy a part of the Urdin cirque, oriented to the north and bounded by the Maliovitsa, Ushite, Mermera, Dodov, Damga peaks, with a length of 3.0 km and a width of 4.0 km from the village of Damka to the village of Elenin (Radev, 1920).The lake group is made up of eight lakes with names - Suhoto, Ribno Urdino, Triagnalnika, Botanichesko, Golyama Panitsa and Malka Panitsa and two nameless lakes, probably of non-glacial origin, which are given the following names: Dodovo - after the village of Dodov and Visoko Urdino, due to its highest position in the lake group (Fig. 1).

а) б)

Sn. 1. Photographs of: a) ez. High Urdino; b) ez. Dodovo (Al. Vassilev)

Urdini lakes belong to the glacial ones, with the exception of Lake Goliamata Panitsa and ez. Malkata Panitsa, which occupy depressions of tectonic origin (Vodenicarov, 1962). The morphology of lake basins classifies glacial lakes to the cirque type (ICIMOD, 2011). There is no anthropogenic pressure on the lake reservoirs, which, together with their altitude, refers them to the so-called remote lakes (Catalan et al., 2013).

Geographic coordinates of the Urdini lake group (according to MAFF) are 42.174 and 42.186 N. and 23.322 and 23.333 i.d. The location of the lakes in altitude (MAFF, 2345 m by Suunto ambit 3 watch) is between 2278 m (Lake Golyama Panitsa) and 2464 m (Lake Dodovo).

The measured area of the lakes on the Google Earth satellite image from 2018 is between 2.0 m2 (Dodovo Lake) and 26.4 m2 (Golyamata Panitsa Lake), slightly smaller than that determined in "Lakes in Bulgaria" (1964), the maximum depth is between 2.0 m (Botanichesko lake) and 7.6 m (Malka Panitsa lake), the water volume is from 6.0x103 m3 (Botanichesko lake) to 89.5x103 m3 (Botanichesko lake . Golyamata Panitsa) (Lakes in Bulgaria, 1964). The general characteristics of the lake group are complemented by the following morphometric data: length of the lakes - between 89.0 m (Dodovo lake) and 257.0 m (Triagnalnika lake), lake width - from 36.0 m (Dodovo lake) up to 166.0 m (Triagnalnika), the length of the coastline - within the limits of 231.0 m (Dodovo) and 747.0 m (Triagnalnika).

The lakes of the studied lake group are fed by precipitation and snowmelt, by streams and water streams flowing into them, and by groundwater. The main expenditure element in their water balance is the outflow in the form of a stream to a neighboring reservoir or to the Urdina River. The insignificant consumption in evaporation is presupposed by the prolonged period with negative air temperatures, in some cases until the month of June near the village of Musala (Climate reference book ..., 1983). Field observations show a lack of islands in the lakes, a blue and blue-green color of the lake waters. Urdini lakes are connected to each other by water streams and give rise to mountain streams.

From the northeastern end of the Golyama Panitsa flows into the Urdina River (marked on some maps with the name Golyama Urdina), a tributary of the Cherni Iskar River (from the river system of the Iskar River). The Urdina River flows north and northeast through a trough valley with steep slopes, which narrows at the mouth, where there are moraine rocks (Radev, 1920). It forms a river system of tributaries that start their course from the lakes: ez. The triangle and the Ribno Urdino give rise to creeks that flow from the left of the main river, from the lake. Malkata Panitsa (Pic. 2) begins one of the right tributaries of the Urdina River, from the lake. Botanical - a steep water An exception is the Mala (Little) Urdina river - right tributary.

Relationships and dependencies between morphometric parameters. The correlation analysis between the measured and calculated morphometric indicators of Urdini lakes shows the closest relationship between the area of water mirrors and the length of the coastline. The correlation coefficient is 0.95 and statistically significant at $\propto$ = 0.01, 0.05 and 0.10. With high values and statistically significant is the relationship between the area and the volume of the lakes in the studied lake group - R = 0.84. The dependence between the length and width (Fig. 11 a) of the water mirrors, between the maximum and the mean depth, is extremely narrow, with R = 0.89 and R = 0.94 at $\propto$ = 0.01, 0.05 and 0.10

Conclusions:

Lakes in Central Rila – 17 lake groups (from two to seven lakes), with eight lake systems (with two lakes each), located above 2000 m (except for one lake), predominantly between 2200–2500 m . The largest number of lakes in this part of the mountain are developed in the Canarsky Division, and most of the lake systems in the Riletsky Division.

The calculated morphometric parameters of the lakes in Central Rila classify them in the group of "small in area", with small depths, lengths, widths and development of the coastline, predominantly with a round shape, approximately the same as those of the lakes in general in the whole mountain. The established similarity is explained by the origin of the lakes and their development in similar drain-forming factors, especially climatic ones.

Empirical relationships between the morphometric parameters of the lakes in this mountain section are supported by the close correlations between lake area and length, between area and width, between shoreline length and water table length, and to a lesser extent – between perimeter and maximum width.

3.1.3. EAST RILLA

Common featureas

Eastern Rila is located between the valleys of the Beli Iskar, Maritsa, Yadenitsa, Mesta and Belishka rivers. The area of the studied territory is 972.73 km2 (37.0% of the total area of Rila Mountain), and the average altitude is 2355 m (Stoychev and Petrov, 1980). In Eastern Rila, six divisions are distinguished - Musalensky, Marishki, Ibersky, Kovashki, Zavrachishki and Belmekenski.

Geographical description

Geographical coordinates. Among the 49 studied lakes in Eastern Rila, the southernmost is Dry Lake (Semkovo) (42.072167°N), the northernmost is the Third Yellow Saragyol Lake. (42.207691°N), the westernmost Dry Lake (Semkovo) – (23.555791°E), the easternmost – ez. Ravnichalsko (Belmekensko) (23.749173° east). The lakes in Eastern Rila are unevenly distributed by mountain sections, by the number of lakes in a lake group and in a lake system. The lakes in Eastern Rila form 12 lake groups, consisting of two to seven lakes.Three lake systems are identified in Eastern Rila, which include between two and four lakes. The Marichina Lake Group and the Daut Lake Group are both lake systems because the lakes are connected to each other by water streams. Golyamo Banen lake system includes two lakes. Marichina lake system, composed of four lake reservoirs.In the Daut Lake Group, two of the lakes are connected and form the Daut Lake System -

Big and Small Daut Lake. In the Yakorud lake group, one lake system is identified - Golyamo Banenska, from two lakes - Ribno Yakorudsko and "Sinyoto Yakorudsko. In the borders of Eastern Rila, the name of the lake reservoir has been assigned: lake “The puddle” (the lake is small and dries up in the summer).

Altitude. All lakes in Eastern Rila are located above 2000 m, with the exception of Lake Lokvata (1867 m) from the Kovaški region and have an average altitude of 2342.4 m. The lowest of the remaining lakes – at 2007 m, is the lake. The fourth Malko Banensko lake, the highest located - at 2713 m is the Ledno Musalensko lake. The largest number of lakes in Eastern Rila - 20 or (40.82% of all lake reservoirs) is concentrated between 2300 and 2400 m.And in this part of Rila, the total area of the mountain sections decreases with increasing altitude, and the number of lakes is greatest around 2400 m. The largest hypsometric differences in the location of the lakes - between the lowest and the highest located - are found in the Kovaški part of Eastern Rila, and the smallest - in the Ibarski and Zavracishki (Mustachalski) parts. In the Kovaški part, the lowest place is ez. Lokvata (1867 m), and the highest point - lake. Malko Murtvo Yakorudsko (2427 m).

Morphometric characteristics of lakes

Area of the lakes. The lakes in Eastern Rila have an area (F) of the water mirror between 0.12 ha - ez. South Leivstansko and 10.2 ha - Ribno Yakorud Lake, with an average value of 1.13 ha. Distribution of the lakes in Eastern Rila by area shows a significant unevenness in distribution according to this morphometric indicator: 35 lakes - 71.43%, have an area of less than 1.0 ha, six - an area of 1.0 ha to 2.0 ha, four - from 2 ha to 3 ha and four lakes with an area of more than 3.0 ha. All lakes in Eastern Rila belong to the group of "very small in area" (0.1–1.0 km2). The largest number of lakes – 15 (30.6% of all a) with an area of less than 1.0 ha, are in the altitude zone 2300–2399 m and about twice as many lakes in the altitude zones 2200–2299 m and 2400–2499 m.

Length of lakes. The length of the water surface of the lakes in Eastern Rila is between 50.0 m (Yuzhno Leevstansko lake) and 486.0 m (Ribno Yakorudsko lake). Lakes with a water surface length between 50.0 m and 99.0 m (46.9% of the lakes in the studied area) and between 100.0 m and 199.0 m (34.7% of all lakes) predominated. The largest number of 0–99 m and 100–199 m lakes are developed in the 2300–2399 m elevation zone.

Width of lakes (B). The width of the lakes in Eastern Rila varies between 23 m (Second Ropalish Lake) and 273 m (Ribno Yakorud Lake) with an average value of 89.61 m, with a clear grouping in the first two classes.

Length of coastline (S). The length of the coastline of the lakes in Eastern Rila is within the limits of 164 m (North Leevstan Lake) and 1569 m (Ribno Yakorud Lake) with an average value of 456.5 m. The largest number of lakes are concentrated in the intervals 100–299 m (18 lake reservoirs – 36.7%) and 300–499 m (15 lakes – 30.6%). The length of the shoreline increases as the size of the lake water surface increases.

Coefficient of shoreline development. The coefficient of shoreline development (Ks) of lakes in Eastern Rila is between 1.08 (Ledeno Musalensko lake) and 2.32 (Sredno Dyavolsko lake) with an average value of 1.47. The lakes Ledeno Musalensko (Ks = 1.08), Tretoto (Alekovo) Musalensko (Ks =1.12) and Sesto Musalensko (Ks = 1.13) have the lowest Ks values. The largest number of lakes is 23 (46.93%), with a coastline development factor between 1.25 and 1.50. With an irregular shape, or with Ks above 1.91 and with an average fragmented coastline in Eastern Rila, are the lakes Ravnichalsko (Belmekensko - Ks = 2.01, Malko Kazanchalsko - Ks = 1.99 and Suhoto (Chaltushko) - Ks = 1 ,91).

Empirical relationships between morphometric indicators

Similar to the empirical dependencies studied so far, statistically significant (at $\propto$ 0.01 and 0.05) correlation dependencies are established between the same morphometric parameters: The closest relationship is found between length L and perimeter (S) of lakes, and between perimeter (S) and maximum width (B).

Conclusions
Lakes in Eastern Rila – 49 lake reservoirs, form 12 lake groups (from two to seven lakes) and three lake systems (from two to four lakes), located above 2000 m, unevenly distributed along mountain sections, predominantly between 2300–2399 and 2393–2713, small in area, length, water table width, shoreline length. The lakes in this part of Rila do not show deviations from the general regularities established so far, which is due to the general geomorphological and climatic conditions for their formation.

The high degree of dependence between morphometric indicators is also preserved in this mountainous section of Rila.

3.1.4. SOUTHWEST RILLA

Common feature
Southwestern Rila is developed between the valleys of the rivers Struma, Rilska, Iliina and Belishka, and in it two mountain ridges (separated by the river valley of Blagoevgradska Bistritsa) several mountain divisions are clearly distinguished: Mechivrashki and Tsarevishki in the northern part, and Parangalishki, Kapatnishki and Hersovsky in the south. Three very small circus lakes are located in this mountain section: Plitkoto (southeast of the village of Ezernik, which gives rise to the river Dobarska), Kodzhakariytsa (Kodzhakaritsa) and Merdjika.

Geographical characteristics of the lakes

Geographical coordinates. Among the investigated lakes in Southwestern Rila, the southernmost is lake The shallow lake (42.0191° N), the northernmost – lake Kojakariitsa (42.0658° N), the westernmost - ez. Plitkoto (23.4358° E.), the most easterly location – ez. Kojakariitsa (23.4478° east). There is 1 lake (33.33% of all lakes) in the Mechivrashki division of Southwestern Rila, and two lakes in the Parangalishki division.

Morphometric characteristics of lakes

Area of the lakes. The lakes in Southwestern Rila have an area (F) of the water mirror between 0.19 ha - ez. Merdjika and 0.55 ha - lake “The shallow one”. All lakes belong to the group of "very small in area" (0.1 - 1.0 km2).
Altitude. The lakes in Southwest Rila are located above 2000 m. Lake Kojakariitsa is located in the altitude zones 2400–2499 m, Lake Merdjika is located in the altitude zones 2300–2399, and Shallow Lake – between 2100 and 2199 m.

Length of lakes. The length of the lake reservoirs is between 80.0 m (Merdjika lake) and 113.0 m (Plitkoto lake). One of the lakes has a length in the range 0–99 m at 2300–2399 and two have a length of 100–199 m. Width of the lakes The width of the lakes (B) in Southwest Rila varies between 40 m (Merdjika lake) and 68 m (Plitkoto lake).

Length of coastline (S). The length of the coastline of the lakes in Southwest Rila is between 300 m (Merjika lake) and 465 m (Plitko lake) with an average value of 367 m. Two of the lakes are included in the 112–113 m interval.

Coefficient of Shoreline Development (Ks). The coefficient of development of the shoreline of the lakes in Southwestern Rila is between 1.77 (Plitkoto lake), 1.95 (Merjika lake) and 1.59 (Kojakariytsa lake), which determines their shape to be irregular.

The small number of lakes in this mountainous part does not ensure statistical dependencies between the studied morphometric indicators.

Conclusions:

The lakes in Southwestern Rila, like most lakes, have a glacial origin, but in this part of the mountain they do not form lake systems and groups, they belong to the highlands - they are located above 2100 m, with a very small area, length, width of the water mirror , coastline length.

3.2. LAKES IN RILLA BY RIVER WATERSHEDS

The lakes in Rila are located within the catchment basins of the rivers Iskar, Maritsa, Mesta and Struma. The largest number of lakes is in the Iskar river catchment - 64 lakes, and the smallest in the Mesta river catchment - 36 lake reservoirs.

3.2.1. WATER COLLECTION BASIN OF THE ISKAR RIVER

In the Iskar river basin, the lakes are located between 42.095633º and 42.200841º N. and 23.322681º and 23.590533º E. The largest lake groups are Musalenski Lakes and Gorno Prekorechki Lakes. The lakes are developed between 2,080 m (Svinsko Lake) and 2,713 m (Ledeno Musalensko Lake) above sea level, concentrated in the hypsometric belt between 2,300 m and 2,400 m, similar to the distribution of lakes by this indicator throughout the territory of Rila. The total area of the lakes of the Iskar river catchment is 671906 m² (0.67 km²).The area of the lakes varies from 703 m² (Malko Chervivo) to 39,306 m² (Dolno Çanakgölsko) lake. and represents 25.32% of the area of the river basin (2625274 m²). The maximum depth of lake reservoirs is between 0.5 m (Fourth Gorno Prekorechko lake) and 16.4 m (Zhaltiya gol lake) (Lakes in Bulgaria, 1964). The length of the coastline ranges from 120 m (Malko Chervivo Lake) to 1017 m (Jozola Lake). The coefficient of development of the coastline is from 1.07 - Golyama Panitsa from the lake group of Urdini lakes to 2.14 - the Botanical lake from the same group.

Catchment basin of the river Cherni Iskar. In the watershed of the Cherni Iskar river are the Canakgyol lake groups (draining into the Prav Iskar river, an initial tributary of the Cherni Iskar river). Vodnichalski (with outflow, beginning of the Mala river), Malyovishki, Malomalovishki and Elenski (in the watershed of the Mala Maliovitsa river, right tributary of the Cherni Iskar river), Gornoprekorechki (giving rise to the Gorna Preka river, left tributary of the river . Iskar), Zhaltiya gol (beginning of Golyama Lopushnitsa river, d. tributary of Cherni Iskar).

Catchment basin of the Levi Iskar river. Within the boundaries of the Levi Iskar river catchment there are the Gornolevorechki lake groups (draining through a water stream into the Gorna Leva river), Vodnichalski (with a water stream which, after the last, fourth lake, is the initial tributary of the Levi Iskar river) , Lake Yozola (one of the most difficult-to-access lakes in Rila, with outflow through a small watercourse to the Levy Iskar River), Dolnolevorechki (through streams that, after merging, form the Dolna Leva River) and Pogledecki (draining through the Dolna River Left).

Catchment basin of the Beli Iskar river. Within the boundaries of the river catchment of the Beli Iskar River are the Zelenovrashki (Dry) lake groups (runoff lakes with several inflowing watercourses and several outflows that flow into the Jendem Dere and Ropalishka rivers, tributaries of the Beli Iskar River), Chervivi (connected water stream, which is a left tributary of the Beli Iskar), Nalbantski (West Kovachki) (with an outflow in the form of a right tributary of the Beli Iskar river), Prekorechki (outflow lakes, connected to each other, with an outflow to the Gorna Preka

river) and Lake Kanarsko (with an inflow of several streams and an outflowing water stream, the beginning of the Beli Iskar river).

3.2.2. WATER COLLECTION BASIN OF MARITSA RIVER

The lakes in the Maritsa river basin are located between 42.156855° and 42.207691° N. and 23.593298° and 23.749173°E, between 2219 m Ravnichalsko Lake (Belmekensko) and 2559 m, Dark Lake (Temnoto) altitude. The river basin of the Maritsa River has the least number of lake groups (4) and systems (1) and single lakes (5) compared to the rest of the watersheds of the main rivers and their first-rate tributaries.In the watershed of the Maritsa river there are the lake groups - Marichini (four run-off lakes connected in a lake system, with several streams flowing into them and the main tributaries of the Maritsa river flowing out) and Sarugyolski (also called Yellow, from tr. - " Saru", yellow: three lakes, two of which are irregularly shaped at the foot of Deno village), and five single lakes: Ravnichalsko (Belmekensko) (from which the Zhodjovitsa river flows, a left tributary of the Kostenetska river), Sredno Chamberlisko, Studeno, Ibersko (with outflow through a stream that flows as a tributary of the Kostenetska river) and Tumno ez.The area of the lakes varies from 1,333 m² (Malko Dyavolsko lake) to 22,575 m² Second (Upper) Marichino lake and represents 5.37% (142,560 m²) of the area of the river basin. The maximum depth of the lake reservoirs is between 5.5 m (Lower Marichino Lake) and 10.8 m (Upper Marichino Lake from the Marichini Lakes lake group (Lakes in Bulgaria, 1964). The length of the coastline is within 256 m (Cold lake) to 1049 m Ravnichalsko Lake (Belmekensko). The coefficient of development of the coastline varies from .17 – First Marichino Lake to 2.01 – Ravnichalsko Lake (Belmekensko).

3.2.3. WATER COLLECTION BASIN ON THE RIVER MESTA

The lakes in the catchment of the Mesta River are located between 42.033425° N - Lake Merjika and 42.163405º N. – Eastern Chaltushka Lake and between 23.426791° E. – Merjika ° and 23.735067° E. Eastern Chaltushka Lake. There are 12 lake groups in the river catchment of the Mesta River, consisting predominantly of two and three lakes - Malkobanenski, Yakorudski, Grncharski, Chaltushki, Vapski, Dautski, Ropalishki, Kazanchalski, Karaalaniski, Kovachki, Leevstanski, Skaliski (Rezhepski) and four single lakes - Lokvata, Suhoto, Merjika and Plitkoto. The circus lakes are located in the valleys of the rivers Grncharitsa, Ropalitsa, Leevshtitsa, Kazanska - the tributaries of the Mesta river.The lakes in the river catchment of the Mesta River are located between 2007 m - the Second Ropalish Lake and 2512 m above sea level, the Fourth Small Banen Lake, prevailing in the hypsometric zone 2100-2200 m and 2300-2400 m. The area of yhe lakes (377,184 m²) is between 589 m - Malko Rezhepsko lake and 102,564 m - Ribno Yakorudsko lake and represents 14.21% of the area of the river basin. The length of the coastline is within the limits of 141 m - Malko Rezhepsko lake. to 1569 m Rybno Yakorud Lake. The coefficient of development of the coastline varies from 1.12 - First Kovacko lake to 1.99 Malko Kazanchalsko lake. The deepest lake in the Mesta River catchment is 16.5 m - Dead Yakorud Lake, and the shallowest, 1.0 m - Second Small Banen Lake. (Lakes in Bulgaria, 1964).

River catchment of the Bela Mesta river. The watershed includes the lake groups: Ropalishki Lakes (three lakes in the valley of the Ropalitsa River, a tributary of the Bela Mesta River), Grancharski Lakes (three lakes, one is outflowing, an initial tributary of the Bela Mesta River), Kazanchal Lakes (two lakes , feeding the Kazanishka River, a tributary of the Bela Mesta River), Yakorud Lakes (three permanent and four seasonal lakes according to data from "Lakes in Bulgaria", 1964, five lakes according to Google Earth, probably due to the drying up of two lakes during the filming),Malkobanenski (four stepped lake reservoirs in the valley of the Malka Banenska river) and lakes Lokvata (in the catchment of the Banenska river, right tributary of the Bela Mesta river) and Suhoto (in the river catchment of the Polenishka river from the river system of the Vothraka river)).

River catchment of the river Cherna Mesta. It includes the Leevshtan Lakes (two lakes that give rise to the Leevshtitsa River, which merges with the Sofanitsa River).

River catchment of Belishka river. The watershed consists of three groups of lakes: Vapski lakes (two outflow lakes, from which the Vapska (Vapata) river flows – one of the initial tributaries of the Belishka river, together with several mountain streams), Skalishki (Rezhepski) lakes (two lakes, giving rise to the Skalishka River, a left tributary of the Belishka River) and Karaalani Lakes (two lakes connected by a watercourse, one of which – Chernopolyansko, gives the beginning of the Karaalanitsa River, a left tributary of the Belishka River).

River catchment of the Draglishka River. There are two lakes in the river basin of the Draglishka River: Lake Merdjika (a very small lake reservoir from which the Usoeto River flows, a right tributary of the Draglishka River from the river system of the Mesta River) and Lake Plitkoto (near the village of Ezernik, flowing through the Dobarska River, a right tributary of the Draglishka River).

3.2.4. WATER COLLECTION BASIN OF THE STRUMA RIVER

The lakes in the Struma river basin are located between 42.065815° and 42.262679° N. and 23.294137° and 23.447851° E. and between 1381m above sea level – Lake Panichishte and 2533 m above sea level Lake Salzata. In the Struma river basin there are 11 lake groups Vodenicharski, Gradinski, Jendemski, Kalinski, Karaomericki, Manastirski, Marinkovski, Popovokapski, Ribni, Sedemte Rilaski, Smradlivi and seven single lakes Otovishko, Panichishte, Mermersko, Kodzhakariytsa, Skakavishko, Suhoto and Ashiqlar. (appendix), with the most lakes in the Rilska river basin. The area of the lakes varies from 478 m² – (Smallest Karaomerichko Lake) to 257723 m² (Smelly Lake 2) and represents 55.10% (1462487 m²) of the area of the river basin. The maximum depth of lake reservoirs is between 1.0 m (Smradlivo Ezero 3) and 37.5 m (Lake Okoto) of the Seven Rila Lakes group (Lakes in Bulgaria, 1964). The length of the coastline is from 110 m (Smallest Karaomerichko Lake) to 2933 m (Smradlivo Lake 2). The coefficient of development of the coastline is 1.13- ez. Jendema up to 2.44 – Golyamo Kalinsko from the Kalin Lakes group. Lakes with a shape close to round predominate.

River catchment lakes of the Rilska River. They belong to the Rilska river basin lake groups: Fish lakes (two circus-connected lakes - Upper and Lower valley of the Rilska River), Marinkovski Lakes (a group of four lakes, two of which give rise to the Marinkovitsa River, a right tributary of the Rilska River), Smradlivi lakes (six lakes located in the Rilska river valley), the Black (Amber) lake (outflowing lake in the valley of one of the tributaries of the main river), Jendemski (Devil's) lakes (seven staggered and interconnected circus lakes, two of which give rise to the Jendema and Dyavolska rivers, flowing into the Rilska river from the left), Karaomerichki ezera

(a lake system of four lakes, the outflow of which forms the Karaomerichka River, an initial tributary of the Iliina River), Manastirski Lakes (four staggered outflow lakes from which the Vodnitsa (Golska) River, a tributary of the Manastirska River, flows). In the river basin of the Iliina river (left tributary of the Rilska river) there are the Karaomerichki lake groups (circus lakes draining into each other, which give rise to the Karaomerichka river, a right tributary of the Iliina river), Mermerski (from which the Mermera River, a right tributary of the Iliina River flows out) and the Kojakariitsa Lake (giving rise to the Kojakariitsa River, a left tributary of the Iliina River).

River catchment of the German River. In the river catchment of the German river there are the lake groups Seven Rila lakes (seven staggered lakes connected by streams and draining through the German river), Kalinsky lakes (six lakes, of which two are permanent, giving rise to mountain streams that through a common flow they pour their waters into the Bistrica (Dupnishka) river, a left tributary of the Jerman river), Vodenicharski (three staggered lakes connected by their drainage into each other and the source of one of the initial tributaries of the Bistrica (Dupnishka) river , left tributary of the German River) and Garden Lakes (with an underground outflow to the Dupnishka Bistrica River).

In this watershed are the lakes Skakavisko (draining through the Skakavitsa river, a left tributary of the German river), Otovishko (a very small lake in terms of area and depth, giving rise to the

Otovitsa river, a left tributary of the German river) and Ashiklarsko (Ptiche) lake (oblong lake in the watershed of the Otovitsa river, from which one of the main tributaries of the main river flows).

SUMMARY

Rila lakes, predominantly cirques, are developed in trough valleys one by one, in lake systems or lake groups, are located between 1381.0 m and 2713.0 m, but almost all above 2000 m (i.e. highland), predominantly between 2300 and 2400 m, which testifies to the places and intensity of exaration, to the young age of the lake basins, the low temperatures of the lake waters and the manifestation of an ice regime.

The 173 lakes studied (with 20 more than previous studies: 16 in Northwestern Rila, two lakes in Southwestern Rila and one lake each in the central and eastern parts of the mountain) are organized into lake groups, within which lake systems (limnosystems)) – lakes connected to each other by watercourses. The lake groups (41 in total) are composed of two to ten lake reservoirs, and the lake systems (22 in total) - from two to seven lakes. The lake groups have a relatively even distribution across mountain sections, with the exception of the Southwest section.Almost all limnosystems are developed in Northwestern and Central Rila. The single lakes are mostly located in the northwestern and eastern parts of the mountain. The lakes and lake groups are unevenly distributed within the borders of the separate parts of Rila, as a result of the complex of geomorphological and climatic factors during their formation.

The lakes in Rila are predominantly small in area (between 0.05 ha and 25.7 ha), with a surface of the water mirror up to 1.0 ha, mostly shallow (up to 1.5 m), with a maximum depth within 1.0 m and 37.5 m, with the length of the water mirror in the range of 36.0 and 876 m, and in the width between 17.0 and 390 m, with an oval or round shape according to the relationship between the above two morphometric indicators, with a coastline length of 110 m to 2933 m (but mostly up to 113 m) and a shoreline development factor between 1.07 and 2.44.

The values of the measured and calculated morphometric indicators:

- Prove the area of the lake water surface as the main factor for the other indicators;
- They do not reveal geographical regularities in the distribution of the lakes according to morphometric indicators and altitude, due to glaciation only in the high mountain part of Rila;
- They do not differ significantly compared to the same ones established in the 1960s (or they are within the permissible errors.), with the exception of the anthropogenically modified lakes, which suggests a relative stability of the natural conditions in Rila.

The obtained correlation dependences between the area and shoreline length of the lakes, the length and width of the water mirror, the length of the water mirror and the length of the shoreline are extremely narrow - with a correlation coefficient above 0.70 to 0.98, they are adequately described by linear and nonlinear regression models and confirm identity studies. The lakes in Rila - an element of the hydrographic structure of the mountain, participate in the local water cycle, give rise to watercourses, forming the initial tributaries of a large number of river currents, and their watersheds, as geosystems, shape the appearance of natural landscapes and are independent or part of the geotopes in the country.

REFERENCE ON CONTRIBUTIONS

1. In a theoretical aspect:
A) the concept of a lake system (limnosystem) is defined: a group of lake reservoirs interconnected by water streams, independently or within the limits of the lake groups.
B) 173 lakes are described geographically and morphometrically:
- with 20 more than previous studies
- with the names of 16 nameless lake reservoirs

- with distribution of each morphometric indicator by altitude, and by relationship between individual morphometric parameters, for the whole mountain, for its main parts and by mountain sections in each part

- with classification by threshold values

C) Statistically significant relations between lake area and shoreline length, water table length and width, water table length and shoreline length were established and graphically described by a linear regression model.

2. In an applied aspect: the results enable:
- comparison with information from other studies
- management of lake water resources
- the contribution of the lakes to ecosystem services
- inclusion of the lakes in the national legislation

PUBLICATIONS, PARTICIPATION IN CONFERENCES AND SCIENTIFIC PROJECTS

Dissertation publications

1. Василев, А. 2019. Хидрографско описание на Мусаленските езера. В: Климат, атмосфера и водни ресурси в условията на климатични промени. Сборник доклади, София, ИИКАВ-БАН, 2019, 55–63.
2. Vasilev, A. 2021. Lake Morphometry Research of Urdini Lakes in Rila Mountain. В: Климат, атмосфера и водни ресурси в условията на климатични промени. Сборник доклади, София, ИИКАВ-БАН, 2021, 214-222.
3. Василев, А., Христова, Н. 2022. Хидрографско описание на езерата в Северозападна Рила. Год. СУ, ГГФ, 114 (2), 87-105

Participation in a university scientific project
Study of glacial lakes in Rila - Project in support of doctoral students at the FNI of SU, 2020. Successfully completed and reported.

DECLARATION OF AUTHENTICITY

I declare that the current dissertation work on the topic "Hydrographic characteristics of the lakes in the Rila Mountains" for the acquisition of the educational and scientific degree "Ph.D." is an independent and original work, and the used empirical information and scientific sources are correctly documented and cited according to the current standards of Republic of Bulgaria.

I guarantee that:

I. Acknowledgment of the foreign authorship of the used texts, tables, diagrams, graphs, images and others is indicated according to the academic style of citation established in the scientific field.

II. The bibliography at the end of the work includes all cited and used printed and electronic sources on the subject.

I hereby declare that I am familiar with the rules in the Code of Ethics of the academic community of Sofia University "St. Kliment Ohridski" for respecting other contributions and correct citation and for the intolerance of plagiarism.

January 2, 2023
Sofia Alexander Vasilev