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# THE INFLUENCE OF MORPHOMETRIC CHARACTERISTICS ON THE FUNCTIONAL USAGE OF LITHUANIAN LAKES

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**Abstract.** Functional usage of lakes is the usage of lake shores and water area in order to meet different needs of people. A lot of factors influence the suitability of a lake for certain activities, i.e. geographical position of a lake, water quality, legal regulations, morphometric indexes of lakes etc.
The aim of this research is to investigate which morphometric characteristics have impact on the possibilities of functional usage of a lake. The following morphometric parameters have been analysed in this research: lake area, average and maximum depth, the length and indentation of a shoreline, the number of islands and water capacity. This research will also investigate which of these morphometric parameters mostly influences and how it influences such areas of usage of lakes as fishery and fishing, navigations, water supply for people and industry, hydroenergetics and recreation. The object of the research is all Lithuanian lakes bigger than 0.5 ha (total 2,835 lakes).

Based on the research of various scientists and legal acts, it was determined which morphometric parameters have the biggest influence on the usage of lakes in a specific area. After grouping the lakes according to the value of morphometric parameters the number of Lithuanian lakes which can perform specific functions was found out.

It was established that the functional use of a lake mainly depends on the area of a lake. This directly and indirectly determines the possibilities of a lake usage in all the areas investigated.

**Key words:** lake, functional usage of lakes, morphometric parameters.

## 1. Introduction

Functional usage of lakes is the usage of lake shores and water area to meet different needs of people. Water Law of the Republic of Lithuania (2003) lists the following types of water pool usage: *to obtain water, recreation, to build hydrotechnical objects, fishery and fishing, to drain sewage, to liquidate natural disasters and accidents, to be used by navigation means.*

Suitability of lakes for certain activities depends on many factors: the geographic position of a lake, the quality of water, legal regulations, morphometric indexes and other. Morphometric indexes are by far the most important parameters that influence the usage of lakes in particular areas.

Scientific research has proved that morphometric parameters of a lake influence many of its limnological processes. Hydochemistry of lake water, optics, thermics, and water balance are closely related to the morphological indexes of lakes. L. Hakanson (2005) states that the size and form of lakes influence many processes that take part in them: sedimentation, outflow which in its own turn regulates the state of many abiotic variables, e.g. the concentration of phosphorus, the chemical composition of water, colour, water clarity which regulates the initial production of a lake and the latter influences the secondary one. L. Hakanson proved by his research that the depth of Secchi disc mostly depends on the morphometry of a lake. K. S.Cheruvelil, P. A. Soranno (2008) by analysing the cover of macrophytes in the ground and the ones floating in water body and water surface found out that the indexes of macrophytes cover can be forecasted according to Secchi disc depth, the average depth of a lake and the morphometrics of a lake catchment. G. A. Weyhenmeyer (2008) analysed 16 physical and chemical variables in the biggest Swedish lakes (Vättern ir Vänern) and 48 smaller lakes during spring over the period 1984–2003 and found out that morphometry influences the alteration of concentration of chemical elements (especially of calcium and magnesium) in lakes.

Morphometric parametres of lakes are vast and various and that is why they are classified according to one or another basis. G. Vereshchagin (1930) classified them in quite a complicated but coherent way by distinguishing indexes that describe lake environment, surface, basin

size and shape and water body. K. Kilkus (1982) puts morphometric indexes into three groups: 1. plan/surface (lake area, shore line, number of islands); 2. capacity (average depth, water capacity); and 3. catchment (catchment area, comparative catchment). *This paper analyses the following morphometric parameters*: lake area, average depth, the length of a shoreline and indentation, the number of islands and water capacity. The paper sets out to find out which of these morphometric parameters has the biggest influence and how it influences such areas of usage of lakes as fishery and fishing, supplying water to people and industry, hydroenergetics and recreation. The object of the research is all bigger than 0.5 ha Lithuanian lakes (total 2,835).

*The aim of the research* is to find out which morphometric characteristics influence the possibilities of functional usage of lakes most.

Based on the research of various scientists and legal acts it was determined which morphometric parameters have the greatest impact on the usage of lakes in a specific area. By grouping lakes according to the morphometric parameters the number of lakes which can perform particular functions was found out. The List of Lithuania SSR lakes with morphometric data (1964) and bathymetrical lake data was used for the analysis of morphometric lake parameters. Morphometric data was processed using the set of statistic software IBM SPSS Statistics 19.0.

## 2. The Results of the Research

The analysis of scientific literature and laws showed that some of the most important morphometric indexes in Lithuania are *the area of a lake (f) and its average depth (h)* which are used in many hydrological and water economy calculations.

It was determined that the area of a lake and its average depth influence **fishing and fishery** because not all the lakes equally suit for the same fishes to live and their productivity can differ.

The scheme of M. Somov (1922) by applying changes according to local conditions was used to classify lakes according to the dominant fish breeds. R. Volskis in 1959 offered to use the following lake types according to Lithuanian conditions: *osmeridae, bream, pike perch, pike and crucian lakes.*

Smelts, ciscos, perches, roaches and breams predominate in big > 100 ha and deep (average depth >20 m) lakes. Pikes are profuse in 100-10 ha and 4-10 m average depth lakes. Small (< 10 ha ) and shallow (2-4 m) lakes are known for perches and crucians. Moreover, the bigger a lake is, the bigger the average productivity of fish is.

There are 742 bathymetrically explored lakes in Lithuania. 313 lakes (42% of total bathymetrically explored lakes) meet the above mentioned conditions for certain kinds of fish to live: 45% suit for pikes, 36% - for crucians, 18% - breams, pike perches (Fig. 1).

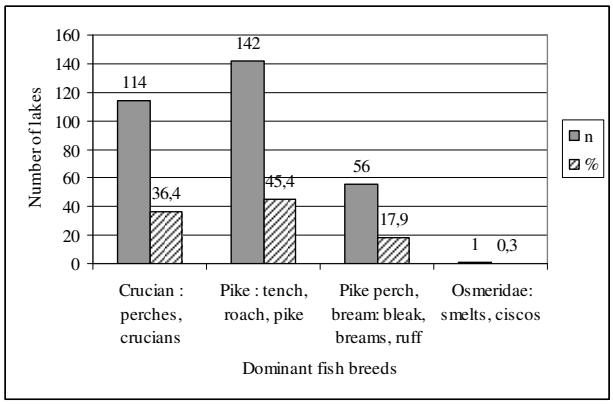


**Fig 1.** Classification of lakes according to fish breeds according to lake size and average depth

If to take lake area into account, lakes suitable for breams, pike perches are predominant (44%); according to the average depth, lakes suitable for crucians are predominant (52%) (Table 1). The more morphometric parameters we take into account, the fewer lakes will meet certain conditions and therefore the results will be more true to life.

**Table 1.** Separate classification of lakes according to fish breeds based on lake size (f) and average depth (h)

| Dominant fish breeds | f, ha | Number of lakes | | h, m | Number of lakes | |
|---|---|---|---|---|---|---|
| | | n | % | | n | % |
| Crucian : perches, crucians | <5 | 114 | 15,4 | <4 | 382 | 51,5 |
| Pike : tench, roach, pike | 20-5 | 142 | 19,1 | 10-4 | 303 | 40,8 |
| Pike perch, bream: bleak, breams, ruff | 100-20 | 328 | 44,2 | 20-10 | 56 | 7,5 |
| Osmeridae: smelts, ciscos | >100 | 158 | 21,3 | >20 | 1 | 0,1 |
| Total | | 742 | 100 | | 742 | 100 |

The area of lakes influences **sailing by sailing means**. The bigger a lake is, the more powerful and various sailing means can be used. Laws (Dėl aplinkosaugos.., 2004) put lakes into the following *groups according to the area: until 10 ha, 10-200, 200-500 and bigger than 500 ha* lakes. It is prohibited to sail by self-propelled sailing means in smaller than 10 ha lakes; if a lake is 10-200 ha, it is allowed to sail by the self-propelled sailing means whose total engine power does not exceed 8 kW; in the lakes that are bigger than 200 ha it is allowed to sail by more powerful, up to 110 kW sailing means. If a lake size is bigger than 500 ha water motorcycles can be used.

There are 2,835 lakes bigger than 0.5 ha. 1,750 lakes are in the territories that are not protected. More powerful sailing means (8- 110 kW (150 HP) can be used just in 4% of all lakes (Table 2).

**Table 2.** Possibilities to use sailing means in the lakes according to the area of a lake in the territories that are not protected (N – non self-propelled means of sailing; S – self-propelled means of sailing).

| Interval of lake's area, ha | Number of lakes | | Sailing means |
|---|---|---|---|
| | n | % | |
| 0,5-10 | 966 | 55 | N |
| 10,1-200 | 723 | 41 | N<br>S (< 8 kW (10,08 HP) |
| 200,1-500 | 48 | 3 | N<br>S (to 110kW (150 HP)) |
| > 500 | 13 | 1 | N<br>S (to 110kW (150 HP)<br>Water motorcycles |
| Total : | 1,750 | 100 | |

Lakes in the protected territories are divided into two groups based on their area: > 50 ha, in which sailing by self-propelled sailing means is prohibited and < 50 ha, in which sailing by not powerful self-propelled sailing means is allowed. There are 1,085 lakes in the protected territories (39% of all bigger than 0.5 ha Lithuanian lakes). Self-propelled sailing means can sail in 15 % of all these lakes (Table 3).

**Table 3.** Possibilities to use sailing means in lakes according to the area of a lake (f) in protected territories. (N – non self-propelled means of sailing; S – self-propelled means of sailing)

| f, ha | Number of lakes | | Sailing means |
|---|---|---|---|
| | n | % | |
| < 50 | 920 | 85 | N |
| > 50 | 165 | 15 | S (4 kW (5,4 HP)) |
| Total: | 1085 | 100 | |

**While supplying water for people and industry** the most important morphometric indicator is *the capacity of lake water*, however, it is closely connected to the area and depth of a lake. Moreover, the usage of lakes in industry greatly depends on the branch of industry and the need of water quantity. The bigger quantity is needed, the lake of bigger area can be used for this purpose. Scientists (Mays 2001; Gleick 1998) have counted the needs of water resources for each industry branch.

The capacity of lake water is also important in using lakes in the area of hydroenergy. The functions of a lake can be twofold in this area – producing hydroenergy and refrigeration. Rivers and ponds are used more widely in hydroenergy, while lakes are used less.

Table 4 shows that the biggest water volume is collected in big, bigger than 500 ha lakes and it makes up even 56 % of the total water volume in lakes. The bigger a lake is, the bigger amount of water is collected in it. The correlation ratio of lake area and water volume is R=0,98.

Thus, for industrial enterprises that need much water for their processes, 8 lakes that have collected more than 100 mln. $m^3$ water can be used for hydroenergy (refrigeration purposes).

**Table 4.** Number, area (f), water volume (v) and average depth (h) of baltimetrically explored lakes

| f, ha | Number of lakes | | v | | h, m |
|---|---|---|---|---|---|
| | n | % | Thou., $m^3$ | % | |
| 0,5-1 | 37 | 5,0 | 597 | 0,01 | 2,84 |
| 1,1-5 | 89 | 12,0 | 8350,6 | 0,15 | 2,68 |
| 5,1-10 | 56 | 7,5 | 12908,4 | 0,24 | 2,93 |
| 10,1-50 | 267 | 36,0 | 333442 | 6,17 | 3,16 |
| 50,1-100 | 142 | 19,1 | 459180,9 | 8,50 | 3,27 |
| 100,1-500 | 120 | 16,2 | 1560865 | 28,90 | 3,81 |
| > 500 | 31 | 4,2 | 3026482 | 56,03 | 5,30 |
| Total | 742 | 100,0 | 5401826 | 100,00 | 3,43 |

Lakes were divided into classes according to water volume (Fig. 2).

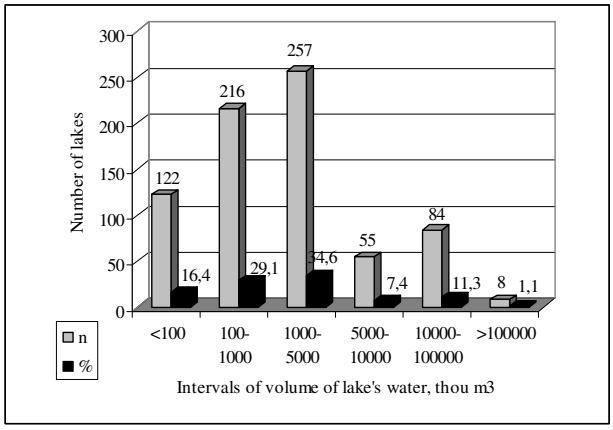


**Fig 2.** Distribution of baltimetrically explored lakes according to water volume

As the concept of **recreation** is quite wide and encompasses many various activities, recreational functions are influenced by many morphometric lake parameters – the length and tortuosity of a shore line, lake area, average depth, number of islands etc. Recreational activities include fishing and sailing by various sailing means which have already been described above.

Mass and individual relaxation can be organised near the lakes. *Lake area and form* were taken into consideration while putting them into categories according to the possibilities of mass recreation. Lakes were divided into categories according to the possibilities of mass recreation (Kavaliauskas and Ignatonis 1985): I – possible to be used very intensively (more than 100 ha), Ia – wide water area, Ib – narrow lengthy water area; II - possible to be used intensively (average size, 20-100 ha); III – possible to be used in a limited way (not big, 5-20 ha); IV – not suitable for mass recreation (smaller than 5 ha).

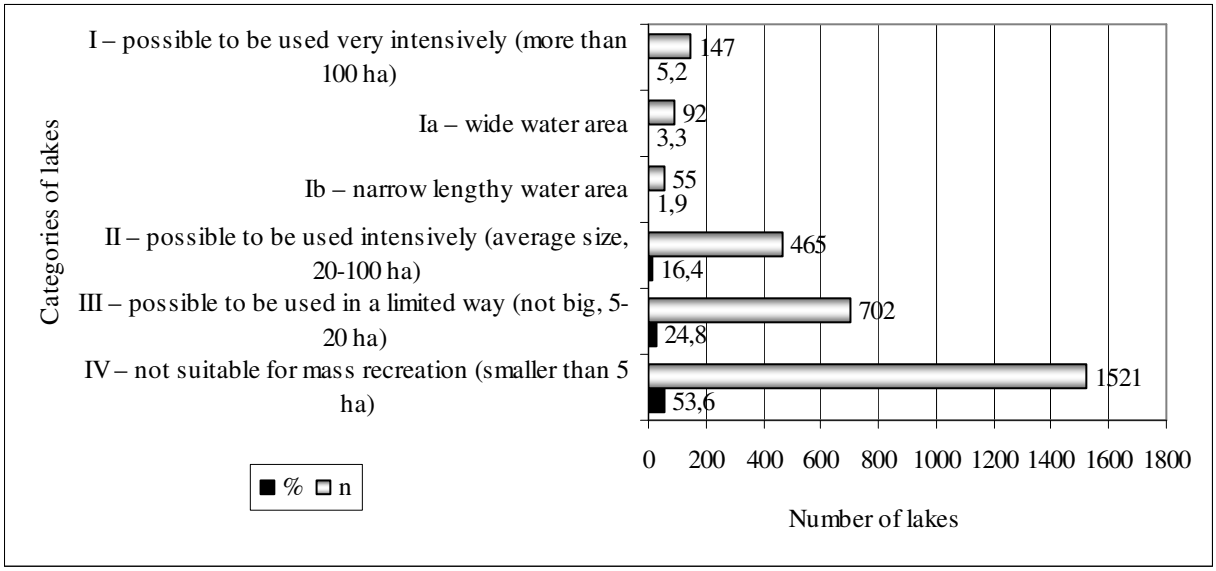


**Fig 3.** Distribution of lakes according to the possibilities of mass recreation

More than a half (54%) of Lithuanian lakes are not suitable for mass relaxation because their area is too small. There are just 5 % of lakes that can be used for very intensive recreation (Fig 3).

*Shore line length (l*, km) is a very important characteristic to plan recreational resources. The longer a shore line is the bigger possibilities to use a lake for recreation are. It is noticed that the bigger area of a lake is the longer its shore line (correlation ratio R=0,56) is. The data about lake shore line lengths is provided in the Catalogue of Lakes in the LSSR (1964), however, not all the lengths have been measured. They were calculated for 2,410 lakes out of 2,835, i.e. 85 % of all the lakes in the catalogue.

**Table 5.** Total shore line length (*l*) of Lithuanian lakes (f ≥ 0,5 ha)

| f, ha | Number of lakes, n | Number of lakes which calculated *l* | ∑ *l* | |
|---|---|---|---|---|
| | | | km | % |
| 0,5-1 | 511 | 121 | 65 | 1,0 |
| 1,1-5 | 1008 | 976 | 700,84 | 10,3 |
| 5,1-10 | 372 | 370 | 439,34 | 6,5 |
| 10,1-50 | 657 | 650 | 1617,96 | 29,4 |
| 50,1-100 | 138 | 137 | 768,71 | 16,1 |
| 100,1-500 | 118 | 120 | 1255,84 | 26,3 |
| > 500 | 31 | 31 | 710,12 | 10,5 |
| Total | 2835 | 2410 | 5557,81 | 100,0 |

The total shore line length is 5,557.81 km (Table 5). Almost 30% of total lake shore line length is made up by the shore lines of 10,1-50 ha lakes. The longest shore line is of Sartai Lake which is 79 km. Lakes were divided into five classes according to the length of shore lines (Fig 4). The majority of Lithuanian lakes have shorter than 5 km shore line, therefore planning of recreational buildings and facilities is limited. Just 8 % of lakes have longer than 5 km shore line.

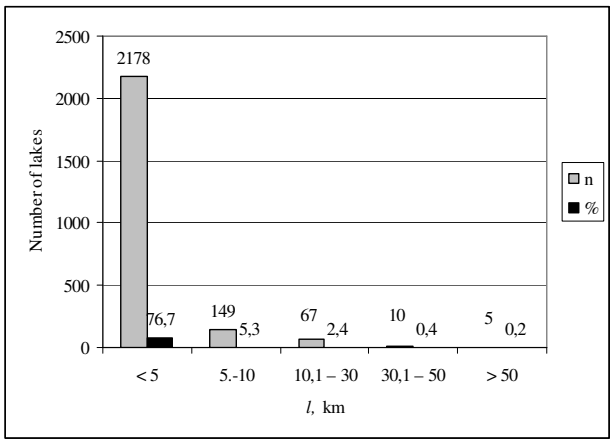


**Fig 4.** Distribution of lakes according to shore line length (*l*)

The shore line of lakes is almost always indented. This feature is quantifiable by Nagel ratio N – the ratio between the lake shore line length ($l_0$) and the length of a circle's ring of the same area ($l_s$). N is a relative lake plan index (morphometric ratio) that shows indentation and extension of a lake (Kilkus 1989, 2005).

$$N= l_0/l_s=l_0/2(A)^{0,5}=0,282\ l_0/A^{0,5} \qquad (1)$$

If the shape of a lake surface is an ideal circle, N=1,0. If the indentation of a shore line increases, N meaning also increases (Fig 5).

Lakes of various morphometric parameters can be used for recreation. For quiet rest smaller lakes are more suitable because the size of a lake limits its possibilities of usage for various recreational purposes. Big lakes are more suitable for mass, active recreation (sailing by various sailing means).

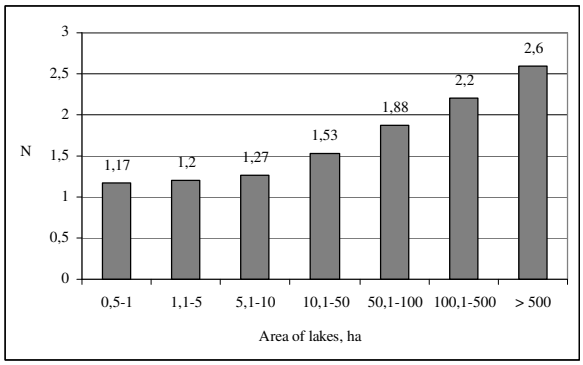


**Fig 5.** Distribution of average Nagel ratio (N) meanings in different classes of lake areas

Recreation is influenced by the attractiveness of lakes which can be evaluated by one of morphometric parameters, i.e. lake islands. There is a tendency that the bigger a lake area is the more and bigger islands it can have. This tendency was also noticed by K. Kilkus (1989) who explained the reasons of such regularity by morphogenetic (smaller lakes are in elementary pools and complex pools are more common among bigger ones – intercrossing hollows – ice beds and other more complex mophosculptures that are of higher state) and hydrologic (the link of a lake with active hydrologic network) factors.

There are total 262 islands in the lakes explored and their total area is 615,7 ha (Table 6). Over 90% of all the islands are in bigger than 100 ha lakes.

**Table 6.** Number of islands in the lakes being explored (according to the Catalogue of LSSR Lakes)

| f, ha | Number of islands | | Area of islands | |
|---|---|---|---|---|
| | n | % | ha | % |
| 0,5-1 | 0 | 0,0 | 0 | 0,0 |
| 1,1-5 | 2 | 0,8 | 0,3 | 0,0 |
| 5,1-10 | 2 | 0,8 | 0,8 | 0,1 |
| 10,1-50 | 24 | 9,2 | 14,3 | 2,3 |
| 50,1-100 | 21 | 8,0 | 23,8 | 3,9 |
| 100,1-500 | 135 | 51,5 | 407,4 | 66,2 |
| > 500 | 78 | 29,8 | 169,1 | 27,5 |
| Total | 262 | 100 | 615,7 | 100 |

Thus, if to evaluate lakes according to the number of islands, so the most attractive ones are those whose area is more than 100 ha.

**Table 7.** Morphometric indexes influencing the usage of lakes

| Lake usage purposes | Most important morphometric indexes for lakes |
|---|---|
| Fishery and fishing | Area, average depth |
| Sailing by water transport means | Area |
| Industrial water-supply, energetic, water usage | Water capacity |
| Recreation (swimming, rest) | Shore line length, tortuosity, area, number of islands |

To summarise, it is possible to conclude that the functional usage of lakes is mostly influenced by the morphometric parameter – lake area – if a lake's area is bigger, it can be used for more various purposes (Table 7). The second important parameter is the average depth of a lake.

## 3. Conclusions

The morphometric parametres of lakes influence the usage of lakes in all the areas explored: the most important morphometric parametres for fishing and fishery are its area and average depth; for sailing by various sailing means – the area of a lake; for industrial water-supply, energetics – water capacity, recreation – area, shore line length, indentation and number of islands.

The functional usage of lakes is mostly influenced by the area of a lake, which directly or indirectly influences the possibilities to use lakes in all the areas explored.

Based on the morphometric lake parametres – area and average depth, lakes, suitable for pikes (45% of all the lakes explored), crucians (36%) and breams, pike perches (18%) predominate.

The bigger a lake is, the more powerful and various sailing means can be used in them. Self-propelled sailing means can be used in 45 % of Lithuanian lakes that are in unprotected territories. More powerful sailing means (8-110kW (150 HP) can be used in just 4% of all the lakes. In protected territories self-propelled sailing means (4 kW (5,4 HP)) can be used in 15% of lakes.

Lakes with big water capacity can be used for industrial water-supply and hydroenergetics. The biggest water capacity is collected in big, bigger than 500 ha lakes and it makes up even 56% of all the water capacity in lakes.

More than 54% of Lithuanian lakes are not suitable for mass recreation because their area is too small. There are just 5% of lakes that can be intensively used for recreation. The majority of Lithuanian lakes (77%) have a shore line shorter than 5 km, therefore planning recreational buildings and facilities is limited next to them. According to the number of islands the most attractive lakes for recreation are the ones whose area is bigger than 100 ha, in which there are 90% of the islands explored.

## References

Cheruvelil, K. S.; Soranno, P. A. 2008. Relationships between lake macrophyte cover and lake and landscape features. *Aquatic Botany*, 88(3): 219–227

Dėl aplinkosaugos sąlygų plaukioti vandens telkiniuose plaukiojimo priemonėmis ir vandens telkinių, kuriuose plaukiojimas tam tikromis plaukiojimo priemonėmis draudžiamas ar ribojamas, sąrašo patvirtinimo. 2004, Nr. 58–2073. [Regarding the Approval of the Environmental Conditions to Sail in Water Bodies by Sailing Means and the List of Water Bodies in which Sailing by Certain Sailing Means is Either Prohibited or Limited] Available on the Internet: <http://www3.lrs.lt/pls/inter3/dokpaiska.showdoc_l?p_id=367592&p_query=&p_tr2=>

Gleick, H. P. 1998. *Water in Crisis: A Guide to the Word's Fresh Water Resources*. New York: Oxford University Press. 473 p. ISBN-10: 0195076281

Hakanson, L. 2005. The importance of lake morphometry and catchment charakteristics in limnology – ranking based on statistical analyses. *Hydrobiologia*, 541(1): 117–137

Kavaliauskas, P.; Ignatonis, J. 1985. Hidrografinio tinklo rajonavimas pagal rekreacinius resursus. [Regioning of hydrographic network according to recreational resources] *Geografija* [Geography], 21: 106–113

Kilkus, K. 1982. *LTSR ežerų morfometrija* [Lake morphometry of LSSR ]. Vilnius : VU leidykla. 94 p.

Kilkus, K. 1989. *Lietuvos ežerų hidrologija* [Lithuanian Lakes hydrology]. Vilnius: Mokslas. 153 p. ISBN 5-420-00258-2

Kilkus, K. 2005. *Ežerotyra* [Limnology]. Vilnius: VU leidykla. 272 p. ISBN 9986-19-805-4

Lietuvos Respublikos vandens įstatymas [Low of water of Lithuanian Republic]. 1997, Nr. l04–2615; 2003, Nr. 36–1544. Available on the Internet*:* <www3.lrs.lt/pls/inter3/dokpaieska.showdoc_l?p_id=233188>

*Lietuvos TSR ežerų sąrašas su morfometriniais duomenimis* [The list of Lithuanian SSR lakes with morphometric data]. 1964. Kaunas: Respublikinis vandens ūkio projektavimo institutas. 127 p.

Mays, L. W. 2001. *Water Resources Engineering*. USA: John Wiley & Sons Ins. 753 p. ISBN 0-471-29783-6

Volskis, R. 1959. *Žuvininkystė ežeruose* [Fishing lakes]. Vilnius: Centrinis techninės informacijos biuras. 39 p.

Weyhenmeyer, G. A. 2008. Rates of change in physical and chemical lake variables – are they comparable between large and small lakes ? *Hydrobiologia*, 599 (1): 105–110.

Верещагин, Г. 1930. Методы морфометрической характеристики озер [Methods of morphometric characteristics of lakes]. *Труды Олонецкой научной экспедиции* [Proceedings Olonetskaya scientific expedition], 1(2): 3–27.

Сомов, М. 1922. Рыбоводство [Pisciculture]. *Естественные производительные силы России* [Natural productive forces of Russia], VI-III (24): 1–68.