Water Resources in Romania and Their Quality in the Main Lacustrine Basins

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The quality of lacustrine waters was studied for each region, river basin and aquatic surface of Romania for use in different fields of activity and for life support for the biological component. Ten-year seasonal campaigns had as their main purpose the complex characterisation of the quality of the lacustrine water, which was performed by interpreting the results of field measurements with reference to their classification into quality classes. A total of 136 lakes were analysed. This number was sufficient to cover the entire surface of Romania and to portray the present state of its lake water quality. Most lakes in Romania, especially those analysed in this study, are naturally anthropogenic. Those of large dimensions are located in the mountains or along the Danube. Most of the natural lakes are small and have no environmental or economic importance (except along the coastal plain and the Danube). The lakes analysed, although situated in different physical and geographical conditions, fall, in the majority of cases, within the category of good waters in terms of their quality (class I), and eutrophic, hypertrophic or mesotrophic in terms of trophicity. Because most of these lakes are man-made, it is clear that they are artificially maintained at this point. Most mountain lakes, or volcanic units, are ultraoligotrophic or oligotrophic. Most water-supply lakes are heavily used by the main settlements and for agriculture. Eutrophication is a phenomenon absent from the anthropogenic lakes and is rarely found in the natural lakes.

Keywords: physico-chemical parameters, pollution, resources, water quality, trophicity

The Romanian water resources have been reduced. Consequently, the current resources are under maximum exploitation. The excessive use of surface waters (lakes and rivers) usually leads to a rapid exhaustion of water resources and a simultaneous increase in pollution.

We analysed all large natural lakes (>1 million m^3) and the most important artificial lakes within all the large hydrographic basins in Romania. The purpose was to determine – for each region, hydrographic basin and aquatic surface – the quality of lacustrine waters for use in different fields of activity and for life support for the biologic component. There are 3,450 Romanian lakes, which occupy 1.1% of the total surface of 2,620km^2. Unfortunately, most lakes are anthropic, and the few natural lakes are also small [1, 2]. Ninety-eight percent of the Romanian hydrographic network depends on the Danube, while only 2% depends on the Black Sea. The underground water resources represent 10%, but there is a current use of 4-6% [3]. Romania has had to build 1,900 complex use lakes. The total volume of all accumulations exceeds 13,000,000,000m^3 (270 basins under the direct management of the National Administration "Romanian Waters").

The imperious need for water, given the droughty climate, impelled Romania to start building, even during the Middle Ages, an impressive number of lakes with complex uses, including irrigation, water for animals, and water supply. The Moldavian Plain holds the largest such lake in Romania: Dracsani. The departments within the Moldavian Plain (the northeast of Romania) have high water coverage, even though they are among the driest areas in Romania: 2.8% of the department of Botosani is covered by lakes, followed by the department of Iasi, with 2.7%. The permanence of these lakes is due to the clay soil, which forms an impermeable layer [4].

The mountain basins appeared after 1960, when Romania started the campaign to become energy independent. Thus, many complex-purpose lakes have been built on the largest hydrographic arteries, with Iron Gates I coming first, Stanca-Costesti second, Izvorul Muntelui third, Vidra fourth, and Vidraru fifth (fig. 1). The greatest difficulty with the study was the relatively large surface of Romania, the large number of lakes studied (136), and the diverse and fragmented relief.

We had in mind the complex analysis of the physico-chemical characteristics of lacustrine waters and their quality for supporting life or for supplying water for localities. Such a study is rarely approached at the level of the entire country, with important omissions concerning certain hydrographic basins or isolated lakes. This is the first such study and it is based on our own data as well as data collected from various governmental institutions monitoring the water resources in Romania: National Administration Romanian Waters, 2003-2009.

The 10-year seasonal campaigns (2001-2010) had as their main purpose the complex characterisation of lacustrine water quality by interpreting the results of field measurements with reference to the their classification

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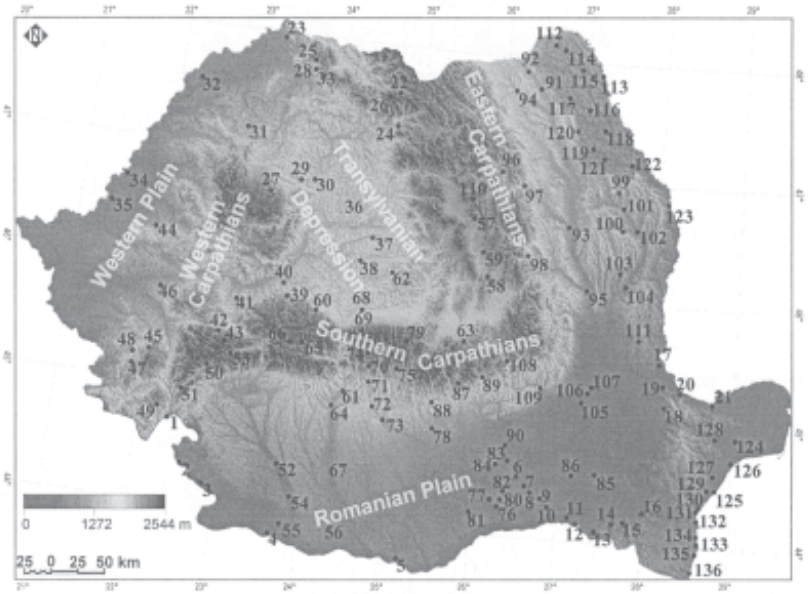

Fig. 1. Distribution of the main Romanian lakes (the number corresponds to the name in table 1)

into quality classes. This theme is extremely complex, and there is a rich body of Romanian and international literature concerning the subject [5-23].

Experimental part

We used a complex mobile laboratory equipped with the HACH Drel/2010 multi-parameter for the measurement of physico-chemical parameters, including *p*H, temperature, dissolved oxygen, salinity, total dissolved salt concentration (TDS). A Nansen bottle was used to obtain samples from a depth of 0.5 m depth and near the bottom. The sampling for the phytoplankton specific to lacustrine waters was performed with the Nansen bottle, and the analysis was performed in the laboratory based on the volumetric method. The trophicity of lacustrine waters showed the need to characterise certain determinant and favourable physico-chemical and biological factors regarding their evolution, including CCO-Cr, CCO-Mn, CBO_5, total mineral nitrogen, total phosphorous, total nitrogen, nutrients (Inkjel WD 20.0 devices and portable DR/820 Colorimeter) and the structure of aquatic biota (the value of phytoplankton biomass, the value of the V90% percentile of the phytoplankton biomass, coliform bacteria). For transparency, we used a Secchi disk.

For water sampling, we used a Nansen bottle at a depth of 0.5 m and near the bottom. The samples were taken during summer. The physico-chemical parameters were interpreted by the Hydrology Laboratory within the Faculty of Geography and Geology (Alexandru Ioan Cuza University), and the biologic factors by the Natural Science Museum of Tulcea. For the lakes that could not be accessed with the equipment, the data were provided by the regional water directions or by the National Administration of Romanian Waters. Starting with 2004, all the institutions in the field used the same equipment with the same standards: Order 1146/2002 in five quality classes. To classify the lakes, we applied the V (90%) percentile system (eliminating the extreme values situated between 0 - 5 and 95 - 100). The monitoring was based on four determinations per year for the sections with a quarterly control rhythm (those within isolated areas) and on twelve measurements for the sections with a monthly rhythm (the lakes with hydro-energetic and water supplying roles).

Results and discussions

The area studied includes the entire surface of Romania, mostly the natural lakes with ecologic and economic importance as well as the most significant artificial lakes (fig. 1). In the western side of Romania there have been hydrotechnical works, eliminating most floodplain lakes, while the situation is reversed in the east. In Moldavia (the Northeastern sector of Romania), we find the oldest and most numerous artificial lakes, most of them small, but some large, with complex roles.

The complex analysis of the lakes was based on hydrographic basins. We took into account the most important lacustrine surfaces (small-sized or those with an economic use of national importance) of all the hydrographic basins. This study also required the study of other lakes that are smaller, but because they are only locally important, they are not included in this material. Additionally, we have not made any reference to the salt lakes within the salt mountains (natural and anthropic) because they present other characteristics, being used only for therapeutic purposes.

Regarding the distribution of lakes in Romania, we noticed there are less lakes in the west, but more in the east. The absence of lakes in the rest of the country (mostly in the west of Romania) is due to the hydrotechnical drainage works performed to prepare the fields for agriculture.

The multitude of lakes in northeast Romania (the basins of Siret and Prut) are due to the reduced hydrological resources and the need to preserve them. For this reason, many lakes were built, some abandoned, and others clogged because of the high degree of soil erosion (friable substrate) [4]. The lakes studied are part of the following categories: 90 anthropic, 13 floodplain, 12 fluvial lagoon, 5 glacial, 6 lagoon, 6 marine lagoon, 1 karsto-saline, 1 subsidence, 1 volcanic and 1 natural barrage (table 1).

Regarding use, the lakes studied can be included in several categories: complex – 64 (in a relatively uniform distribution within the Romanian territory); energetic – 15 (on rivers with high hydro-energy potential); fishing – 14 (in the lower areas or in the Danube floodplain); water supply for localities or industrial objectives – 16 (the mountain area); tourism – 11 (the natural lakes, accessible to visitors – glacial, natural barrage, volcanic, etc.); therapeutic – 4 (subsidence lakes or those in the littoral area); irrigation – 1 (the Romanian Plain); without practical use, with only landscape purposes – 10 (those falling into the category of moors or the glacial lakes within unreachable areas) (table 1).

Table 1

MORPHOMETRIC CHARACTERISTICS AND TROPHICITY OF THE LAKES IN ROMANIA

No.	Lake	Type of lacustrine basin (genesis)	Water course	Usage**	Volume mln.m^3***	Surface (ha)	Maximum depth (m)	Water quality (category)****	
								Nutrients (total nitrogen, total phosphorous)	Biology
Danube river basin									
1	Portile de Fier I	H	Danube	E	2900.0	10441	-	E	M
2	Portile de Fier II	H	Danube	E	1000.0	5200	-	E	M-E
3	Gârla Mare	F	-	-	-	-	1,7	E-H	H
4	Bistretu	F	-	-	-	-	-	E-H	H
5	Suhaia	F	-	-	-	-	-	E	H
6	Mariuta	H	Mostistea	C	14.0	-	-	M	H
7	Fundulea	H	Mostistea	C	49.5	440	-	E	H
8	Gurbanesti	H	Mostistea	C	124.5	680	-	M	H
9	Frasinet	H	Mostistea	C	180.0	1460	-	E	O
10	Iezer	H	Mostistea	C	280.0	2600	-	E	M
11	Galatui	F	Berza	F	8.5	750	2,0	E-M	H
12	Greaca	Fb	-	-	Ag-d	-	-	E	E
13	Bugeac	L	Danube	F	41.1	3002	1.70	E-H	H
14	Oltina	L	Danube	F	60.0	2509	1.50	E-H	H
15	Dunareni	L	Danube	F	-	768	0.70	E	H
16	Cochirleni	L	Danube	F	-	-	1.40	E	H
17	Brates	F	Prut	C	-	7420	3,5	E	H
18	Saraturi	F	Danube	-	-	75	1,3	E	E
19	Jijila	F	Danube	F	-	2500	1.5	E	H
20	Crapina	F	Danube	F	-	10000	-	E	H
21	Ciuperca	F	Danube	R	-	-	2.5	M	E
Tisa river basin									
22	Buhaescu	G	-	-	0.004	0.2	5	M-E	O
23	Calinesti-Oas	H	Tur	C	29.0	160	9	E	E
Somes river basin									
24	Colibita	H	Bistrita	C	101.2	314	50	E-H	O
25	Firiza	H	Sasar	C	-	110.0	37.5	E	O
26	Lala	G	-	-	-	0.6	2	UO	UO
27	Gilau	H	Somesul Mic	C	4.2	70.0	9	M-E	UO
28	Strâmtori	H	Firiza	C	16.6	113.0		E	M
29	Stiucilor	KS	Fizes	C	1.8	68.7	12.7	M	O
30	Geaca	H	Fizes	C	V	-	-	O-M	M
31	Vârsolt	H	Crasna	C	39.9	-	-	M	M
32	Dindesti	H		C	-	-	-	M	M
33	Bodi-Mogosa	F	Sasar	C	0.3	1.6	7	E-H	UO
Crisuri river basin									
34	Cefa	H	Collecting Channel	F	-	925	-	M	M
35	Tamasda	H	Crisul Negru	F	-	200	-	M	M
Mures river basin									
36	Zau de Câmpie	H	Ludus	C	V	117	-	E	M
37	Bezid	H	Cusmed	C	31.0	150.0		E	O
38	Ighis	H	Ighis	WS	13.4	-		E-H	H
39	Nedeiu	H	Sebes	E	-	-	3	E	M
40	Petresti	H	Sebes	E	1.7	-		M	O
41	Teliuc	H	Cerna	WS	41.0	867	40	M	UO
42	Hateg	H	Râul Mare	C	14.5	-		M	UO
43	Bucura	G	Râul Mare	-	0.487	8.9	15.5	UO	UO
44	Taut	H	Nadas	C	-	20	-	M	O
Bega-Timis river basin									
45	Trei Ape	H	Timis	C	6.3	53	30	H	E
46	Surduc	H	Gladna	C	66.3	460		E	H
47	Gozna	H	Bârzava	C	12.0	60.0	40	H	E
48	Secu	H	Bârzava	C	15.1	105	30	H	E
Nera-Cerna river basin									
49	Taria	H	Taria	WS	-	-	-	H	E
50	Valea lui Iovan	H	Cerna	C	126.0	292.0	107	H	M
51	Herculane	H	Cerna	C	15.7	86.6	-	H	M
Jiu river basin									
52	Isalnita	H	Jiu	WS	1.4	-	-	H	O
53	Valea de Pesti	H	Jiul de Vest	WS	5.0	-	53	M	UO
54	Lacul Mic	G	Barbat	T	-	-	10	M-E	E
55	Gârla Mare	S	Jiu	T	0.600	-	-	M-E	E
56	Rotunda	F	Jiu	T	1.4	100	-	H	H
Olt river basin									
57	Mesteacanu	H	Olt	WS	1.1	15	16	M-E	UO
58	Sfânta Ana	V	-	T	0.250	19.5	7.5	M	M
59	Frumoasa	H	Frumoasa	WS	10.6			O-M	UO
60	Gura Râului	H	Cibin	WS	15.5	65	17	M	H
61	Râmnicu Vâlcea	H	Olt	E	19.0	-	-	E	M
62	Dopca	H	Valea Mare	WS	0.7	-		E	M
63	Sacele	H	Târlung	WS	18.3	-	37	M-E	UO
64	Babeni	H	Olt	E	78.3	-	-	H	UO
65	Bradisor	H	Lotru	C	38.0	-	-	M	H
66	Vidra	H	Lotru	C	340.0	1035	109	M	O
67	Slatina	H	Olt	E	31.0	498	10	H	E
68	Scoreiu	H	Olt	E	5.2	-	-	H	E
69	Bâlea	G	Cârtisoara	T	0.240	180	11.35	UO	UO

			Arges river basin						
70	Zigoneni	H	Arges	E	13.4	-	-	E	E
71	Vâlcele	H	Arges	E	44.0	-	-	E	M
72	Budeasa	H	Arges	C	55.0	-	-	E	O
73	Golesti	H	Arges	C	86.0	680	-	H	M
74	Vidraru	H	Arges	C	473.0	893	155	OM	O
75	Râusor	H		E	68.0	-	-	E	O
76	Facau	H	Ilfovat	Is	3.0	-	-	H	M
77	Gradinari	H	Ilfovat	C	12.4	-	-	E	M
78	Vacaresti	H	Dâmbovita	C	54.0	189	-	H	O
79	Pecineagu	H	Dâmbovita	E	69.0	182	-	E	O
80	Morii	H	Dâmbovita	E	19.6	246	-	E	E
81	Comana	F	Neajlov	T	6.0	1000	-	H	M-E
82	Cernica	H	Colentina	C	8.8	311	-	H	E
			Ialomita river basin						
83	Caldarusani	L	Ialomita	T	4.5	224	5	H	E-H
84	Snagov	L	Ialomita	T	17.2	576	9	E-H	M-E
85	Amara	L	Ialomita	Th	2.6	156	3	M-E	M-E
86	Fundata	L	Ialomita	Th	10.0	510	5	E-H	M-E
87	Paltinu	H	Doftana	WS	62.3	215	107	E-H	O
88	Pucioasa	H	Ialomita	WS	11.0	105	30	H	UO
89	Maneciu	H	Teleajen	C	58.0	192	-	H	O
90	Dridu	H	Ialomita	C	60.0	-	-	H	E
			Siret river basin						
91	Bucecea	H	Siret	C	24.5	475	-	M-E	O
92	Rogojesti	H	Siret	C	48.4	800	9	M-E	O
93	Galbeni	H	Siret	C	71.0	1123	-	E-H	E-H
94	Dragomirna	H	Dragomirna	WS	17.0	106	-	M-E	M
95	Calimanesti	H	Siret	E	44.3	-	-	E-H	O
96	Izvorul Muntelui	H	Bistrita	C	1230.0	3000	90	M	M
97	Bâtca Doamnei	H	Bistrita	E	10.0	235	16	E	O
98	Poiana Uzului	H	Uz	WS	90.0	335	75	E-H	M
99	Tungujei	H	Sacovat	C	25.0	-	-	E	UO
100	Puscasi	H	Racova	C	20.7	-	-	H	O
101	Cazanesti	H	Stavnic	C	20.6	-	-	H	O
102	Solesti	H	Vasluiet	C	47.0	-	-	H	O
103	Cuibul Vulturilor	H	Tutova	C	54.6	1150	-	E-H	O
104	Râpa Albastra	H	Simila	C	25.8		-	H	UO
105	Jirlau	L	Valea Boului	F	5.6	900	-	H	M
106	Amara	L	Buzoel	F	3.6	600	3,0	H	M
107	Balta Alba	L	Boldul	Th	5.1	1012	4	H	M
108	Siriu	H	Buzau	C	158.0	360	-	E	O
109	Cândesti	H	Buzau	C	4.4	-	-	E-H	M
110	Rosu	Nb	Bicajel	T		13	7.5	M-E	UO
111	Rediu	H	-	-	-	-	-	E	M
			Prut River basin						
112	Cal Alb	H	Baseu	C	11.9	-	-	H	E
113	Stânca-Costesti	H	Prut	C	1400.0	140000	-	H	O
114	Mileanca	H	Podriga	C	9.5	-	-	H	E
115	Negreni	H	Baseu	C	19.8	304	-	M	O
116	Dracsani	H	Sitna	C	9.5	574	-	H	E
117	Catamaresti	H	Sitna	F	14.0	-	-	H	M
118	Halceni	H	Miletin	WS	49.5	-	-	E-H	O
119	Tansa	H	Bahlui	C	33.0	360	7	E-H	UO
120	Pârcovaci	H	Bahlui	WS	5.5	-	-	M-E	UO
121	Podul Iloaiei	H	Bahluiet	F	-	-	-	E	E
122	Ciric	H	-	C	-	-	-	E	E
123	Gorban	F	-	-	-	-	1,4	E	E
			Black Sea Hydrographic basin						
124	Razim	Lg	-	C	909.0	39400	3	E	M
125	Sinoie	Lg	-	C	-	17150	2.3	H	H
126	Golovita	Lg	-	C	-	11870	2.5	H	H
127	Zmeica	Lg	-	C	-	5460	1.5	H	H
128	Babadag	L	Taita	F	-	2470	3	E-H	H
129	Nuntasi	Lg	-	C	-	1050	1.3	H	H
130	Corbu	ML	Cargalâc	C	7.7	528	2	H	H
131	Tasaul	ML	Casimcea	C	60.0	2306	3.5	H	H
132	Siutghiol	Lg	-	T	91.0	1960.0	17.5	H	H
133	Techirghiol	ML	Urluchioi	Th	41.8	1161.0	9.75	H	H
134	Agigea	ML	Agigea	T	0.3	64.0	0.7	H	H
135	Tatlageac	ML	Tatlageac	C	2.2	141.0	2.5	H	H
136	Mangalia	ML		C	15.7	261.0	6	E	H

* H-anthropic, F- floodplain, Fb-floodplain (brook), Hb- anthropic (brook), L-fluvial lagoon, ML-marine lagoon, KS-karsto-saline, G-glacial, S-subsidence, V- volcanic, Nb-natural barrage, Lg- lagoon; ** E-energy, C-complex, F-fishing, T-tourism, Th-therapeutic, WS-water supply, I-Irrigation, R-recreational; *** Ag-d-agriculture (draining), V- variable; **** H-hypertrophic, E-eutrophic, M-mesotrophic, O-oligotrophic, UO-ultraoligotrophic.

The degree of trophicity for the lakes within the main Romanian hydrographic basins was based on the analysis of chemical aspects (according to the nutrient value) and the evolution of aquatic cenoses (according to the value of phytoplankton biomass). The qualifiers are given by the following levels: hypertrophic (H), eutrophic (E), mesotrophic (M), oligotrophic (O), ultraoligotrophic (UO), and intermediary levels (eutrophic-hypertrophic E-H, mesotrophic-eutrophic M-E, oligotrophic-mesotrophic O-M).

Eutrophic lakes are characterised by strong primary productivity, leading to a rich nutrient content. In contrast, oligotrophic lakes have very few nutrients, which means they are far less productive. Between the two categories,

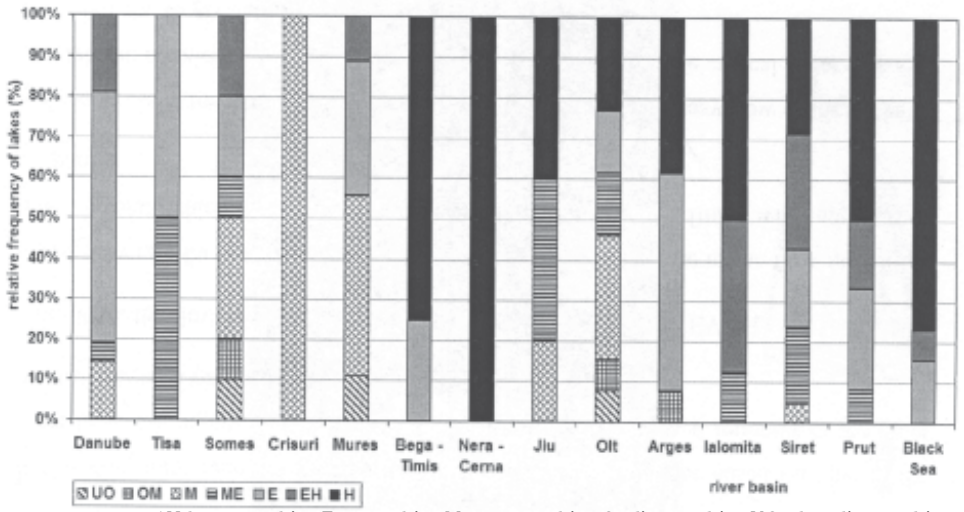

Fig. 2. Lacustrine water trophicity according to the nutrient value

*H-hypertrophic; E-eutrophic; M-mesotrophic; O-oligotrophic; UO-ultraoligotrophic

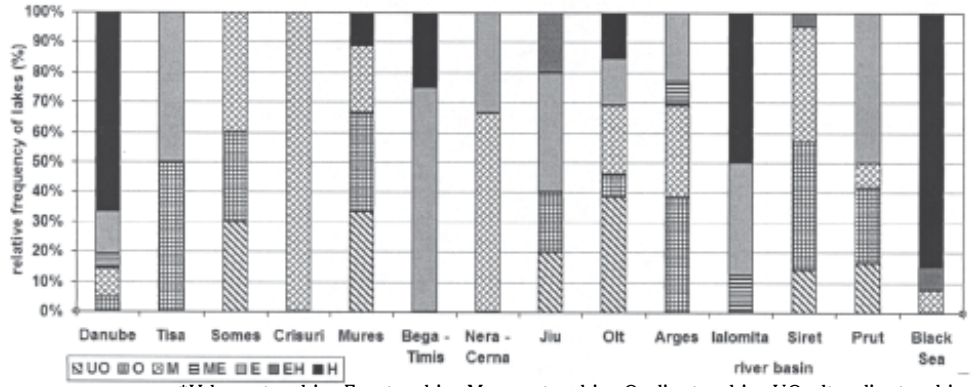

Fig. 3. Trophicity of lake waters according to the phytoplankton biomass value

*H-hypertrophic; E-eutrophic; M-mesotrophic; O-oligotrophic; UO-ultraoligotrophic

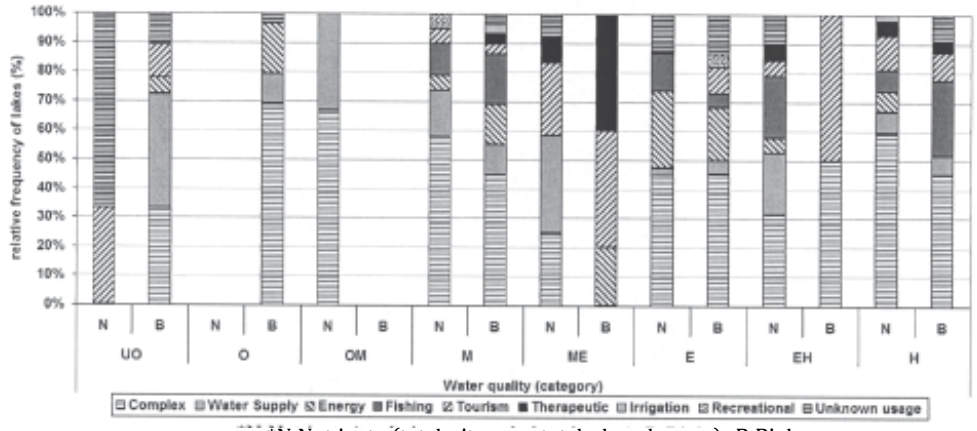

Fig. 4. Total number of lakes and trophicity type on categories of use

*N-Nutrients (total nitrogen, total phosphorous); B-Biology.

we find the mesotrophic lakes, with exhibit intermediary productivity. At the two extremes are the hypertrophic and ultraoligotrophic lakes. The geographic location of the lakes, depending on the landform (mountain, hill, plain, coast) creates different environments that are manifested in different degrees of trophicity.

We note that, according to nutrient value, most lakes fall into the categories of mesotrophic, meso-eutrophic, eutrophic, eutro-hypertrophic, and hypertrophic (121 of a total of 136, 88.97%) (Fig. 2). For the mesotrophic category, there are 18 lakes (13.23%). At the two extremes there are 3 ultraoligotrophic (2.2%) and 42 hypertrophic lakes (30.88%). If we take as a criterion the value of the phytoplankton biomass, there are more ultraoligotrophic, oligotrophic and oligo-mesotrophic lakes (91 out of 136, meaning 66.91%) (fig. 3), and there are 29 mesotrophic lakes (21.32%). At the two extremes, there are 17 ultraoligotrophic lakes (12.5%) and 33 hypertrophic lakes (24.26%).

The most numerous lakes, with complex use, are included in the category of hypertrophic waters (fig. 4). Those used for water supply fall into the category of ultraoligotrophic waters, and the energy-oriented lakes are eutrophic. The other lakes are categorised according to their natural environment and their origin. Most hypertrophic lakes are situated in lower landforms where temperatures are high, and there is a large amount of nutrients. The best area for high trophicity is that of the Danube floodplain. Most ultraoligotrophic lakes are situated in the high mountain area. All glacial lakes are included in this category, to which we also add the accumulations containing cold waters reposing on hard rocks.

In the area with the highest lake density (the northeast of Romania), there are aquatic surfaces with good and

very good trophicity (the basins of Siret and Prut), which is why many of the basins in the Moldavian Plateau are also the most important aquatic surfaces for fish culture (the second area in the country after the Danube Delta). Aside from the climate, the trophicity is also highly influenced by factors such as the nature of the rocks (sedimentary, metamorphic, volcanic and their corresponding chemical elements) within the drained hydrographic basin, the erosion rate, the transparency and the turbidity. The majority of lakes analysed are part of the category of lakes with average, high, and qualitative trophicity, being used in different fields of activity.

Conclusions

The Romanian lakes are many in number, but they are often small. The most numerous lacustrine surfaces are anthropic and are situated mostly in the centre (Transylvania) and in the northeast (Moldavia). Most anthropic lakes were built in the droughty areas (for water supply or for irrigation) and in the mountain regions (with hydro-energy and flood-attenuation roles). The lakes analysed were delimited within the hydrographic basins. We have not included the salt lakes within salt mountains because they present other characteristics, being used only for therapeutic purposes.

The degree of trophicity is given by five main qualifiers (hypertrophic, eutrophic, mesotrophic, oligotrophic, ultraoligotrophic), which distinguish the Romanian lakes on landforms and, implicitly, depending on the climate. Trophicity may also be influenced by the nature of the geologic substrate through its influence on the chemical composition of water. Concerning the nutrient value, most lakes fall within the categories of mesotrophic, meso-eutrophic, eutrophic, eutro-hypertrophic, and hypertrophic. Concerning trophicity, we underline that there are 33 hypertrophic lakes and 17 oligotrophic lakes. The other lakes fall into the intermediary categories (86). The lakes with the best trophicity are also used for fish culture (central and Northeastern Romania) and water supply (Northeastern and Southern Romania). Most lakes have a complex character. The high eutrophicity of certain lakes is given by the use of agriculture fertilisers (e.g., Mangalia, Razim, Brates) or by food used for fish culture (e.g., Podul Iloaiei, Gorban, Tungujei, Iezer).

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