Water resources and wetlands, *Editors: Petre Gâştescu, William Lewis Jr., Petre Breţcan*
Conference Proceedings, 14-16 September 2012, Tulcea - Romania
ISBN: 978-606-605-038-8

HYDROCHEMICAL FEATURES OF THE SOUTH DOBROGEA'S LAKES AND IMPACT OF THE CLIMATIC CONDITIONS ON THESE FEATURES

Camelia Eliza Telteu
University of Bucharest, Faculty of Geography, Bucharest, Romania, *elizapascu25@gmail.com*

Abstract

The present paper presents some hydrochemical features of the South Dobrogea's lakes. The study includes the lakes on the Black Sea shore (Siutghiol, Tăbăcărie, Techirghiol and Tatlageac) and on the right side of the Danube River (Bugeac, Oltina, Mârleanu, Iortmac şi Vederoasa). The analysis is based on the processing of data concerning the hydrochemical parameters for the years 2006 – 2008 (the data were provided by the "Romanian Waters" National Administration) and the data regarding the pH, the dissolved oxygen (mg/l), the total dissolved solids (g/l) and the salinity (g/l), obtained during summer 2011 (with Hanna intrument HI 9828). The concentration of the major ions are: chlorine (51.78 – 33737 mg/l), sulfate (50.93 – 6296 mg/l), magnesium (38.30 – 2470.42 mg/l) and calcium (25.93 – 206.40 mg/l). The values of the total mineral nitrogen (0.925 – 3.384 mg/l), of the total phosphorus (0.069 – 0.673 mg/l), of the phytoplankton biomass (5.99 – 19.46 mg/l) and of the chlorophyll "a" (44.590 – 601.449 µg/l) include the lakes to the eutrophic and hypertrophic status. In case of the Bugeac, Oltina and Siutghiol lakes, the analyze highlights statistically significant correlations, α = 0.05, between the precipitation (for 10 days, 20 days and 30 days), the daily air temperature and some hydrochemical parameters. Applying Carlson's Trophic State Index, based on the lakes's transparency values during summer 2011 (which were estimated with the Secchi disk), the Bugeac, Oltina, Mârleanu and Tatlageac lakes belong to the hypertrophic status.

Keywords: Lake, Eutrophication, Physico-chemical parameters, South Dobrogea.

1 INTRODUCTION

The hydrochemical features of the lakes are the result of the morphometrical and morphological features of their basins and catchment areas, of the physico-geographical factors (the climatic conditions, the soils, the vegetation) and of the human activities (pollution) (Kalff, 2002). The present paper presents some hydrochemical features of the South Dobrogea's lakes. The study includes the lakes on the Black Sea shore (Siutghiol, Tăbăcărie, Techirghiol and Tatlageac) and on the right side of the Danube River (Bugeac, Oltina, Mârleanu, Iortmac şi Vederoasa). Important contributions regarding the hydrochemical features of the South Dobrogea's lakes have been brought by Gâştescu (1971), Breier (1976), Gâştescu&Breţcan (2003), Dinu&Radu (2004), Romanescu&Romanescu (2005), Godeanu&Galatchi (2007), Romanescu (2008) etc. This paper has the aim to highlight the hydrochemical features of the lakes and to present their trophic status, and to show the links between these hydrochemical features and the climatic parameters.

1.2 Database and methodology

The analysis is based on the processing of data concerning the hydrochemical parameters for the years 2006 – 2008 (the data were provided by the "Romanian Waters" National Administration) and the data regarding the pH, the dissolved oxygen (mg/l), the total dissolved solids (g/l) and the salinity (g/l), obtained during summer 2011 (with Hanna instrument HI 9828). The analysis of the linear correlations between the hydrochemical and climatic parameters have been accomplished using the daily precipitation and the daily air temperature data from the Călăraşi and Constanţa weather stations (2006 – 2008), which are close to the Bugeac, Oltina and Siutghiol lakes (the data source: European Climate Assessment&Dataset – *ECAD*) (figure 1). The methodology includes statistical analyses and linear correlations between the climatic and hydrochemical parameters. The Bravais – Pearson statistical test has been used to establish the statistical significance of the correlations.

2. THE STUDY AREA

The South Dobrogea is a structural plateau, tabular, which is developed on the Sarmatian limestone covered by thick loessoid deposits (Popescu&Ielenicz, 2003). In the studied area, the mean elevation is 81.65 meters and the highest elevation is 220 meters (the data represent the results of the spatial analysis, using

GIS methods, of the Romanian Topographic Map, at scale of 1:25 000, the second edition, the Military Technical Institute, 1982).

Due to its geographical position, the South Dobrogea has a temperate continental climate characterized by dryness (Ciulache&Torică, 2003), with mean multiannual values of the air temperature which ranged between 10.9 ºC (at Adamclisi weather station) and 11.7 ºC (at Constanța weather station) (1965 – 2008). The mean multiannual values of the precipitation ranged, on the whole region, between 424.36 mm (at Mangalia WS) and 486.30 mm (at Adamclisi WS) (1965 – 2008). The mean multiannual values of the potential evapotranspiration ranged between 692.14 mm (at Adamclisi WS) and 718.75 mm (at Constanța WS), so the values of precipitation are exceeded between April and November (Telteu, 2012) (figure 1).

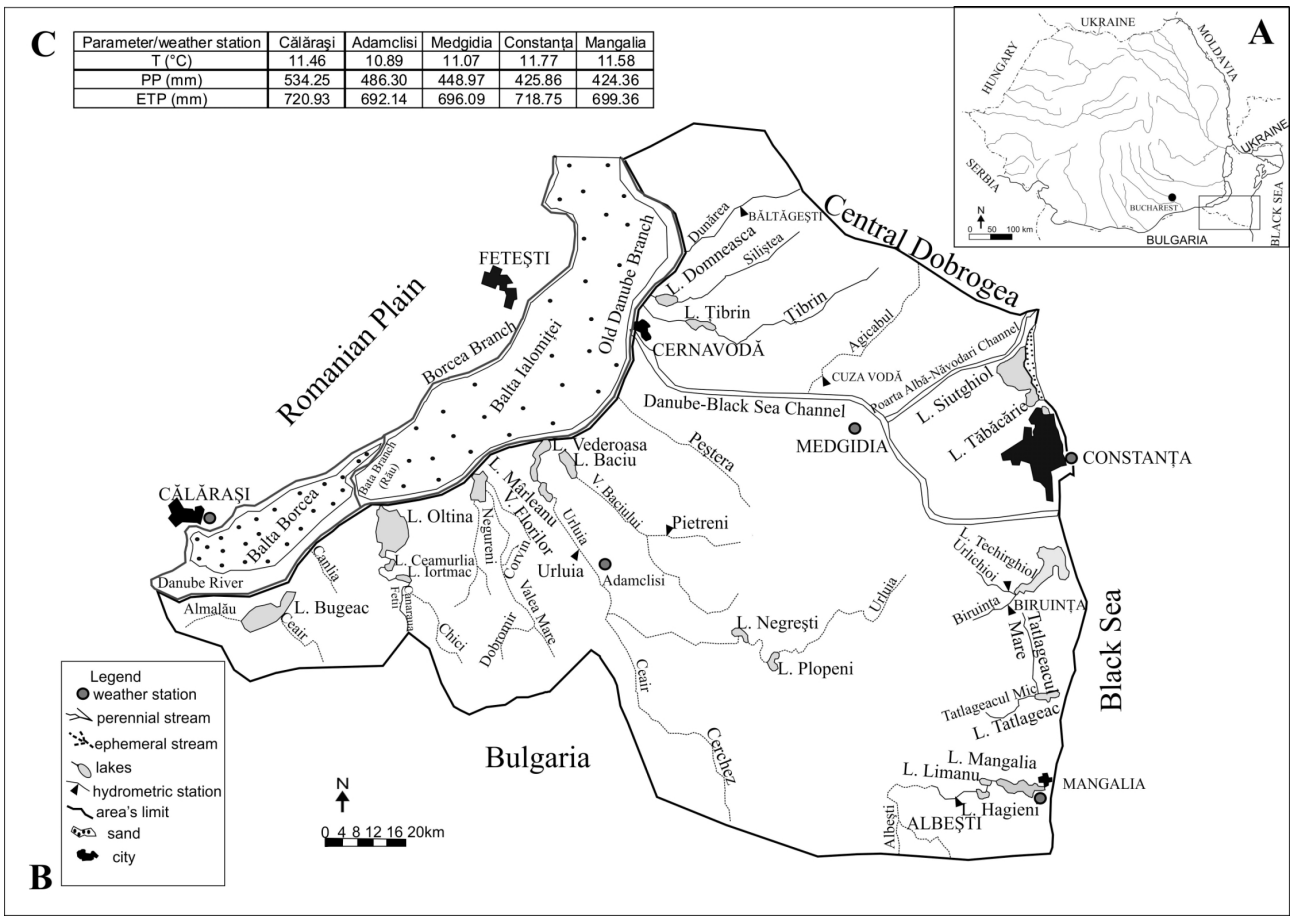

Fig. 1. The South Dobrogea Region. A. The location in Romania. B. The hydrographical map. C. Table with data on the mean multiannual values of the air temperature (T ºC), precipitations (PP mm) and potential evapotranspiration (ETP mm) for the period 1965 – 2008 (after L. Zaharia and I. Pişota, 2003, with additions)

From a hydrographical point of view, the South Dobrogea is characterized by a very weak drainage network due to the climatic and lithological conditions (Zaharia&Pişota, 2003). The South Dobrogea's lakes are fluvial lakes/fluvial – maritime lakes (*limane*) and lagoons which have been formed due to the level variations of the Black Sea and Danube River (Gâştescu&Breier, 1969; Banu, 1964). Between the lakes, the Oltina Lake has the highest area (25.09 km²). The Siutghiol Lake has the highest volume (88.70 mil. m³) and the highest mean depth (4.75 m) and the Vederoasa Lake has the highest catchment area (table 1). Generally, a high catchment area, with a low percent of forest and a high percent of arable land, facilitates the increase of the nutrients in the lakes water due to the erosion process and to the soils washing process (for example: the Vederoasa Lake). The nutrients values are influenced, on the one hand, by the mean depth of the lakes and, on the other hand, by the amount of water that flows out. The ratios between the lake's area or volume and the mean depth highlight the lake's dilution potential, the lake area over which the wind blows, the thermal stratification of the lake and the lake's potential to absorb heat (Kalff, 2002) (table 1).

Lake	LA* (km²)	V* (mil.m³)	D_m (m)	CA• (km²)	CA/LA	LA/D_m	V/D_m	CA/D_m	The lake type*
Bugeac	17.74	41.09	1.50***	201.02	11.33	11.83	27.39	134.01	fluvial lake
Oltina	25.09	59.95	1.50***	167.08	6.66	16.73	39.97	111.39	fluvial lake
Mârleanu	6.21	51.91	1.00***	335.78	54.07	6.21	51.91	335.78	fluvial lake
Vederoasa	1.50	3.75	1.00***	907.00	604.67	1.50	3.75	907.00	fluvial lake
Iortmac	1.87	0.94	1.00***	73.38	39.24	1.87	0.94	73.38	fluvial lake
Siutghiol	19.00	88.70	4.75**	51.16	2.69	4.00	18.67	10.77	lagoon
Tăbăcărie	0.99	2.10	2.30**	22.82	23.05	0.43	0.91	9.92	lagoon
Techirghiol	11.61	41.80	3.60**	174.23	15.01	3.23	11.61	48.40	fluvial-maritime lake
Tatlageac	1.78	14.00	1.60**	161.00	90.45	1.11	8.75	100.63	fluvial-maritime lake

Table 1 Data regarding the morphometrical parameters of the South Dobrogea's lakes

The data source: * *Atlasul Cadastrului Apelor din România, 1992*; ** Gâştescu, 1971; *** "Romanian Waters" National Administration – the Dobrogea Water Branch, 2004; • Romanian Topographic Map, at scale of 1:25 000, the second edition, the Military Technical Institute, 1982.

LA = lake area; V = lake volume; D_m = mean depth; CA = catchment area.

3. RESULTS

3. 1 Hydrochemical features of the lakes and their trophic status

The chemical composition of the lakes water is determined by several factors, as: the chemical composition of the tributaries water; the physico-geographical features of the area where the lakes are located, the genesis of the lake basins, how the lake is supplied or loses water (the hydrological budget), the organisms activities from the lake, the morphometrical features of the lake, the diffusion from the atmosphere (Trufaş&Trufaş, 1975; Wetzel, 2001).

In the lakes water, between the period 2006 – 2008, the chlorides concentrations ranged between 51.78 mg/l (Vederoasa lake) and 33737 mg/l (Techirghiol lake) and the sulfates concentrations oscillated between 50.93 (Vederoasa lake) and 6296 mg/l (Techirghiol lake). The magnesium concentrations ranged between 38.30 (Bugeac lake) and 2470.42 mg/l (Techirghiol lake) and the calcium concentrations oscillated between 25.93 (Iortmac lake) and 206.40 mg/l (Techirghiol lake). The values of the total mineral nitrogen (0.925 – 3.384 mg/l), of the total phosphorus (0.069 – 0.673 mg/l), of the phytoplankton biomass (5.99 – 19.46 mg/l) and of the chlorophyll "a" (44.590 – 601.449 µg/l) include the lakes to the eutrophic and hypertrophic status.

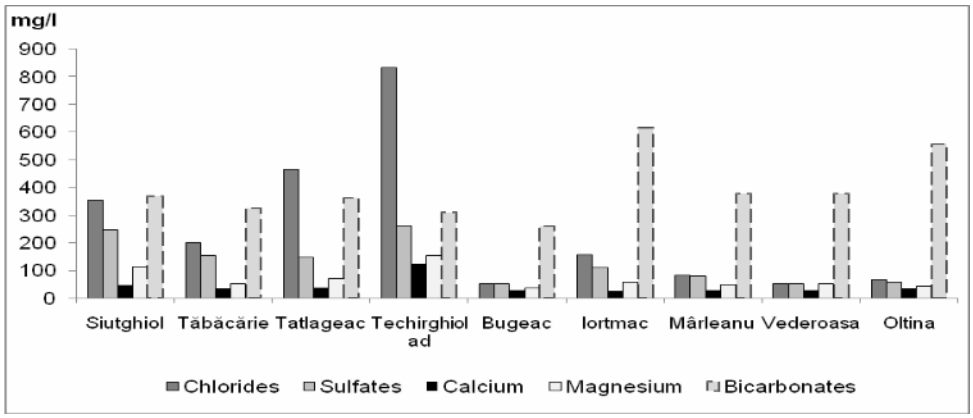

Fig. 2 The mean multiannual values of the major ionic constituents from the lakes water (2006 – 2008) Techirghiol ad = the Techirghiol lake with freshwater

During the summer 2011, in the Bugeac, Oltina, Mârleanu and Tatlageac lakes, the pH ranged between 7.98 (Bugeac lake) and 8.26 (Mârleanu lake), the dissolved oxygen between 8.51 mg/l (Oltina

lakes) and 9.29 mg/l (Tatlageac lake), the total dissolved solids between 0.29 g/l (Bugeac lake) and 1.29 (Tatlageac lake), the salinity 0.29 g/l (Bugeac lake) and 1.33 (Tatlageac lake) (table 2).

Lake	Date	T (°C)	pH	ORP	OD (%)	OD (mg/l)	C (µS/cm)	TDS (g/l)	Salinity (g/l)
Tatlageac	10.08.2011	26.67	8.22	8.71	116.82	9.29	2590.28	1.29	1.33
Bugeac	08.08.2011	26.41	7.98	19.68	108.07	8.71	714.55	0.29	0.29
Oltina	06.08.2011	24.33	8.23	51.18	101.41	8.51	831.22	0.37	0.36
Mârleanu	04.08.2011	25.72	8.26	67.31	106.01	8.63	812.01	0.39	0.39

Table 2. Data regarding the mean instant values of the hydrochemical parameters (summer 2011)

T = water temperature; ORP = oxido-redox potential; OD (%) = oxygen saturation; DO (mg/l) = dissolved oxygen; C = conductivity; TDS = total dissolved solids.

In the case of the Bugeac, Oltina, Mârleanu and Tatlageac lakes, has been analyzed their trophic status according to Carlson's Trophic State Index (TSI) based on the lakes's transparency values during summer 2011 (which was estimated with the Secchi disk) and applying the formulas 1 – 3 (Carlson, 1977):

$$TSI\ (Chl) = 10 \times (6 - (2.04 - (0.68 \times (\ln(chl)))/\ln(2))) \quad (1)$$

$$TSI\ (TP) = 10 \times (6 - (\ln(48/TP)/\ln(2))) \quad (2)$$

$$TSI\ (SD) = 10 \times (6 - \ln(SD)/LN(2)) \quad (3)$$

Chl (mg/m³) = chlorophyll „a"; TP (mg/m³) = total phosphorus; SD (m) = transparency value estimated with the Secchi disk.

At the end of the analysis, the lakes were included to the hypertrophic status applying Carlson's Trophic State Index (table 3).

Lake	Date	Transparency (m)	TSI (TP)	TSI (Chl)	TSI (SD)	TSI	Trophic status
Tatlageac	15.08.2011	0,25	81.62	89.03	80.00	83.55	Hyperthrophic
Bugeac	08.08.2011	0,17	87.50	94.79	85.76	89.35	Hyperthrophic
Oltina	06.08.2011	0,15	89.14	96.40	87.37	90.97	Hyperthrophic
Mârleanu	04.08.2011	0,12	92.25	99.45	90.42	94.04	Hyperthrophic

Table 3 Data regarding the trophic status of the South Dobrogea's lakes during summer 2011

3.2 The impact of the climatic conditions on the hydrochemical parameters

To identify the links between the hydrochemical parameters and the climatic conditions linear correlations were made between these parameters and the precipitation from the previous days (10 days, 20 days and 30 days) and the daily air temperature.

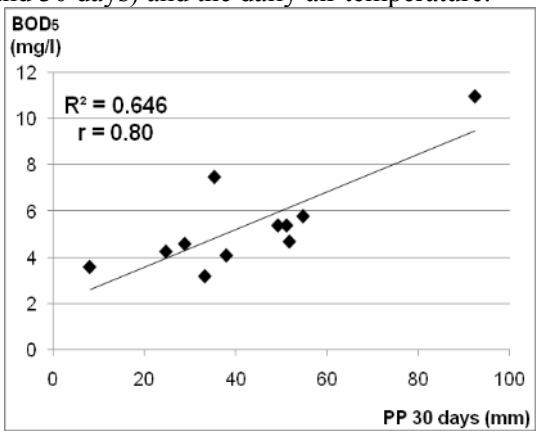

Figure 3. The correlation between the mean annual values of the 5-day biochemical oxygen demand and the precipitation for 30 previous days (Bugeac lake, 2006 – 2008)

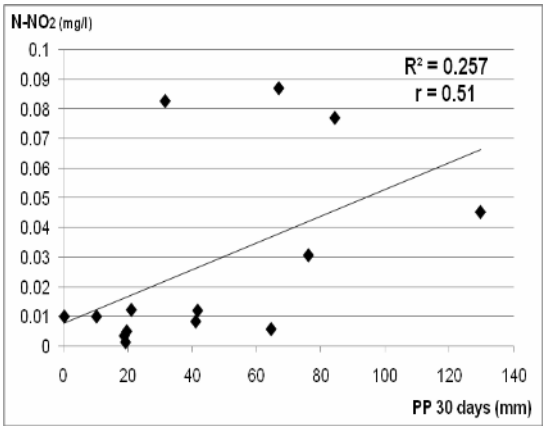

Figure 4. The correlations between the mean annual values of the nitrites and the precipitation for 30 previous days (Siutghiol lake, 2006 – 2008)

In the case of the Bugeac, Oltina and Siutghiol lakes, were found statistically significant relations (for an error risk $\alpha = 0.05$, according to the Bravais – Pearson statistical test) between the mean daily air

temperature and the water temperature, the dissolved oxygen, the orthophosphates (Bugeac lake: the correlation coefficient – r = 0.64), the sulfates (Oltina lake: r = 0.75), the nitrites and the total mineral nitrogen (Oltina lake: r = 0.68 and r = 0.69) (table 4). In the case of the precipitation, were found the statistically significant relations between these and the anions concentrations (chlorine and sulfate), the cations (the calcium and the magnesium), the nutrients (the phosphorus and the nitrogen), the phytoplankton density (table 5, the figures 3 and 4). The statistically significant relations identified highlight the important role of the climatic conditions on the chemical and biological processes of the lakes water.

Correlation	Correlation coefficient (r)	Coefficient of determination (R^2)
CLTA – TaB	0.93	0.878
CLTA – O_2B	0.58	0.338
CLTA – P-PO_4B	0.64	0.409
CLTA – TaOl	0.96	0.916
CLTA – SO_4Ol	0.75	0.567
CLTA – O_2Ol	0.62	0.387
CLTA – N-NO_3Ol	0.68	0.457
CLTA – TMNOl	0.69	0.483
CTTA – TaS	0.97	0.932

Table 4. Data regarding the correlation coefficients and coefficients of determination between the daily air temperature and the hydrochemical parameters (2006 – 2008) CL = Călăraşi; CT = Constanţa;B = Bugeac;Ol = Oltina; S = Siutghiol; TA = daily air temperature; Ta = water temperature; SO_4 = sulfates; O_2 = dissolved oxygen; P-PO_4 = orthophosphates; TMN = total mineral nitrogen.

Correlation	Correlation coefficient (r)	Coefficient of determination (R^2)
CLPP_{30} – MgB	0.80	0.648
CLPP_{20} – ClB	0.61	0.370
CLPP_{30} – O_2B	0.64	0.410
CLPP_{30} – BOD_5B	0.80	0.646
CLPP_{30} – COD-MnB	0.75	0.556
CLPP_{30} – TPB	0.66	0.441
CLPP_{10} – DFB	0.58	0.338
CLPP_{30} – DFB	0.70	0.491
CLPP_{30} – SO_4Ol	0.63	0.399
CLPP_{30} – O_2Ol	0.77	0.558
CLPP_{10} – N-NO_3Ol	0.59	0,349
CLPP_{10} – TMNOl	0.58	0.335
CLPP_{20} – DFOl	0.63	0.397
CTPP_{30} – CaS	0.66	0.43
CTPP_{30} – MgS	0.67	0.444
CTPP_{20} – SO_4S	0.64	0.413
CTPP_{30} – SO_4S	0.66	0.433
CTPP_{30} – N-NO_2S	0.51	0.257

Table 5. Data regarding the correlation coefficients and coefficients of determination between the precipitation at different intervals and the hydrochemical parameters (2006 – 2008) CL = Călăraşi; CT = Constanţa; B = Bugeac; Ol = Oltina; S = Siutghiol; PP_{10} = precipitation for 10 previous days; PP_{20} = precipitation for 20 previous days; PP_{30} = precipitation for 30 previous days; Ca = calcium; Mg = magnesium; Cl = chlorine; SO_4 = sulfates; O_2 = dissolved oxygen; BOD_5 = the 5-day biochemical oxygen demand; COD-Mn = chemical oxygen demand; N-NO_2 = nitrites; N-NO_3 = nitrates; TP = total phosphorus; TMN = total mineral nitrogen; DF = phytoplankton density.

4. CONCLUSIONS

The hydrochemical features of the South Dobrogea's lakes are caused by several factors of which the most important are the morphometrical features of the lakes and the physico-geographical features of the catchment areas (especially, the climatic conditions). The analysis highlights statistically significant relations (for an error risk α = 0.05) between the hydrochemical and meteorological parameters (the air temperature,

the precipitation). Generally, the lakes belong to the eutrophic and hypertrophic status and have favorable conditions for fish production.

Acknowledgements
This work was supported by project: POSDRU/88/1.5/S/61150 "Doctoral Studies in the field of life and earth sciences", project co-financed through Sectorial Operational Program for the Development of Human Resources 2007-2013 from European Social Fund.

REFERENCES

Aquaproiect, (1992), *Atlasul Cadastrului Apelor din România*, Ministerul Mediului, Bucureşti, 694 p.

Banu, AC., (1964), *Date asupra transgresiunii de vârstă istorică în Bazinul Mării Negre şi al Dunării inferioare,* Hidrobiologia, 5, 237-252.

Breier, A. (1976), *Lacurile de pe litoralul românesc al Mării Negre. Studiu hidrogeografic*, Editura Academiei Române, Bucureşti.

Carlson, R. E. (1977), A trophic state index for lakes, Limnology and Oceanography, 22 (2): 361-369.

Ciulache, S. et Torică, V., 2003 : Clima Dobrogei *Analele Universității Bucureşti*, LII, 83-105.

Dinu, C., Radu, A. (2004), *Date privind condiţiile hidrobiologice din limanele Bugeac şi Oltina (Constanţa)*, Delta Dunării, Tulcea, p. 25-38 at http://www.icemtl.ro/delta_dunarii_II.html accessed on 15.05.2012.

Gâştescu, P. et Breier, A. (1969), Lacurile din Dobrogea, Studii Geografice asupra Dobrogii, Lucrările Primului Simpozion de Geografie a Dobrogii, Constanța, 5-6 octombrie 1968, pages 97-104.

Gâştescu, P. (1971), Lacurile din România, Editura Academiei Române, Bucureşti, 372 pages.

Gâştescu, P., Brețcan, P. (2003), Aspecte privind starea actuală a lacurilor Siutghiol şi Techirghiol, Analele Universității "Valahia" Târgovişte, Seria Geografie, Tomul 3, p. 134-138.

Geicu A. et Becheanu V., 2008 : Stratul de zăpadă, In Sandu I., Pescaru V. I., Poiană I., Geicu A., Cândea I. et Ţâştea D., (Eds.) *Clima României*. Editura Academiei Române, 304-311.

Godeanu S., Galatchi L.D. (2007), *The Determination of the Degree of Eutrophication of the Lakes on the Romanian Seaside of the Black Sea*. Ann. Limnol.-Int. J. Lim.; 43 (4): 245-251.

Kalff J., (2002), Limnology-Inland Water Systems. Prentice Hall, Upper Saddle River, New Jersey, 592 pages.

Păltineanu, C., Mihăilescu, I. F. et Seceleanu, I., 2000 : *Dobrogea-Condiţiile pedoclimatice, consumul şi necesarul apei de irigaţii pentru principalele culturi agricole*. Editura EX Ponto. Constanța, 258 pages.

Popescu N, Ielenicz M. (2003), Relieful Podişul Dobrogei – caracteristici şi evoluţie, Analele Universității Bucureşti, LII: 5-58.

Romanescu Gh, Romanescu G. (2005), *Caracteristicile fizico-chimice ale lacurilor litorale diun sectorul românesc al Mării Negre (Capul Midia-Vama Veche),* Seminarul Geografic "D. Cantemir", nr. 25, pages 97-117.

Romanescu, Gh. (2008), *The ecological characteristics of the romanian littoral lakes-The sector Midia Cape-Vama Veche*, Lakes, reservoirs and ponds, vol.1-2:49-60, December 2008, Romanian Limnogeographical Association.

Telteu, C. E. (2012), *Relations entre les conditions climatiques et les ressources en eaux dans la Dobrogea de Sud (Roumanie),* Actes du 25ème colloque de l'Association Internationale de Climatologie, in press.

Trufaş, V., Trufaş, C. (1975), *Hidrochimie*, Tipografia Universității din Bucureşti, Bucureşti.

Zaharia, L, Pişota, I., (2003), *Apele Dobrogei*, Analele Universității Bucureşti, LII, 107-143.

Wetzel, R .G. (2001), *Limnology*, 3rd edition, Academic Press, New York, 1006 pages.

***(2004), *Planul de management al Fluviului Dunărea, Deltei Dunării, Spaţiului Hidrografic Dobrogea şi Apelor Costiere*, 594 pag. at http://www.rowater.ro/dadobrogea/SCAR/Planul%20de%20management.aspx?RootFolder=%2fdadobrogea%2fPlanul%20de%20Management%20Bazinal%2fPlan%20de%20Management%20al%20Fluviului%20Dunarea%2c%20Deltei%20Dunarii%2c%20Spatiului%20Hidrografic%20Dobrogea%20si%20Apelor%20Costiere&FolderCTID=&View=%7b02A39433%2d949F%2d40C6%2d9DF4%2d54F3511B7DA7%7d accessed on 02.05.2004.

*** http://eca.knmi.nl