Bulletin UASVM Animal Science and Biotechnologies, 66 (1-2)/2009
Print ISSN 1843-5262; Electronic ISSN 1843-536X

The Study of some Physical–Chemical Parameters of Water and Relationship with Phytoplankton in Fish Pond

Cristina HEGEDUS[1], Silvana POPESCU[2], Anca BOARU[1], Cristin BORDA[2], Alin FORNADE

[1]University of Agricultural Sciences and Veterinary Medicine, Faculty of Animal Science and Biotehnologies, 3-5 Manastur Street, 400372 Cluj-Napoca, Romania; cristina.hegedus@yahoo.com
[2]University of Agricultural Sciences and Veterinary Medicine, Faculty of Veterinary Medicine, 3-5 Manastur Street, 400372 Cluj-Napoca, Romania

Abstract. Paper presented to the investigation conducted in two fish ponds on biological year March to October 2008. The study highlights the fluctuations physical - chemical: temperature, dissolved oxygen, organic substance, nutrients along with the dynamics of phytoplankton development season and ecological analysis of this group in relation to the variables analyzed, the factors that concur at degree impurification of water.

Water temperature increases simultaneous with the air temperature, highest value recorded in the summer. Evolution of phytoplankton fallow an variables season in depending of physical-chemical parameters studied; the spring season is dominated by blue algae (16-18 species), their number decreasing with increasing values of temperature, number of blue algae were relatively constant throughout the year, the share increase is green algae species dominated in summer and autumn. Dissolved oxygen shows a gradual fall with submission to the summer months leading to an intensification of the processes of degradation of organic matter, influence such variations that occur at the pH, which increases and fluctuations of nutritive elements based on nitrogen N-NH_4, N -NH_3-N NO_2-, NO_3-N and phosphorus P-PO_4, depending on which water falls into the category mesosaprobic. Meet excellent indicators of a class of water quality mesosaprobic: *Synedra, Nitzschia, Melosira, Closteriopsi acicularis, Actinastrum hantzschi, Monoraphdyum grifitti, Scenedesmus opoliensis, Pediastrum duplex*

Keywords: physical - chemical parameters, phytoplankton, biological indices

INTRODUCTION

Algal growth is dependent on factors: temperature, luminosity, the particular species, the biogenic elements, the negative repercussions of excessive growth leading to impairment of water quality and in particular by affecting the pH, the occurrence of oxygen deficiency, alteration of water color, etc. (WEIZEL RL 1979). BARINOVA SS (2004) points out that algae is excellent for determining indicators of water quality, nutrient or organic enrichment of it, and also an indicator for major ions, dissolved oxygen, pH of water. Aquatic life is affected by processes taking place in water level fluctuations and several parameters acting simultaneously nutrients in the water affects the entire aquatic because they are the necessary resources to primary producers and these fluctuations affect the whole food chain produced (HUSTEDT mentioned by JOHN D., 2002). On the other hand high amounts of nutrients can have serious negative repercussions, increasing the excess of primary producers with effects on consumers (INGA LIPS, 2005). Total taxonomic diversity increased in parallel with the decline of nutrients in the water. (KAMENIR Y., MORABITO G. 2009).

MATERIALS AND METHODS

Collection and examination of samples was performed according to Order 161/2006, following between physical parameters, temperature (epilimnion and hipolimnion) and chemical parameters studied on biological year was: pH of water, dissolved oxygen; the nutrient regime expressed by: N- NH_4, N-NH_3, N- NO_2, N-NO_3, and P-PO_4.between elements who has phosphorus, this inorganic parameter being the most soluble in water, and CCOMn. The analysis highlights the ecological freshwater in relation to the variables: pH, organic, nutrients.

After the physical-chemical interpretation of the results was prepared according to Order 161/2006 for approving norm concerning the classification of surface water quality in order to establish environmental bodies of water. The results were interpreted as indicators of light physical - chemical and biological ones integrated characterized trophic level and degree of eutrophication of the ponds studied. In parallel biological indicators were analyzed using the Palmer index (API-Pollution Algal Index, (PALMER C.M 1969) values obtained showing the trophic level and intensification at eutrophication process of fish pond at the presence of reliable eutrophication of types of algae are most tolerant to organic pollution.

RESULTS AND DISCUSSION

Water temperature. The mean seasonal value of studied parameter it finds in table 1 and 2. Because the fishponds have had reduced depth 2-2.5 m, the water temperature is subject to air temperature. Spring season afloat average is around 12.751±2.98^{o}C and 10.02±3.30^{o}C at bottom of pond, lower values reduced 9.15^{o}C-6.55^{o}C are in the first month (March); values who increase with the warming air, reaching at 16.7^{o}C respectively 14.45^{o}C. Beginning of the summer heat felt through beds of water from the epilimnion and hipolimnion temperature values obtained were between 22.90^{o}C (bottom ponds) and 28^{o}C (surface); the season mean with values ranging 25.99±1.259^{o}C–surface and 25.22±1.71^{o}C-bottom ponds. During autumn the water temperature follows a downward curve, the values ranging between 18.012±1.44^{o}C–surface and 17.07±1.575^{o}C-bottom, with minimum limits between 16.20–15.30^{o}C and maximum values between 15.75^{o}C şi 16.20^{o}C. Significant differences in the same season between the two layers are observed in spring when P=0.0449 (t=2.127 for 22 G.L). The same distribution of values of temperature meets for the second pool, but the spring values of the two layers are significant P=0.082 (t=1.81, 22 G.L) and very significant from a statistical viewpoint summer P=0.0011 (t=3.77,22 G.L) although the mean season does not differ very much 25.875 ±2.381^{o}C epilimion 24.845± 2.991^{o}C hipolimnion.

Dynamic trend of the temperature follows the same distribution, the average spring values being 11.709±4.09^{o}C on surface and 9.23±2.33^{o}C–bottom pond, and autumn values are variable as follows: 18.787±3.926^{o}C epilimnion–16.77±4.04^{o}C–bottom of pond Low temperature during the spring determine dominance of Bacillariophyceae and Cyanophyceae where the species meet are *Cymbella helvetica, Navicula cryptocephala, Cyclotella sp*. and *Gomphonema angustum* which do the transit of clean water at eutrophic water. Of Bacilaryophyceae during spring prevails *Chrococcus dispersus, Gomphospaeria lacustris* and *G. aponina*, with heating water *Aphanizomemnon flos – aque and Mycrocystis aeruginosa. Summer is characterized by the Chlorophyceae dominance.*

Dissolved oxygen. Water temperature influences the maximum amount of dissolved oxygen and the activity for all aquatic organisms; between the two parameters there is an inverse relationship, and the resulting correlation coefficient obtained, strongly negative at the epilimnion r=-0.8294 (4), r = -0.9291 (9) r = -0.67 (9), respectively r = -0.77 (4) at hipolimnion level. Maximum values of this parameter were obtained in spring9.06±1.34 - 7.65±1.34 mgO_2/l (9) respectively 8.61±1.58 -7.86±1.89 mgO_2/l (4), followed by a decline in summer 5.33± 0.55- 4.78± 0.33 mgO_2/l (9) and 6.56±0.37-5.90±0.32 mgO_2/l (4) with a recovery in the same time with decrease of temperature in autumn 6.33±0.28-5.90±0.31 mgO_2/l (9), 6.35± 0.80-5.28± 0.76 mgO_2/l (4). The annual average fall water ponds at this parameter in the water for good growth of Cyprinidae species. 6.98±1.90 mgO_2/l epilimnion- 6.13±1.43 mgO_2/l hipolimnion (bazin 9) and 7.27±1.48 mgO_2/l epilimnion- 6.48±1.64 mgO_2/l hipolimnion (fish pond 4); optimum limits being by 6 mg/l O_2 (BUD I., 2004)

The pH of the water. Impairment of water quality can interpret indirectly in particular by affecting the values of this parameter. Values obtained on the biological year 7.83±0.38 unit pH (9), and 7.71± 0.58 unit.pH (4) are consistent with the regulatory requirements and speciality literature (BURA M., 1995, 2003, GROZA A., 2006) but seasonal variation of this parameter is particularly high in summer 8.14±0.29 (9) şi 8.15±0.42 unit pH (4).

Not observed large fluctuations in the same season, this thing being found of the small coefficient of variability 4.14%, 3,.65%, 3.62%, on biological year this coefficient with a value of 4.85% (9). Values with the upward trend in the summer season to find the pond (4) where the average value on the season was 8.15±0.42 unit. pH, in other seasons the present values show a slightly alkaline water 7.24±0.55 unit. pH, spring and 7.769±0.20 unit. pH autumn. We finds significant differences in the values between spring vs. summer seasons** P<0.01 (q=5.402). Species of algae such as *Eunotia capitata* was seen in the first month of the period studied, where pH values are still low but the species *Gomphonema parvulum* released in April indicates increasing pH.

The nutrients regime: ammonium, ammonia, nitrites, nitrates.

The *nitrate* parameter present seasonal fluctuations with lower values in summer season 2.28 ±0.91 mg $N\text{-}NO_3$/l (9), respectively 3.36±0.89 mg $N\text{-}NO_3$/l (4), highest values recorded in the spring 4.44±0.66; 5.95±1.89 mg $N\text{-}NO_3$/l and autumn 5.55±1.0, 6.26±1.33 mg $N\text{-}NO_3$/l.

Season values obtained are expressed by highly significant differences (P = 0.025) between summer vs. spring *** P <0.001 (q = 7.036) summer vs. autumn *** P <0.001 (q = 7.048). There are no significant differences between seasons summer vs autumn P> 0.05 If the basin (4) highly significant values were found between the summer season compared with the other two seasons namely spring and autumn: summer vs. Spring *** P <0.001 (q = 11.85), summer vs. autumn *** P <0.001 (q = 8.757) and distinct values significant as the media could see calculated values between spring and autumn where ** P <0.01 (q = 4.018). The obtained values are according with reference value necessary in carp raising (MAN C., 2006).

Tab. 1

The season variation of study parameter, pond 4

The parameter study	Number of sample						Number of early samples 32		Valori referință
	12		12		8				
Water temperature epilimnion ^{0}C	$\overline{X} \pm s_{\bar{x}}$	V%	$\overline{X} \pm s_{\bar{x}}$	V%	$\overline{X} \pm s_{\bar{x}}$	V%	$\overline{X} \pm s_{\bar{x}}$	V%	$\overline{X} \pm s_{\bar{x}}$
	11.7±4.09	34.93	25.87±2.3	9.19	18.77±3.96	20.87	18.70±7.0	37.73	25.0±1.01
Water temperature hipolimnion ^{0}C	9.23±2.33	25.24	24.84±2.9	12.03	16.75±4.02	24.08	16.83±7.6	45.27	25.0±0.803
pH unit. pH	7.24±0.55	7.69	8.15±0.42	5.19	7.769±0.206	2.65	7.71±0.58	7.62	7.0±0.803
O_2 dissolved epilimnion mgO_2/l	8.61±1.58	18.33	6.56±0.37	5.70	6.35±0.80	12.74	7.27±1.48	20.33	6.0±1.27
O_2 dissolved hipolimnion mgO_2/l	7.86±1.89	24.12	5.90±0.32	5.57	5.28±0.76	14.54	7.27±1.48	20.42	6±1,04
Amonium mg/l	0.07±0.04	64.86	0.25±0.21	81.85	0.05±0.04	70	0.13±0.16	116	1±0.08
Ammonia mg/l	0.09±0.05	51.54	0.08±0.0	11.23	0.04±0.02	50.0	0.08±0.04	55.0	0.050±0.0
Nitrates mg/l	4.44±0.66	14.86	2.28 ±0.91	39.89	5.55±1.00	18	3.90±1.58	40.58	15.0±0.84
Nitrites mg/l	0.06±0.03	60.3	0.16±0.05	31.67	0.08±0.03	35.63	0.10±0.06	56	0.2±0.08
Phosphates mg/l	0.630±0.436	69.20	0.89±0.20	22.47	0.7±0.302	42.85	0.74±0.34	45.94	0.8±0.14
CCO mgO_2/l	5.51±0.79	14.41	8.14±0.89	10.99	7.62±0.58	7.63	7.02±1.42	20.22	25.0±5.14

Tab. 2

The season variation of study parameter, pond 9

The parameter study	Number of sample						Number of early samples 32		Valori referință
	12		12		8				
Water temperature epilimnion ^{0}C	$\overline{X} \pm s_{\bar{x}}$	V%	$\overline{X} \pm s_{\bar{x}}$	V%	$\overline{X} \pm s_{\bar{x}}$	V%	$\overline{X} \pm s_{\bar{x}}$	V%	$\overline{X} \pm s_{\bar{x}}$
	12.75±2.98	23.37	25.99±1.25	4.84	18.01±1.44	8.02	19.03±6.2	32	25.0±0.80
Water temperature hipolimnion ^{0}C	10.02±3.30	32.95	25.22±1.71	6.78	17.075±1.57	9.23	17.48±7.09	40.56	25.0±0.80
pH unit. pH	7.64±0.31	4.14	8.14±0.29	3.65	7.66±0.27	3.62	7.83±0.38	4.85	7.0±0.80
O_2 dissolved epilimnion mgO_2/l	9.06±1.34	14.88	5.33± 0.55	10.39	6.33±0.28	4.47	6.98±1.90	27.22	6.0 ±1.27
O_2 dissolved hipolimnion mgO_2/l	7.65±1.34	17.51	4.78± 0.33	6.89	5.90±0.31	5.37	6.13±1.43	23.29	6.0±1.2
Amonium mg/l	0.47±0.36	73.72	0.48±0.18	37.91	0.43±0.07	16.24	0.46±0.24	52	1.0 ±0.08
Ammonia mg/l	0.21±0.18	70	0.43±0.21	48.61	0.15±0.09	63.25	0.28±0.21	75.17	0.050±0.008
Nitrates mg/l	5.95±1.89	31.71	3.36±0.89	27	6.26±1.33	18	5.06±1.91	37.74	15±0.84
Nitrites mg/l	0.18±0.12	70.71	0.44±0.35	79.36	0.18±0.12	67.20	0.28 ±0.26	93.57	0.20±0.08
Phosphates mg/l	0.64±0.49	76.56	0.82±0.45	54.87	0.91±0.29	31.68	0.78±0.441	55.83	0.8±0.14
CCO mgO_2/l	5.44±1.94	10.31	11.75±1.19	9.52	11.02±0.71	6.5	9.20±3.28	35.62	25.0 ±5.14

Tab. 3

Multiple correlation pond 4

	A: pH	B: $N\text{-}NH_4$	C: $N\text{-}NH_3$	D: $N\text{-}NO_2$	E: $N\text{-}NO_3$
A:pH	1.00	0.10	0.31	0.30	-0.35
B:$N\text{-}NH_4$	0.10	1.0	-0.02	0.55	-0.40
C:$N\text{-}NH_3$	0.31	-0.02	1.0	0.19	-0.26
D:$N\text{-}NO_2$	0.30	0.55	0.19	1.0	-0.49

Tab. 4

Correlation matrix results water temperature-CCO-pH

Basin 4			
	Water temperature	CCO	pH
Water temperature	1.0	0.81	0.92
CCO	0.81	1.0	0.76

Tab. 5

Multiple correlation pH- $N\text{-}NH_4$- $N\text{-}NH_3$-. $N\text{-}NO_2$ - $N\text{-}NO_3$ Pond 9

	A: pH	B: $N\text{-}NH_4$	C: $N\text{-}NH_3$	D: $N\text{-}NO_2$	E: $N\text{-}NO_3$
A:pH	1.0	0.01	0.27	0.61	-0.40
B:$N\text{-}NH_4$	0.01	1.00	0.46	0.06	-0.13
C:$N\text{-}NH_3$	0.27	0.46	1.00	0.47	-0.37
D:$N\text{-}NO_2$	0.61	0.06	0.47	1.00	-0.59

Tab. 6

Multiple correlation water temperature-CCO-pH , pond 9

Pond 9			
	Water temperature	CCO	pH
Water temperature	1.0	0.88	0.69
CCO	0.88	1.0	0.54

Species identification *Nitzschia* sp at both ponds denotes the presence of inorganic nitrogen in water, and disappears in the months with lower values of NO_3 (pond 4) and high water temperatures. Species *Aphanizomemnon flos –aque* frequency increases when theis a sharp decrease inorganic nitrogen but only in the presence of phosphate, as confirmed by the literature (LARSON, 2001). Average obtained is 3.908±1.586 mg $N\text{-}NO_3$/l in the pond (4) and 5.06±1.91 mg $N\text{-}NO_3$/l pond (9) which water falls in this category parameter in mesosaprobic category of water.

Nitrites. In terms of this parameter fall class water quality mesosaprobic / polysaprobic pond (4) 0.10 ± 0.06 mg/l $N\text{-}NO_2$ being given the same class for the other ponds (9), but higher values tend attests further eutrophication of water. 0.28 ±0.26 mg/l $N\text{-}NO_2$.

Values much higher compared to the reference values for the Cyprinidae species (BUD I. 2004, 0.2 mg /l,) during summer 0.44±0.35 mg/l $N\text{-}NO_2$ are influenced by intensifying processor decomposition of organic matter under conditions of slower oxidation of the nitrite $N\text{-}NO_2$ in nitrate $N\text{-}NO_3$. This is reflected in the following simple correlation CCO:NO2 where r =0.393 is the average P value is 0.025 (pond 9), and strong positive correlation r =0.633 P value is <0.0001 (pond 4).

Ammonium and ammonia. Higher values of the two forms of inorganic nitrogen, $N\text{-}NH_3$ and $N\text{-}NH_4$ recorded in pond 9 were the annual average had had a value of 0.46±0.24 mg/l $N\text{-}NH_4$ compared to 0.13±0.16 mg/l $N\text{-}NH_4$ and $N\text{-}NH_3$ where the annual value is 0.28 mg/l to 0.08±0.04 mg/l (pond 4). Class of water falling in clean freshwater. The $N\text{-}NH_3$ value is largely in comparison with speciality literature where find maximum value from this parameter by 0.1 mg/l (HORVATH L., 2002) or 0.05 when pH of water speed 8.5 unit pH (SCHLOTFELDT H.J., 1995) the obtained value in pond (9) are bigger.

Phosphate. Phosphates quantity is relatively constant over the entire length of study period. At pond (4) level is observed insignificant increase of values during summer 0.89 ± 0.20 mg P- PO_4/l;, average value 0.74 ± 0.34 mg P- PO_4/l; a dynamic upward throughout year (pond 9), the average appointment within the reference 0.78 ± 0.44 mg P- PO_4 / l. Increased soluble phosphorus leads to a development of phytoplankton and especially green algae, affecting the concentration of dissolved oxygen when decomposing them. The relationship between the two parameters is inverse r = -0.32 (P = 0.06), pond (9) and strongly correlated (r) = -0.53; P is 0.0017, pond (4). The average overall time from falling water in the pond water mesosaprobic /polysabrobic (Class III/ IV)

Organic substance is an upward curve by enhancing the processes of degradation of organic matter; the maximum average on the summer season was by 11.02 ± 0.71 mgO_2 / l (9) and 7.62 ± 0.58 mgO_2 / l (4); the annual average allow to raising carp and other species from the same family, this fact is sustained also by different authors (BURA M., 2002), 9.20 ± 3.28 mgO_2 / l (9), 9.20 ± 3.28 mgO_2 /l (4)

Comparison of average values by season it is translate by extremely significant differences between spring vs. summer *** P <0.001 (q = 7.19) (9) and spring. vs. autumn *** P <0.001 (q = 5.69) (9).

Decomposition of organic matter is influenced by temperature and dissolved oxygen as it emerges from the correlation of variables and organic substance - dissolved oxygen - temperature reveals the close relationship between these parameters, there is a strong correlation between CCOMn positive-temperature and strong negative between CCOMn and dissolved oxygen (table7).

The similary value was obtained by OROIAN T et all, 2006 in fish pond from MM county.

Tab. 7

Correlation between organic matter-dissolved oxygen –water temperature

Number of rows analyzed: 32	Oxygen dissolved - surface	Oxygen dissolved- bottom	Water temperature- surface	Water temperature- bottom
CCOMn pond 9	-0.97	-0.94	0.88	0.91
CCOMn pond 4	-0.85	-0.79	0.92	0.91

Depending on the annual values obtained from this parameter 9.20 ± 3.2 mgO_2 /l pond (9) respectively 7.02 ± 1.42 mgO_2/l (4) the water catchment in clean freshwater

Multiple values of correlations between different parameters taken in the study (table 3,4) highlights the strong links between pH: N-NO_2 (r = 0.61 pond 9) and middle (r = 0.30 for basin 4). Middle negative correlation was found between variables pH: N- NO3 (r = - 0.40 pools 9, r = - 0.35 pond 4) Among the variables temperature-CCOMn-pH (table 5,6) are strong positive linkages in both pond studied. Simple correlations between O_2: N-NO_3, reveals a connection to the middle pond (9) r = 0.37 (P =0.037), and between water temperature and in the CCOMn expressed mg P-PO_4 /l correlation is extremely strong r = 0.88 (P <0.0001), the same significance encounter in pool 4, r = 0.924, (P <0.0001) between O_2: N-NO_3 is no significant correlation r = 0.114 (P = 0.532)

The concept of indicator organisms and communities indicator has been frequently used by Palmer in particular at the level of organic polluted water (table 8).

Tab. 8

Algal species	Pollution index	Pond 9	Pond 4
Ankistrodesmus facatus	2	+	+
Chlorella vulgaris	3	+	+
Cyclotella meneghianiana	2	+	+
Euglena sp.	1	+	-
Closterium	1	+	+
Gomphonema parvulum	1	+	+
Navicula cryptocephala	2	+	+
Nitzschia palea	3	+	+
Synedra ulna	3	+	-
Pandorina morum	3	+	-
Scenedesmus quadricauda	4	+	+
Stigeoclonium tenue	2	+	+
TOTAL		29	22

Score obtained (table 8) in both ponds 29,22 point, indicates water pollution with organic matter. The summer and autumn Euglenophytelor representatives of species as common or *Trachelomonas hispida, Phacus sp*. preferendum have a higher than the quantity of organic substance in water.

Clorohyceaele of plankton are dominant genera *Scenedesmus*, *Crucigeniella, Langerheimia, Pediastrum.* Indicators of water pollution with the basic elements of nitrogen belonging to the class as mezosaprobe beta and *componeți*: diatomeele: *Synedra, Navicula, Surirella*, of chlorophyceae: *Pediastrum boryanum, P.simplex, Tetrastrum elegans, Scenedesmus opoliensis, Coeşastrum microsporum*. Species *Achanthes lanceolata, Cymbella helvetica* in the water basin are indcatoare of clean water.

CONCLUSIONS

1. Variation of water temperature correlated with reduced basin depth leads to an increase in trophic level of the ponds taken mesosabrobic study.
2. The level of the ponds trophic level correlated with moderate amounts of nutrients and the presence of a large number of green algae species can support high productivity of fish.

REFERENCES

1. Bud I (2004). Raising carp and other fish species Ed. Ceres, Bucuresti.
2. Bura M., Groza A., Cornea I., Gergheni I. (1995). Creşterea crapului în iazuri şi heleşteie. Ed. Mirton, Timisoara.
3. Groza Adrian (2007). Ciprinicultura. Ed Mirton, Timisoara.
4. Man C, A. Man (2006). Fish hygiene. Ed. Risoprint, Cluj–Napoca.
5. Horvath L., (2005). Pestele si crescatoriile de peste. Ed.M.A.S.T., Bucuresti.
6. John D., Robert G. Sheath. Fresh algae in North America. Ecology and classification. Ed. Cambrige University.
7. Oroian T.(2007). Selectia asistată de markeri la crap. Ed Risoprint, Cluj–Napoca.
8. Weizel R.L. (1979). Periphyton measurements and application. Methods and mesurementsof periphyton communities. Review.ASTM STP 690, American Society for Testing and Materials,pag.3-33.
9. Kamenir Y., Morabito.G (2009). Lago Maggiore oligotrophication as seen from the long–term evolution of its phytoplankton taxonomic size structure. Limnology, vol 68 (1) pp. 146-161.
10. Palmer C.M. (1969). Algae and Water Pollution, Journal Phycol., valo.5, 78-82.

11. Schlotfeldt H.J. & col. (1995). What should I Do. A practical quide for the fresh water fish farmer – The European Association of fish pathologists, pag.5 –38.

12. Barinova S.S., Anissimova O.V, Nevo E., Jarygin M.M, Wasser S.P (2004). Diversity and ecology of algae from the Nahal Qishon river, Northen Israel. Plant biosystem, vol 138, nr.3, november, pag. 245 – 259.

13. Inga Lips, (2005). Abiotic factors controling the cyanobacterial bloom occurence in the Gulf OF finland. Teză doctorat. Institutul de Zoologie şi Hydrologie, Facultatea de Biologie şi Geografie, Universitatea din Tartu, Estonia ISBN 9949-11-082-3.

14. Ruperto Cintron Jessica M. (2008). - The macroinvertebrates as indicators of water quality in the Yaguez river, Mayaguez, Puerto Rico. Thesis for the degree of Master of Science in Biology,UniversityofPuertoRico.