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Water quality, welfare and pathology of fish cultured in sport fishing lakes and ponds from Romania

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Abstract. Fish welfare and their health depend on a large extent on the water quality where they live. Variation in physical, chemical or biological characteristics, in limits too high or very short time, represent serious stress factors for fish. Stress factors reduce the animal's overall resistance to pests and diseases and increase the virulence of some pathogenic biotic agents or conditioned pathogens. This research has proposed emphasizing the impact of medial water parameters situated at the limit of discomfort, or even normal limits by point of view by Order 161/2002, correlated with fish welfare assessed by relationship with some morbid states occurring in fish populations in lakes and ponds studied. Our observations have led to identification and description of interesting episodes caused by the impact of physical-chemical parameters of water and some biotic pathogenic agents, and their action over fish health. Mortality of fish was found in summer season when water quality depreciation noted in terms of main indicators: increasing water temperatures, decrease of dissolved oxygen levels, increases in pH and organic matter decomposition which led to the installation of hypoxia. Haemorrhagic septicemia was favored by conditions of biotic stress and abiotic factors, being recorded in the case of Asian cyprinids: *Ctenopharyngodon idella* and *Hypophthalmichthys molitrix.* Due to the lack of quarantine ponds, prophylactic bathing conditions and due to other technological neglects, several frequent problems were observed, such as: bleeding and skin lesions, infestation of entire fish stock in lakes or ponds with *Argulus foliaceus,* infestation with *Saprolegniaceae.* Excessive administration of manure to ponds led to water degradation in short time and installation of mortality in juvenile carp at 21 days.
Key words: water quality, fish ponds, lakes, animal welfare, pathological response.

Introduction. Differences between mammals and fish consist in the characteristics associated with aquatic life; the damage on the fish welfare is related to degradation of environmental quality by physical-chemical and biotic parameters modifications (Barton 1997; Stouthart et al 1996; Mitrănescu et al 2009ab). In aquaculture, there are many factors that can compromise fish health and welfare, such as: handling, transport of fish, one of the most important stress factor (Specker & Schreck 1980; Barcellos et al 2001), but, regardless of production system approach in pisciculture, the main feature on which depends the fish welfare is related to the quantity and quality of aquatic environment (Conte 1992).

Material and Methods. Systematic research has been performed in three sport fishing lakes and three ponds of fish culture from Romania (P_A-P_F), the dominant species being the common carp. Indicators which were analyzed: temperature, dissolved oxygen (DO) (electrochemical method with sensor: SR EN 25814/1999) and pH, were determined in situ at the time of sampling at 30-50 cm below the water mirror, depth, and the bottom of the pond; for the analysis of chemical parameters were used reference methods corresponding to current requirements: chemical oxygen demand using the method STAS 9887/74, total hardness (E.D.T.A. methods) N-NO_2 (STAS 9800-/71, spectrophotometric), N-NO_3 (2-6 spectrophotometric method - dimethylphenol SR 7890/1). Following the results obtained has been determined seasonal media and the degree of correlation (Spearman) between different parameters in the study.

At the same time, we aimed to monitor fish behavior at changing environmental factors that led to detection of various and complex mechanical and chemical negative effects on fish, conditions favorable to parasitic invasions and infectious diseases, episodes resulting in high mortality (see also Akhondzadeh Basti et al 2011; Ebrahimzadeh Mousavi et al 2011; Mehdizadeh Mood et al 2011).

Results and Discussion. ***Temperature***. In Table 1 are presented decadal mean values of air temperature with major impact on water chemistry. The seasonal course of temperature is characterized by minimum between -12.5 and -2.7 °C and maximum range between +15.3 and +20 °C in the spring season. The amplitude of temperature differences during this period is 7.5-22.5 °C, but reported by calendar year, the biggest variation is recorded in august, 29.9 °C. In the autumn temperature values are typical to this season, gradually with decreasing, the alternating hot-cold temperature are visible especially in November, when we meet values below 00C: -6.3 °C and maximums of +15.7 °C.

Table 1

Evolution of air temperature

Month	*Decade*			*Period*	*Decade*			*Period*	*Decade*			*Period*
	1-10	11-20	21-31	1-31	1-10	11-20	21-30	1-30	1-10	11-20	21-31	1-31
Value		March				April				May		
Min.	-12.5	-3.1	-2.7	-12.5	0.4	3.3	5.1	0.4	3.9	6.7	8.2	3.9
Max.	15.3	8.2	20.0	20.0	21.2	18.4	23.9	23.9	20.8	24.3	32.2	24.3
		June				July				August		
Min.	12.6	18.1	22.5	12.6	20.1	19.9	20.1	19.9	12.5	16.1	18.0	12.5
Max.	36.9	37.3	41. 6	41. 6	40.0	42.4	42.0	42.4	36.5	38.0	42.4	42.4
		September				Octomber				November		
Min.	10.6	10.2	7.8	7.8	7.5	2.7	5.1	2.7	3.5	-0.4	-6.3	-6.3
Max.	27.8	34.1	34.1	34.1	29.0	23.1	20.0	29.0	15.1	12.2	15.7	15.7

Among the physical factors, water temperature is very important; all parameters taken into study: physical, chemical and biological are strictly dependent on water temperature. The main cause of the tight connection between variables, mainly result from depth relatively low of ponds and lakes: 2.5m in P_A, P_B, P_C, 0.5 – 6m in P_D, 0.5 – 3.5m in P_E, and 0.5 – 1.5 m in P_F which leads to homogenization of temperature the entire depth. Water temperature variation follows the air temperature variation closely throughout the study as shown in Table 2. The lowest seasonal mean values are specific to spring season 11.70±4^{0}C (P_A), 12.75±2.9^{0}C (P_B), 11.06±1.6^{0}C (P_C), 13.93±7^{0}C (P_D), 15.38±6.6^{0}C (P_E), 12.36±4.4^{0}C (P_F), followed by those recorded in autumn, in accordance with decreasing in parallel of air temperature. Maximums were recorded in summer: 26.63±2.8^{0}C (P_A), 25.9±1.2^{0}C (P_B), 26.84±2.3^{0}C (P_C), 25.20±2.7^{0}C (P_D), 24.23±1^{0}C (P_E), 23.08±2.2^{0}C (P_F). Depending on the water temperature there were observed hemorrhagic lesions of traumatic nature, at the skin level of carps and other species of cyprinids, produced by thin layers of ice formed on the water surface in November, when the air temperature was –5^{0}C and the fish was collected to be passed into

Fig.1. Ice on water surface leads to Carp skin lesions.

Fig.2. Infestation with *Piscicola geometra*.

wintering ponds, being a technological mistake (Fig.1). Infestation with *Piscicola geometra* (Fig.2), non-specific parasites that can cause major economic damage, was found in summer and autumn when the juvenile carp was collected from P_A; temperature level was 17^{0}C.

pH. Dynamics of the pH curve shows a constantly changing and increasing value until the end of the summer season. The fact is explained by biological activity of ponds and lakes which exerts pressure on this indicator. The cyprinid fish species seem to be able tolerating these values.

Water reaction in the spring season, fall depending on season mean: slightly acidic water 6.80±0.2 (P_A), 6.66±0.4 (P_D), 6.88±0.48 (P_F) or neutral slightly alkaline 7.6±0.31 (P_B), 7.46±0.3 (P_C), 7.06±1.15 (P_E). Summer months indicate the instability of this parameter, the seasonal value incresing but falling within the normal range: 8.2±0.76 (P_A), 8.1±0.2 (P_B), 7.99±0.5 (P_E) and slightly above those values for ponds and lakes P_C, P_D and P_F: 8.52±0.4 (P_C), 8.56±0.50 (P_D), 8.84±0.86 (P_F). The alkaline reaction installed in summer is tempered in autumn.

Fig.3. Fish infested with *Argulus foliaceus.*

Argulus. In summer was noted invasion, caused by *Argulus foliaceus* (Fig.3), identified in lakes P_E, and P_B. In these two lakes fish stocking was done without appropriate sanitary veterinary control, without prophylactic bathing or prophylactic quarantine. In these circumstances were added predisposing factors who participated in the parasitic infestation: high water temperature (23.48^{0}C – 25.20^{0}C; alkaline pH 8.45-8.55 and even 9.10 units pH). Parasite eradication was done by bathing with sodium chloride, 0.6 g/L. Thermal regime of water, increased degradation of organic matter, oxygen depletion in this period led to increases in pH. The connection between temperature and pH values, calculated in terms of degree of correlation, indicates that: the higher proportional increase of the two parameters, the more tight is the correlation between them r=0.69(P_A) – 0.79(P_B); which indicates indirectly a decreasing of the buffering capacity of water.

Dissolved oxygen shows a clear seasonal variation, with good values and return in the spring season of oxygen dissolved in autumn. The summer season matches with an orthograde decrease in quantity of DO: 5.35±0.7 mg/dm^3 (P_A), 5.33±0.5 mg/dm^3 (P_B), 4.63±1.1 mg/dm^3 (P_C), 5.80±0.95 mg/dm^3 (P_D), 5.13±1.0 mg/dm^3 (P_E), 5.50±0.78 mg/dm^3 (P_F). Values are in part within the normal parameters, DO being itself an independent indicator. In this period was found hypoxia (Fig.4) and massive mortality was recorded in pond P_C: a dramatic episode resulted in loss of about five tonnes of fish including: carp (C*yprinus carpio*), Prussian carp (*Carrasius gibelio*) silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella)* and pike-perch (*Sander lucioperca*). Environmental factors which favored the occurrence of hypoxia were the following: water temperature 26.9^{0}C, dissolved oxygen 3.9 mg/ dm^3O_2 in superficial layers, 2.9 mg/ dm^3O_2 at the bottom of the ponds, chemical consume of oxygen (CCO) 10.14±2.36 mgO_2/ dm^3, pH 8.26 units, 0.3 mg/ dm^3 N-NO_2. Episodes of low intensity occurred in all other lakes and ponds. Correlation coefficients show very strong negative relationship between water temperature and dissolved oxygen as shown in Table 3: r=-0.72 (P_E), r= -0.92 (P_A).

Fig.4. Hypoxia and mortality.

Organic matter. Data in Table 2 show high dissolved oxygen consumption by microorganisms due to organic matter degradation in the summer season: 7.44±0.7

mg/dm^3 (P_A), 7.14±0.8 mg/dm^3 (P_B), 9.20±0.96 mg/dm^3 (P_C), 6.87±1.7 mg/dm^3(P_D), 7.67±4.9 mg/dm^3 (P_E). We notice a consumption of 10.09±4.0 mg/dm^3, in pond P_F, in summer season, that is against good water oxygen level and favors the development and spread of Saprolegniaceae.

Table 2

Seasonal evolution of the parameters studied

The parameter study	$\bar{X} \pm$ s (P_A)			$\bar{X} \pm$ s (P_B)			$\bar{X} \pm$ s (P_C)		
	spring	summer	fall	spring	summer	fall	spring	summer	fall
Water temp.	11.70±4	26.63±2.8	18.63±5	12.75±2.9	25.9±1.2	18.01±1	11.06±1.6	26.84±2.3	17.63±3.4
Water buffery $mgHCl/dm^3$	2.39±0.1	1.91±0.2	2.57±0.1	2.6±0.26	2.02±0.1	2.3±0.1	1.3±0.2	1.98±0.2	2.0±0.16
pH	6.80±0.2	8.27±0.7	7.94±0.3	7.6±0.31	8.1±0.2	7.6±0.3	7.46±0.3	8.52±0.4	7.89±0.2
DO mg/dm^3	7.77±1.0	5.35±0.7	5.4±0.44	9.06±1.3	5.3±0.5	6.3±0.2	7.17±0.8	4.6±1.1	5.58±0.4
CCO mg/dm^3 O_2	5.31±0.6	7.44±0.7	7.0±0.56	5.51±0.7	7.14±0.8	7.6±0.5	5.27±0.6	9.20±0.9	8.44±2.3
Total hardness	7.94±0.5	7.83±0.2	8.1± 8.3	8.42±0.5	7.91±0.8	8.1±0.8	7.74±0.10	7.1±0.07	7.5±0.08
$N\text{-}NO_3/dm^3$	9.91±2.0	4.25±1.6	10.6±4.3	5.95±1.8	3.36±0.8	6.2±1.1	8.85±2.2	4.56±0.9	7.12±1.0
$N\text{-}NO_2/dm^3$	0.28±0.1	0.12±0.1	0.27±0.1	0.15±0.0	0.10±0.	0.11±0	0.15±0.3	0.27±0.5	0.21±0.3
	$\bar{X} \pm$ s (P_D)			$\bar{X} \pm$ s (P_E)			$\bar{X} \pm$ s (P_F)		
	spring	summer	fall	spring	summer	fall	spring	summer	fall
Water temp.	13.93±7	25.20±2.7	13.91±5	15.38±6.6	24.23±1	14.03±5	12.36±4.4	23.0±2.2	12.6±4.3
pH	6.66±0.4	8.56±0.50	8.08±0.8	7.06±1.15	8±0.5	7.6±0.6	6.88±0.48	8.8±0.86	7.91±0.4
DO mg/dm^3	8.26±1.0	5.80±0.9	7.31±0.7	8.61±1.1	5.13±1.0	7.2±0.3	8.60±1.30	5.5±0.78	7.11±0.6
CCO mg/dm^3 O_2	4.83±2.7	7.45±2.7	6.87±1.7	4.56±4.9	7.7±4.9	7.1±2.7	4.37±3.55	10.1±4.0	8.16±3.3
$N\text{-}NO_3/dm^3$	5.73±0.7	3.16±1.3	3.20±0.8	3.45±0.4	1.4±0.5	2.1±0.6	9.78±1.16	5.5±1.03	7.78±1.3
$N\text{-}NO_2/dm^3$	0.22±0.0	0.19±0.0	0.20±0.0	0.21±0.0	0,17±0	0.16±0	0.35±0.04	0.35±0.0	0.32±0.0

Table 3

The degree of correlation between the parameters recorded

	(r)	r^2	P		(r)	r^2	P
Water temperature - DO				Water temperature - DO			
(P_A)	-0.92	0.86	< 0.0001 - extremely significant	(P_D)	-0.88	0.78	< 0.0001 - extremely significant
(p_B)	-0.84	0.72	< 0.0001 - extremely significant	(P_E)	-0.72	0.59	0.002 - very significant
(P_C)	-0.86	0.75	< 0.0001 - extremely significant	(P_F)	-0.89	0.73	< 0.0001 - extremely significant
CCO - DO				CCO - DO			
(P_A)	-0.97	0.94	< 0.0001 - extremely significant	(P_D)	-0.76	0.58	0.0002- extremely significant
(p_B)	-0.92	0.86	< 0.0001 - extremely significant	(P_E)	-0.71	0.52	0.0005 - extremely significant
(P_C)	-0.87	0.76	< 0.0001 - extremely significant	(P_F)	-0.80	0.65	< 0.0001 - extremely significant
CCO - water temperature				CCO - water temperature			
(P_A)	0.88	0.78	< 0.0001 - extremely significant	(P_D)	0.54	0.29	0.0202 - significant
(p_B)	0.91	0.84	< 0.0001 - extremely significant	(P_E)	0.36	0.13	0.1413 - not significant
(P_C)	0.71	0.50	0.0021 - extremely significant	(P_F)	0.59	0.35	0.0092 - very significant
CCO - pH				pH - water temperature			
(P_A)	0.85	0.29	0.0014 - extremely significant	(P_A)	0.69	0.48	< 0.0001 - extremely significant
(p_B)	0.86	0.75	< 0.0001 - extremely significant	(p_B)	0.79	0.62	< 0.0001 - extremely significant
(P_C)	0.72	0.53	0.0006 - extremely significant	(P_C)	0.75	0.56	0.0007 - significant

Fig. 5. Fish affected by Saproligniaceae.

Infestation with Saprolegniaceae (Fig.5) was found in lake P_D and pond P_C where the high incidence of the disease was due to handling during fishing when appear small injury on the surface of fish skin. Manifestation of disease is dependent on poor maintenance conditions of fish with direct reference to water quality in terms of organic matter: large amounts of organic matter in suspension, but also high density of fish per m^2.

From the values obtained, very significant degree of correlation (negative correlation) was found between organic matter and DO: r= -0.71 (P_E) – (-0.97 P_A). This correlation underlines the important role of oxygen in water for decomposition of organic matter. Another close connection is noted between indicators pH and organic matter expressed by an extremely strong positive correlation, which shows once again that: degradation of organic matter leads to an increase in pH values especially in summer season: r= 0.85 (P_A), r= 0.86 (P_B), r= 0.72 (P_C).

We found a parallelism between increased levels of temperature in the surface layers toward summer season simultaneously with increasing the amount of organic matter decomposition in similar periods, which indicates an extremely significant relationship (r) of these parameters in ponds and lakes P_A –r= 0.88, P_B –r= 0.91, P_C –r= 0.71 and lake P_F –r= 0.59, significant for lake P_D -r= 0.54 and insignificant for lake P_E -r= 0.36. Close connections reflected not only statistically, but also by direct action of the unfavorable condition over hydrobionts. In this sense has been found mortality in juvenile stock under 21 days (Fig.6).

Fig.6. Juvenile mortality at 21 days.

Administration of too high amounts of organic fertilizer with no laboratory tests to establish several chemical key parameters of water in the reproductive ponds led to excessive enrichment of water with organic matter. This, together with adverse weather conditions (rain, dark sky, low atmospheric pressure) and combined with decreased water level 1.3-1.4 m, water temperature 21.2^{0}C, DO 2mg/dm^3, alkalinity 1.98 mg HCl/L, and hardness 7.8 german degree has led to massive mortality of juveniles under the age of 21 days. The day of collection of juveniles the values of hydrogen sulfide in water was 0.3 mg/dm^3.

Total hardness. The curve values are rather unstable during the biologically active year, but without large fluctuations between seasonal mean values. A slight decrease in values 7.83±0.22 german degrees (P_A), 7.91±0.8 german degrees (P_B), 7.12±0.07 german degrees (P_C), recorded in summer at the seasons beginning and at the end of the biologically active year, where water fits in moderately hard water, good for carrying of aquatic life.

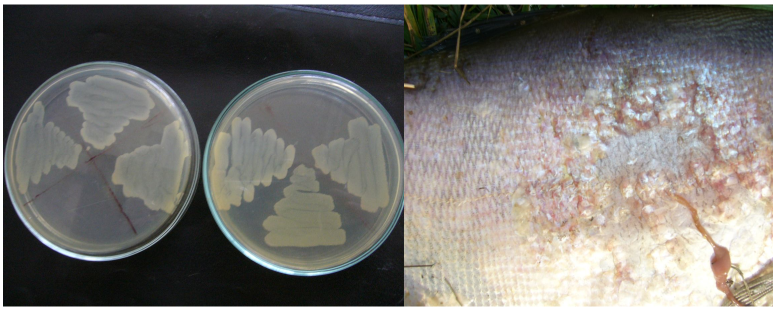

Fig. 7. Hemorrhagic septicemia caused by *Pseudomonas sp.*

Haemorrhagic septicemia, was diagnosed in November, in pond P_B (Fig.7). Disease was favored by reducing fishes immunity passed through a period of infestation with *Argulus foliaceus* to which were added unfavorable factors from living environment: water temperature 15.8^{0}C, pH 8.4, hardness 7.9 german degrees, organic matter 12.79 mg/dm^3, DO 4.8 mg/dm^3, plus the stress caused by catching and stocking the fish into wintering ponds. Etiologic agent, *Pseudomonas fluorescens,* was isolated and cultivated on solid medium (agar), confirming bacteriological disease.

N-NO$_3$. Values of the starting and ending seasons of the biologically active year represent the top values of the study period 9.91±2.0 - 10.62±4.3 (P_A), 5.95±1.89 - 6.26±1.1 (P_B), 8.85±2.29 - 7.12±1.02 (P_C), 5.73±0.7 - 3.20±0.8 (P_D), 3.45±0.4 - 2.15±0.6 (P_E), 9.78±1.16 - 7.78±1.35 mg/dm^3 (P_F), which shows a better oxygenation of the water in parallel with a less intense activity of aquatic life. Nevertheless there have been found hemorrhagic lesions at the skin level, produced in May in pond P_A, due to luxurious development of blue algae (*Anabaena flos-aque* and *A. spiroides*), producing large losses especially in the case of *Hypophthalmichthys molitrix.* In these episodes, water contained large quantities of organic substances, it was rich in nutrients, DO 6.03 mg/dm^3, N-NO_3 8.16±1.34 mg/dm^3, N-NO_2 0.3-0.4 mg/dm^3, P-PO_4 0.5-0.6 mg/dm^3) and water temperature 15.83 – 16.03^{0}C.

Excess mortality due to residual chlorine. Farmers use to clean the bottom of the pond and disinfect with chloride of lime. In some cases, fish (in this particular case pike-perch) were introduced in pond without preliminary evacuation of the initial water, where mortality occurred in 100% of the pike-perch. The amount of chlorine was 0.38 mg/L, which is well above the norm tolerable.

Conclusions. Proper technological management and monitoring the water quality are priorities in maintaining the welfare, obtaining high yields without unnecessary losses and use of healthy fish.

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