Scientific Papers. Series D. Animal Science. Vol. LXIII, No. 1, 2020
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

WATER QUALITY DURING THE VEGETATION PERIOD IN A STURGEON CAGE FARM

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Abstract

A complex characterization of the physicochemical parameters of the water was performed in a sturgeon cage farm located in a dam in Southeastern Bulgaria during the different stages of the vegetation period. Water monitoring included key indicators for fish farming: temperature, dissolved oxygen, oxygen saturation, electrical conductivity, total hardness, pH, permanganate oxidability, biochemical oxygen demand over five days; ammonium nitrogen; nitrate nitrogen, orthophosphate content. There were significant negative correlation relationships: water temperature with dissolved oxygen levels (Rp = -0.702; P <0.05) and nitrate nitrogen (Rp = -0.867; P<0.01). Positive significant correlations were found between the electrical conductivity of the water with the water hardness (Rp = 0.636; P <0.05); water hardness with dissolved oxygen level (Rp = 0.855; P<0.01) and water saturation with oxygen (Rp = 0.958; P <0.001); dissolved oxygen and nitrate nitrogen in water (Rp = 0.647; P<0.05); phosphates with ammonium nitrogen levels (Rp = 0.598; P<0.05).

Key words: *aquaculture, characteristics of water, correlation relationships, sturgeon.*

INTRODUCTION

In recent years, sturgeon farming has developed rapidly in a number of countries, with Bulgaria one of them (Bronzi et al., 2019). Bulgarian production is mainly represented by industrial cage farms located in large reservoirs (Nikolova, 2019).

Industrial aquaculture in general can only develop if it provides good conditions for the cultivated species and does not have a negative impact on the environment. A number of studies have demonstrated the effects of cage farms on the reservoirs in which they are located (Dochin & Stoyneva, 2014; Dochin, 2015). Among the dominant species in the reservoirs with cages, the occurrence of cyanoprokaryotes, a potential producer of toxins, has been identified (Dochin, 2019; Dochin and Iliev, 2019).

European Commission policy on water protection is a priority, with particular emphasis on ensuring that aquaculture production does not adversely affect the ecosystems in which it is localized (Viella, 2007). Knowledge of the dynamics of individual aquatic indicators and the interrelationships between them is at the heart of sustainable aquaculture, which ensures optimal conditions for the cultivated species and is environmentally friendly (Nikolova, 2013). In developing approaches to increase the sustainability of aquaculture, and its important component - 'environmental sustainability', one of the most important tasks is to keep the reservoirs in good 'healthy' and productive condition (Nikolova, 2020). The water quality is crucial for the bio-friendly growing of hydrobionts.

We present in this paper the results of our monitoring studies of the water during the growing season, at a sturgeon cage farm located in a large reservoir in Southeastern Bulgaria.

MATERIALS AND METHODS

The study was conducted during the vegetation period (April - December incl.) on a cage sturgeon farm located in Kurdzhali Reservoir. According to its type, the reservoir refers to large and deep ones. Its area is 16.07 km^2, the volume is 532.9 x 10^6 m^3. The reservoir is located in South-East Bulgaria, at 41°37’ N latitude and 25°20’ E longitude. It falls into the South Bulgarian climate zone, East Rhodope climate region.

Russian sturgeon (*Acipenser gueldenstaedtii*); Beluga (*Huso huso*); Siberian sturgeon (*Acipenser baeri*); Sterlet (*Acipenser ruthenus*); Stellate sturgeon (*Acipenser stellatus*); hybrids between species are grown on the farm. Feeding has been performed with a commercial granulated sturgeon feed.

To study temperature (TW, °C), dissolved oxygen (DO, mg.dm^{-3}) and oxygen saturation (DOS, %), *in situ* daily measurements were performed with an Elke Sensor MJ2000 Marvet junior oximeter.

For a full *ex situ* analysis of the water, samples were taken on a monthly basis and were immediately transported to a laboratory. A total of 9 samples were analysed. The analyses were performed in the laboratory complex of the Agricultural University - Plovdiv, accredited in accordance with the BSS (Bulgarian State Standard) EN ISO 17025/2018. The analysis included basic indicators for fish farms: conductivity (EL, µS.cm^{-1}) - determined according to BSS EN 27888: 2002; total water hardness (Ht, mg eqv.dm^{-3}) - according to BSS 3775: 1987; pH - according to BSS 3424: 1981; oxidability by $KMnO_4$ (OP, mgO_2.dm^{-3}) - by analytical method (BSS 17.1.4.16:1979, ISO synchronized); biochemical oxygen demand over five days (BOD_5, mg.dm^{-3}) - BSS 17.1.4.07:1978; ammonium nitrogen (N-NH_4^+, mg.dm^{-3}) - according to BSS ISO 7150-1: 2000; nitrate nitrogen (N-NO_3^-, mg.dm^{-3}) - BSS ISO 7890-3: 1998; orthophosphate content (P-PO_4, mg.dm^{-3}) - according to BSS 7210: 1983).

For statistical processing the IBM SPSS Stasistics 21 was used.

RESULTS AND DISCUSSIONS

Our study shows that, as a whole, the water parameters were within the limits of technological standards for fish farming, in the cultivation of thermophilic freshwater fish species. The average water temperature during Spring varied from 12.47 to 17.10°C (Table 1).

As the vegetation period progressed, it gradually increased from 22.04°C to the maximum for the studied period of 26.06°C in August. At the beginning of Autumn (September) the average temperature drops to 24.49°C and at the end of the period (November) to 16.08°C (Table 2).

Table 1. Results of the complete water analysis in the spring-summer period

Indicators	Months				
	IV	V	VI	VII	VIII
TW, ^{0}C	12.47	17.10	22.04	25.17	26.06
EL, µS.cm^{-1}	300	300	450	180	160
Ht, mg eqv.dm^{-3}	3.95	3.96	3.82	1.32	1.60
pH	7.35	6.79	7.31	8.80	7.42
DO, mg.dm^{-3}	9.86	8.99	7.04	5.25	4.75
DOS, %	128.9	129.5	112.1	88.5	81.2
N-NH_4, mg. dm^{-3}	0.22	0.17	0.15	0.27	0.14
N-NO_3, mg. dm^{-3}	1.50	1.40	1.30	1.1	1.00
P-PO_4, mg. dm^{-3}	0.04	0.17	0.08	0.05	0.06
OP, mgO_2. dm^{-3}	4.16	4.00	2.93	3.44	4.90
BOD_5, mg. dm^{-3}	4.22	1.29	3.82	3.03	9.10

Table 2. Results of the complete water analysis in the autumn-winter period

Indicators	Months			
	IX	X	XI	XII
TW, ^{0}C	24.49	20.44	16.08	10.60
EL, µS.cm^{-1}	320	320	175.5	159.5
Ht, mg eqv.dm^{-3}	1.50	1.46	1.50	1.50
pH	8.15	6.88	6.81	7.50
DO, mg.dm^{-3}	4.67	5.30	5.72	7.05
DOS, %	77.7	81.8	80.8	88.3
N-NH_4, mg. dm^{-3}	0.96	0.22	0.21	0.17
N-NO_3, mg. dm^{-3}	1.00	1.50	1.30	1.60
P-PO_4, mg. dm^{-3}	0.18	0.11	0.08	0.08
OP, mgO_2. dm^{-3}	3.40	3.63	3.22	4.66
BOD_5, mg. dm^{-3}	1.36	1.00	0.95	2.03

In terms of temperature, each type of fish has an area of ecological and physiological optimum when all life processes are best coordinated, with potential growth opportunities determined by the total heat that the fish receive throughout the year, especially during the fattening period (Golovanov, 2011). The author emphasizes that only in the gradient of the environmental factors (temperature, pH etc.), when hydrobionts have a choice, the conditions for maximum effective nutrition, growth and development can be ensured. There is no such opportunity in cages, which is why the adequacy of the conditions in which the fish are forced to exist is particularly important.

The results we have obtained show that the water temperature in the farm we study provides good conditions for growth. The vegetation period is prolonged and even at the beginning of Winter (December) the average temperature was above 10°C.

The maximum average temperature is at the upper limit indicated for sturgeon. Golovanov and Golovanova (2015) indicate that sturgeon optimal temperature for growth is lower than thermophilic eurythermal carp species, but is higher than cold-water stenothermal trout fish. According to the authors, the area for the ecological and physiological optimum for sturgeons is in the range of 18-26°C, while for the older, the optimum range is lower than for the younger ones. When sturgeon species are fattening, the water temperature is recommended to be 19 to 24°C (Vasilieva et al., 2006).

Electrical conductivity characterizes the concentration of dissolved salts in water reservoirs (Woynarovich et al., 2010). The indicator gives an idea of the level of mineralization and trophicity, as higher nutrient concentration would have higher values of electrical conductivity (Kutty, 1987). In our study we found significant dynamics of the indicator during the different stages of the vegetation period. EL in Spring is 300 $\mu S.cm^{-1}$, in Summer - 160 to 450 $\mu S.cm^{-1}$, in Autumn - 175.5 to 320, and in Early Winter - 159.5 $\mu S.cm^{-1}$.

In a study by Traykov (2005) of the trophicity of the same reservoir in which the farm studied by us is located, the maximum electrical conductivity values - 223.5 µS/cm were established at the end of the vegetation period and the minimum in Spring - 110.6 µS/cm. The average electrical conductance levels found in one of the later studies of the same reservoir are in the range of 272-343.2 $\mu S.cm^{-1}$ (Dochin, 2015). Comparison of the values indicated for the whole reservoir with the average electrical conductance in our study (262.8 $\mu S.cm^{-1}$) shows relatively low levels in the cage farm.

The recommended water hardness values for sturgeon farms are 6-8 mg/l (Chebanov and Galich, 2013). In large reservoirs, hardness can change significantly throughout the year. In our study, the indicator ranged from 1.32 to 3.96 mg $eqv.dm^{-3}$ during the spring-summer period and from 1.46 to 1.50 mg $eqv.dm^{-3}$ during the Autumn and Winter months.

Wurts and Durborov (1992) state that the water hardness in fish ponds is relatively stable and usually changes within weeks or months, while the pH concentration may change daily.

For all hydrobionts, the favorable pH values are close to neutral. When keeping thermophilic fish species, pH values in the range of 6.5-8.5 are considered optimal (Grigorjev and Sedova, 2008). For sturgeon species, water with a pH of 7-8 (Chebanov and Galich, 2013) is considered appropriate, and higher values of 7.5-8.5 (Vasilieva et al., 2006) are allowed when grown in cage farms. In our study, for most of the spring-summer period, the pH of the water was within technological limits. Only in July the value of the indicator was above the optimum upper limit, reaching 8.8, but at the next control normal levels were found. During the autumn-winter period the pH is within the optimum range for the farmed fish species.

Sturgeon species belong to the group of fish with relatively high requirements for oxygen content in water (6-7 mg/l), but are able to live at lower values (5-6 mg/l) (Ivanov, 1988). For optimal DO when growing sturgeon in cages, Vasilieva et al. (2006) indicate values of 8-9 $mg.dm^{-3}$. The authors cite 5 $mg.dm^{-3}$ dissolved oxygen as the minimum concentration for the sturgeon. According to Chebanov and Galich (2013) the lower limit for DO is 4 $mg.l^{-1}$. In the sturgeon farm we studied, at the beginning of the Summer, the amount of DO was within the technological standards, falling below 6 $mg.l^{-1}$ in July. The period below the optimum values was reported from July to September, and it should be noted that the minimum limit was above 4 $mg.l^{-1}$.

The water saturation with oxygen was in the optimum range, throughout the observation period. During the spring-summer period, DOS ranges from 81.2 to 128.5% and in the autumn-winter period from 77.7 to 88.3. Todorov and Ivancheva (1992) indicate for optimal fish growth waters with DOS over 70% and for life over 35-40%. According to Moorings (1991), the minimum optimal DOS level for sturgeons is 60%.

Nitrogen and phosphorus are biogenic elements important for reservoir productivity, but at high concentrations lead to degradation of aquatic ecosystems. The nitrogen forms in aquaculture ponds depend on the way the fish are fed, the individual characteristics of the pond, the aeration, etc. (Bhatnagar and Devi, 2013). In our study, ammonium nitrogen varied from 0.14 (August) to 0.27 $mg.dm^{-3}$ (July) during the spring-summer period, and in the autumn-winter one from 0.17 (December) to 0.96 $mg.dm^{-3}$ (September). In September, the amount of ammonium nitrogen exceeded 0.5

mg.l^{-1}, cited by Chebanov and Galich (2013) as optimal for sturgeon farming, but below the 1 mg.l^{-1} specified by Kozlov (1998) as the norm for fish farming ponds.

An important indicator in monitoring is nitrates, which are an end product of nitrification in reservoirs and can have a negative effect on fish at concentrations higher than 100 mg/l (Bregnballe, 2015). Generally, in fish ponds, the nitrate content should be in the range of 0.2 to 2.0 mg/l with a tolerable limit of 3.0 mg/l (Kozlov, 1998). In our study during the spring-summer period, the amount of nitrates ranged from 1 to 1.50 mg.dm^{-3}, and during the autumn-winter period from 1 to 1.60 mg.dm^{-3}.

The phosphate rate in fish farming ponds is 0.2 mg/l at a tolerable limit of 2 mg/l (Kozlov, 1998). Water with phosphate content of not more than 0.3 mg/l is considered to be optimal for sturgeon growing by Chebanov and Galich (2013). In our study, phosphate levels are well below this limit. During the spring-summer period, the indicator varied from 0.04 to 0.17 mg.dm^{-3} and during autumn-winter one from 0.08 to 0.11 mg.dm^{-3}.

Technological standards also include the level of oxidability. The permanganate oxidability of water in sturgeon farms should not exceed 10 mgO$_2$.dm^{-3} (Vasilieva et al., 2006; Chebanov & Galich, 2013). In the spring-summer period the indicator ranges from 2.93 to 4.90, and in the autumn-winter - from 3.22 to 4.66 mgO$_2$.dm^{-3}.

Another indicator related to the amount of organic matter in water is BOD$_5$. No more than 10 mg/l BOD$_5$ is recommended for fish ponds (Grigorjev and Sedova, 2008). Chebanov and Galich (2013) indicate the value of 2 mgO$_2$/l as optimal for sturgeon species. Chattopadhyay et al. (1988) as a result of experiments have found that the optimal range for BOD$_5$ in fish farming is 10 -20 mg/l.

In our study, the mean BOD$_5$ in the spring-summer season was 4.3 mg.dm^{-3}, and in the autumn-winter - 1.34 mg.dm^{-3}, the variation being broad. In the spring-summer values range from 1.29 to 9.10 mg.dm^{-3}, and in the autumn-winter - from 0.95 to 2.03 mg.dm^{-3}. The maximum value was set in August when the water temperature increased to the maximum values during the vegetation period and the DO level dropped below 5 mg.dm^{-3}. At the same time, it should be noted that the levels of permanganate oxidability and pH in August were within technological limits.

The correlation analysis we performed shows complex relationships between the studied water indicators (Table 3). Wurts and Durborov (1992) noted that the interaction between the different chemical components determines the water quality in the fish farming ponds, and most of the water characteristics are not constant.

We found significant negative correlations of water temperature with dissolved oxygen levels (Rp = -0.702; $P < 0.05$) and nitrate nitrogen (Rp = -0.867; $P < 0.01$). A negative relationship between water temperature and nitrate content has been reported by Dochin et al. (2015). At the same time, the negative relationship between water temperature and phosphate content discovered by the authors does not correspond with our results.

In our study, temperature correlates negatively with hardness, water saturation with oxygen and permanganate oxidability, and positively with electrical conductance, pH, ammonium nitrogen, phosphates and BOD$_5$, but the dependencies are insignificant.

Wurts and Durborov (1992) state that a number of water characteristics, among which pH and total water hardness are interrelated and can determine reservoir productivity, oxygen content etc.

Table 3. Correlations between different water indicators

Variables	El	Ht	pH	DO	DOS	N-NH$_4$	N-NO$_3$	P-PO$_4$	OP	BOD$_5$
TW	0.119	-0.307	0.472	-0.702*	-0.415	0.338	-0.867**	0.136	-0.263	0.370
El		0.636*	-0.198	0.293	0.467	0.181	0.122	0.346	-0.557	-0.203
Ht			-0.369	0.855**	0.958***	-0.286	0.337	0.047	-0.089	0.060
pH				-0.378	-0.292	0.464	-0.553	-0.158	-0.095	0.145
DO					0.935***	-0.378	0.647*	-0.078	0.163	-0.102
DOS						-0.350	0.429	-0.012	0.025	0.006
N-NH$_4$							-0.493	0.598*	-0.289	-0.296
N-NO$_3$								-0.123	0.150	-0.422
P-PO$_4$									-0.206	-0.525
OP										0.538

*Correlation is significant at the * 0.05, ** 0.01, *** 0.001*

Water hardness in our study correlates negatively with pH.

Positive significant correlations were found between total water hardness with conductivity (Rp = 0.636; $P < 0.05$), dissolved oxygen level (Rp = 0.855; $P < 0.01$) and water saturation with oxygen (Rp = 0.958; $P < 0.001$). A high and significant positive correlation was discovered between dissolved oxygen and nitrate nitrogen (Rp = 0.647; $P < 0.05$). Phosphates significantly correlated only with ammonium nitrogen levels, with a positive relationship (Rp = 0.598; $P < 0.05$).

The results of our study are in line with those of many authors. Thus, Traykov et al. (2010), in a study of a number of reservoirs in Bulgaria, found a high negative correlation of total phosphorus with the level of dissolved oxygen in water and pH, while the relationship of phosphorus with electrical conductance and total nitrogen was positive.

Zhen et al. (2019), in aquaculture ponds, have discovered a high, significant, negative correlation between nitrate content and dissolved oxygen in water. The authors indicate that 99.3% of the nitrate behavior can be explained and predicted by dissolved oxygen. Luo et al. (2019) report negative correlations between water temperature and dissolved oxygen level, between oxygen and ammonium nitrogen, and a positive correlation between water temperature and ammonium nitrogen. In their study, Bhatnagar and Devi (2012) found a negative correlation between DO and BOD_5 and between DO and ortho-phosphate.

CONCLUSIONS

The conducted study in a sturgeon cage farm showed that generally water parameters were within the limits of technological standards for fish farming, in the cultivation of thermophilic freshwater fish species.

During the vegetation period, significant dynamics of individual indicators were observed. Water temperature provides good conditions for growth. The vegetation period is prolonged and even at the beginning of Winter the average temperature was above 10°C.

A single increase in pH above the upper optimal limit was observed in July. A period with lower than optimal oxygen values was reported from July to September, and it should be noted that the minimum values were above the sturgeon limits.

The oxygen saturation of water was in optimal range throughout the studied period. There are no deviations from the water requirements for thermophilic fish species related to nitrogen and phosphorus; oxidability and biochemical oxygen demand.

Significant negative correlations of water temperature were found with dissolved oxygen levels and nitrate nitrogen. Positive significant correlations were discovered between total water hardness with electrical conductivity, dissolved oxygen level and water saturation with oxygen. A high and significant positive correlation was discovered between oxygen dissolved in water and nitrate nitrogen. Phosphates significantly correlated only with ammonium nitrogen levels, with a positive relationship.

ACKNOWLEDGEMENT

This study was supported by Scientific Research Center of Agricultural University - Plovdiv, financing scientific project 06-17.

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