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THE INFLUENCE OF THE STOCKING DENSITY ON THE SURVIVAL RATE OF THE PIKE-PERCH (*SANDER LUCIOPERCA* LINNAEUS, 1758) DURING THE COLD SEASON IN INDUSTRIAL AQUACULTURE SYSTEMS

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Abstract

The survival rate of one summer old pike-perch's (Sander lucioperca L., 1758) during the cold season is low (50-75%) due to lower temperatures which lead to a decrease in metabolism. The feed sources are becoming scarce and, as a result, the fish are consuming their adipose tissue accumulated during the warm season, becoming prone to disease due to weight loss. The research was carried out during 2018, 2019 and 2020 years at the Fish Culture Research and Development Station, Nucet. The fish wintering was done in ponds, in two experimental versions: Variant 1 - no feed was administered and Variant 2 - live food was administered (fish species without economic importance). The experiments for each variant were performed in three densities, as follows: 200 kg/basin (2000 kg/ha), 500 kg/basin (5000 kg/ha) and 700 kg/basin (7000 kg/ha). The best results for survival rate were obtained in variant 2 in 2020 at 200 kg/basin density, with a 98.8% survival rate. The weight gain rate in variant 2 for 2018 at 500 kg/basin density, obtained a growth rate of 137 kg/wintering season.

Key words*: density, pike-perch, survival, wintering.*

INTRODUCTION

The pike-perch (*Sander lucioperca* L., 1758) is both a commercial fishing valuable species and for recreational sport fishing (Rundberg, 1977; FAO, 1984; Lehtonen, 1985; Ibanescu, 2020; Dobrotă, 2021). This species is used as a biomanipulation tool in order to reduce the number of undesirable fish, usually cyprinids without economic value (Van Densen & Grimm, 1988; Benndorf, 1990; Dörner et al., 1999; Mehner et al., 2001; Wysujack, 2003).

The pike-perch habitat preferences differ throughout the year and vary depending on age and environmental conditions (Lappalainen et al., 1995, FAO, 2022).

Water temperature influences many variables, such as: metabolism, oxygen content in water, the amount of oxygen that organisms need, including food availability (Hokanson, 1977), so growth is related to temperature which is correlated with latitude (Ferguson, 1958; Hokanson, 1977).

The weight and numerical losses reduction during the cold season in the one summer old pike-perch, is an important factor for obtaining a larger population and an additional income for aquaculture farmers.

MATERIALS AND METHODS

The researches were carried out in 2018-2020 period at the Fish Culture Research and Development Station Nucet, Dâmbovița County. The experimental basins are located in the major riverbed of the Ilfov brook downstream of the Ilfoveni accumulation dam. For the wintering of the pike-perch, the material base consisted of wintering ponds with an area of 1000 m². The depth of the wintering ponds is between 1.5-2.4 m.

The harvest fishing was carried out between 10 and 25 November each year. The one summer old pike-perch, with an average weight between 142-362 g/ex, had been stocked for wintering in 1000 m² earth ponds, in monoculture. During the

warm season, the wintering ponds were left to dry and were disinfected with lime chloride, more intensely in wet areas.

The water supply was made from a common channel, through a concrete monk outlet structure, where metal grids were installed with a 4 mm screen was mounted, in order to prevent the penetration of other fish species. Because the supply channel was common, it can say that in all experimental basins the physio-chemical characteristics of the water were identical.

The stocked fish for wintering were made in two variants, in each variant three densities were experienced, as follows:

- Variant 1 (where no fish feed was administered), with three fish densities: 200 kg/basin (2000 kg/ha), 500 kg/basin (5000 kg/ha) and 700 kg/basin (7000 kg/ha);
- Variant 2 (where live food composed of fish with no economic importance was administered), with three fish densities: 200 kg/basin (2000 kg/ha), 500 kg/basin (5000 kg/ha) and 700 kg/basin (7000 kg/ha).

The harvest fishing of pike-perch at the end of the cold season, in the three experimental years, was carried out between March 22 and April 11, after approximately 135 wintering days.

The methods for determining the chemical parameters of water were:

- pH, dissolved oxygen and chlorides were determined using the portable multiparameter HQ 40d;
- Dissolved organic matter (CCO-Mn), hardness, calcium ion concentration, magnesium ion concentration and alkalinity were determined in the laboratory by volumetric methods;
- The concentration of nitrogen anion, nitrite anion, phosphate anion and ammoniacal nitrogen were determined in the laboratory by the spectrophotometric method (Griess-Ilosvay method).

The growth rate was calculated by subtracting the quantity of stocked fish from the harvested quantity.

The results of stocking density on the survival rate of the pike-perch experimental groups, during the cold season, were statistically analyzed using descriptive statistics and Microsoft Excell (Office 2010) for Windows.

RESULTS AND DISCUSSIONS

During the experiments, the water physico-chemical parameters were monitored. The obtained results interpretation was performed in accordance with the provisions of the "Norm regarding the classification of surface water quality", correlated with the data from the specialized literature in waters for fish use (OMMGA no. 161/2006) (Table 1).

In those three years of study (2018-2019; 2019-2020 and 2020-2021) the cold season was similar, with high temperatures compared to the normal period. The exception was the year 2020-2021, which recorded positive air temperatures in January and February with low amounts of rainfall, the month of March was cold, with negative temperatures both day and night with snowfall episodes. In April 2021 it was recorded lower temperature for this period than normal.

During the experiments, the water temperature recorded average values in the range of 2.2-8.9°C, and during the day positive average air temperatures of up to 11°C were recorded (Table 2). The nights were cold with average temperatures of -15.0°C. During certain periods of the cold season, an ice bridge with transparent ice was formed, for 10-15 days, without loss of fish.

In Variant 2 (with feeding), in all the three experimental seasons, live food was composed of fish species without economic value and small dimensions (5-20 g/ex), like Prussian carp (*Carrassius gibelio*); rudd (*Schardinius erytrophthalmus*); European bitterling (*Rodeus amarus*) and stone maroko (*Pseudorasbora parva*). The live food administration was performed monthly, in an amount of 10% of the total stocked quantity. Live food was administered on December 2018 and in the first decade of January, February, March of 2019. The total food amount administered in the 2018-2019 season was as follows: at 200 kg/basin density - 80 kg; at 500 kg/basin density - 200 kg; and at 700 kg/basin density - 280 kg. The same amount of live food was administered in the 2019-2020 and 2020-2021 winter periods of study.

In the 2018-2019 winter season, the stocking actions were made between 12-20 November 2018, with pike-perch (*Sander lucioperca*) with

an average live weight, as follows: in Variant 1 at 200 kg/basin - 142 g/ex, at 500 kg/basin density - 318 g/ex and at 700 kg/bazin density - 154 g/ex. In Variant 2, the average live weight was: at 200 kg/basin density - 234 g/ex, at 500 kg/basin density - 151 g/ex and at 700 kg/basin density - 343 g/ex. The specimens number was different depending on the average weight of the fish and the stocked quantity, which was between 855-4545 ex/pond, in both variants.

Table 1. Average values of the physico-chemical parameters of the water in 2018-2020 period

No.	Chemical parameters		U.M.	Parameter values		
				Source	Experimental ponds	Optimally according to quality standards
				Optimally according to quality standards		
1	pH		unit pH	7	7.6	7-7.8
2	Alkalinity		mg/l	140	166	200-400
3	Calcium (Ca^{2+})		mg/l	44.2	43.8	90-120
4	Magnesium (Mg^{2+})		mg/l	20.7	19.8	10-40
5	Ca^{2+}/ Mg^{2+}		mg/l	2.1	2.2	5
6	Organic matter		mg $KMnO_4$/l	14	28.5	20-60
7	Oxygen		mg/l	14.6	9.7	5-10
8	Ammonia (NH^{+}_3)		mg/l	missing	missing	missing
9	Nitrates (NO^{-}_3)		mg/l	missing	0.21	2.5-4
10	Nitrogen (NO^{-}_2)		mg/l	0.001	0.002	0.03
11	Phosphates (PO^{3-}_4)		mg/l	missing	0.04	0.05-1.5
12	Chlorides	Cl^{-}	mg/l	8.13	8.23	30
		Na Cl	mg/l	14.21	14.04	20
13	Ammonia (NH^{+}_4)		mg/l	missing	0.017	0.5-1
14	Total hardness		(^{0}D)	13.6	15.5	12

Table 2. Water and air temperature during the study

Month and year	Water temperature			Air average temperature
	T min. (°C)	T max. (°C)	T med. (°C)	T air (°C)
Season 2018-2019				
December 2018	1.5	4	2.2	-2.2
January 2019	1.5	3	2	-0.4
February 2019	2.5	5	3.6	4.3
March 2019	3.5	13	8.9	11
Season 2019-2020				
December 2019	2	5	3.8	5
January 2020	1.5	2.5	2.3	0.9
February 2020	2.5	6.5	4.1	5.9
March 2020	5	12.5	9.6	10.5
Season 2020-2021				
December 2020	3.5	5	4.2	2.3
January 2021	2	5	3.5	3.2
February2021	3	7.5	4.7	4.3
March 2021	5	10.5	7.7	9.9

The spring fishing was carried out between April 4 and 11, 2019, with the following results (Table 3):

- The average weights were: in Variant 1 at 200 kg/basin density - 131 g/ex, at 500 kg/basin density - 287 g/ex and at 700 kg/basin density - 137 g/ex, and in Variant 2 at 200 kg/basin density - 276 g/ex, at 500 kg/basin density - 196 g/ex and at 700 kg/basin density - 377 g/ex.;
- The quantities harvested were as follows: in Variant 1 at 200 kg/basin density - 128 kg, at 500 kg/basin density - 325 kg and at 700 kg/basin

density - 422 kg, and in Variant 2 at 200 kg/basin density - 225 kg, at 500 kg/basin density - 637 kg and at 700 kg/basin density - 743 kg;
- The survival rate had lower values in Variant 1 (at 200 kg/basin density - 69.4%; at 500 kg/basin density - 72.0%; and at 700 kg/basin density - 67.7%), with an average of 69.7%, compared to Variant 2 (at 200 kg/basin density - 95.5%; at 500 kg/basin density - 98.2%; and at 700 kg/basin density - 96.6%), with an average of 96.8%.

In the winter season 2019-2020, the wintering stockings were made between November 19 and 25, 2019, with pike-perch (*Sander lucioperca*) that had an average weight, as follows: in Variant 1 at 200 kg/basin density–241 g/ex, at 500 kg/basin density - 321 g/ex and at 700 kg/basin density - 167 g/ex, and in Variant 2 at 200 kg/basin density - 222 g/ex, at 500 kg/basin density - 354 g/ex and at 700 kg/basin density–151 g/ex.

The number of specimens was different, depending on the average weight of the fish and the stocked quantity, between 830-4636 ex./pond, in both versions.

The spring fishing was carried out between March 26 and April 3, 2020, with the following results (Table 4):
- The average weights were: in Variant 1 at 200 kg/basin density -212 g/ex, at 500 kg/basin density - 287 g/ex and at 700 kg/basin density - 137 g/ex, and in Variant 2 at 200 kg/basin density - 267 g/ex, at 500 kg/basin density - 372 g/ex and at 700 kg/basin density - 186 g/ex.;
- The harvested quantities were as follows: in Variant 1 at 200 kg/basin density - 146 kg, at 500 kg/basin density - 283 kg and at 700 kg/basin density - 393 kg, and in Variant 2 at 200 kg/basin density - 231 kg, at 500 kg/basin density - 483 kg and at the 700 kg/basin density - 842 kg;
- The survival rate had lower values in Variant 1 (at 200 kg/basin density - 82.8%; at 500 kg/basin density - 63.4%, at 700 kg/basin density - 68.5%) compared to Variant 2 (at 200 kg/basin density - 95.9%; at 500 kg/basin density - 91.9%; and at 700 kg/basin density -97.6%).

In the winter season 2020-2021, the wintering stocking were made between November 10 and 17, 2020, with pike-perch (*Sander lucioperca*) (Figure 1), which had the average weight, as follows: in Variant 1 at 200 kg/basin density - 348 g/ex, at 500 kg/basin density - 168 g / ex and at 700 kg/basin density - 233 g/ex, and in Variant 2 at 200 kg/basin density - 360 g/ex, at 500 kg/basin density - 146 g/ex and at 700 kg/basin density - 231 g/ex. The number of specimens was different depending on the average weight of the fish and the stocked quantity, which was between 556-3425 ex/pond, in both variants.

The spring fishing was carried out between March 22 and 30, 2021, with the following results (Table 5 and Figure 2):
- The average weights were: in Variant 1 at 200 kg/basin density - 312 g/ex., at 500 kg/basin density - 141 g/ex. and at 700 kg/basin density - 212 g/ex., and in Variant 2 at 200 kg/basin density - 401 g/ex., at 500 kg/basin density -168 g/ex. and at 700 kg/basin density - 267 g/ex.;
- The quantities harvested were: in Variant 1 at 200 kg/basin density - 119 kg, at 500 kg/basin density - 319 kg and at 700 kg/basin density - 391 kg, and in Variant 2 at 200 kg/basin density - 220 kg, at 500 kg/basin density - 559 kg and at 700 kg/basin density - 798 kg;
- The survival rate had lower values in Variant 1 (at 200 kg/basin density - 66.5%; at 500 kg/basin density - 76.0%, and at 700 kg/basin density - 61.4 %) compared to Variant 2 (at 200 kg/basin density - 98.8%; at 500 kg/basin density - 97.1%, and at 700 kg/basin density -98.6%).

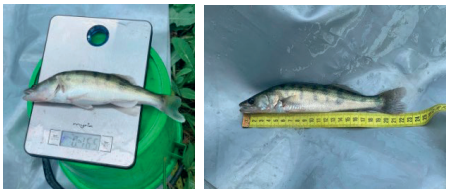

Figure 1. Pike-perch in autumn, 2020

Figure 2. Pike-perch fishing in spring, 2021

Weight loss and growth increase (g) per year and experimental variants

In the 2018-2019 season, in Variant 1 (without feeding) in all three densities was a decrease in individual weight, the most pronounced being recorded in the 500 kg/basin density of 31 g/ex.,

the lowest being recorded at 200 kg/basin density of 11 g/ex., and at the 700 kg/basin density a loss of 17 g/ex. was registered. In Variant 2 (with feeding) it was an increase in individual weight, the highest being recorded at 500 kg/basin density of 45 g/ex., the lowest being recorded at 700 kg/basin density of 34 g/ex., and at 200 kg/basin density was recorded an increase of 42 g/ex. (Table 3).

Table 3. The results obtained on experimental versions in 2018-2019 winter season

Registered parameters	Variant 1 (without feeding)			Variant 2 (with feeding)		
Density (kg/basin)	200	500	700	200	500	700
Number of specimens	1408	1572	4545	855	3311	2041
Ex./ha	14085	15723	45455	8547	33113	20408
kg/ha	2000	5000	7000	2000	5000	7000
W med. autumn (kg)	0.142	0.318	0.154	0.234	0.151	0.343
Nr. specimens collected	978	1132	3078	816	3251	1972
W med. spring (kg)	0.131	0.287	0.137	0.276	0.196	0.377
Survival (%)	69.4	72	67.7	95.5	98.2	96.6
Fish quantity harvested (kg)	128	325	422	225	637	743

Table 4. The results obtained on experimental versions in 2019-2020 winter season

Registered parameters	Variant 1 (without feeding			Variant 2 (with feeding)		
Density (kg/basin)	200	500	700	200	500	700
Number of specimens	830	1558	4192	901	1412	4636
Ex./ha	8299	15576	41916	9009	14124	46358
kg/ha	2000	5000	7000	2000	5000	7000
W med. autumn (kg)	0.241	0.321	0.167	0.222	0.354	0.151
Nr. specimens collected	687	987	2871	864	1298	4526
W med. spring (kg)	0.212	0.287	0.137	0.267	0.372	0.186
Survival (%)	82.8	63.4	68.5	95.9	91.9	97.6
Fish quantity harvested (kg)	146	283	393	231	483	842

Table 5. The results obtained on experimental versions in 2020-2021 winter season

Registered parameters	Variant 1 (without feeding			Variant 2 (with feeding)		
Density (kg/basin)	200	500	700	200	500	700
Number of specimens	575	2976	3004	556	3425	3030
Ex./ha	5747	29762	30043	5556	34247	30303
kg/ha	2000	5000	7000	2000	5000	7000
W med. autumn (kg)	0.348	0.168	0.233	0.36	0.146	0.231
Nr. specimens collected	382	2261	1845	549	3326	2989
W med. spring (kg)	0.312	0.141	0.212	0.401	0.168	0.267
Survival (%)	66.5	76	61.4	98.8	97.1	98.6
Fish quantity harvested (kg)	119	319	391	220	559	798

In the 2019-2020 season in Variant 1 (without feeding) in all three densities was a decrease in individual weight, the most pronounced being recorded in 500 kg/basin density of 38 g/ex., the

lowest being recorded at 200 kg/basin density of 29 g/ex. and at the 700 kg/basin density a loss of 30 g/ex. was registered. In Variant 2 (with feeding) was an increase in individual weight, the highest being recorded at 200 kg/basin density of 45 g/ex., the lowest being recorded at 500 kg/basin density of 18 g/ex. and at 700 kg/basin density was recorded an increase of 35 g/ex.

In the 2020-2021 season in Variant 1 (without feeding) in all three densities there was a decrease in individual weight, the most pronounced being recorded in 200 kg/basin density of 36 g/ex., the lowest being recorded at 700 kg/basin density of 21 g/ex. and at the 500 kg/basin density there was a loss of 27 g/ex. In Variant 2 (with feeding) there was an increase in individual weight, the highest being recorded at 200 kg/basin density of 41 g/ex., the lowest being recorded at 500 kg/basin density of 22 g/ex. and at 700 kg/basin density was recorded an increase of 36 g/ex.

Weight loss and growth increase (g) per year and experimental variants are presented in Figure 3.

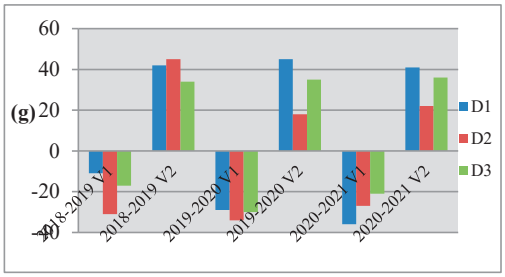

Figure 3. Weight loss and growth increase (g) by year and experimental variants

The numerical losses during on three years of study on experimental variants

In the 2018-2019 season in Variant 1 (without feeding) the survival rate registered values between 67.7-72.0%, the lowest being registered in the700 kg/basin density where the survival was of 67.7%, the highest being registered at the 500 kg/basin density where the survival was 72.0%, and at the 200 kg/basin density a survival of 69.4% was registered. In Variant 2 (with feeding), the highest survival was recorded at 500 kg/basin density of 98.2%, the lowest being recorded at 200 kg/basin density of 95.5%, and at 700 kg/basin density there was a survival of 96.6 %.

In the 2019-2020 season in the Variant 1 (without feeding) the survival registered values between 63.4-82.8%, the lowest being registered in the 500 kg/basin density where the survival was 63.4%, the highest being recorded at 200 kg/basin density where the survival was 82.8%, and at 700 kg/basin density a survival of 68.5% was recorded. In Variant 2 (with feeding), the highest survival was recorded at 700 kg/basin density of 97.6%, the lowest being recorded at 500 kg/basin density of 91.9 %, and at 200 kg/basin density there was a survival of 95.9 %.

In the 2020-2021 season in Variant 1 (without feeding) the survival registered values between 61.4-76.0%, the lowest being registered in the 700 kg/basin density where the survival was 61.4%, the highest being registered at the 500 kg/basin density where the survival was of 76.0%, and at the 200 kg/basin density a survival of 66.5% was registered. In Variant 2 (with feeding), the highest survival was recorded at 200 kg/basin density of 98.8%, the lowest being recorded at 500 kg/basin density of 97.1%, and at 700 kg/basin density there was a survival of 98.6%.

The survival rate (%) during on three years of study on experimental variants are presented in Figure 4.

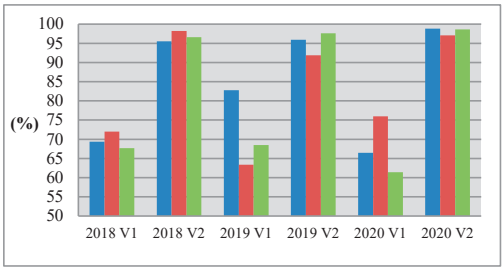

Figure 4. Survival rate variation (%) on experimental variants in 2018-2020 period

Quantitative losses by years and experimental variants

In the 2018-2019 season in Variant 1 (without feeding) it was found that the most accentuated decrease of fish material was registered in the 700 kg/basin density of 40%, the smallest being registered at the 500 kg/basin density of 35 %, and at the 200 kg/basin density recorded a loss of 36%. In Variant 2 (with feeding) the largest decrease in the amount of fish material was recorded at 500 kg/basin density of 27%, the smallest being recorded at 700 kg/basin density

of 6%, and at 200 kg/basin density there was a decrease of 13%.

In Variant 1 of the 2019-2020 season (without feeding) it was found that the most accentuated fish material decrease was registered in the 700 kg/basin density of 44%, the smallest being registered at the 200 kg/basin density of 27%, and at the 500 kg/basin density it was recorded a loss of 43 %. In Variant 2 (with feeding), the largest amount decrease in fish material was recorded at 700 kg/basin density of 20 %, the smallest being recorded at 500 kg/basin density of 3%, and at 200 kg/basin density there was a decrease of 15%.

In the 2020-2021 season, in Variant 1 (without feeding) it was found that the most accentuated fish material decrease was registered in the 700 kg/basin density of 44%, the smallest being registered at the 500 kg/basin density of 36%, and at the 200 kg/basin density recorded a loss of 40%. In Variant 2 (with feeding), the largest amount decrease in fish material was recorded at 700 kg/basin density of 14%, the smallest being recorded at 200 kg/basin density of 10%, and at 500 kg/basin density there was a decrease of 12%.

The pike-perch survival rate in Variant 2 was clearly superior to Variant 1, in all densities and in all three years of study (Figure 5).

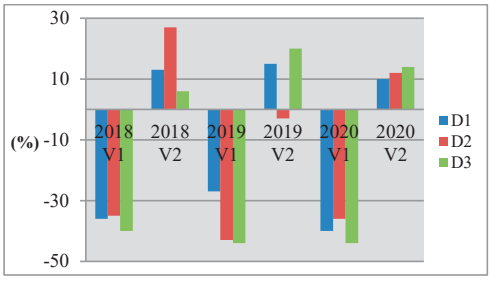

Figure 5. The fish material lost amount (%) and growth increase by years and experimental variants

In Variant 1 it was between 61.4-82.8%, compared to Variant 2 where was 91.9-98.8%, showing that when the pike-perch is fed even if the temperature is low, the losses in the cold season are lower.

CONCLUSIONS

From the weight losses point of view, in Variant 1 it was found that the highest losses were in the 2020-2021 season at 200 kg/basin density with the value of 36 g/ex., and the lowest losses were in the 2018-2019 season at 700 kg/basin density with the value of 17 g/ex. In the case of Variant 2, there is an increase in average weight in all study years and at all densities, with values between 18-45 g/ex.

The fish material total amount (weight and numerical losses) in Variant 1 decreased, the percentage of losses was not influenced by the average weight. In Variant 2, the fish material amount registered increases in all years of study and in all densities, except for the year 2019 (500 kg/basin density), where, in the spring the pike-perch had a higher average weight comparing to the stocking moment (autumn), it recorded a survival rate of 91.9%, which led to a loss of 3% of the total population.

In conclusion, feeding the pike-perch during the cold season with live fish with no economic value, leads to a high survival rate and an increase in individual weight, so that, in the spring, resulted a vigorous stocking biological material with very few numerical losses and from a quantitative point of view there have been increases.

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