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Parameters of pikeperch (*Sander lucioperca*) produced by natural spawning with further growing in tanks

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Abstract. Pikeperch is a valuable object of fisheries around the world. Accordingly, the cultivation of this species under controlled conditions is a promising direction of aquaculture development. However, the technology of its cultivation needs improvement, as there are currently certain difficulties, especially at the early stages of ontogenesis, when a transition to artificial nutrition occurs and high mortality rates are observed. Therefore, we carried out a study the results of which suggest that natural spawning allows obtaining high-quality fish seeds. Weight of pikeperch during one growing season reaches 50 g that facilitates wintering and contributes to high rates of yield from it. The experiment was carried out on age-4–6 females and age-3–5 males, selected according to their outer appearance. The average individual body weight of the females was 2.4 kg and such of males was 2.0 kg. At the same time, females were characterized by a more slender body and a higher body weight than the males, but these differences were insignificant. According to the results of work with the brood fish, 810.7 kg of juvenile pikeperch were harvested from spawning ponds. They were characterized by the average body weight ranging 2.41 g to 2.50 g and the Fulton's condition factor measuring 3.5. The industrial fecundity of females based on the output of 3-week-old fry amounted to the average of 43.5 thousand ind. per female. According to the test catches, the highest body weight was observed in young-of-the-years, grown at the stocking density of 2.5 thousand ind./m^2 (second experimental group). They also had the highest rate of daily weight gain, exceeding such in the other experimental groups, 18.2% in the first and 2.7% in the second, with the stocking densities of 1.5 thousand ind./m^2 and 2.0 thousand ind./m^2, respectively. In general, the dynamics of daily weigh gain in all experimental groups was progressing, measuring 0.05–0.10 g in the first 50 days of cultivation and 0.20–1.04 in the following days (from the middle to the end of the experiment). The absolute and relative weight gains confirm the obtained results. In particular, the minimum values of the absolute weight gain of pikeperch were recorded in the first half of the experiment. However, the relative increase did not have a clear trend in the experimental groups. In the first experimental group, a clear peak (32.5–39.0%) of the weigh gain was observed on days 67–85 of cultivation with a decline (29.1–15.3%) starting from day 99 until the end of the growing season. At the same time, similar growth peaks were not recorded in the second and third experimental groups. By contrast, there was a decline on day 67, increasing to 30% on day 71, and further having a tendency to decrease until the end of the season. The highest individual weight and absolute weigh gain were recorded in the second and third experimental groups, where the maximum fish productivity was achieved from 1 m^2, being 61.2 and 78.8 kg, respectively. At the same time, the survival rate, which is important for aquaculture conditions, was lower in these two groups than such in the first experimental group, 1.6% and 1.4%, respectively. Thus, the results of our study can help in ensuring the availability of high-quality pikeperch seeds, which in turn would be positive for both the consumer market of fish products and the state of native fish populations.

Keywords: aquaculture; fish farming; juvenile fish; spawning in ponds; fish hatcheries; survival rate.

Introduction

The modern global aquaculture faces an increase in demand for the cultivation of not only traditional pond fish species but also relatively new ones, including pikeperch (*Sander lucioperca*) among the leading. This is because of high taste and nutritional qualities of its meat, which is dietetic and rich in amino acids. Also, pikeperch has a relatively fast growth rate and a relatively high tolerance to diseases (Craig, 2000; Fontaine, 2008; Polishchuk & Simon, 2023).

In aquaculture in Ukraine, pikeperch has been traditionally used as an additional object in pond aquaculture for polycultures with common and Chinese carps, which can control trash fish (Hrynzhevskyi & Pekarskyi, 2004; Andriushchenko et al., 2006; Hrytsyniak et al., 2008). Implementation of the abovementioned polyculture allows for a targeted formation of the ichthyofauna of water bodies with increase in their fish productivity. It also reduces the number of low-value fish species and improves the ichthyopathological status of ichthyocenoses. Therefore, the use of this species in aquaculture in this aspect can improve fattening conditions for the main objects of polyculture. At the same time, continuous commercial harvest of pikeperch from natural water bodies increases the total amount of pikeperch catches because the demand for it is growing both on the domestic and foreign markets (Martseniuk, 2014; Polishchuk & Simon, 2023). However, due to human impact (overfishing, poaching, regulation of rivers, ecological transformations), commercial fishery cannot fully satisfy all the demand, even by increasing pressure on wild pikeperch populations. Therefore, scientists have begun to develop methods of artificial breeding of this species (Hrynzhevskyi et al., 2001; Martseniuk, 2014; Kononenko et al., 2016).

The existing methods of breeding and rearing pikeperch usually focus on pond aquaculture (Melnyk, 1966; Hrynzhevskyi et al., 2008; Tretiak et al., 2008). At the same time, numerous scientific studies have confirmed that the growth rate of this species can be significantly increased. Nonetheless, peculiarities of nutrition, which most piscivorous fishes have, make it hard to transition the fish to external nutrition, which can take up to 21 days and greatly complicates the process of rearing the fish at the early stages of development. Because of these difficulties, juvenile pikeperch is characterized by a significant (up to 80%) mortality rate, primarily caused by prolonged starvation (Bilyi, 1958; Policar et al., 2019; Colchen et al., 2020). Improved methods of feeding can help solve this problem. Using the method of continuous, round-the-clock feeding of larvae in small portions significantly improves the feeding efficiency (Żakęś et al., 2006; Wang et al., 2009; Schram et al., 2014). As specialized feeds had emerged on the market, this element of cultivation technology should be facilitated, but there are still some unresolved issues regarding stocking density.

Taking into account this information, it is possible to draw conclusions about the prospects of using pikeperch as an object of aquaculture. However, the existing problems of its cultivation, in particular the stage of reproduction and rearing of juveniles at the early stages, require improvement, and were therefore in the focus of our studies.

Material and methods

The study was conducted in 2020 at the Khmelnytskrybhosp PrJSC. The fish reproduced naturally in ponds. Three ponds with the area of 0.7 ha each were used for spawning. Age-4–6 females and age-3–5 males were used for spawning. The ratio of females to males was 1:2. The spawning campaign was carried out according to the guidelines for pikeperch breeding (Kuznetsova, 1958; Poltavchuk, 1959; Tretiak, 2008).

The pikeperch juveniles were kept up to the age of 3 weeks in the same ponds. Further, the juveniles were reared up to the stage of young-of-the-years (YOY) in 4.8 m^2 tanks. For this purpose, individuals with an average weight body weight were selected and divided into 3 groups into three tanks, using three stocking densities – 1.5, 2.0, and 2.5 thousand ind./m^2. Further, every 14 days, in order to prevent cannibalism, they were sorted and the survival rate was determined. The duration of the experiment was 127 days.

The growth rate was determining according to weight and length during test catches. The main productive and biological parameters were studied according to the methods generally accepted in fish farming (Pravdin, 1979; Kotljar, 2004). The body length at the initial development stages was determined using graph paper, and then using a measuring tape with 1 mm accuracy. At the first stage, the fish were weighed on torsion scales, and later on electronic scales with the accuracy of 0.01 g. Population-growth indicators were determined using the following formulas:

– absolute weight increment: $R = P_n - P_o$ (g), where P_n is the final average body weight (g) and P_o is the initial average body weight (g);

– average daily absolute growth: $C = R/t$ (g), where R is the absolute average growth (g) and t is the growing period (days);

– relative growth: $R\% = R / P_0 * 100\%$ (%); where R is the absolute average weight (g) and P_o is the initial body weight (g) (Chugunova, 1952).

The experiments were carried out in compliance with the requirements of the European Convention for the Protection of Vertebrate Animals used for Experimental and other Scientific Purposes (1986).

Differences between the values of experimental groups were calculated in the Statistica 7.1 program (StatSoft Inc., USA) using the Tukey's Test, taking into account the Bonferroni's Correction, where differences were considered significant at $P < 0.05$. The data are presented as x ± SD (mean ± standard deviation).

Results

For the spawning campaign, we selected nine largest age-4–6 females and 18 age-3–5 males from the main stock based on their exterior parameters. The average individual body weight of the females was 2.4 kg, and such of the males was 2.0 kg (Table 1). In all three experimental groups, females were characterized by a more slender body and a higher condition factor than the males, but those differences were insignificant (Fig. 1).

In total, 810.7 kg of juveniles were caught in the spawning ponds. The average body weight of the pikeperch ranged 2.41 to 2.50 g and the Fulton's condition factor equaled 3.5. Since all the females spawned in the first and second spawning ponds and only two spawned in the third pond, we may state that the industrial fertility of the females - in terms of the output of 3-week-old juveniles - amounted to the average of 43.5 thousand ind. per female, ranging 38.2–48.8 thousand ind. (Table 2).

In accordance with the scheme of experiment, further rearing of the juvenile pikeperch took place in plastic tanks. According to the data of the test catches, the highest body weight – 5,085 ± 642 mg – was observed in the YOYs grown at the stocking density of 2.5 thousand ind./m^2, i.e. in the third experimental group. In this group, the highest daily weigh gain was observed – 384 mg, 18.2% and 2.7% higher than in the first and second experimental groups, respectively. In general, the dynamics of daily weight gain in all experimental groups had a progressive pattern, accounting for 50 to 100 mg in the first 50 days of cultivation and 200–1,040 mg from the middle to the end of the experiment (Fig. 2).

Table 1
Morphometric measurements of sexually mature pikeperch used in natural spawning (x ± SD, $n_♀ = 3$; $n_♂ = 6$)

Parameters	Spawning pond No. 1		Spawning pond No. 2		Spawning pond No. 3	
	♀	♂	♀	♂	♀	♂
Body weight, kg	2.31 ± 0.36^{ab}	1.93 ± 0.17^{a}	2.72 ± 0.15^{c}	2.23 ± 0.15^{ab}	2.39 ± 0.15^{b}	2.13 ± 0.17^{ab}
Body length, cm	51.33 ± 2.85^{ab}	48.58 ± 0.01^{a}	54.33 ± 0.88^{c}	49.92 ± 1.19^{a}	52.33 ± 0.67^{b}	49.67 ± 1.26^{a}
Body height, cm	17.33 ± 0.83^{ab}	16.08 ± 0.61^{a}	17.67 ± 0.73^{b}	16.33 ± 0.42^{a}	16.67 ± 0.33^{ab}	16.08 ± 0.47^{a}
Body girth, cm	38.17 ± 3.98^{bc}	34.08 ± 0.68^{a}	42.33 ± 2.03^{c}	36.67 ± 0.99^{b}	37.83 ± 1.17^{b}	36.08 ± 1.46^{ab}

Note: different letters within line indicate samples that are significantly different from each other according to the results of the Tukey's test with the the Bonferroni's Correction. Differences were considered statistically significant at $P < 0.05$.

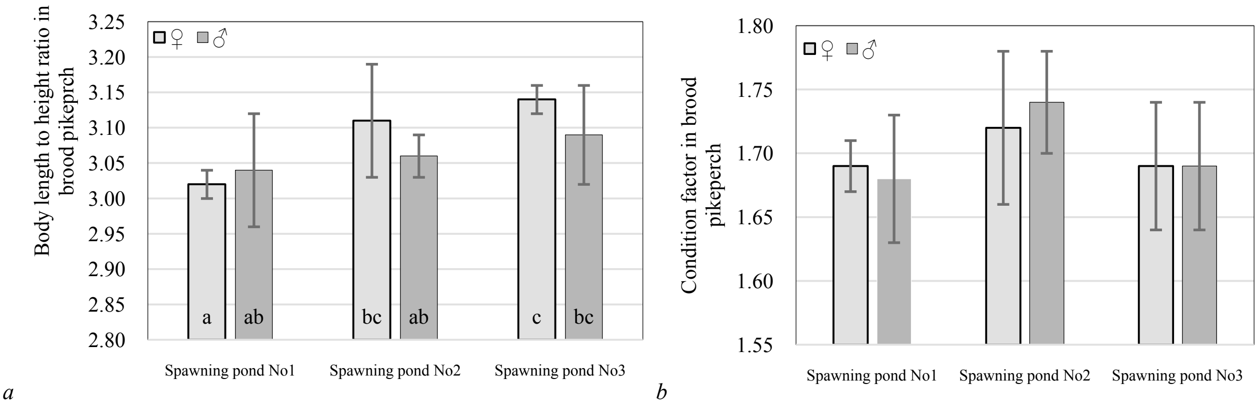


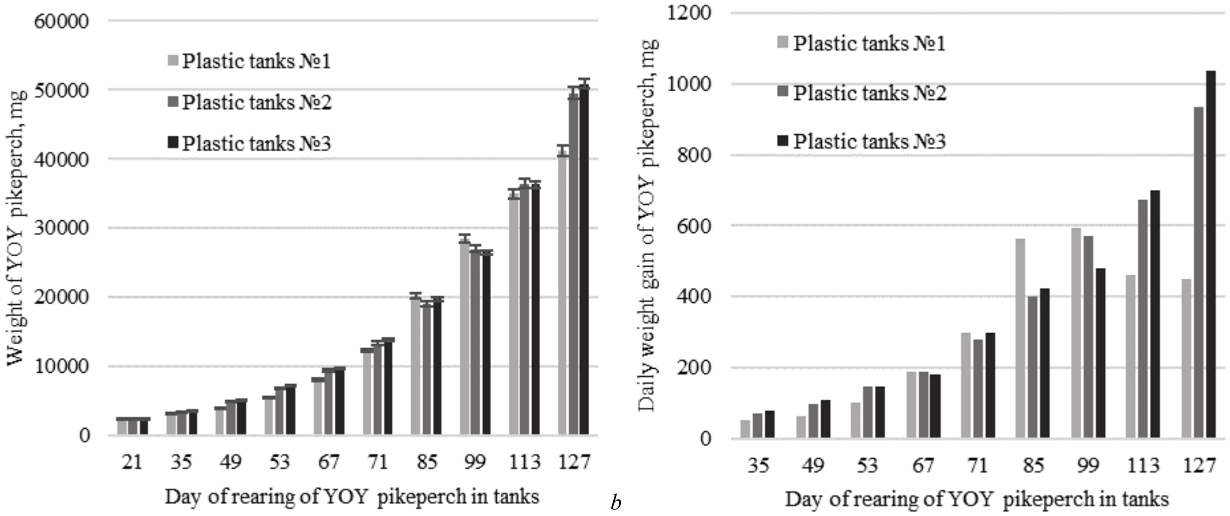
Fig. 1. Coefficients of fatness and high density of pikeperch broodfish used in spawning (x ± SD, n = 8): different letters within the column indicate samples that are significantly different from each other according to the results of the Tukey's test with the Bonferroni's Correction; differences were considered statistically significant at $P < 0.05$

The results of improving the technology of pikeperch breeding and reproduction are confirmed by the values of absolute and relative weigh gains. The minimum absolute weight gains (800–2,000 mg) were recorded during the first half of the growing season. Starting from day 67, weight gain of the pikeperch was from 2,600 to 13,500 g. However, we observed no clear relationship between the relative weigh gain in relation to the experimental group. In particular, in the first experimental group, where the stocking density was the lowest among the groups, a clear weight gain peak was observed on day 67–85 of cultivation. It reached 32.5–39.0% with decline from 29.1% to 15.3% starting from day 99 and until the end of the growing season. At the same time, no similar weight gain peak was observed in other two experimental groups. On the contrary, on day 67 of pikeperch cultivation, it declined from 29.7% and 30.1% to 27.5% and 25.9%, respectively. However, from day 71, it increased up to 30%, and by the end of the growing season had a downward trend (Fig. 3).

Table 2
Results of seining fish from spawning ponds after natural spawning of pikeperch (x ± SD)

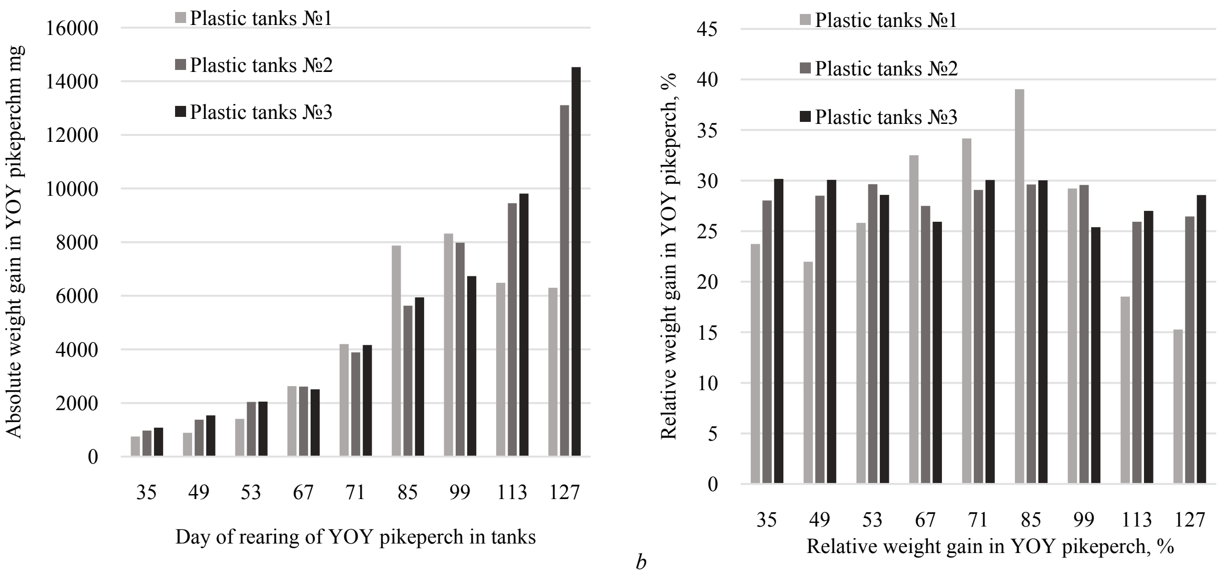
Pond number	The total number of harvested juvenile pikeperch, thousands ind.	Total weight of harvested juvenile pikeperch, kg	Average individual body weight (g, n = 15)	Average length (cm, n = 15)	Fulton's condition factor (units, n = 15)
1	140.5	337.3	2.41 ± 0.05[a]	3.98 ± 0.21[a]	3.45 ± 0.95[a]
2	127.4	299.3	2.49 ± 0.05[b]	4.05 ± 0.24[a]	3.54 ± 0.97[a]
3	77.4	174.1	2.50 ± 0.03[b]	4.12 ± 0.15[a]	3.52 ± 0.79[a]

Note: see Table 1.



a *b*

Fig. 2. Growth dynamics of young-of-the-year pikeperch by: *a* – body weight (x ± SD), *b* – daily body weight gain



a *b*

Fig. 3. Growth dynamics of YOY pikeperch: *a* – absolute body weight gain, *b* – relative body weight gain

Despite the fact that the greatest individual weight and increment in absolute weight were observed in the second and third experimental groups, where the stocking density was 2.0 and 2.5 thousand ind./m^2, the survival rates in them were 1.6% and 1.4% than in the first experimental group, where the stocking density was 1.5 thousand ind./m^2. At the same time, the second and third experimental groups were characterized by the maximum fish productivity, equaling 1 m^2 – 61.2 and 78.8 kg, respectively (Table 3).

Discussion

For decades, freshwater pikeperch has been a highly valued object of domestic and foreign aquaculture (Wuertz et al., 2012; Żarski et al., 2012; Bohnes et al., 2022). Cultivation of this species under controlled conditions is promising for the development of the global aquaculture (Fontaine, 2008; Martins, 2010). However, the technology of its reproduction is characterized by a number of complex problems, especially at the early stages of cultivation. First of all, this is due to the transition to external nutrition, consumption of artificial feeds, start of sensitive periods of ontogenesis and, accordingly, high mortality rates (Martseniuk, 2014; Lepic, et al, 2017). However, supplementation of feeds with *Artemia salina* nauplii and various nutrients (Dabrowski et al., 2000; Zakęś, 2007; Ljubobratović, 2021) allows reproducing this species even in non-traditional periods for the spawning campaign. In addition, many studies are aimed at improving the combined technology of feeding juvenile pikeperch, for example, starting feeding with *A. salina* and gradually replacing it with artificial feeds (Schulz et al., 2006; Kestemont et al., 2007; Ljubobratović et al., 2015).

Table 3
Parameters of harvesting fish
from experimental tanks with YOY pikeperch

Parameters	Experiment I	Experiment II	Experiment III
Duration of rearing, days	127	127	127
Stoking density, ind./m^2	1500	2000	2500
Tank area, m^2	4.8	4.8	4.8
Survival rate of YOYs, %	63.4	61.8	62.0
Total production, kg	188.3	293.9	378.3
Productivity, kg/m^2	39.2	61.2	78.8

The results of experiments in our study show that it is possible to produce high-quality pikeperch seeds resulting from natural spawning. Their weight on days 21 of growing can reach more than 200 mg. However, it is worth noting that seining fish from the spawning ponds in May, when the average daily air temperature can exceed 20 °C, complicates this process. Therefore, mortality rate of juvenile pikeperch can increase, exceeding 25%. This is due to the fact that this species is very sensitive to mechanical movements, which decreases its survival rate (Lepic et al., 2017; Colchen, 2020).

At the same time, stoking density was observed to have a significant impact on the results of growing juveniles under controlled conditions (Szkudlarek & Zakęś, 2002; Szkudlarek & Zakęś, 2007; Policar, 2013). That is why, in our experiment, the use of three stocking densities, equaling 1.5, 2.0 and 2.5 thousand ind./m^2 of tank, produced positive results. However, it is worth noting that the juvenile pikeperch had a significant period of adaptation to the new conditions. Accordingly, no significant growth rate was observed during the first period of cultivation. This was reflected in the dynamics of absolute and relative weight gains. Similar results were observed for combined cultivation in ponds and recirculated aquaculture systems (RAS) (Policar et al., 2019; Péter et al., 2023). However, the results we attained using this technology have been lower in comparison with the classic tank technology (Polishchuk, 2022). Therefore, the decisive factor for introduction of these technologies would be their economic effect. Therefore, it is necessary to conduct an analysis of the costs associated with the spawning campaign and the subsequent rearing of juvenile pikeperch.

Conclusion

The combined technology of reproduction and breeding of pikeperch has been effective. According to this technology, first the fish spawn naturally in ponds and then the juveniles are cultivated in tanks. This provides controlled conditions for pikeperch cultivation during the most vulnerable stages of its ontogenesis. Thus, the mortality rate decreases and the economic efficiency of aquaculture production increases.

The use of the combined technology can produce sustainable fish seeds. The young-of-the-year pikeperch grown using this technology have had the average individual body weight of 500 mg and the survival rate above 60%. These parameters meet the needs of farmers in high-quality fish seeds and can help preserving natural pikeperch populations.

Juvenile pikeperch at this stage of cultivation is very sensitive to mechanical damage and oxygen regime. Therefore, the technology of pikeperch harvest needs additional development and tolerance to the hydrochemical regime needs more research.

In addition, it is promising to perform economic studies of different types of spawning and geographical zoning based on the economic feasibility of using a particular (pond, tank, combined) technology of reproduction and cultivation or their combination.

The study of the productive and biological parameters of YOY pikeperch (*Sander lucioperca*) produced using combined technology, which is a combination of natural spawning and commercial cultivation in tanks, was financed within the framework of the scientific research program of the National Academy of Agrarian Sciences of Ukraine for 2021–2025 – 32 System of Comprehensive Scientific Support of Fisheries in Inland Water Bodies of Ukraine under the task To Develop a System of Comprehensive Evaluation of the Gene Pool of Cultivated Fish Species in Order to Improve the Selection Process (state registration No. 0116U001218).

The authors declare no conflicts of interest.

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