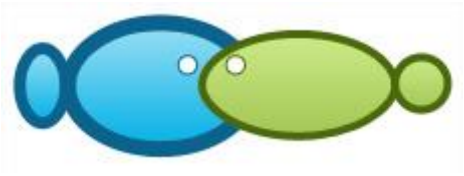

The effect of domestication on the productive and reproductive parameters of pikeperch (*Sander lucioperca* L.) broodstock in pond aquaculture in Ukraine

[1]Oleksii M. Polishchuk, [2]Hanna A. Kurinenko, [2]Maria Y. Simon, [2]Igor I. Hrytsyniak, [1]Nataliia Y. Rudyk-Leuska, [2]Natalia O. Borisenko, [1]Mykhailo V. Leuskyi

[1] National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine;
[2] Institute of Fisheries of the National Academy of Agrarian Sciences of Ukraine, Kyiv, Ukraine. Corresponding author: H. A. Kurinenko, annazakharenko@ukr.net

Abstract. The work is devoted to the study and comparison of productive and reproductive indicators of breeding stock from natural and domesticated herds of pikeperch (*Sander lucioperca* (Linnaeus, 1758)). The research found that domesticated breeding stock had an advantage in terms of morphometric indicators. According to the overall average indicator, domesticated females surpassed females of the natural population by 5.7% in terms of egg production and 13.5% in terms of working fertility. At the same time, domesticated females produced larger eggs, with an average of 1,165.97 eggs per gram, while in the natural population this figure was 1,181.71 eggs. The average ejaculate volume in domesticated males was 2.0 mL^3, which was 7.5% higher than that of males from natural water bodies. With an average working fertility of 4.52 million spermatozoa in males from the natural population and 5.79 million spermatozoa in domesticated males, the average duration of active forward movement of spermatozoa in wild males was 96.7 seconds, and 94.9 seconds for domesticated males. The young obtained from natural populations were characterised by higher survival rates of 2.1% for pre-larvae and 3.0% for larvae. However, the young obtained from natural populations were more sensitive to lighting, sounds in the incubation room, and mechanical manipulations, indicating low resistance to stressful situations.
Key Words: eggs, ejaculate volume, genesis, gonadotropic injections, growth rate, mass, sperm, working fertility.

Introduction. European pikeperch (*Sander lucioperca* (Linnaeus, 1758)) is a common species in freshwater and brackish water bodies of western Eurasia (Craig 2000; Collette & Banarescu 1977; Kestemont et al 2015). Due to its numerous biological and economic advantages over other native species, it has been successfully cultivated in aquaculture for over 50 years (Antalfi 1979; Wuertz et al 2012; Steinberg et al 2018). Therefore, it is currently possible to state the existence of wild and domesticated populations of this species (Dahl 1984; Fontaine et al 2015; Kestemont et al 2015; Policar et al 2019).

Genetic diversity in wild and domesticated populations of European pikeperch is at a fairly high level, in both cases. This is primarily achieved by the purposeful avoidance of inbreeding in aquaculture. At the same time, for more than 15 years, a clear division of both types of populations of pikeperch into two groups has been observed - Northern and Central. If the first comes from Baltic countries (primarily Denmark, Finland, Sweden), the second is characterized by a mostly Hungarian-Czech origin. Accordingly, two haplogroups have been identified: type "A" (observed in most European and Asian populations of pikeperch) and type "B", which is much less common (dominant only in the countries of the lower Danube River) (Collette & Banarescu 1977; Craig 2000; Celik et al 2008; Kohlmann et al 2013). Breeding works between them are extremely promising, but require considerable caution, primarily to avoid harming wild populations (Linfield & Rickards 1979; Dalsgaard et al 2013).

The behavior of fish from domesticated and wild populations differs significantly. First of all, this is explained by the expression of more than 740 genes transmitted through the maternal line. Thus, at the cellular level, the adaptation of the individual to certain environmental conditions begins. As a result, domesticated individuals are characterized by a reduced reaction speed to the presence of danger (Kucharczyk et al 2007; Sipos et al 2019; Péter et al 2023).

The protein profile of the gonads of pikeperch from wild and domesticated populations, in agreement with the above, also differs. First of all, these differences concern immune responses and features of the course of metabolic processes. For example, individuals from domesticated populations are less tolerant to sudden and prolonged changes in environmental temperature, a decrease in the qualitative and quantitative parameters of the diet, and the action of pathogens. Another example is that the biochemical and structural parameters of the muscles of fish from wild and domesticated populations differ significantly (Jankowska et al 2003; Tsaparis et al 2022; Tönißen et al 2024).

The effect of domestication on genotype and phenotype is significant and long-lasting, persisting for at least several generations. For example, domesticated individuals, for the most part, are distinguished by clear morphological features. For example, they have smaller skull sizes and larger body sizes, as well as higher growth rates and reproductive performance. The complex of differences inherent in domesticated individuals is combined under the name "domestication syndrome" (Ferreira et al 2023; Falahatkar et al 2025).

The effect of domestication on the functional state of the fish body begins already in the first year of living in aquaculture conditions. For example, the process of gametogenesis and reproductive performance of pikeperch are largely determined by the previous conditions of existence - the method of cultivation, the age of domestication, the diet before and after it, and photothermal parameters (Hilge & Steffens 1996; Khendek et al 2018; Nynca et al 2020).

Thus, from the beginning of domestication, changes begin at the anatomical, physiological, and molecular levels of organization. Accordingly, the use of hormonal stimulating products is more effective in works with domesticated pikeperch individuals (Blecha et al 2016; Żarski et al 2020; Dietrich et al 2021; Polishchuk et al 2023). Therefore, taking into account the current state of development of Ukrainian aquaculture and the need for pike perch planting material, it is appropriate to conduct a comprehensive comparative analysis of the productive and reproductive indicators of sexually mature pike perch individuals, and determine the impact of domestication on these indicators.

Material and Method. The study was carried out in 2019-2022 at PrJSC "Khmelnytskrybgosp". The farm is located in the Khmelnytskyi region of Ukraine and is characterized by a long tradition of freshwater aquaculture, as it was created in the process of reorganization of the Khmelnytskyi State Production Regional Fish Hatchery founded in the 1950s. Since then, it has been one of the leading enterprises in Ukraine in growing fish seeds and table fish, as well as conducting breeding works. All of the listed fields of fish farming require significant areas, which is why currently six production units are successfully operating within PrJSC "Khmelnytskrybgosp". The experiment was conducted within the fish farming areas "Medzhibizh" and "Stara Synyava".

The material for the study were: sexually mature pikeperch of different ages and their gonads obtained during reproduction as a result of artificial stimulation, and juvenile pikeperch obtained as a result of the process of incubation of fertilized eggs. Prelarvae of pikeperch during the transition to exogenous nutrition, with the remains of the yolk sac, were collected from incubation devices and transferred to tanks.

All experiments were carried out in accordance with the requirements of the "European Convention for the Protection of Vertebrate Animals Used for Experimental and Scientific Purposes" (European Convention for… 1986).

Comparative analysis of productive and reproductive indicators was carried out between domesticated spawners and individuals from natural reservoirs caught in the Ikra and Buzhok rivers. The spawners were caught from natural reservoirs in the autumn-winter period and kept in the pond until the onset of spawning temperatures.

In order to avoid traumatization and stress of fish during manipulations, their heads were wrapped with a damp and dark cloth. During hormonal injections, clove oil was used as an anesthetic at the rate of 1 mL per 10 L of water.

The brood pikeperch were weighed and their morphometric parameters were determined according to the method developed by Pravdin (1939) (Figure 1). Based on the results of the measurements, the main body structure indices were calculated - body length to body girth ratio (L/G) and the body length to body height ratio (L/H). Brood pikeperch were fed with live fish, in accordance with generally accepted standards.

Figure 1. Measurements of pikeperch according to Pravdin (1939) (aφ - total length, cm; av - standard length, cm; qμ - large body height, mm).

Injections of drugs to stimulate reproduction were carried out according to the standard method, using a medical syringe, through the dorsal muscle, above the lateral line. Doses were calculated based on the fish weight. Between injections, females were maintained a 12-h time interval. Males were injected during the administration of the second (decisive) dose of the drug to females.

In general, ovulated pikeperch eggs were obtained in traditional terms - at the end of March and the beginning of April. The spawning campaign lasted an average of 14-16 days. Fertilization of pikeperch eggs was performed by the "dry" method. Caviar de-gluing was carried out using powdered milk, at the rate of 50 mg of milk per 1.5 kg of pikeperch eggs, in accordance with the standard method. Egg incubation was carried out in a 8-L Weiss apparatuses. The volume of ejaculate was determined using an "Eppendorf" pipette-dispenser with an accuracy of 0.1 cm^3. Sperm quality was determined using a Zeiss Axiostar plus optical microscope with a 20x/0.40 phase contrast objective, a JVC TK-C1480BE video camera, a Makler counting camera, and the Video Test Sperm 2.1 software from VideoTest LLC.

The condition factor was determined using the Fulton index, which was calculated according to the formula:

$$CF = \frac{m}{l^3} \times 100$$

where: m = fish weight (g);
l = fish standard length (cm).

Differences between the values of the experimental groups were calculated in the Statistica 7.1 program (StatSoft Inc., USA) using the Fisher test, where differences were considered significant at $p < 0.05$. Data are presented as x±SD (mean±standard deviation).

The methods used in the study are generally used and are widely found in domestic and foreign studies. Thus, the results obtained are reliable, which allows them to be used for analysis and comparison.

Results. Morphometric analysis (Tables 1 and 2) showed that domesticated brood fish had a higher growth rate, and accordingly had higher body weights and lengths than their peers from natural water bodies. For example, the average weight of domesticated age-5 females was 2.8±0.31 kg, while females of this age caught from natural water bodies had an

average body weight of 1.58±0.24 kg. In general, domesticated age-4 and older females had a body weight of 2.5-2.8 kg, while females from natural water bodies reached this weight only at 7-8 years of age (Table 1).

Table 1

Morphometric parameters of female pikeperch of different genesis

Age category (years)	*Weight (kg)*	*Standard body length (cm)*	*Total body length (cm)*	*Head length (cm)*	*Small body height (cm)*
		Wild population			
5 (n = 3)	1.58±0.24	42.3±4.35	45.5±5.14	11.6±0.48	9.7±0.36
7 (n = 2)	2.3±0.25	45.3±4.53	49.6±4.41	13.3±0.53	11.0±0.48
8 (n = 2)	2.7±0.28	49.5±4.97	53.5±4.18	14.9±0.64	11.4±0.57
10-12 (n = 2)	3.35±0.37	54.0±5.13	59.0±3.27	15.0±0.71	15.0±0.69
		Domesticated population			
3 (n = 2)	1.7±0.26	43.9±4.59	47.2±3.36	12.8±0.41	10.9±0.35
4 (n = 3)	2.5±0.27	45.7±4.57	49.8±4.54	13.1±0.38	11.3±0.3
5 (n = 2)	2.8±0.31	48.9±4.86	54.1±4.79	14.8±0.32	11.1±0.27
8-10 (n = 3)	3.6±0.37	56.0±5.36	60.1±5.35	17.0±0 .28	18±0.25

Similar dynamics of weight accumulation were recorded among males. Domesticated age-3-4 males had a body weight of 1.7 to 1.8 kg, while males from natural water bodies did not reach this value even at age-5 (Table 2).

Table 2

Morphometric parameters of male pikeperch of different genesis

Parameters	*Wild population*		*Domesticated population*		
Fish age (years)	4 (n = 4)	5 (n = 2)	2 (n = 2)	3 (n = 3)	4 (n = 2)
Weight (kg)	1.34±0.14	1.6±0.21	1.41±0.18	1.7±0.16	1.83±0.41
Body length (cm)	38.6±0.56	42.0±0.71	39.2±1.52	42.5±1.73	44.7±0.83
Head length (cm)	11.23±0.64	12.1±0.17	11.4±1.62	12.7±0.78	13.1±0.19
Large body height (cm)	9.6±0.25	9.55±0.36	9.9±0.24	9.58±0.28	9.84±0.14
Small body height (cm)	3.5±0.14	3.7±0.15	3.6±0.05	3. 9±0.10	4.2±0.17
Big body girth (cm)	22.5±0.14	23.2±0.49	21.9±0.41	22.9±0.47	24.7±0.54
Small body girth (cm)	8.75±0.13	9.6±0.20	8.5±0.12	9.4±0.16	10.1±0.24

It is worth noting that after gonadotropic injections, the "wild" form of broodfish needed significantly more time to mature than the domesticated males. The average maturation time of domesticated females was on average 27-32 hours, and that in natural ones was 37-43 hours, respectively. However, this problem was not observed in males and the average time in both groups was 27-33 hours.

Analysis of reproductive parameters showed that domesticated females outperformed females of the natural population by 5.7% in terms of egg production, and 13.5% in working fertility. At the same time, domesticated females produced slightly larger eggs, respectively, the number of eggs per 1 g was on average 1165.97±40.63, while that in the natural population was 1181.71±65.63 eggs (Table 3).

The obtained data indicate that working fecundity depends on female body weight. Females with a higher individual body weight produced more eggs, and accordingly their working fecundity was higher. The correlation coefficient between body weight and working fecundity in females of the wild population, which had lower values compared to those of domesticated females, was 0.7382, while that of domesticated females was 0.8579 (Figures 1 and 2).

Table 3

Characteristics of reproductive parameters of female pikeperch

Age category (years)	*Weight of produced eggs (g)*	*Number of eggs in 1 g*	*Working fecundity (thousand eggs)*	*Obtained eggs in % of body weight*
		Wild population		
5 (n = 3)	181.3±7.50	1098.0±130.4	192.9±8.31	6.94±0.19
7 (n = 2)	204.1±13.4	1112.05±175.2	199.5±7.42	7.01±0.18
8 (n = 2)	238.8±15.6	1217.1±193.5	204.8±8.66	7.34±0.22
10-12 (n = 2)	261.8±22.2	1309.0±201.1	209.4±8.99	7.42±0.27
Average	217.23±12.34^{a}	1181.71±65.63^{a}	200.93±3.53^{ab}	7.16±0.10^{ab}
		Domesticated population		
3 (n = 2)	187.90±12.2	1098.1±111.02	209.8±14.77	6.82± 0.13
4 (n = 3)	208.5±14.63	1140.0±112.74	222.4±16.46	7.42±0.15
5 (n = 2)	226.5±17.85	1192.0±123.22	225.3±16.55	7.87±0.14
8-10 (n = 3)	277.3±25.85	1218.6±153.32	263.2±23.91	8.21±0.38
Average	229.81±12.92^{b}	1165.97±40.63^{b}	232.22±8.66^{ab}	7.64±0.19^{ab}

Note: Differences between experimental groups according to Fisher's exact test results are indicated by different letters and were considered statistically significant at $p < 0.05$.

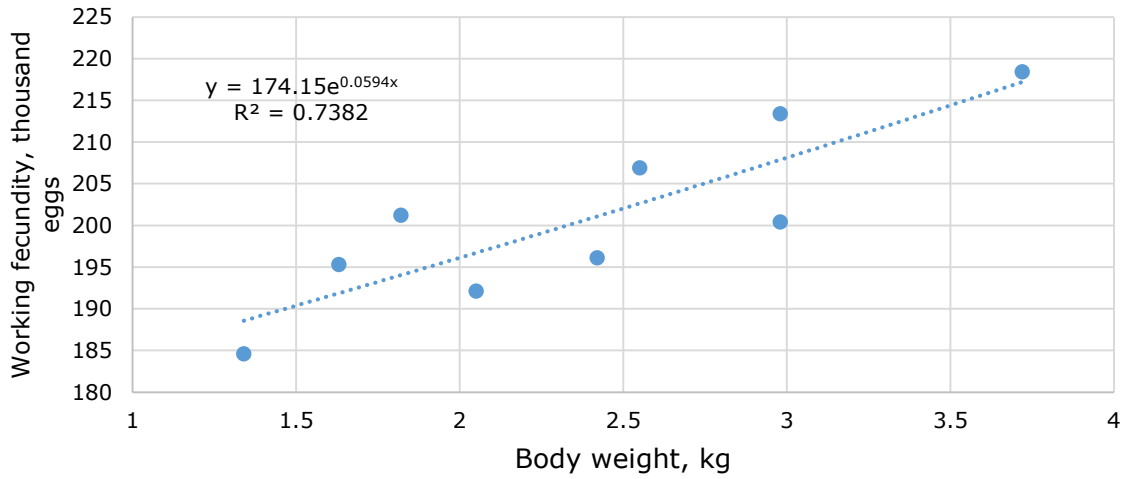

Figure 1. Relationship between working fecundity and body weight in wild female pikeperch.

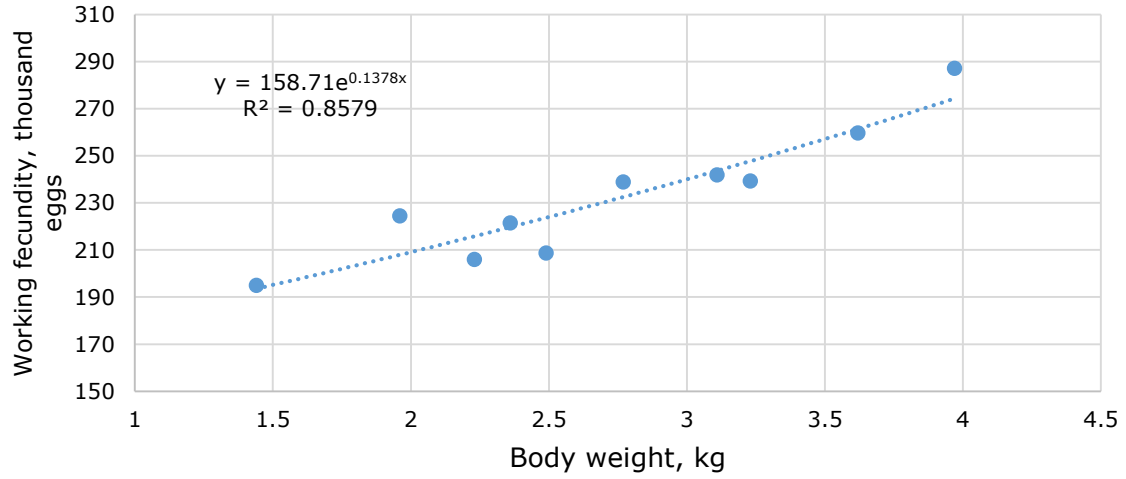

Figure 2. Relationship between working fecundity and body weight in domesticated female pikeperch.

A similar relationship was observed between body weight and the number of eggs produced relative to body weight. This parameter in domesticated females was 0.9504 and exceeded that in females from a natural water body by 20.8% (Figures 3 and 4).

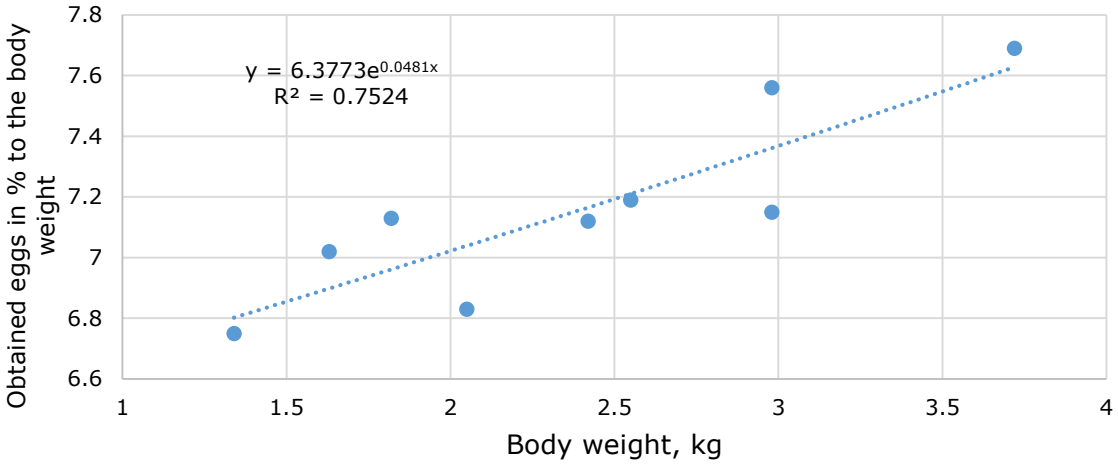

Figure 3. Relationship between egg production and body weight of wild female pikeperch.

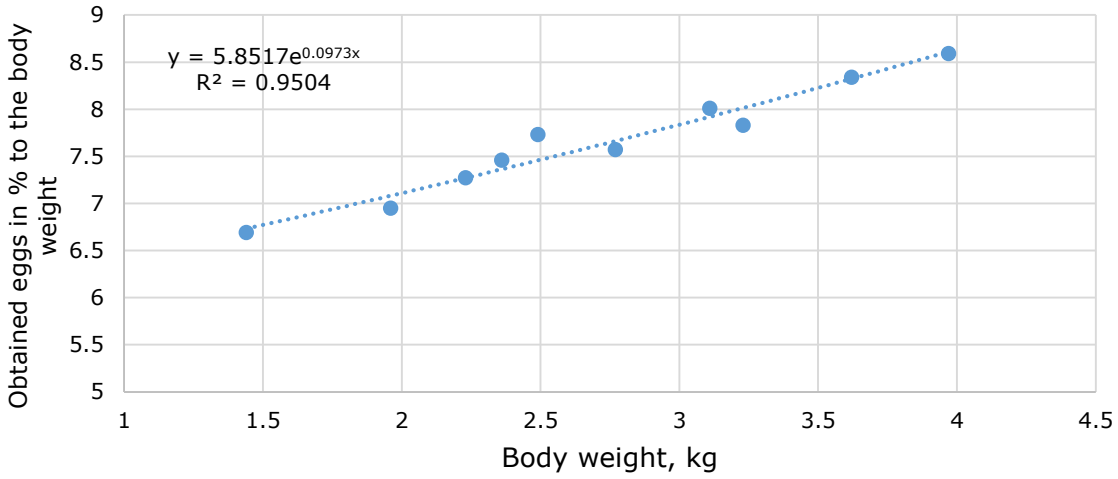

Figure 4. Relationship between egg production and body weight of domesticated female pikeperch.

In males, reproductive parameters had corresponding differences. For example, the average ejaculate volume in domesticated fertile males was 2.0 mL^3, and was higher, respectively, than in wild males by 7.5%. However, in terms of the duration of active translational motion of sperm, males from the natural populations showed better performance. The average value of this parameter was 96.7 s, while that in domesticated fertile males was 94.9 s. With an average working fecundity of 4.52 million spermatozoa in males of the natural population, the number of live spermatozoa on average was 89.9%, while domesticated males were superior, and these values were 5.79 million spermatozoa and 93.5%, respectively (Table 4).

Unlike the values of females, no direct proportional relationship was found between the maximum body weight and the maximum ejaculate volume. For example, domesticated males, despite the higher body weight and ejaculate volume, had a lower correlation than that observed in wild males 14.15% (Figures 5 and 6).

Similar dynamics were observed for parameters characterizing the relationship between body weight and working fecundity of males. Thus, males caught from natural water bodies had higher correlation coefficient by 19.7% (Figures 7 and 8).

The use of broodstock from two populations in the spawning campaign shows that despite lower reproductive parameters such as ejaculate volume and working fecundity of

male pikeperch, broodstock caught from a natural water bodies had higher fertilization rate by 0.7%, prelarvae hatching from fertilized eggs by 2.1%, and larval survival from prelarvae by 3.0% (Figure 9). From which we can conclude that it is appropriate to continue using wild broodstock to obtain offspring of pikeperch with its subsequent use for aquaculture purposes in the absence or small number of individuals of domesticated stocks.

Table 4

Analysis of reproductive parameters of male pikeperch of different genesis

Age category (years)	*Ejaculate volume (mL^3)*	*Duration of active translational motion of spermatozoa (s)*	*Working fecundity (million spermatozoa)*	*Number of alive spermatozoa, of total number (%)*
		Wild population		
4 (n = 4)	1.81±0.14	90.05±3.04	4.88±0.35	88.25±2.34
5 (n = 2)	2.08±0.16	103.25±3.6	5.95±0.37	91.42±2.53
		Domesticated population		
2 (n = 2)	1.68±0.23	89.15±3.70	5.32±0.28	89.63±1.22
3 (n = 3)	2.1±0.27	101.69±4.55	5.97±0.36	98.66±1.98
4 (n = 2)	2.23±0.3	93.7±4.85	6.07±0.38	92.15±2.04

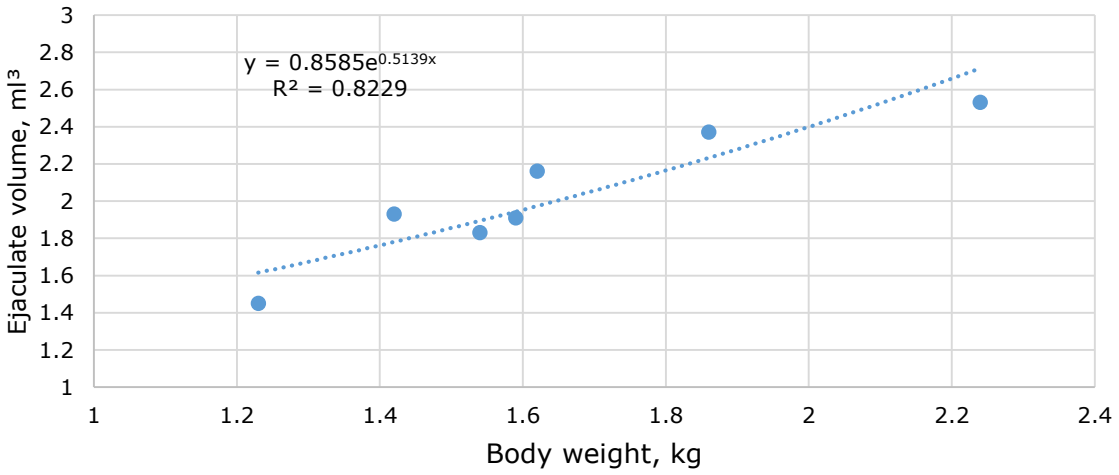

Figure 5. Relationship between body weight and ejaculate volume of domesticated males.

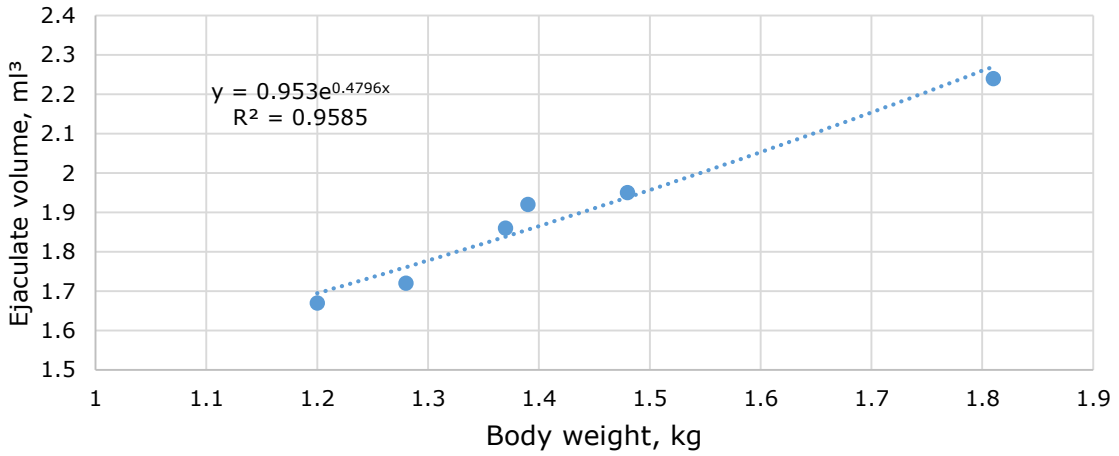

Figure 6. Relationship between body weight and ejaculate volume of wild males.

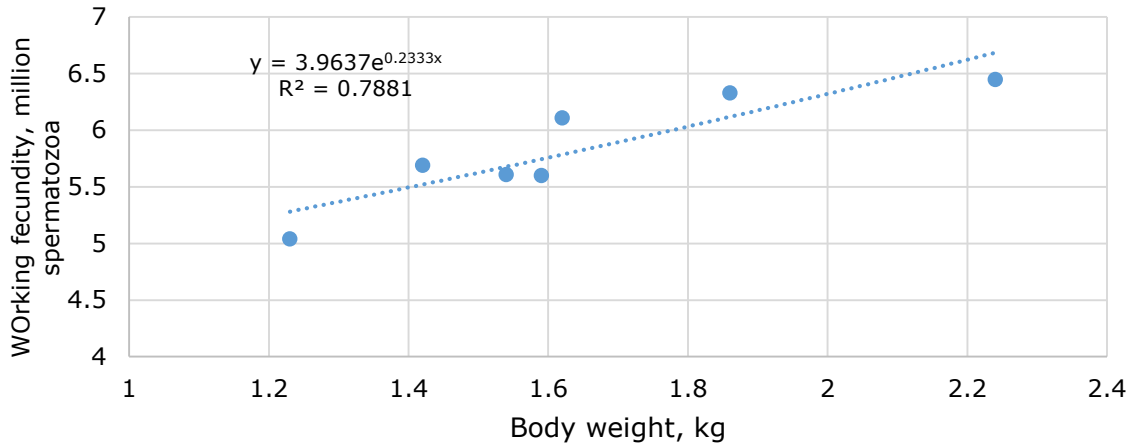

Figure 7. Relationship between body weight and working fecundity of domesticated males.

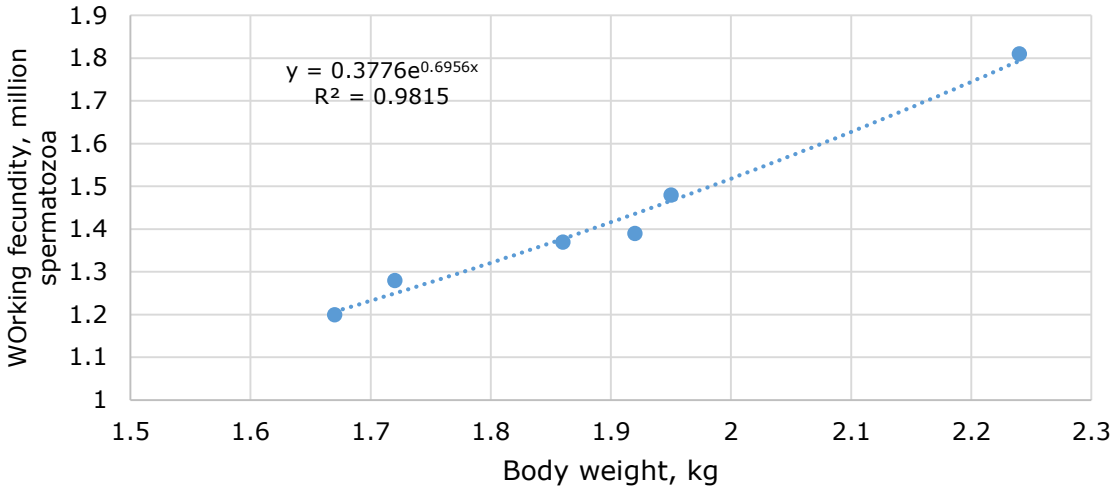

Figure 8. Relationship between body weight and working fecundity of wild males.

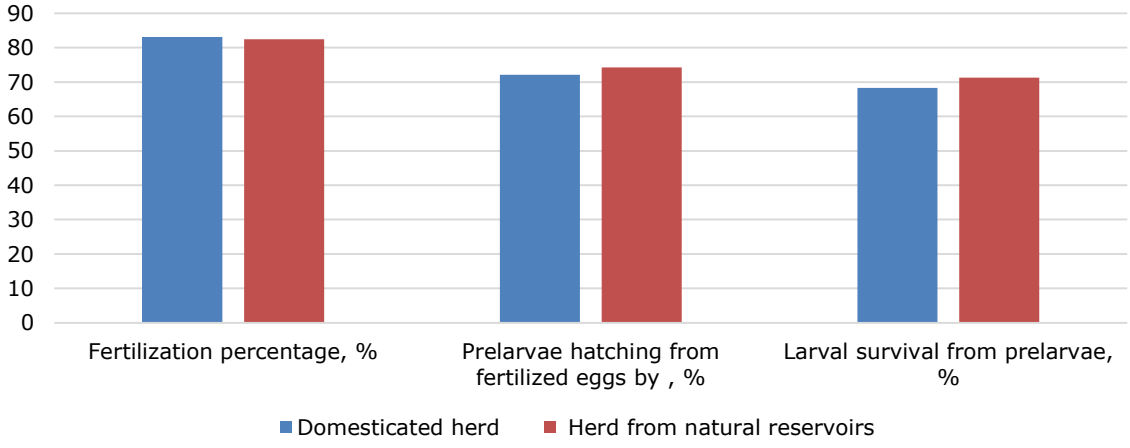

Figure 9. Results of incubation of fertilized pikeperch eggs from different populations.

Discussion. Pikeperch in aquaculture of a number of European countries is a valuable object (Fontaine et al 2008; Diversify 2018; FAOStat 2025). However, scientific studies do not allow the development of a full-fledged technology that would fully ensure reproduction with subsequent cultivation of marketable products. Studies conducted within the framework of the Diversify project (Diversify 2018) has established that at least three populations have been formed in Europe (Fontaine et al 2015; Fontaine 2018).

However, one of the problems in artificial reproduction of pikeperch is the sensitivity of spawners to manipulations. Sexually mature individuals during the spawning period have an increased response to various stimuli, including vibration (Gal et al 2005; Bodis et al 2008; Sarameh et al 2012; Hermelink et al 2013; Ammar et al 2015). Therefore, one of the directions of domestication is the adaptation of broodstock to artificial conditions. In the course of our study, qualitative differences were found between broodstock of wild pikeperch and those grown in aquaculture conditions. In particular, broodstock from the natural populations of pikeperch had significant lags in the age to weight ratio, which is due to more difficult habitat conditions. The morphometric analysis performed indirectly confirmed the importance of the availability of food of appropriate quality and quantity, since all main parameters (body and head lengths, their heights and girths) were characterized by higher values in domesticated pikeperch. This trend was observed in all studied age groups and did not depend on fish sex.

Analyzing the data on reproductive parameters of females from natural (wild) and domesticated stocks, it can be stated that working fecundity and all related parameters (weight of produced eggs, number of eggs in 1 g, proportion of obtained eggs to body weight) were higher in domesticated individuals. At the same time, in individuals from both stocks these parameters did not significantly differ from each other and their dynamics developed according to identical principles. In particular, the oldest females stand out among other age groups with the highest values of the studied parameters both among the natural (wild) herd and among domesticated fish.

The reaction to hormonal stimulants differed in pikeperch individuals by sex and origin. Domesticated individuals were distinguished by the latter, by greater sensitivity, and therefore by a shorter time of positive reaction to injection. Similar values were observed in females. In general, it can be concluded that hormonal stimulants act most effectively on domesticated female pikeperch, while their effect on males from natural (wild) and domesticated spawning stocks was almost identical.

According to the analysis of reproductive parameters of males from natural (wild) and domesticated spawning stocks, it is possible to state significant differences between both groups. For example, the ejaculate volume was lower than that of males from natural (wild) stocks compared to domesticated ones. At the same time, in males from natural (wild) stocks, the duration of active translational motion of spermatozoa was longer than that of domesticated individuals. The translational motion and the share of live spermatozoa from their total number did not differ significantly between both groups. Accordingly, there is a need for further studies to clarify the prospects for using domesticated males and wild males from natural water bodies.

In general, it is already possible to conclude about the feasibility of further practice of using broodstock from general water bodies to obtain pikeperch offspring with its further use for aquaculture.

Conclusions. The analysis of morphometric parameters of the broodfish of the two stocks shows that the domesticated form had a superiority in these parameters. The reproductive parameters of females of wild and domesticated broodfish were at a high level, however, females from natural water bodies of the same age category were inferior to the brooofish of the domesticated stock in all reproductive parameters. According to the general average value, domesticated females exceeded females of the natural population by 5.7% in terms of the produced eggs, and 13.5% in working fecundity. At the same time, domesticated females produced slightly larger eggs, respectively, the number of eggs in 1 g on average was 1165.97 eggs, while that in the wild population was 1181.71 eggs.

The average ejaculate volume in domesticated males was 2.0 mL^3, and was 7.5% higher than that of males from natural water bodies. With an average working fecundity of 4.52 million spermatozoa in males of the wild population and 5.79 million spermatozoa in domesticated males, the average duration of active translational motion of spermatozoa in wild males was 96.7 s, and that in domesticated males was 94.9 s.

However, it should be understood that these discrepancies require further studies, since the stress factor and "handling" have a significant effect on the result.

However, the juveniles obtained from broodstock of wild populations were characterized by higher survival rates of prelarvae by 2.1% and larvae by 3.0%. However, the juveniles obtained from broodstock of wild populations reacted more sensitively to lighting, sounds of the incubation workshop, and mechanical manipulations, which indicates low resistance to stressful situations.

Conflict of interest. The authors declare that there is no conflict of interest.

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Authors:
Oleksii Mykovaiovych Polishchuk, Department of Aquaculture, National University of Life and Environmental Sciences of Ukraine, Heroiv Oborony Street, No. 15, Kyiv, 03041, Ukraine, e-mail: alik93poliwyk@gmail.com
Hanna Anatoliivna Kurinenko, Institute of Fisheries of the National Academy of Agrarian Sciences of Ukraine, Obukhivska Street, No. 135, 03164, Kyiv-164, Ukraine, e-mail: annazakharenko@ukr.net
Maria Yurievna Simon, Institute of Fisheries of the National Academy of Agrarian Sciences of Ukraine, Obukhivska Street, No. 135, 03164, Kyiv-164, Ukraine, e-mail: seemann.sm@gmail.com
Ihor Ivanovych Hrytsyniak, Institute of Fisheries of the National Academy of Agrarian Sciences of Ukraine, Obukhivska Street, No. 135, 03164, Kyiv-164, Ukraine, e-mail: hrytsyniak@ukr.net
Nataliia Yaroslavivna Rudyk-Leuska, Department of Aquaculture, National University of Life and Environmental Sciences of Ukraine, Heroiv Oborony Street, No. 15, Kyiv, 03041, Ukraine, e-mail: rudyk-leuska@ukr.net
Natalia Olexandrivna Borisenko, Institute of Fisheries of the National Academy of Agrarian Sciences of Ukraine, Obukhivska Street, No. 135, 03164, Kyiv-164, Ukraine, e-mail: b_natalia@i.ua
Mykhailo Viktorovych Leuskyi, Department of Aquaculture, National University of Life and Environmental Sciences of Ukraine, Heroiv Oborony Street, No. 15, Kyiv, 03041, Ukraine, e-mail: e-mail: leuskyi@nubip.edu.ua

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