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Experience in reproduction and cultivation of pike (*Esox lucius*) stocking material in industrial environments of fish farms of Kazakhstan

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Abstract. Importance of the industrial aquaculture development in Kazakhstan is evident nowadays due to a sharp decline in the commercial fish stocks. Pike is of special interest, as it is considered a target of aquaculture cultivation in the Republic of Kazakhstan. Pike is reproduced and cultivated in industrial environments of fish farms of Kazakhstan for the first time. According to the conducted researches, a scheme of technological processes for reproduction and cultivation of the pike has been developed in the industrial environments of Bukhtarma Spawning and Breeding Farm, LLP. The scheme included catching pike producers, adaptation in hatchery tanks, valuation of quality of pike breeders and separation by gender, stimulation of spawning pikes by pituitary injections; getting sexual products through the industrial method; degumming of eggs in the Weiss incubators using starch emulsion, incubation of pike eggs in the incubators of Amur type. Pike juveniles have been reared in the fish-breeding tanks (basins and Amur incubators). In 20 days of rearing pike juveniles reached the average weight of 120 mg. Growing the pike stocking material was performed in tanks (recirculation aquaculture systems). In 90 days yearlings reached the average weight of 19.5 g due to the artificial feed. The conducted researches describe the fundamental possibility to reproduce and cultivate pike stocking material artificially in the industrial environments of the fish farms of Kazakhstan. Theoretical and practical grounds were given to fish farmers to apply biotechnical methods to reproduce and cultivate the pike. The research results obtained will be used as the ground to make recommendations for artificial reproduction and cultivation of the pike stocking material in the current natural, climatic and economic conditions of Kazakhstan.

Keywords: pike, producers, spawning, incubation, eggs, larvae, juveniles, yearlings, Amur incubators, tanks

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Научная статья

Опыт воспроизводства и выращивания рыбопосадочного материала щуки (*Esox lucius*) в индустриальных условиях рыбоводного хозяйства Казахстана

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Аннотация. Актуальность развития индустриальной аквакультуры в Казахстане в настоящее время на фоне резкого снижения промысловых запасов рыб бесспорна. Особый интерес как объект аквакультурного выращивания в Республике Казахстан представляет щука. Работы по воспроизводству и выращиванию щуки в индустриальных условиях рыбоводного хозяйства в Казахстане проводятся впервые. По результатам проведенных исследований была разработана схема технологических процессов воспроизводства и выращивания рыбопосадочного материала щуки в индустриальных условиях ТОО «Бухтарминское НВХ». Схема технологических процессов включала отлов производителей щуки, адаптационные мероприятия в бассейнах инкубационного цеха, бонитировку производителей щуки и разделение их по полу, проведение стимуляции нереста щуки с помощью гипофизарных инъекций; получение половых продуктов заводским методом, обесклеивание икры в аппаратах Вейса с использованием эмульсии крахмала, инкубацию икры щуки в инкубационных аппаратах

«Амур». Подращивание молоди щуки проходило в рыбоводных емкостях (бассейнах и аппаратах «Амур»). За 20 суток подращивания молодь щуки достигла средней массы 120 мг. Выращивание рыбопосадочного материала щуки осуществлялось в бассейнах (в установках замкнутого водоснабжения). За 90 суток сеголетки при кормлении искусственными кормами достигли средней массы 19,5 г. В результате проведенных исследований показана принципиальная возможность искусственного воспроизводства и выращивания рыбопосадочного материала щуки в индустриальных условиях рыбоводных хозяйств Казахстана. Заложены теоретические и практические основы применения биотехнических приемов воспроизводства и выращивания щуки для рыбоводов-фермеров. Данные, полученные в результате исследований, послужат основой для разработки рекомендаций по искусственному воспроизводству и выращиванию рыбопосадочного материала щуки применительно к современным природно-климатическим и экономическим условиям Казахстана.

Ключевые слова: щука, производители, нерест, инкубация, икра, личинки, молодь, сеголетки, аппараты «Амур», бассейны

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Introduction

Development of aquaculture in Kazakhstan is the most popular trend in terms of providing food safety, removing anthropogenic load from natural water bodies as a result of their excessive exploitation, restoring fish stocks and ensuring the conservation of fish biological diversity.

Pike is the most valuable species of fish farming. Due to tastiness, high protein content and relatively low-fat content (0.5%), pike meat is considered as a dietary product. This is one of the reasons why pike is bred widely in the number of countries (France, Czech Republic, Germany, USA). Resistance of pike to oxygen deficiency, high water temperature (up to 30 °C) and relatively low pH values (up to 4.3) allows it to be successfully bred in different conditions [1].

Value of pike as a fish farming target is that being a biological ameliorator it increases fish productivity of ponds for 60–120 kg/ha for carp, and it removes competitors in nutrition for crucian carp and other reared species. Resulting gain is often rather higher than the gain of pike itself [2, 3].

One of the promising directions of aquaculture is to cultivate valuable species in recirculating aquaculture systems. Chance to regulate living conditions in the RAS provides year-round fish farming regardless of climatic conditions [4, 5].

Successful development of industrial technologies of fish farming in terms of water scarcity in Kazakhstan opens wide opportunities to cultivate valuable species promising for domestic fish farming such as pike, the breeding of which in natural reservoirs is limited by temperature regime [6–8].

Countries of near abroad have developed technologies in order to cultivate pike in ponds and industrial environments of fish farms [9–13].

For the first time in 2021, within the framework of the project Development and Implementation of Industrial Technologies to Cultivate Promising Finfish and Invertebrate Aquatic Organisms at Fish Farms, the effective biotechnical methods have been developed for reproduction and cultivation of pike stocking material (*Esox lucius*) at fish farms in Kazakhstan.

The research goal was to estimate possibilities of artificial reproduction and cultivation of pike stocking material in the industrial environments of the Bukhtarma Spawning and Breeding Farm, LLP.

Materials and methods of research

Pike stocking material was artificially reproduced and cultivated at the Bukhtarma Spawning and Breeding Farm, LLP (the East Kazakhstan Region, III fish-breeding zone). In order to conduct the researches, we involved the entire capacity of a hatchery of the fish farm.

Targets of the research were the breeders, eggs, larvae, juvenile, and yearlings of pike.

To assess the influence of abiotic environmental factors on reproduction and cultivation of pike, we monitor dynamics of temperature and oxygen regimes. Water temperature and oxygen content in the water were measured by MARK-302E analyzer. The content of nutrients and pH index (pH) of water was determined by “Sera” rapid tests (Germany). The water quality was estimated under generally accepted methods in hydrochemistry [14, 15].

Fish-breeding and biological indicators of pike were determined according to the methods adopted in fish farming [16]. The growth rate of pike juveniles and yearlings was studied and estimated according to the results of final catching.

In reproduction and cultivation of pike stocking material in industrial environments of the BukhtarmaSpawning and Breeding Farm LLP, we used foreign regulatory and technological literature [17–21].

Daily food ration of pike was calculated under the results of control caught and based on the international experience [22–25].

We use RAS (Recirculating aquaculture system) in order to reproduce pike at the Bukhtarma Spawning and Breeding Farm, LLP. Main RAS elements are the

following: the Weiss incubators assembled in two racks of 10 pieces from each side; 5 pieces of Amur incubators on each side; water collector tanks (barrel); pumps supplying water to the incubators; heating elements. The hatchery has 12 pieces of 2m^3 tanks.

Pike juveniles was reared at the Bukhtarma Spawning and Breeding Farm, LLP in tanks and incubators Amur located in the hatchery within 20 days in two replications. We use volumetric counting method for stocking fish tanks with pike larvae.

Pike yearlings were cultivated from the reared juveniles adapted to artificial feed in tanks (RAS) in 3 stages, 30 days each stage.

Determination of the rating place of the obtained results was performed by expert evaluation method.

Student's t-test was conducted according to the following formula:

$$t = \frac{M_1 - M_2}{\sqrt{m_1^2 + m_2^2}},$$

where M_1 – an arithmetic mean of the final mass of larvae of the first compared group (incubator Amur); M_2 – an arithmetic mean of the final mass of larvae of the second compared group (tanks); m_1 – an average error of the first arithmetic mean; m_2 – an average error of the second arithmetic mean.

Statistical processing and analysis of the information material was carried out according to widely accepted methods and with the help of Microsoft Excel 8.0 computer program [26].

Research results

Estimation of the water quality used for fish farming at the Bukhtarma Spawning and Breeding Farm, LLP. Water source of the Bukhtarma Spawning and Breeding Farm, LLP is the Kurchum River. The river water enters the sediment pond through the canal and pumped to the hatchery. Main hydrochemical indicators of the sediment pond water are presented in Table 1.

Table 1

Main hydrochemical indicators of the sediment pond water

Ph	O_2		Biogenic compounds, mg/dm^3				Organic substance, mgO/dm^3	Mineralization, mg/dm^3
	mg/dm^3	Saturation, %	NH_4	NO_2	NO_3	PO_4		
7.1	8.1	90.2	0.14	0.010	0.007	0.014	2.9	81.3

According to classification of water by pH index, the sediment pond water is neutral with a good degree of oxygen saturation (90.2%). According to the value of mineralization, the water is fresh (content of dry residue is 81.3 mg/dm^3). According to the values of total mineralization, the water is low-mineralized and belongs to bicarbonate-calcium class. According to the research results, the concentration of all nutrients was within the established standards.

Results of hydrochemical analysis for determining concentrations of the main ions are presented in Table 2.

Table 2

Content of main ions in sediment pond water

Sampling place	Bicarbonates, mg/dm^3	Chlorides, mg/dm^3	Sulphates, mg/dm^3	Calcium, mg/dm^3	Magnesium, mg/dm^3	Potassium, sodium, mg/dm^3
Sediment pond	48.8	3.05	51.1	34	8.5	13.8
Rates for ponds of III fish breeding zone						
Values	25–40	10–30	60–120	40–60	up to 30	up to 120

The table shows that the content of hydrocarbons slightly exceeds the technological standard although it does not exceed the values of Fishery maximum allowable concentration. Chloride content in the pond is below the fish farming standards. Values of concentration of sulfates, calcium and magnesium in the pond water are also lower than the technological fish farming standards. Thus, according to the results of hydrochemical studies, the pond water in the BukhtarmaSpawning and Breeding Farm, LLP is suitable for fish farming.

Reproduction of pike in industrial environments of the Bukhtarma Spawning and Breeding Farm, LLP. Incubation RAS was created in order to stabilize thermal, oxygen and hydrochemical regimes during pike spawning campaign.

Presence of the RAS allows conducting pike spawning campaign in optimal time.

Artificial reproduction of pike was conducted in the controlled conditions of the hatchery of the Bukhtarma Spawning and Breeding Farm LLP. Pike spawning campaign at the Bukhtarma Spawning and Breeding Farm, LLP began on April 14. Pike is a single spawner. For the purpose of reproduction, 10 female and 5 male pike breeders were caught from the farm ponds. Pike males are always smaller in size than females [27].

During the valuation of quality of breeders, we visually determined maturity stage of the females. To stimu-

late delivery of sexual products (in case of no free delivery of eggs), we placed females with expanded and soft belly in the tanks. Males and females were kept for 3 hours at a temperature of 8-10 °C. At the same time, temperature and oxygen content were under control.

To stimulate maturation, pike breeders were injected with a pike pituitary lobe at the rate per 1 kg weight - 3-4 mg for females and 1.5-2 mg for males. Sexual products were selected by intravital method.

During 2021 spawning campaign at the Buktarma Spawning and Breeding Farm, LLP, pike females weighing from 1.2 kg to 2.4 kg and males weighing from 1.1 kg to 1.5 kg were selected. For reproductive purposes, the eggs were taken from ten females with fertility level up to 20 thous.pcs, and the sperm was taken from 5 males.

After decantation of sexual products (eggs and sperm), the eggs were inseminated. The insemination was carried out by a dry method. The sperm was added to the eggs simultaneously from two males for heterosperm insemination [6].

Fish eggs and milt were thoroughly mixed with feathers for even sperm distribution. Pike eggs were inseminated in tanks adding physiological solution to the water. And then, the same quantity of water was gently added to cover eggs. Valuation of quality of pike eggs was carried out using starch emulsion in a ratio of 1 : 20. At the first stage, fertilized eggs were laid in the Weiss incubator at the rate of no more than 200 thous.pcs per incubator. To combat saprolegnia, the eggs were periodically treated with a malachite green solution. For prophylactic purposes, we use a solution concentrated at the rate of 1:100,000 [28].

After obtaining sexual products, pike breeders were placed in tanks for recovery. Then, the processed pike breeders have been released to the pond.

For incubation, the eggs were placed in Amur incubators where the larvae were hatched. Incubation of pike eggs lasted up to 14 days at the Bukhtarma Spawning and Breeding Farm, LLP. Development of the eggs lasted up to 14 days at average temperature of the water 10 °C, and at the temperature 17 °C, it lasted up to 8 days.

Length of the hatched pike larva averaged 7 mm. After 6 days being kept at a temperature of 14 °C, transition of the larvae to external nutrition began. Active nutrition of the larvae was noted on the 7th day after hatching with yolk presence which dissolves on the 10th day. Influence of the temperature regime was noted during pike larvae development, drops in the water temperature in Amur incubators are not permissible.

During the incubation period of pike eggs, temperature and oxygen content in the water, as well as water exchange in the incubators were regularly monitored. At the same time, the values of oxygen content in the water did not fall below 6 mg O/l, and the water exchange in Amur incubator constituted 9 l/min.

Rearing of pike larvae in the industrial environments of the Bukhtarma Spawning and Breeding Farm, LLP. Rearing pike larvae is an intensification measure. Rearing is a necessary step as it increases efficiency of further cultivation of pike yearlings. Survival rate of pike yearlings comparing with the reared juveniles increases to 60% within 20 days. Optimum temperature pike juveniles rearing was 18-20 °C.

To conduct an experiment, one-sized pike larvae were selected. Stocking density was identical and amounted to 20 thous.pcs/m^3. In the period of rearing of pike larvae, the daphnia was used as a feeder food at the experiment start, and then, the Artemia salina cultivated on the fish farm was used for feeding. The mass of feeder food in “Amur” apparatus and in the tank was maintained at maximum level. Starting from the 3rd day of rearing, we began gradually introduce an artificial starter trout feed of Aller Aqua Company to the ration of pike larvae. During the cultivation, the frequency of feeding was up to 10 times a day. The complex work devoted for fish breeding was to maintain intensive water exchange, provide regular feeding, systematic cleaning from excrement and dead fish, and monitor the growth rate of juveniles.

Results of rearing of pike juveniles in the Amur incubators and tanks are presented in Table 3.

Table 3

Pike juveniles rearing results

Indicators	Values	
	“Amur” incubator	tank
Duration of cultivation, day	20	20
Stocking density, thous. pcs/m^3	20,0	20,0
Initial mass of larva, mg	11,5 ± 0,04	11,5 ± 0,04
Final mass of juveniles, mg	121,5 ± 1,3	115,5 ± 1,8
Survival rate, %	56	52
Survival rate, pcs.	10 600	10 400
Absolute gain, mg	110	104
Average daily gain, mg	5,5	5,2
Feed coefficient for combined feed, pcs	0,9	0,96

According to the experiment results, for 20 days of rearing, the best values of fish-breeding indicators of pike juveniles were noted in Amur incubator (#1 rating place). Here, the values of absolute and average daily gain were higher than the values of the tanks for 6 mg and 0.3 mg, correspondingly. The survival rate was

higher by 4% in this case. During the rearing period, pike juveniles adapted well to artificial combined feed.

Distinctions of values of final weight of pike juveniles in the compared groups during rearing in the Amur apparatus and in the pool were reliable at significance level of $p \leq 0.01$.

According to the results of conducted calculations, it was concluded that there are statistically valuable differences in the final mass of pike juveniles in the compared groups (reared in Amur incubator and tank).

Cultivation of pike yearlings in tanks. Hydrochemical indicators of the water in tanks were within optimal limits. The water temperature during this period was 19-22 °C. Oxygen content in the water did not fall below 6.2 mg/l. Calculation of the daily food ration of pike was carried out according to the results of control catches. Initial stocking density was 5 000 pcs./m^3. "Aller Aqua" Artificial trout food was used to feed the yearlings. Frequency of feeding during the period of pike rearing was 6 times a day. Before each feeding, the tank bottoms were cleaned of excrement and feed residues.

Table 4 contains results of rearing of pike yearlings at stage I in the tanks (RAS) of the Bukhtarma Spawning and Breeding Farm, LLP.

Table 4

Results of rearing of pike juveniles in tanks at stage I

Indicators	Values
Period of cultivation, day	30
Larvae stocking density, pcs./m^3	5 000
Survival rate, %	32
Survival rate, pcs.	1 600
Starting mass, g	0,12 ± 0,06
Final mass, g	5,28 ± 0,13
Absolute gain, g	5,16
Average daily gain, g	0,17
Feed coefficient, units	1,3

According to the data above, the mass of pike juveniles changed from 0.12 g to 5.28 g at I stage of cultivation in tanks which lasted 30 days. At the same time, the absolute and average daily gain was 5.16 g and 0.17 g, respectively, and the survival rate was 32%.

Table 5 consists results of rearing of pike yearlings in tanks at stage II at the Bukhtarma Spawning and Breeding Farm.

Table 5

Results of rearing of pike yearlings in tanks at stage II

Indicators	Values
Period of cultivation, day	30
Larvae stocking density, pcs./m^3	1 600
Survival rate, %	59
Survival rate, pcs.	944
Starting mass, g	5,28 ± 0,13
Final mass, g	11,43 ± 0,25
Absolute gain, g	6,15
Average daily gain, g	0,2
Feed coefficient, units	1,4

As a result, the mass of pike yearlings varied from 5.28 g to 11.43 g during 30 days of Stage II of the cultivation period in tanks while the absolute and average daily increase was 6.15 g and 0.2 g, respectively, and the survival rate was 59%.

Table 6 specifies results of rearing of pike yearlings in tanks at stage III at the Bukhtarma Spawning and Breeding, LLP.

Table 6

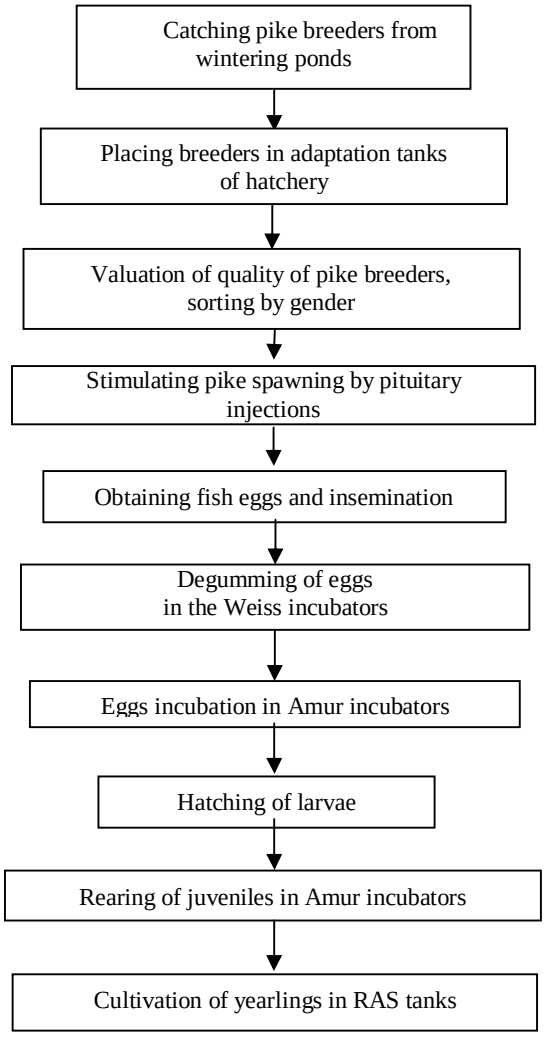
Results of rearing of pike yearlings in tanks at stage III

Indicators	Values
Period of cultivation, day	30
Larvae stocking density, pcs./m^3	944
Survival rate, %	67
Survival rate, pcs.	597
Starting mass, g	11,43 ± 0,25
Final mass, g	19,53 ± 0,34
Absolute gain, g	8,1
Average daily gain, g	0,27
Feed coefficient, pcs.	1,5

The mass of pike yearlings changed from 11.43 g to 19.53 g during 30 days of Stage III of the cultivation period in tanks while the absolute and average daily gain was 8.1 g and 0.27 g, respectively, and the survival rate constituted 67%.

As a result of the research conducted, it was found out that for 90 days of cultivation of pike yearlings in the tanks at the Bukhtarma Spawning and Breeding Farm, LLP, a high-quality stocking material with an average weight of 19.5 g was obtained from the reared pike juveniles weighing 120 mg.

Based on the researches, the below scheme of technological processes was developed to reproduce and cultivate pike stocking material at the Bukhtarma Spawning and Breeding Farm, LLP (Fig.).



Scheme of technological processes of reproduction and cultivation of pike stocking material at the Bukhtarma Spawning and Breeding Farm, LLP

Discussion of results

Based on the results of the researches conducted at the fish farm of the Bukhtarma Spawning and Breeding Farm, LLP, we hereby determine that:

– for reproduction purposes, pike breeders shall be caught from wintering ponds in the East Kazakhstan region in the second decade of April at a water temperature above 5 °C;

– pike breeders will be placed in adaptation chutes of the hatchery for prespawning maintenance;

– pike spawning shall be conducted at fish farms in the East-Kazakhstan region (III fish-breeding zone) in the period from 10^{th} to 30^{th} April at a water temperature 10 °C;

– optimal mass of spawned pike females is from 1.2 kg to 2.4 kg, males – from 1.1 kg to 1.5 kg; breeding power of females constituted up to 20 thousand eggs;

– stimulation of pike spawning was conducted with the help of pituitary injections per 1 kg weight – 3-4 mg for females, and 1.5-2 mg for males;

– insemination of pike eggs was performed by the dry method; the sperm was added to eggs simultaneously from two males for heterosperm insemination;

– degumming of eggs was made in the Weiss incubators; for degumming pike eggs, a starch emulsion was used in a ratio of 1 : 20;

– in order to prevent saprolegnia, the eggs were treated with a malachite green solution concentrated at the rate of 1 : 100000;

– incubation of eggs in Amur incubators lasted up to 14 days;

– during incubation of pike eggs, it is important to control strictly temperature and oxygen regime of water and water exchange process in the incubators; oxygen content in the water was above 6 mg O/l, water exchange process – not less than 9 l/min; drops in water temperature are not allowed;

– pike larvae were cultivated up to average weight of 120 mg within 20 days;

– pike yearlings were cultivated in the RAS tanks up to average weight of 19.5 g within 90 days;

As a result of cultivation in tanks, we received a high-quality pike stocking material adapted to artificial feed.

Obtained research outcomes will serve as a ground for development of effective biotechnical methods of artificial reproduction and industrial cultivation of pike stocking material at fish farms of Kazakhstan. Using the data received managers and specialists of fish farms and private entrepreneurs may conduct works on reproduction and cultivation of pike at fish farms of Kazakhstan.

Conclusion

Based on the results of researches conducted at the Bukhtarma Spawning and Breeding Farm, LLP in 2021, the biotechnical methods were developed to reproduce and cultivate pike stocking material in artificial environments of the RAS.

Pike spawning campaign was conducted in the farm hatchery. The water is supplied to the Bukhtarma Spawning and Breeding Farm, LLP from the Kurchum River which enters the sediment pond via the canal. The water from the sediment pond is pumped to hatchery. As a result of the hydrochemical analysis of the water quality, it is found out that the water is suitable for fish farming.

Main stages of pike artificial reproduction at the Bukhtarma Spawning and Breeding Farm, LLP consisted of catching pike breeders from wintering ponds and placement for prespawning maintenance; making pituitary injections to pike breeders to stimulate spawning; obtaining sexual products (eggs and sperm); eggs insemination; degumming of eggs in the Weiss incubators; incubation of pike eggs in Amur incubators; hatching of larvae; placement of larvae who switched to external nutrition in the tanks in order to breed and cultivate yearlings in the RAS.

Rearing of pike larvae was conducted in Amur incubators and tanks within 20 days. In the indicated period, the juveniles from average weight of 11.5 mg reached a weight of 121.5 mg in Amur incubators, and in the tanks they reached a weight of 115.5 mg with a survival rate of 56% and 52%, respectively.

Cultivation of pike yearlings was performed in 3 stages for 30 days each. As a result, the survival rate of juveniles at the stage I constituted 32%, at the stage II it was 59% and at the third stage – 67%. At the same time, the absolute gain in pike juveniles at 3 stages of cultivation was 5.16 g, 6.15 g and 8.1 g, respectively. As a result, pike yearlings reached an average weight of 19.5 g in 90 days of cultivation in the tanks. High-quality stocking material was obtained during cultivation in industrial environments of the Bukhtarma Spawning and Breeding Farm, LLP.

As a result of the researches, the scheme of technological processes has been developed for reproduction and cultivation of pike stocking material at the Bukhtarma Spawning and Breeding Farm, LLP. Biotechnical methods of reproduction and cultivation of pike stocking material in industrial environments of the Bukhtarma Spawning and Breeding Farm, LLP have been developed for the first time and available to farmers of Kazakhstan; the indicated methods may be applied for breeding and cultivation of pike at fish farms of the Republic of Kazakhstan.

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