Formation of pedigree brood stock of wild carp/domestic carp in the industrial conditions of the South of Kazakhstan

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Abstract. The article presents the experience of the formation of commercial pedigree brood stock (PBS) of wild carp, *Cyprinus carpio*, caught in Lake Bilikol (Zhambyl region) and Bugun reservoir (Turkestan region) and domestic carp. The structure and characteristics of PBS, as well as the conditions of its formation and operation, are described. The technology of harvesting wild carp brood fish in natural reservoirs, their preparation for spawning campaign, and obtaining reproductive products by factory method in the conditions of the South Kazakhstan region has been developed. The results showed that for the economic and natural conditions of Kazakhstan, it is expedient to catch pedigree and mature individuals which have grown up in the natural environment, with subsequent use to replenish the brood stock of fish farms and for artificial breeding. It should be expected that the intensive metabolism caused by favorable feeding conditions in natural conditions will have a positive effect on the growth rate and survival of the obtained fish seed for pond farms and stocked reservoirs. It is recommended to create at least one of the bred lines from wild carp brood fish harvested in natural reservoirs in fish farms – this allows periodically updating brood stock and enriching the gene pool of bred fish. As a result, methods of harvesting wild carp in reservoirs and adaptation to artificial conditions were worked out, the optimal mode of feeding and wintering of wild carp in basins was determined, and the structure of PBS of wild carp/carp was developed by taking into account the harvesting sites, age and sex, the reproductive quality of wild carp in artificial conditions.

Key Words: fish breeding, biological characteristics.

Introduction. The cultivation of carp (*Cyprinus carpio*) is an important area of fish farming and aquaculture in Central Asia and the Caucasus. Its annual production volumes, since 2010, amount to about 140,000-150,000 tons (FAO 2014), but the potential is much higher. The process of growing carp begins with the selection of producers, the formation and management of a repair and breeding stock in order to produce larvae and juveniles. Consultations conducted with the participation of fish farmers from the countries of Central Asia and the Caucasus region allow us to talk about the need to develop technologies in this area for fish farms in the formation and management of breeding herds (Zsigmond 2020). The rational use of fish stocks in fishing reservoirs implies, in particular, a well-founded strategy for stocking reservoirs with juveniles of valuable fish species. In reservoirs used for commercial fishing, the ichthyofauna has the ability to reproduce itself: in the process of natural fish spawning, further replenishment formation occurs. With intensive fishing and unstable hydrological regime, this ability of populations is disrupted, therefore, measures to preserve populations are required to maintain a stable number of fish. For this purpose, the stocking of natural reservoirs in which commercial fishing is conducted is carried out. Currently, the stocking of fishing reservoirs in Kazakhstan is mainly carried out by larvae and fingerlings of carp and herbivorous fish, which give a meager commercial return (Isbekov et al 2018). Socio-economic changes of the last decade in Kazakhstan have led to a significant increase in the number of entrepreneurs willing to engage in the artificial breeding of wild carp. For these purposes, it is necessary to have a stock of mature individuals that can be used in reproduction. However, the maintenance of the pedigree brood stock of wild carp implies the presence of pond or cage lines, which is associated with the costs of construction maintenance and of conducting the breeding-related activities. As a result, for the economic and natural conditions of Kazakhstan, the harvesting of wild carp brood fish in reservoirs remains relevant and the most cost-effective. The biotechnics of carp reproduction has been developed with sufficient completeness, however, all the developed technological schemes and standards are not suitable for harvesting wild brood fish in reservoirs. Therefore, the development of the basic techniques of aboriginal wild carp breeding based on the factory method is a relevant topic.

The purpose of scientific and production works, the results of which are presented below, was the formation of an effective pedigree brood stock (PBS) of wild carp by harvesting wild individuals in natural reservoirs and a comparative assessment of the formed herd, based on reproductive indicators. The wild carp specimens were acclimatized at the beginning of the last century and the population from the Chu River was at the origin of this community (Mitrofanov et al 1988; Mitrofanov et al 1992). To solve this problem, the following tasks were identified: development of optimal methods for harvesting wild carp in reservoirs; a study of the optimal feeding and wintering mode of wild carp; development of the structure of wild carp/carp PBS, taking into account the harvesting sites; assessment of the quality of fish seed obtained from wild brood fish in comparison with the domestic carp. The study aimed to develop a complex technology for harvesting brood wild carp in natural reservoirs, preparing them for the spawning campaign, and obtaining reproductive products by the factory method, in the conditions of the South Kazakhstan region.

Material and Method

Sample collection. The object of the study were wild carp specimens caught in Lake Bilikol (Zhambyl region) and Bugun reservoir (South Kazakhstan region), as well as individuals of domestic carp brought from farm ponds. The wild carp's PBS was formed by harvesting wild individuals for 3 years. The choice of reservoirs was determined by the presence of aboriginal herds of the Aral wild carp. The natural area of the Aral wild carp includes the Bugun reservoir, in the Lake Bilikol (Talas River basin).

Research location. The study was carried out at the basis of LLP "Aksanat Engineering". LLP "Aksanat Engineering" is located in the South Kazakhstan (Turkenstan) region, in the village of Kereit (Figure 1).

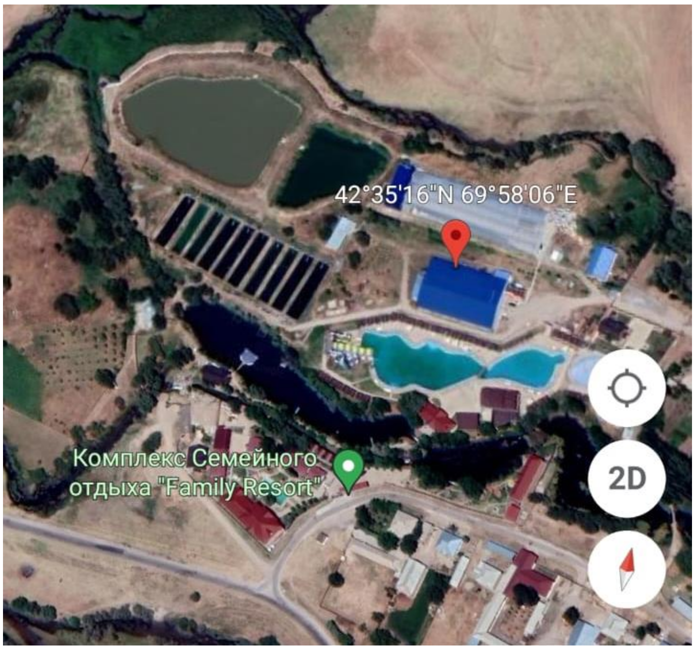

Figure 1. Location of LLP "Aksanat Engineering".

The farm has fish tanks, ponds and a recirculating water system. The study used pools and ponds. Bugun reservoir is located in the South Kazakhstan region of Kazakhstan. It was formed in 1967 in the lower reaches of the Bugun River. The area is 65 km^2. The waters of the Arys and Bugun rivers replenish it. Bilikol Lake, located in the Zhambyl region of Zhualy district, is a large reservoir in the south of Kazakhstan, located at the foot of the Karatau mountains. The main power source of the lake is the Asa River (the left tributary of the Talas River). The lake area is 86.5 km^2.

Data collection and analysis. The catch of the experimental specimens was carried out by the method of trap fishing, the caught individuals were concentrated in cages installed on the reservoir. The main fishery-biological characteristics were determined for each individual – age, length and weight. Determination of the biological indicators used in the primary database was carried out according to the methods adopted in the pond and industrial fishery (Katasonov 1991; Jahan et al 2020; Shatokhin et al 2019). Monitoring of thermal and oxygen modes of ponds and basins was carried out according to generally accepted methods (Mitrofanov et al 1988; Mitrofanov et al 1992; Bogeruk 2006). The content of biogenic elements in the water was determined using rapid tests. The assessment of the growth rate of brood wild carp/carp was carried out based on the results of control catches and final catches during feeding and wintering (Pravdin 1966). During the spawning campaign in females, working fertility was determined by calculating the relative fertility per 1 kg of fish weight, as a percentage of fertilization (Katasonov 1991; Pravdin 1966; Kryukova et al 2007; Zalepukhin 2009). A visual assessment of the ovulated unfertilized eggs was carried out (color, consistency, amount of ovarian fluid, appearance of eggs) the presence of foreign inclusions, the one-time duration or elongation of ovulation were determined and the egg sifting was also performed (Zalepukhin 2009). Samples of laid eggs and hatched yolk fry were taken daily and their quality was evaluated under the "Sigeta CAM-07" USB microscope. An analysis of embryonic development was carried out and the following indicators were determined in fertilized eggs:

- a percentage of fertilization;
- development of embryos at different stages;
- duration of hatching;
- a percentage of larvae hatching;
- the length of the larvae at hatching and when switching to external nutrition (Mitrofanov et al 1988).

Stages and phases of embryonic development of the carp were determined in accordance with the methodological recommendations developed by Pravdin (1966), Zalepugin (2009) and Shatokhin et al (2019). The age of the fish was determined on the annuali, from the scales (Pravdin 1966).

Results and Discussion. The formation and use of PBS includes a set of organizational and biotechnical measures aimed at providing the fish farm with the necessary number of brood fish and the rational use of brood stocks; when forming the PBS of wild carp in water bodies, the activities were divided into the following stages and sub-stages:

1. Harvesting of wild carp individuals in natural reservoirs:
- catching wild carp in natural reservoirs by set fishing and their transportation;
- adaptation to artificial conditions of maintenance, sorting and distribution into groups;
- formation of PBS (taking into account the sex and age structure, the timing of obtaining reproductive products, harvesting sites);
2. Maintenance of brood fish and rearing:
- summer foraging;
- autumn valuation;
- wintering in basin and pond conditions;
- spring valuation;
3. Conducting a spawning campaign:
- incubation and hatching of embryos;
- rearing of larvae before their transition to a mixed diet.

Harvesting of wild carp individuals in natural reservoirs. Harvesting wild carp at the Bugun reservoir was carried out in the spring-summer period of 2021, with the expectation of obtaining offspring for the next year. Harvesting wild carp at Lake Bilikol meant catching fish (brood fish) ready for spawning and obtaining reproductive products immediately after the adaptation process. Transportation to the place of cultivation from natural the reservoirs was carried out in specialized containers equipped with oxygen supply to the container. Fishery biological indicators were determined in the caught individuals, age and sex were determined, a primary examination was immediately carried out on the reservoir and individuals with well-identified secondary sexual characteristics were selected, those with visible signs of disease and injuries being rejected (Table 1). To prevent the depletion of the gene pool, a low degree of selection intensity was used (Kryukova & Muzalevskoy 2007).

Table 1

Fishery-biological indicators of caught wild carp fish selected in the PBS

Indicator	*Bugun reservoir*	*Lake Bilikol*
Survival during transportation, %	99.8	97.6
Survival in the first 3 days, %	95.1	97.2
Juveniles, %	89.22	33.12
Mature individuals, %	11.02	67.16
Males (from mature individuals), %	61.1	55.3
Females (from mature individuals), %	38.7	45.1
Weight of fish		
Average	2.2±0.2	3.1±0.7
Max	9.4±0.08	14.8±0.065
Min	1.2±0.02	1.1±0.02
Length of fish		
Average	41.3±1.1	49.5±0.8
Max	78.3±1.2	84.7±1.12
Min	19.4±0.08	14.4±0.08

The process of adaptation of the wild carp to the basin conditions consisted in keeping the fish in the basins and accustoming them to artificial feed. The entire adaptation period is 30 days; during this period, 89% of wild carp have already learned to eat artificial feed and gained weight (according to the standards developed for carp) (Shatokhin et al 2019; Kadhim & Al-Zaidy 2021). Data on fishery biological indicators are given in Table 2.

Table 2

Fishery-biological indicators of wild carp, obtained during adaptation to basin conditions

Indicators	*Values*	
	Bugun reservoir	*Lake Bilikol*
Adaptation period, days	30	
Initial weight, g (x±m)	2.2±0.2	3.1±0.7
Final weight, g (x±m)	2.78±0.5	3.72±0.9
Fulton's condition factor (initial), (x±m)	2.7±0.09	2.4±0.1
Fulton's condition factor (final), (x±m)	2.9±0.11	2.7±0.1
Absolute growth, g	58	62
Average daily gain, g	1.93	2.06
Feed conservation ratio, units	3.8	3.3
Survival, %	100	100

When forming the brood stock, the preservation of aboriginal herds of wild carp, adapted to local conditions and relatively resistant to diseases, was a priority. The work was carried out according to the principle of three-line breeding, the structure provided the possibility of unrelated industrial crossing (Katasonov 1991). For this purpose, as well as in order to preserve the genetic polymorphism of wild carp/carp, three groups (lines) were formed on the farm - the Bugun and Bilikol groups and domestic carp. Each of these groups was reproduced "in purity" to replenish the PBS, and, for the commercial breeding, intergroup crossings were used (Figure 2).

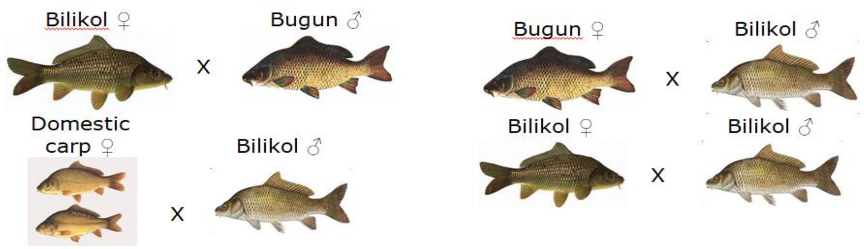

Figure 2. Scheme of crosses to obtain commercial hybrids of the first generation.

In order to prevent inbreeding, at least 5 pairs of brood fish were included in the brood stock for each breeding line, for each year (Katasonov 1991). During the autumn valuation, a corrective selection was carried out, culling about 28% of fish that were severely stunted (not adapted), injured individuals. The selection for PBS was carried out mainly among two-year-old and three-year-old (Katasonov 1991; Zalepukhin 2009). When transferring fish to a herd, 78% of the females were left, while 95% of the males were left. The structure of the formed PBS of wild carp and carp is shown in Table 3.

Table 3

The number of wild carp/carp individuals and the structure of the formed PBS

Age	*Bugun reservoir*		*Lake Bilikol*		*Carp*	
	♀	♂	♀	♂	♀	♂
1+	-		14		-	
2+	22		28		-	
3+	58	47	22	31	-	
4+	18	22	102	54	-	
5+	15	5	13	12	13	7
6+	1	16	15	12	11	5

Thus, the method of trap fishing for brood wild carp is convenient, provided that cages are installed at the collection sites. The method applied (of adaptation to the basin conditions of the caught individuals) showed a high degree of conservation of individuals. The structure of the formed PBS implies a three-line breeding and allows saving the aboriginal herds of the Aral wild carp, as well as to receive annually intergroup hybrids for commercial breeding.

Maintenance of rearing and brood fish. Summer feeding of wild carp was carried out in basins. The conditions of keeping the individuals selected in the PBS from the beginning ensured a good fattening of fish, which was achieved due to the spaced planting of fish, the optimal temperature keeping (23-25°C) and full feeding, with Polish specialized feeds from AllerAqua (Kłobukowski et al 2018; Krainyuk et al 2019; Tumenov et al 2019). Brood fish and rearing groups were kept separately in the basins: Bilikol individuals were kept separately from carp and Bugun fish (Table 4). During the summer maintenance of wild carp in the basins, the hydrochemical mode was optimal, no sharp fluctuations were observed.

Table 4

Conditions for summer maintenance of PBS wild carp in basins

Indicator	*Bugun reservoir*		*Lake Bilikol*	
	Brood fish	*Rearing group*	*Brood fish*	*Rearing group*
Planting density (u/m^3)	5	20	8	20
Daily feeding rates (%)	2	2.1	2	2.1
Survival rate (%)	88.1	95.4	97.2	97.3
Basin volume (m^3)	45			

An important indicator of the state of breeding fish is their growth (Katasonov 1991; Kłobukowski et al 2018). Approximate body weight values for rearing groups are given in Figure 3. The graph shows figures for the annual growth of fish, however, the winter maintenance is not reflected, since in winter the fish indicators were not monitored, in order to avoid stress.

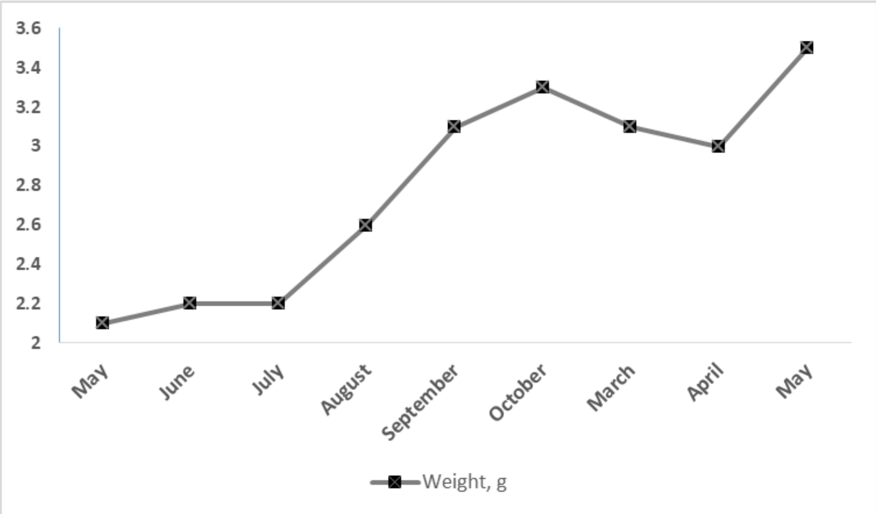

Figure 3. The annual growth of wild carp individuals, caught in the Bugun reservoir.

Wintering. The PBS was planted for wintering after a steady drop in water temperature below 10°C in November. Wintering was carried out in two ways: pond and basin (Figure 4). Brood stocks were planted in the basins, from which it was planned to obtain reproductive products after wintering. Rearing groups of fish were planted in the ponds.

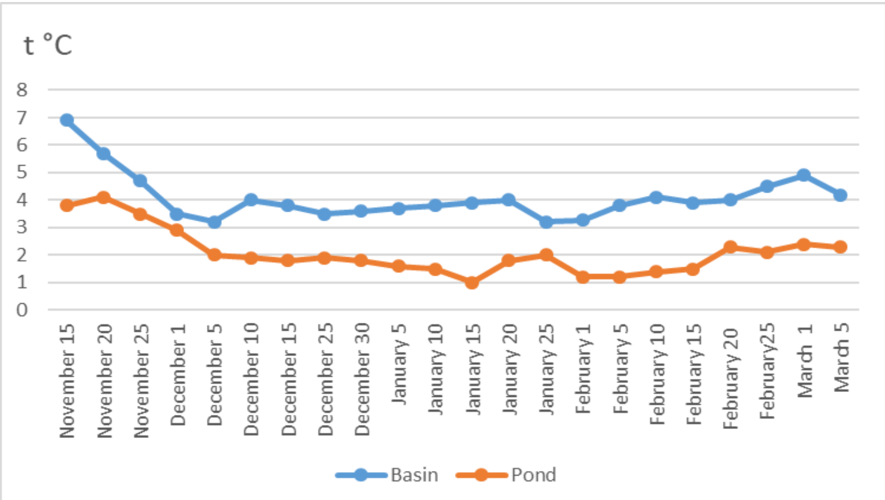

Figure 4. Temperature mode during wintering.

Fishing of wintering ponds with PBS began in March, during the spring valuation of rearing groups, individuals with injuries and severely emaciated individuals were rejected (12%). After accounting, fish were sent for fattening in the basins. The basins with brood fish were fished in April and the final valuation and selection for the spawning campaign were carried out. After valuation, females and males were seated separately for pre-spawning maintenance in basins. For the pre-spawning maintenance of brood fish, basins provided with low-temperature running water (spring water with a temperature of 15°C) were used. Keeping fish on running cold water made it possible to obtain high-quality reproductive products from mid-April to the end of May.

Spring valuation. The main purpose of the spring valuation was to distribute brood fish into groups according to the readiness of fish for spawning, the indicator of which is the severity of readiness for spawning (Katasonov 1991; Zalepukhin 2009). Among females, three classes were distinguished:
- the best fish with a well-developed, soft abdomen, without signs of disease, were assigned to the first class. This group was the first to participate in the first spawning campaign. This group included 79 females.
- the second class included young females (not large) and fish with a round but firm abdomen. Sexual products from this group were obtained at a later date at the end of May. This group included 23 females (from 15 of which, caviar of high fish-breeding quality was subsequently obtained).
- the third class included females with very mild signs, injured and sick fish. This group was sent for maturation and fattening.

Males were selected based on the size of the female. Smaller males were selected for large females and large males were selected for small females. The visual assessment of breeding fish during valuation was supplemented with individual measurements of fish. Percentage of ripe brood fish and juveniles in the formed PBS is presented in Table 5

Table 5

Percentage of ripe brood fish and juveniles in the formed PBS

Indicator	*Bugun reservoir*	*Lake Bilikol*
Mature females (%)	77.3	57.9
Mature males (%)	97.8	83.7
Juveniles (%)	13.2	15.9
Undefined* (%)	4.8	-

*Individuals whose sex could not be determined by external characteristics.

Carrying out a spawning campaign. Obtaining reproductive products was carried out during the months of April-May. To keep brood fish and incubate eggs, a small incubation RAS equipped with mechanical and biological filters was used. To stimulate spawning, brood fish were injected with the carp pituitary gland (for females, the injection was fractional, the total dose was 2.52 mg kg^{-1}), with a gradual rise in water temperature by 1.5°C (Jahan et al 2020; Kryukova et al 2007). The selection of ovulated eggs and fry was carried out by straining.

The insemination of eggs was carried out by the dry method. The eggs of each female were inseminated with the sperm of 3-6 males and incubated in separate devices in accordance with the generally accepted biotechnology of carp hatchery reproduction (Katasonov 1991; Brzuska 2021). Removal of mucilage was carried out with a mixture of milk and water in a ratio of 1:20, for an exposure duration of 45 minutes. Control of incubation consisted in monitoring the thermal and oxygen modes. The development of eggs took place under a stable thermal mode, at 21-22.5°C. Survivalship of eggs reached 59% and fertility reached 84%. The duration of embryonic development at this temperature was 3 days (70 hours). The eggs were incubated in a Weiss apparatus. At the stage of the pigmented eye, the eggs were transplanted into the "Amur" apparatus, and the yolk fry were hatched and kept in these apparatuses. The conditions for the incubation of carp and wild carp eggs are shown in Table 6.

Table 6

Conditions for the incubation of domestic carp and wild carp eggs

Indicator	*Unit of measurement*	*Average values*	*Fluctuations*
Water temperature	°C	21.7	21-22.5
Oxygen content in water	mg L^{-1}	8.4	7.7-9.1
Flow rate			
Weiss apparatus	L min^{-1}	6	1-10
"Amur" apparatus	L min^{-1}	15	5-22

At 2.5 hours after fertilization in wild carp, in some eggs (15%), 2 blastomeres can already be observed. The stage of 2 blastomeres begins in carp at 3.5 hours after fertilization, the furrow is clearly visible approximately after the 3rd hour.

The assessment of the quality of eggs and the percentage of fertilization was carried out according to typical crushing at the stage of 4-8 blastomeres (Makeyeva 1992). In the common wild carp, the percentage of formation of asymmetrically located blastomeres of different sizes, at this stage, is 12%, which is apparently due to the fact that in several females the eggs did not reach definitive (normal) sizes; it was this caviar that gave such a large percentage of eggs with developmental disorders. The appearance of an excess number of blastomeres at this stage (most often of different sizes) indicates a low breeding quality of eggs, which is associated with the immaturity of females at the time of hormonal stimulation. In carp, the percentage of disorders in eggs is much lower, 2.8%, which is the norm (Makeyeva 1992).

At the stage of gastrulation in wild carp (8.5-9 hours after fertilization), there were eggs with incomplete fouling of the yolk with cellular material. The appearance of the embryonic ridge in some eggs was recorded at the 18th hour of development, which is very clearly visible at the stage of closure of the yolk plug. The stage of eye pigmentation in wild carp begins at 51 hours after fertilization, the same stage in carp begins at 52 hours after fertilization. At 68-70 hours of development, the appearance of single yolk fry (the beginning of hatching) of wild carp from eggs was recorded. The length of larvae in both carp and wild carp corresponds to the norm (Mitrofanov et al 1988; Mitrofanov et al 1992). Comparative fishery-biological indicators of wild/domestic carp during the spawning campaign are presented in Table 7.

Table 7

Comparative fishery-biological indicators of wild carp and domestic carp during the spawning campaign

Indicator	*Domestic carp*	*Wild carp*
Fertility (%)	84.3	76.9
Duration of incubation, (days)	3	3
Presence of pathologies (%)	2.83	12.1
Larvae hatching duration (hours)	8	21.5
Yield of larvae (%)	38.3	59.1
Larva size at hatching (mm)	3.8±0.1	4.2±0.15
Size of the larva in the transition to a mixed diet (mm)	4.7±0.08	5.9±0.03

A comparative analysis of the working and individual fertility of carp and wild carp females is presented in Table 8.

Table 8
Working and relative fecundity of domestic carp and wild carp females

Indicator	*Wild carp Bugun reservoir*	*Wild carp Lake Bilikol*	*Domestic carp*
Average working fecundity	148.8±12.1	119.2±23.1	261.4±23.1
Average relative fecundity	193.3±11.1	154.7±9.8	311.2±21.1

A comparative analysis of the quality of the stocking material for carp and wild carp showed that in both cases the quality of the larvae corresponds to the reference (Mitrofanov et al 1988; Mitrofanov et al 1992; Petlina & Romanova 2004; Nedoluzhko et al 2020; Krainyuk et al 2019; Tumenov et al 2019). It is also practically confirmed that it is possible to obtain high-quality stocking material for wild carp using the factory method of reproduction.

Conclusions. The results of the study showed that, given the economic and natural conditions of Kazakhstan, it is expedient to catch rearing and mature individuals that have grown in the natural environment, with subsequent use to replenish the brood stock of fish farms and for the purpose of artificial breeding. An intensive metabolism, due to favorable feeding in natural conditions, will have a positive effect on the growth rate and viability of the resulting fish stock in pond farms and stocked water bodies. It is recommended to create in fish farms at least one of the bred lines from brood wild carp fish harvested in natural reservoirs, which periodically updates the brood stock and enriches the gene pool of bred fish. Methods for harvesting wild carp in water bodies and adapting to artificial conditions were worked out, the optimal mode for feeding and wintering wild carp in basins was determined, the structure of the PBS of wild/domestic carp was developed, taking into account harvesting sites, age and sex, and the reproductive quality of wild carp was determined in artificial conditions.

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Conflict of interest. The authors declare no conflict of interest.

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