Common carp maturation and fecundity and reproduction optimization in Uzbekistan

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Abstract. Reproductive biology of cultured common carp in Uzbekistan was studied. The ages, total lengths of the samples studied ranged 1-5 years, 5.0 - 87.0 cm in standard length. In spring, 1-year-old fish (8.0-25.0 cm) had gonads at stage I; 2-years-old females (18.0–33.0 cm) had gonads at stage I (23 \%) and II (77 \%); 3-years-old females (25.6–47.1 cm) had ovaries at stage II (43 \%) and III-IV (57 \%); all 4-year-old and 5-year-old females were mature. Females mature when they reached 32 cm in standard length. Absolute fecundity varied 131–1830 thousand eggs, relative fecundity was 190.5–344.0 eggs/g of gutted fish body, real fecundity was 200.0–1300.0 thousand eggs. Average individual ripe egg size varied 1.32–1.52 mm. Positive correlation between maturation, absolute fecundity and growth was determined. For broodstock forming optimization, additional (to body size) fish characteristic should be entered to selection; fish growth could be recommended as such measure. Annual artificial selection of fishes with standard length at different ages (at least SL\textsubscript{1} – 13 cm; SL\textsubscript{2} - 25 cm; SL\textsubscript{3} – 32 cm) would form broodstock which mature at 3-years-old age with real fecundity 800 – 1300 thousand eggs.

1. Introduction
Since 2009, aquaculture production was sharply increased in Uzbekistan from 6-9 thousand to more than 100 thousand tons/year. Quantity of fish farms increased from 30 to more than 3000 total pond area increased from 14-15 thousand ha to more than 36 thousand ha. Main fish production growth failed on phytoplankton feeder silver carp, Hypophthalmichthys molitrix (80 \% of total production); but further growth of this species is improbable from ecological (species reached its limit in ponds productivity) and social (species occupied its segment in market) points of view. But, the country needs following sharp growth of aquaculture production (more than several times). In the nearest future, common carp, Cyprinus carpio, is single pretender to obtain such growth; it has fast growth, good tasty, popularity as commercial fish in local and regional level. Scale of reproduction is one of the main limits for species production increasing.

Common carp is one of the major aquaculture species in the world; global aquaculture production reached 4.557 million tons in 2016 [1]. It is also one of major fishes in Uzbekistan; more than 22 thousand tons were produced in 2019.

Cultured fish mass reproduction is one of the bases for aquaculture success, especially in deeply continental countries. Domesticated common carp is used in Uzbekistan [2]. Reproduction is completely artificial based on gonadotrophic stimulation of sex products maturation and correspond with modern global level [3, 4]. But quality of broodstock could be optimized strongly. Our analysis showed that variability of real fecundity in local broodstock is very high (192 – 1 540 thousand eggs per female in
hatchery in Tashkent region). Program of national fish culture growth needs sharp increasing of common carp production. In environments of arid climate and water deficiency, broodstock average fecundity increasing and technology sustainability development are essential. Technology was developed in 1960-1980s and is based on breeder selection due to body size. Since 1980s, common carp reproduction biology studies were poor and fragmental. Reasons of such high variability of reproduction characters of breeders has to be studied. Level of fish female maturity relates with stage of the most developed oocytes in ovaries and more developed oocytes has larger size [5]. Aim of this work was to study reproductive biology of cultured common carp, find mechanism of fecundity high variability appearance and develop proposals for breeding programs in local fish culture.

2. Material and Methods

Study site. ‘Balyktchy’ fish farm is situated in the vicinity of Tashkent, nearly 40°53’ north and 168°45 east; the total area of ponds is 2500 ha. Broodstock formation is managed in ponds of farm’s hatchery with total area about 40 ha. The climate is extremely continental, arid. The lowest average monthly temperature is in January at -1.1 - -2.1°C; during some winters, ice cover ponds 10-15 cm for about 1 - 1.5 months. The highest average monthly temperature is in July at 27 – 29.1°C; in daytime often air temperature may be 35-40°C and higher. Water in the ponds may reach 29 – 31°C in the daytime. In Tashkent region, the annual precipitation of 185 – 193 mm falls mainly in November – May.

In fish farms, pond silver carp, *Hypophthalmichthys molitrix*, are stocked together with common carp, bighead carp, *H. nobilis*, and grass carp, *Ctenopharyngodon idella*; the following stocking density is used for common carp brood stock forming: fry 15,000 – 20,000 individuals per ha (in 1st year of fish culture), yearlings 3,000 individuals per ha (in 2nd year of table fish culture), further all ages are kept together, selection is based on fish body size and maturation (due to visual control in spring). So, farmers raise table common carp two vegetation seasons and then simply take a part of generation to hatchery pond for broodstock forming.

Sample collection and analyses. Common carp samples were collected in February – May 2018 and 2019 during wintering ponds total catch by using dragnet with 4, 8, 10, 14, 18, 24, 32, 40 mm in mesh size.

The standard length (SL) without caudal fin (to the end of scale coverlet) in the nearest 1 mm and body weight (W) in the nearest 1 g were recorded for each fish.

Scales (3-4 samples) were taken from 1st row above lateral line under 1st ray of dorsal fin, cleaned and examined under binocular microscope for the age determination and growth back-calculation. Scales were measured with the aid of a microfiche under magnification 10.0x. Annuli measurements were taken along diagonal between lateral and front sectors. Tissue samples of gonads were fixed in Bouin’s solution; paraffin wax sections of 5-7 µm were stained in hematoxylin. Ovarian development was classified into six stages according to Makeeva [6]. Diameters of the largest 30 oocytes on one histological section were measured and average character was calculated for female (DO, mcm). Gonad weight (q) was determined for females in the nearest 0.1 g. Individual absolute fecundity (AF) was recorded for fish caught in April and early May as the number of eggs which were soon to be spawned. Individual relative fecundity (RF) was calculated as RF=eggs/body weight of the gutted fish. Real fecundity (quantity of ovulated eggs from female) (Real. Fec.) was calculated. Female ripe egg size (D, mm) was calculated as average of 100 egg diameter measurement. Correlation and regression analyses were done to describe fecundity equations; statistical significance was tested to p < 0.05.

3. Results

A total 300 specimen of common carp were sampled. Overall sex ratio between females and males was 1 – 1.1 (148 females and 158 males). The ages, total lengths and weights of the samples studied ranged between 1 to 5 years, 5.0 to 87.0 cm; all age groups used in local fish culture were represented in our sampling.
Maturation. In spring, 1-year-old common carp reached 8.0 - 25.0 (mean 17.9) cm in standard length and 24.2 – 246.8 (131.4) g in weight (n = 30 individuals). In the first year, ovaries developed rather slowly. In the spring, all 1-year-old females had gonads at stage I. The ovaries weighed a few mg and they were visible as colorless to translucent-brown thin threads; histologically, nests of oogonia and a few pre-vitellogenetic oocytes were visible (Figure 1).

![Figure 1](image1.png)

**Figure 1.** Histological section of common carp female gonads: at the left – gonads on stage I, at the right – on stage II

At the same time, larger 1-year-old females had more developed ovaries: \( r_{SL-DO} = 0.54, r_{W-DO} = 0.53 \) (Figure 2)

![Figure 2](image2.png)

**Figure 2.** State of ovaries development (DO, mcm) and back-calculated growth rate of 1-year-old common carp females

In spring, 2-years-old females reached 18.0 – 33.0 (25.9) cm in standard length (n = 38). Noticeable variability in maturation was noted. So, 23 % of females still had gonads at stage I; but, 77 % of females had more developed gonads at stage II. In second group, increasing number of advanced pre-vitellogenetic oocytes were evident microscopically in addition to oogonia. Average diameters of the 30 largest oocytes (the most developed in maturation) on the section was 73.8 – 116.5 micrometers. The ovarian weight increased to 3.5 – 11.2 g.

This age group could be segregated into two groups according to ovarian development: all females with gonads at stage I were 18.0 – 21.0 (18.6) cm, at stage II – 17.5 - 33.0 (25.1) cm.

In spring, 3-years-old females were 25.6 – 47.1 (36.4) cm in standard length (n = 36). Differences in developmental stage of the ovary in females of the same age were also recorded for 3-years-old fish in spring: 43 % had gonads at stage II and 57% - at stage III – IV. Females with gonads at stage III-IV had opaque or brownish – green ovaries with oocytes visible to the naked eye. Histologically, vitellogenetic
oocytes were seen in addition to previtellogenic oocytes and oogonia (Figure 3). So, females of second group had already matured.

![Image](https://example.com/image1.png)

**Figure 3.** Histological sections of common carp females: at the left – gonads at stage III-IV, at the right – at stage IV

All females with gonads at stage II were 17 – 36 cm in standard length, females with gonads at stage III-IV were 32 – 47.1 cm. Back-calculated growth analysis showed that all matured females had at the least following rate: $SL_1 = 13$ cm $SL_2 = 25$ cm, $SL_3 = 32$ cm and higher.

In this age group strong relationship between female growth and stage of maturity was determined: $r_{SL, DO} = 0.85$ (Figure 4). Growth on the first year of female life was the most important for fast maturation ($r_{t1, DO} = 0.70$). All matured at age 3-years females had growth rate $SL_1 = 13$ cm, $SL_2 = 25$ cm, $SL_3 = 32$ cm and faster. When DO reach 120 mcm (due to our methodology to measure 30 largest oocytes), female ovaries reach stage III in maturation, in April those females will mature.

![Image](https://example.com/image2.png)

**Figure 4.** State of ovaries development (DO, mcm) and back-calculated growth rate of 3-year-old common carp females

In spring, all 4-year-old and 5-year-old common carp females were mature. Fish were 36.0 – 87.0 cm in standard length.

Fecundity. Common carp broodstock females were at age 3 – 5 years, 32 – 87 cm in standard length;
there absolute fecundity varied 131 – 1830 thousand eggs. Absolute fecundity of common carp females at different age is given in table 1. Note, that all 3-years- old females were firstly mature, a part of 4-years-old females were firstly matured, another part – repeatedly matured, all 5-years-old – repeatedly matured. Absolute fecundity had positive correlation with body size (Figure 5).

| Age, years | Standard length, cm | Absolute fecundity, thousand eggs |
|------------|---------------------|----------------------------------|
| 3          | 26 - 47             | 131 - 580                        |
| 4          | 36 - 62             | 158 - 980                        |
| 5          | 59 - 87             | 690 - 1830                       |

Figure 5. Relationship between real fecundity and common carp standard length

Relative fecundity of common carp varied 190.5 – 344.0 (224.4) eggs/g of gutted fish body weight. Relative fecundity varied independently from age and body size ($r_{SL,rf} = -0.03; r_{W,rf} = -0.1$).

Real fecundity (quantity of ovulated eggs). Females used in artificial reproduction were 44 – 80 cm in standard length. Rea fecundity varied 200.0 – 1300.0 (580.0) thousands egg. Positive correlation between real fecundity and body size was determined: $r_{SL,real fec}=0.69; r_{W,real fec}= 0.67$ (Figure 3).

Ripe eggs size. Sample of 120 females used in ‘Balyktchy’ fish farm reproductive company was studied; the females were 47 – 83 (60) cm in standard length and 2100 – 11 060 (5 150) g in weight at age 4-5-years. So, all females were repeatedly matured. Real fecundity in Broodstock varied 200 – 1600 (580) ml
(or 192 – 1 540 thousand eggs) per female. On ripe egg diameter frequency diagram normal distribution was observed for all samples. Minimal individual ripe egg diameter varied in sample from 1.09 to 1.4 (1.24) mm; maximal individual ripe eggs diameter varied 1.42 – 1.73 (1.56) mm. Average individual ripe egg size varied 1.32 – 1.52 (1.41) mm in sample. Individual coefficients of variation varied 3 – 6.5%. Average ripe eggs diameter varied independently from female body size: $r_{SL,D}=0.15$; $r_{SL,W}=0.11$. So, character was very stable for female stock.

4. Discussion
The ecological adaptive flexibility of common carp, its ability to withstand various environments has made it one of the major aquaculture species in the world. In India, Ethiopia and other tropic countries, common carp mature in first year, has small body size at first maturing (14.5 cm in total length and 47 g in weight), absolute fecundity is 3.1 – 629 thousand eggs, relative fecundity – 21.0 – 223.0 (91.17) egg/g of total body weight. In Turkey and Middle East countries, common carp females reach first maturation at age III – IV, in Europe – at age IV-V [7-18]. In common, in temperate climate, total length at common carp first maturity is variable, ranging from 35 to 43 cm [19].

Study on growth, maturation and fecundity is an important part of fishery science including aquaculture as it has direct bearing on fish production and on fish culture technology improving. The reproductive cycle and pattern of ovaries development greatly depends on the ambient water temperature and other abiotic factors [20].

In environments of pond hatcheries in Uzbekistan, common carp female matures for the first time at age III – IV when they reach about 32 cm in standard length and 700 – 900 g in body weight. Those data well correspond with data from other countries and showed, that common carp growth maturation rate and fecundity level are one the highest for temperate climate. Common carp has high fecundity, including real one (the basic character for mass reproduction).

In common, reproductive technology used in the country conforms to international level. But identified variability of maturation, absolute and real fecundity could be used for noticeable optimization of technology. Recently, farmers raise table fish and simply take a part of that stock to hatchery ponds for further culture up to maturation. Breeders selection is managed according to body size. In this case, mixture of females at different age and with different growth rate easily and spontaneously occurs in broodstock. As a result, among female with one standard length females there could be individuals with different rate of maturation and with different absolute fecundity. But, gonadotrophic injection is calculated due to body size. So, for females with small absolute fecundity such injection dose would be too high, for individuals with high fecundity – it will be too low; that is why high variability of real fecundity was observed. Main strategy for broodstock forming optimization is to limit variability of maturation and fecundity. Determined positive relationship between growth rate and maturation, fecundity could be used. Injection concentration used in the country shows the best results with females 60 – 70 cm in standard length.

We highly recommend to use selection of fish to broodstock from the summerlings / yearlings. Strong influence of age to broodstock reproductive traits was also shown in some other developed countries [21]. The goal is to form broodstock at least with following growth rate: $SL_1 = 13$ cm; $SL_2 = 25$ cm; $SL_3 = 32$ cm. In this case, females in broodstock will mature at age III, they could be used in reproduction at age IV, further repeatedly used at age V and then sold as very commercial product (hatchery will catch good profit). Due to our study real fecundity of breeders will be 800 – 1300 thousand eggs which is noticeably higher than recent characteristic (about 500 thousand eggs).

All age groups should be raised in separate pond; we recommend use densities and feeding regime according to norms of broodstock formation for VII zone of fish culture.

5. Conclusions
1. Common carp has found favourable environments in pond fish farms in Uzbekistan; its growth, rate of maturation and fecundity is the highest for temperate climate. At the same time, technology of broodstock formation used obtain high variability in maturation and fecundity; that is noticeable limitation for real fecundity.
2. For broodstock forming optimization, additional (to body size) fish characteristic should be entered to selection; we recommend fish growth as such measure. Annual artificial selection of fishes with standard length at different ages (at least SL1 – 13 cm; SL2 - 25 cm; SL3 – 32 cm) would form broodstock which mature at 3-years-old age with real fecundity 800 – 1300 thousand eggs.

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