Morphological characteristics of yearlings of Grass carp (*Ctenopharyngodon Idella*) in the fish farm of Bukhara region, Uzbekistan

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Abstract. The study focused on the morphological variability of one-year-old grass carp (Ctenopharyngodon idella), a commercially important fish species in Uzbekistan. Various meristic indicators were examined, revealing specific characteristics: D III 7, A III 7-8 (average 8), 39 - 45 (42) lateral line scales, and 19 – 22 (21) rakers on the first gill arch. These indicators provide insights into the unique morphological features of grass carp at this developmental stage. Additionally, plastic parameters were assessed using both classical methods for cyprinid fish measurement and geometric morphometry. These parameters provide a more detailed understanding of the physical traits and variations within the grass carp population. The use of geometric morphometry allows for a more comprehensive analysis of shape and size variations, offering valuable insights into the overall morphology of the fish. Overall, the study's findings contribute to a better understanding of the morphological characteristics of one-year-old grass carp, which is crucial for effective management and conservation strategies. This research provides a foundational understanding of the species' morphology, which can aid in future studies related to growth patterns, population dynamics, and conservation efforts.

1. Introduction

China was home to the grass carp, or *Ctenopharyngodon idella* (Valenciennes, 1844) which found its natural habitat in freshwater areas of Asian rivers that flowed into the Pacific Ocean. By the beginning of the 20th century, grass carp was recorded also in the Amur River in the Far East of Russia [1]. Grasse carp, a representative of the cyprinids family (*Cyprinidae*), is one of the main global objects of pond fish farming; it feeds on higher aquatic vegetation, i.e. provides important products, occupying the niche of herbivorous fish. Grass carp is also a valuable bioreclamation fish that can effectively clean irrigation channels of overgrowth. Consequently, during the 20th century, it was introduced for fish farming purposes into more than 80 nations worldwide [2].

Early in the 1960s, Uzbekistan received four batches of grass carp larvae (three from the northern region of China and one from the Amur River) along with silver carp (Hypophthalmichthys molitrix). They were stocked into newly created ponds in the Tashkent region in the middle stream of the Syrdarya River. Soon, methods of artificial reproduction of these species and the common carp (*Cyprinus carpio*) were developed here. The mass production of those carp species is used from those times up to now. Since the 1960s, these fishes, including grass carp, have become the main objects of fish farming in Uzbekistan. They were widely distributed from the Tashkent region to all pond fish farms of Uzbekistan, and were also stocked in reservoirs and lakes on the plains of the Aral Sea basin in Uzbekistan [3-5].

Reproduction of the species has been conducted in Uzbekistan since the early 1960s; fish breeders aged four to five years are the primary source of fish for reproduction; thus, almost fifteen full generations have passed under novel conditions for the species. Monitoring the biological traits of fish species and their alterations is a crucial responsibility. It is possible to give quantitative qualities regulated by polygenes through morphological research. Documenting phenotypic changes in a species during its ontogeny is crucial [6]. Despite the importance of grass carp in the aquaculture sector of Uzbekistan, no research work has been carried out on its morphological features. In pond fish

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farming, the main age groups are yearlings, table fish (two-year-old) and breeders (3-5-year-olds). The aim of this study was to examine the morphological traits of commercial grass carp (age 1+) in the lower stream of the Zarafshan River in the Bukhara region of southern Uzbekistan.

2. Material and Methods

Samples were collected in April 2023 at the 'Nodir Nozim quli' fish farm. The farm is located in the lower stream of the Zarafshan River, Vobkent district, Bukhara region. Water is supplied through the Central Drainage Canal (this is the old bed of the Zarafshan River). The Aral Sea basin is located in the center of the largest continent - Eurasia. The region is closed to the east and south by the mountains of Highland Asia and open to steppes and deserts to the west and north. This explains the dryness and extremely climate continentality. Very sharp temperature fluctuations, both daily and seasonal are usual for the region. Summer is dry, very hot, average daily temperatures in summer reach 25-31°C (air yemperature in daytine are often up to 40°C or more from late June to late August). Winter is relatively cold and wet, sometimes with severe frosts. Average air temperatures in the study region drop to -6 - -8°C. The region receives less than 300 mm of precipitation per year.

The Zarafshan River is born between the Turkestan, Gissar and Zarafshan ranges of the Tien Shan in high mountains exceeding a height of 5000 m. There are about 400 glaciers in the Zarafshan catchment area. The middle and lower streams pass through hot steppes and deserts. The river ends blindly in the desert, giving up its water for irrigation, evaporation and filtration into the soil. There are powerful irrigation systems here. Some of the canals have a capacity higher than most rivers in Central Asia (Figure 1).

Fig. 1. Map of Uzbekistan and region of lower Zarafshan River (circled in a square)

We randomly selected 25 grass carp at the age of 1 year during a total harvest of a wintering pond for summer feeding. Morphological identification and systematic status of grass carp were made, using characters given by Berg [3] and Salikhov et al. [7].

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

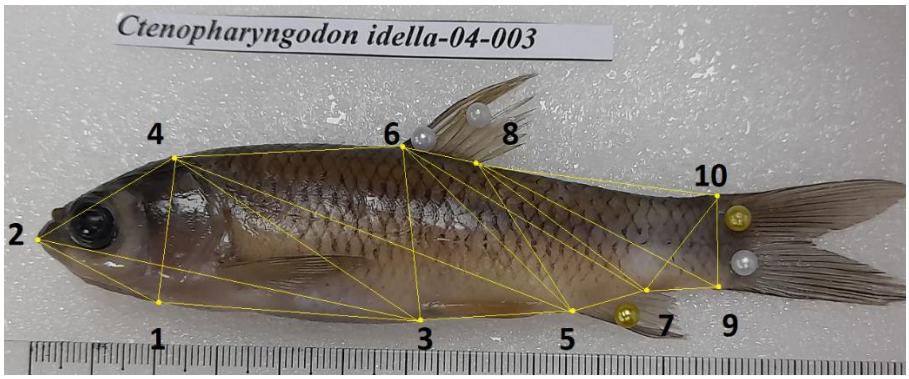

Fig. 2. Landmarks for 'truss-protocol' for grass carp yearlings, pond fish farm, the lower stream of the Zarafshan River, 2023

The plastic characteristics of the fish were measured from digital photographs using the ruler tool in the 'Photoshop' program. The magnification was determined and the results were converted into absolute units of length (mm). Classic plastic characteristics were measured according to the measurement scheme for cyprinids [8]. There were ten markers found around the circumference of the fish body (Figure 2). Using a fixed tripod, each fish was captured at an exact correct angle. The so-called "truss" procedure, which measures distances in a straight line between landmarks, was

created using the images [9, 10]. A straight-line measurement between landmarks 2 and 4 is indicated by the formula "2–4", which is used to specify the sounding lines.
The absolute plastic feature characters were converted into indexes in %% of the standard body length. Statistic characters including coefficient of variation (C_T, %) were calculated; for statistical tests, P values ≤ 0.05 were considered significant.

3. Results

Two-year-old grass carp are characterized by an elongated ridged body and a semi-inferior mouth, with a relatively wide forehead. In the studied sample of one-year-old grass carp, individuals exhibited a total length ranging from 12.6 to 15.2 cm, with an average of 13 ± 0.16 cm, and a standard length ranging from 10.0 to 12.3 cm, averaging 10.77 ± 0.13 cm. This indicates a rapid growth rate of grass carp in pond polyculture environments in the lower stream of the Zarafshan River.
A strong relationship was observed between the standard body length (SL) and total body length (TL) of grass carp yearlings, which was accurately described by the linear regression equation: SL = 0.8624*TL – 1.665 (r = 0.99) (Figure 3). This relationship provides valuable insights into the growth patterns of grass carp at this developmental stage and can be utilized for further studies related to growth modeling and population dynamics.
The morphological characteristics of the grass carp (Ctenopharyngodon idella) are crucial for understanding its biology and ecology. In the studied sample, the meristic indicators provide insights into the typical features of this species. The presence of D III 7 and A III 7-8 indicates the fin ray counts on the dorsal and anal fins, respectively. The lateral line, consisting of 39 - 45 scales, plays a vital role in detecting vibrations and movements in the surrounding water. Additionally, the presence of 19 - 22 rakers on the first gill arch contributes to the fish's feeding behavior and respiratory efficiency.
Notably, grass carp is distinguished by its large scales, which serve as a protective covering for the body. These scales play a crucial role in minimizing injuries and protecting against external parasites. Furthermore, the size and arrangement of scales can vary among individuals, providing a unique pattern that aids in individual identification.
Understanding the meristic indicators of grass carp is essential for researchers and fisheries managers to accurately identify and monitor populations. This knowledge can inform conservation efforts and sustainable management practices for this valuable species.

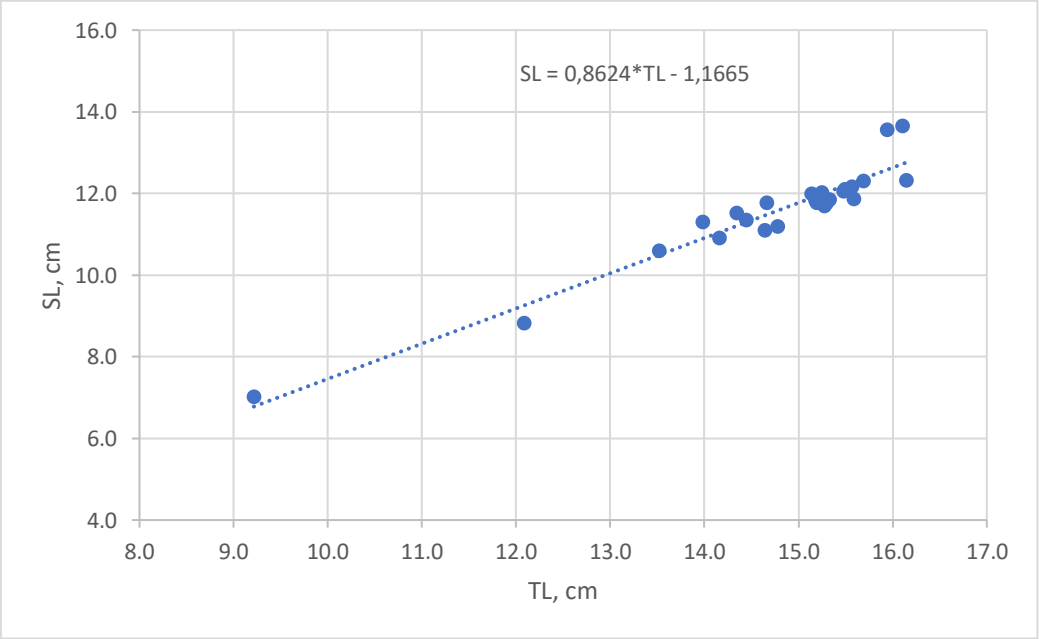

Fig. 3. Relationship between standard body length and total body length of grass carp yearlings, lower stream of Zarafshan River

The plastic characteristics of grass carp (Ctenopharyngodon idella) provide important insights into its body shape and structure. These characteristics are essential for understanding the overall morphology and functional adaptations of the species. In Table 1, the classical scheme for measuring cyprinid fish includes various indices that describe the body proportions and dimensions of grass carp. These indices, such as body depth, head length, and caudal peduncle length, help characterize the overall body shape and proportions of the fish.

Table 1. Indices of plastic characteristics of yearlings of grass carp according to the classical scheme of cyprinids measurements, lower Zarafshan River, 2023

Indicator	Min. – Max.	Mean ± S_M
Total body length (TL)	123.1 – 130.1	127.15 ± 0.38
Body length	64.4 – 89.2	72.7 ± 0.89
Snout length	3.6 – 7.3	5.65 ± 0.20
Eye diameter	5.3 – 11.3	6.83 ± 0.24
Postorbital length of the head	10.7 – 18.6	14.04 ± 0.32
Head length	21.0 – 29.2	25.83 ± 0.44
Head height at the back	15.2 – 20.66	17.44 ± 0.27
Maximum body height	20.2 – 25.2	22.70 ± 0.25
The smallest body height	9.6 – 13.2	11.90 ± 0.16
Antedorsal distance	53.2 – 56.6	54.80 ± 0.18
Postdorsal distance	29.8 – 37.0	33.02 ± 0.46
Caudal peduncle length	7.1 – 14.3	10.88 ± 0.41
Dorsal- fin base length	12.2 – 18.8	14.72 ± 0.31
Dorsal- fin the greatest height	17.9 – 24.2	21.35 ± 0.29
Anal- fin base length	9.5 – 15.9	13.90 ± 0.29
Anal- fin the greatest height	13.1 – 19.3	16.07 ± 0.34
Pectoral- fin length	11.7 – 23.2	19.38 ± 0.50
Ventral- fin length	13.1 – 20.3	15.17 ± 0.34
Pectoral – pelvic fins distance	28.8 – 35.9	31.71 ± 0.40
Ventral – anal fins distance	16.8 – 21.6	19.42 ± 0.23

Table 2 presents the indicators of geometric morphometry, specifically the "truss-protocol," which provides a more detailed analysis of the fish's body shape using a series of linear measurements between specific anatomical landmarks. These measurements capture the spatial relationships between different body parts and provide a more detailed assessment of body shape variation within the species.

Table 2. Indices of plastic characteristics of geometric morphometry (truss-protocol) of grass carp yearlings, lower stream of Zarafshan River, 2023

Indicator	Min. – Max.	Mean ± S_M
2-4	20.8 – 28.3	23.98 ± 0.31
4-6	31.6 – 36.0	33.58 ± 0.20
6-8	10.4 – 15.4	12.64 ± 0.27
8-10	28.5 – 38.3	31.70 ± 0.50
9-10	11.7 – 14.8	13.39 ± 0.17
7-9	7.0 – 13.3	10.47 ± 0.32
5-7	7.2 - 22.6	12.31 ± 0.58
3-5	22.1 – 39.4	25.75 ± 0.75
1-3	49.2 – 60.5	54.48 ± 0.51
1-2	18.0 – 42.7	21.84 ± 0.93
3-4	20.5 – 22.8	21.52 ± 0.13
2-3	31.6 – 43.5	35.48 ± 0.59
1-4	35.7 – 45.0	39.79 ± 0.56
5-6	30.6 – 35.1	33.10 ± 0.21
3-6	24.0 – 32.8	28.11 ± 0.46
4-5	57.7 – 65.2	61.26 ± 0.38
7-8	20.4 - 25.1	22.99 ± 0.26
5-8	34.1 – 43.8	39.88 ± 0.51
6-7	20.0 – 29.5	23.52 ± 0.46
7-10	11.9 – 17.8	15.55 ± 0.29
8-9	31.9 – 39.2	35.96 ± 0.41

By combining the information from both tables, researchers can gain a comprehensive understanding of the morphological variability of grass carp populations. This knowledge is valuable for studying the evolutionary adaptations, ecological roles, and population dynamics of grass carp, ultimately contributing to more effective conservation and management strategies for this species

4. Discussion

Fish species that occupy the initial links of the food chains in hydroecosystems (herbivores) and have fast growth, good taste, have prospects in extensive and semi-intensive pond aquaculture. Grass carp is very promising in this regard. The species can live in both tropical and temperate climates. It is gluttonous, it feeds on higher aquatic vegetation. Grass carp has fast growth rate. It can also perform another important function as a biological melioration agent. Grass carp effectively clears irrigation canals from overgrowth by higher plants. Over 80 countries worldwide were introduced to grass carp throughout the latter part of the 20th century. Grass carp is an important commercial fish species in many of these countries. Among cultivated fish, grass carp holds a prominent position in global aquaculture [11].

The ichthyofauna has been impacted in recent decades by the construction of massive irrigation systems, an increase in water pollution, and other human-caused problems. The species' gene bank is also impacted by fish acclimation programs and the stocking of reservoirs with fish raised in fish farms. It's critical to keep an eye on changes in the biological traits and genetic circumstances of aquaculture species and other commercial fish species [12]. To establish a benchmark for their natural populations, China, the world's leader in the fisheries industry, is continuously researching the growth and morphology of the primary fish farming objects [13]. Morphometric investigations are one of the primary ways to quantify traits regulated by polygenes, as they capture both genetic traits and the capacity for adaptation in a species.

Grass carp is a major commercial fish in Uzbekistan, particularly in aquaculture. Simultaneously, fish hatcheries artificially create grass carp, ensuring constant selection occurs. This has an impact on this species' gene bank as well. Simultaneously, the species was introduced into Uzbekistan's aquatic environments in multiple batches of larvae throughout the early 1960s, resulting in a very small gene pool. It is important to determine the current state of the species in new conditions and monitor changes in the species.

One of the regions where grass carp have been introduced since the 1960s is the lower reaches of the Zarafshan River. It is the southern part of temperate climate. There are fish hatcheries in the region that have mastered the artificial reproduction of the species. To characterize the phenotypic changes of grass carp during their ontogeny, we measured the external morphological characteristics of grass carp yearlings in the region.

The following meristic characteristics are seen in the Russian portion of the native grass carp area: D III 7, A III 8, 12–18 uncommon short rakers on the first gill arch, and 39–47 scales in the lateral line [1, 3, 7].

The following meristic traits of grass carp in the middle reaches of the Syrdarya River were identified previously (in the 1970s) in Uzbekistan: in the dorsal fin III 7 and in the anal fin III 7-8. The lateral line has 39–45(42) scales. There are 19–22 of these small, sparse gill rakers on the first arch. [7].

5. Conclusions

In the studied sample of grass carp yearlings, several meristic indicators were observed. The specimens exhibited a dorsal fin with 7 rays (D III 7) and an anal fin with 7-8 rays (A III 7-8, averaging 8). Along the lateral line, there were 39-45 scales (average 42), indicating a relatively large-scale size characteristic of grass carp. Additionally, the first gill arch possessed 19-22 rakers (average 21).

Notably, the increase in the number of rakers on the first gill arch is a significant finding. This may indicate a developmental or environmental influence on the fish, as changes in gill raker number can reflect adaptations to feeding habits or environmental conditions.

It is important to highlight that the specimens analyzed were yearlings, indicating that they were in an early stage of development. As immature individuals, they may exhibit different morphological characteristics compared to adult grass carp. Understanding these meristic indicators and their variations in different stages of development is crucial for comprehensive studies on the biology and ecology of grass carp populations.

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