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Morphology, Age and Growth of Grass Carp (*Ctenopharyngodon idella*) in Tudakul Reservoir of Uzbekistan

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Abstract: ***The study was carried out from November 2017 to October 2018 in Tudakul reservoir, Uzbekistan. A total 170 grass carps, Ctenopharyngodon idella, were sampled including 81 females and 89 males. Meristic and morphometric parameters were obtained from matured 20 males and 20 females separately. Scale of grass carp is cycloid, large, with straight edges. Annuli on scale of immature fish appeared in March and of mature fish appeared in May (during spawning period). The ages, total lengths and weights of the samples ranged between 1 to 5 years, 16 to 109 cm and 58 to 17000 g, respectively. The relation between total length (TL, cm) and weight (W, g) could be described by equation*** $W=0.0153*TL^{2.9205}$ ***(r = 0.99). The relationship between total length (TL) and standard length (SL) could be described by linear equation: TL = 1.1231*SL+1.3462 (r = 0.99). Mean back calculated total length was at age I – 26.9 cm, II – 58.0 cm, III – 80.4, IV – 94.4 cm, V – 109.1 cm.***

Keywords: grass carp, morphometric characters, age, growth

1. Introduction

The grass carp, *Ctenopharyngodon idella*, is the most biological candidate to control the water weeds in temporary climate zone. The grass carp, a freshwater species native to water bodies of China and far-eastern Russia, have been introduced in more than 100 countries in Asia, Europe, America (Shireman and Smith, 1983). Fry of grass carp together with silver carp, *Hypophthalmichthys molitrix*, and bighead carp, *H. molitrix*, were introduced to aquaculture farms in Tashkent region (Uzbekistan) from northern China and River Amur (Russia) in 1961-1963 (Kamilov, 1973; Kamilov and Urchinov, 1995). Artificially reproduced seeds of those asian carps are used as for fish culture so for regular stocking of plain waters for improving of commercial ichthyofauna and weed control. Asian carps did not find favourable conditions for natural reproduction in most of reservoirs and lakes of the country (Salikhov et al., 2001). Grass carp is important species as for fish culture so for plants overgrowing control as in ponds so in irrigation network of channels.

Many aspects of grass carp biology were studied in conditions of pond fish culture in region, including growth (Verigin et al, 1981). But morphology after naturalization to local environments so as growth of grass carp in wild conditions of the region are poor studied. The objective of this work is to study morphology, age and growth of grass carp in Tudakul reservoir.

2. Material and methods

Tudakul reservoir (fig. 1) was created in the lower reach of Zerafshan River, Uzbekistan (39°51'15"N 64°50'29"E). Summer is hot (average monthly air temperature in July is about 29°C, in daytime often is about 35-42°C). Winter is rather cold (average monthly temperature in January is -2°C, standing water bodies often are covered by ice for 1.5 months). Total area of reservoir is about 22 000 ha, average depth is about 5 m, maximal depth is 22 m. Tudakul reservoir is stocked by large grass carp summerlins (70 – 120 g) so as by silver carp, bighead carp and common carp, *Cyprinus carpio*, each Autumn by "Aqua-Tudakul" fisheries company; stocking density of grass carp was 3-7 summerling/ha in 2004-2010. "Aqua-Tudakul" is a single company carried out fish capturing in reservoir. Fishermen use 5 commercial seines with large mesh (70 – 90 mm mesh in wings of seine net) because catch is oriented to large fishes (more than 2 kg). Catch of grass carp in Tudakul reservoir was 11-50 tones in 2009-2010 years.

Fish samples were collected each 15 days from November 2017 to October 2018 from the Tudakul reservoir by using gill nets with 24, 32, 36, 40, 50, 60, 70, 90, 100, 110 and 120 mm in mesh size. Fish capturing data were kindly provided by administration of "Aqua-Tudakul" fisheries company.

The total length (TL) in the nearest 1 mm and weight (W) in the nearest 1 g were recorded for each fish. Because of standard length (without caudal fin, to the end of scale coverlet) is main body size parameter for fish growth studies in the former USSR and in CIS countries (and much of information is based on this parameter) the relationship with total length for transformation was studied. Standard length (SL) was also measured to the nearest 1 mm for each fish.

All measurements were taken on the left side of fresh fish by the same person in order to minimize measurement bias. In order to examine external morphology, 40 adult individuals were measured using callipers to the nearest 0.1 mm, according to Pravdin (1966). All mensural characters were expressed in % to total and standard length and their basic

statistics (limits, mean, standard error (SE), coefficient of variation (CV) were provided.

Scales (3-4 samples) were taken from 1st row above lateral line under 1st ray of dorsal fin. Scales were cleaned in water and examined under binocular microscope for the age determination. Scales were measured with the aid of a microfiche under magnification 10,0x. Annuli measurements were taken along diagonal transect (radius) between lateral and front sectors of scale.

Index of relative scale size (J) was calculated for each fish according to Galkin (1958) by using the formula:

$$J = (d*100) / SL,$$

where J = index, d = longitudinal diameter of scale in millimeters, SL = fish length without tail in millimeters.

The length-weight relationship was determined according to the equation given by Ricker (1975): $W = a* TL^b$, where W = fish weight in grams, TL = total length in centimeters, 'a' and 'b' are constants.

3. Results

A total 170 grass carps were sampled including 81 females and 89 males. Overall sex ratio between females and males was 1 : 1.1.

Morphomethry. Meristic and morphometric (as percentage in relation to total length and standard length) characters are given for both sexes separately (tables 1, 2).

Scale of common carp is cycloid with central focus and flat edges. Common carp belongs to fishes with large scale; index of relative scale size varied from 4.72 to 5.78 (mean 5.36). Quantity of scales in lateral line varied from 36 to 40 (mean 38).

During the colder months the sclerites (ridges) are crowded together on scales; during the warmer months sclerites are spaced further apart (wide to each other). Annuli (true year mark) are characterized by crowded sclerites. Rather often false rings can be found on scales of grass carp as a result of different unusual events (when growth stop) during vegetation season. False ring are thin and open-ended, visible not around the whole scale, situated in zone of apart sclerites.

Annuli on scale of immature grass carp appear in March and of mature fish appear in May (after spawning which occurs in second half of April – early May).

Annuli are visible in all sectors studied but better on diagonal radius between lateral and front sectors. That's why we have selected this transect for scale and annuli size measurement.

Total length – scale size relationship had strong positive significant correlation (P – 0.05) for transect studied. Relationship between scale size and total length was described by equations *V=0.2127*TL+0.95* and *TL=4.6838*V-4.2616*, where TL = total length, cm, V = size of diagonal radius, mm (fig.2). According to equations found, back-calculations were accomplished by using Fraiser-Lee's modification of direct proportional method (Chugunova, 1963).

Length– weight relationship. There were no significant differences between lengths of the sexes, so all of calculations were made using combined date (female + male). The ages, total lengths and weights of the samples ranged between 1 to 5 years, 16 to 109 cm and 58 to 17000 g, respectively. The relation between total length and weight were plotted for combined sexes (fig. 3).

The relationship between total length (TL) and standard length SL) could be described by linear equation: *TL=1.1231*SL+1.3462* (r = 0.99).

Growth. The limits, mean lengths and weights of different ages of grass carp are given in table 3. Back-calculated growth of grass carp is given in table 4.

4. Discussion

Morphometry has been employed for the identification and classification of fishes including studies of the population structure of species. Quantitative variations of morphological traits have been extensively used to describe the population structure in many organisms (Murta, 2000; Silva, 2003; Clabaut et al., 2007; etc.).

It was found that genetic modification occurs inadvertently in a cultured population. Since there is no competition for food and fear for predators, a farmed fish population experiences different kinds of selection regimes unprecedented in natural waters. It becomes domesticated after some generation of breeding and culture, which bring changes in the gene pool. Changes may also occur in morphology of the domesticated fish (Utter, 1981; Taylor, 1991; Verneau et al., 1994). Adaptation to a local environment of introduced wild fish population also occurred and is resulted by genetic modification which may be revealed by the analysis of morphological traits (Langerhans et al., 2003; Langerhans et al., 2007; Aguirre et al., 2008; Páez et al., 2008; Kristjánsson et al., 2011). In Uzbekistan water bodies we have complex of artificial reproduction (artificially reproduced fry are permanently distributed all over the country including restocking of water bodies) and wild reproduction in the middle streams of Amudarya and Syrdarya rivers.

Grass carp is one of the most important aquaculture species in the world (FAO, 2012). In Uzbekistan, grass carp is also important species for aquaculture and so as for commercial ichthyofauna improving and weed control in irrigation system including reservoirs and lakes for residual waters storage. In Tudakul reservoir, fisheries management uses regular stocking of grass carp with density 3-7 summerlings/ha since 2003. The idea is to produce bigger fish (more than 2 kg), so it will not be in competition with cultural grass carp (0.8-1.5 kg) and more valuable at the same time.

Shireman and Smith (1983) summarized grass carp data and noticed that little variation in gross morphology has been

reported and no subspecies are known. Grass carp body oblong with moderate to large scales. Lateral line complete, running medially on side of the tail, consists of 40-45 scales. Dorsal and anal fins short and without spines. Unfused gill rakers short, lanceolate, and widely set. Pharyngeal teeth biserial and 2.5 - 4.2, 2.4 - 4.2, 2.4 - 5.2, or 1.4 - 5.2. Formula of fins: D - III, 6-8, A – III, 7-8, V – 10 rays.

In our study mainly meristic characteristics are the same except quantity of scales in lateral line: females have 38-44 scales and males 40-48 ones.

A few studies have been conducted on aging grass carp using calcified structures. Otoliths were considered as accurate bony structure for estimating ages of grass carp (Beamish, McFarlane, 1983; Stich et al., 2013). Morrow and Kirk (1995) have used otoliths for age estimation and scales for back-calculation. They have used the Fraser-Lee method with a correction factor calculated by regressing total length against distance to scale margin. Alekseenko (1979) has used back and front radiuses of scales for aging and back-calculation. In this study we have used diagonal radius (between front and lateral sectors) of scale because of better marking of annulies.

Scales grow only when the fish grows. Therefore, size of the scale should be proportional to the fish's length. It was shown that some other calcified structures, for example otoliths continue to grow with age regardless of fish growth (Beamish and McFarlane 1987). We recommend to use diagonal radius (drawn between lateral and front sectors of scale) for aging and measurement for back-calculation purpose because of better marking of annuli and use another calcified structure for aging in addition.

For grass carp both linear (Morrow and Kirk, 1995; this study) and non-linear (Alekseenko, 1979) relationships have been noticed to describe the relationship between the body length and scale radius. The direct proportional method is based on the hypothesis that the scale grows in exact proportion to the total length of the individual. In this study we also use direct proportional method for the grass carp.

Fish growth study including back-calculation models are important tools in fisheries research and management that are used to determine past lengths and growth from the bony structures of fishes. Growth data provides confidence to fisheries biologists about fish population under environments in different ecosystems or management manipulations (Klumb et al., 1999).

The grass carp under optimal conditions, exhibits an intrinsic growth rate perhaps greater than any other fish species. It regularly grows to 1 kg in the first year and at 2-3 kg per year thereafter in temperate latitudes or up to 4.5 kg per year in the tropics, but mainly grass carp growth is studied under aquaculture conditions with regular artificial feeding (Shireman & Smith, 1983). Less results are provided on growth rates in a naturally occurring population.

In previous many-years studies, length without tail was used to estimate growth parameters of inland fishes including common carp in the former-USSR, and the total length in many other countries. All the comparisons were done ignoring this situation (table 5).

Fish growth can be affected by such factors as temperature, stocking density, food availability, and food quality (Gasaway, 1978, Bonar et al., 1993). In Tudakul reservoir, grass carp growth increased at the higher rate during first 3 years of age, whereas, during further years, growth rate slowed due to the fish maturation. In Tudakul reservoir, grass carp growth rate is more or less the same as in lakes of Florida and Alabama, USA, and distinguishly higher then in River Amur, Russia, (from which they were introduced) and reservoirs of neighbouring Kazakhstan (table 5).

Some words about R. Lee phenomenon. Morrow and Kirk (1995) noticed that in Lake Guntersville (Alabama, USA) grass carps at age up to 9 years were studied and Rosa Lee's phenomenon was not detected because there was no any catch of this species in lake. In Tudakul reservoir, phenomenon of R. Lee did not show because "Aqua-Tudakul" fishing company is oriented to the catch of large size (more than 2 kg) fish. So, catch do not take away fish of first two-three years, all fish with different growth are presented in reservoir.

We can make a conclusion that as environments of Tudakul reservoir, so fisheries management in total and stocking rate in particular, are favorable for grass carp population at present. Growth analysis shows that maybe stocking rate can be increased noticeably and this is the subject for future experiments in management manipulation in Tudakul reservoir.

Experience of fisheries management in Tudakul reservoir done by 'Aqua-Tudakul' company (with great attention to creation of local hatchery for direct stocking to reservoir) can be useful for other plain water bodies of Uzbekistan.

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Table 1: Morphological characters of grass carp female in Uzbekistan (n=20)

	Min	Max	Average	Sx	Cv, %
Total length, mm					
Standard length (SL)	370	699	563,1	23,10	15,3
Total body weight (W)	1000	5540	3230,4	372,05	43,1
Scale along lateral line	38	44	40,6	0,45	4,2
Scale above lateral line	6	7	6,4	0,13	7,8
Scale below lateral line	4	6	4,4	0,20	17,1
Dorsal hard fin rays	3	3	3	-	-
Dorsal soft fin rays	7	7	7	-	-
Anal hard fin rays	3	3	3	-	-
Anal soft fin rays	7	8	7,7	0,13	6,2
Pelvic hard fin rays	2	3	2,1	0,07	12,9
Pelvic soft fin rays	8	8	8	-	-
Pharyngeal teeth count	2.4-5.2.	2.4-5.2.	2.4-5.2.	-	-
Gill rakers	13	21	17,4	0,50	10,7

Characteristics	% of TL			% of SL		
	Min-max	Mean± S_x	C_v,%	Min-max	Mean± S_x	C_v,%
Eye diameter	2.3-3.4	2.7±0.08	10	2.6–3.8	3±0.09	0.09
Postorbital length	9.8-12.3	10.8±0.2	6.4	11–13.9	12.2±0.22	0.22
Head length	18.6-22.2	19.8±0.25	4.7	20.9–25	22.3±0.28	0.28
Snouth length	6.7-7.9	7.2±0.1	4.7	7.5–8.9	8.1±0.11	0.11
Head depth	12.7-17.8	14.7±0.33	8	14.3–20	16.6±0.37	0.37
Head width	10.3-12.5	11.10±0.17	5.3	11.6-14.1	12.5±0.19	0.19
Maximum body length	22.8-24.1	18.2±1.57	31.1	25.7-27.1	20.5±1.77	1.77
Minimum body length	7.6-12.3	9.7±0.28	10.7	8.6–13.8	10.9±0.32	0.32
Pre-dorsal length	40.3-46.6	42.8±0.44	3.7	45.4-52.4	48.2±0.5	0.5
Post-dorsal length	34.3-40.4	38.1±0.43	4	38.6-45.5	42.9±0.48	0.48
Pre-pectoral length	19.1-22.0	20.5±0.24	4.1	21.5-24.8	23.1±0.27	0.27
Pre-pelvic length	44.0-49.0	45.0±0.4	3.3	49.5-55.2	50.7±0.45	0.45
Pre-anal length	66.3-70.0	67.9±0.28	1.5	74.6-78.8	76.4±0.31	0.31
Caudal peduncle length	14.2-16.8	15.4±0.18	4.2	16-18.9	17.3±0.2	0.2
Dorsal fin length	8.5-9.6	9.1±0.11	4.3	9.6-10.8	10.2±0.12	0.12
Dorsal fin depth	15.0-16.4	11.7±1.87	56	16.9-18.5	13.2±2.1	2.1
Anal fin length	6.4-8.0	7.3±0.14	7	7.2-9	8.2±0.16	0.16
Anal fin depth	11.9-12.7	8.8±1.41	57.3	13.4-14.3	9.9±1.59	1.59
Pectoral fin length	16.3-17.0	13.1±1.63	45.1	18.4-19.1	14.7±1.84	1.84
Pelvic fin length	14.3-15.0	11.5±1.0	31.4	16.1-16.9	12.9±1.13	1.13
Distance P-V	24.2-27.8	25.9±0.28	3.9	27.2-31.3	29.1±0.31	0.31
Distance V-A	20.2-23.8	22.6±0.28	4.4	22.7-26.8	25.4±0.31	0.31

Table 2: Morphological characters of grass carp male in Uzbekistan (n=20)

	Min	Max	Average	Sx	Cv, %
Total length, mm					
Standard length (SL)	542	649	587	15,3	6,9
Total body weight (W)	2530	4400	3433	309,7	23,9
Scale along lateral line	40	48	43	1,0	6,2
Scale above lateral line	6	7	7	0,2	7,3
Scale below lateral line	4	5	5	0,2	11,7
Dorsal hard fin rays	3	3	3	-	-
Dorsal soft fin rays	7	7	7	-	-
Anal hard fin rays	3	3	3	-	-
Anal soft fin rays	8	8	8	-	-
Pelvic hard fin rays	2	2	2	-	-
Palvic soft fin rays	8	8	8	-	-
Pharyngeal teeth count	2.4-5.2	2.4-5.2	2.4-5.2	-	-
Gill rakers	17	22	19	0,8	10,8

Characteristics	% of TL			% of SL		
	Min-max	Mean± S_x	C_v,%	Min-max	Mean± S_x	C_v,%
Eye diameter	2.6-2.9	2.8±0.01	2.6	2.9-3.3	3.1±0.1	5.6
Postorbital length	10.0-11.6	10.5±0.02	10.0	11.3-13	11.8±0.2	4.6
Head length	18.7-20.4	19.1±0.03	18.7	21-23	21.5±0.3	3.5
Snouth length	6.4-7.7	6.9±0.02	6.4	7.2-8.7	7.8±0.2	6.5
Head depth	14.4-15.6	14.8±0.02	14.4	16.2-17.5	16.7±0.2	2.6

Head width	1.3-11.3	10.8±0.01	1.3	1.5-12.7	12.2±0.1	3.2
Maximum body length	18.8-21.6	20.4±0.04	18.8	21.2-24.3	23±0.4	4.8
Minimum body length	9.5-10.7	9.9±0.02	9.5	10.7-12	11.1±0.2	4.6
Pre-dorsal length	41.8-47.3	43.6±0.07	41.8	47-53.2	49.1±0.8	4.4
Post-dorsal length	37.1-39.2	38.0±0.03	37.1	41.7-44.1	42.8±0.3	1.9
Pre-pectoral length	19.4-21.1	19.8±0.03	19.4	21.8-23.8	22.3±0.3	3.1
Pre-pelvic length	43.5-46.6	45.0±0.04	43.5	49-52.4	50.6±0.4	2.3
Pre-anal length	66.2-68.5	67.2±0.04	66.2	74.5-77.1	75.6±0.4	1.2
Caudal peduncle length	14.4-17.2	15.9±0.04	14.4	16.2-19.4	17.9±0.2	5.6
Dorsal fin length	8.2-10	9.1±0.02	8.2	9.2-11.2	10.2±0.2	5.7
Dorsal fin depth	14.3-15	10.6±0.28	14.3	16.1-16.9	11.9±3.1	68.3
Anal fin length	7.0-7.8	7.4±0.01	7.0	7.9-8.8	8.3±0.1	3.8
Anal fin depth	11.6-12.1	6.4±0.22	11.6	13.1-13.6	7.2±2.5	94
Pectoral fin length	17.1-17.7	14.0±0.24	17.1	19.2-19.9	15.8±2.7	44.7
Pelvic fin length	11.0-12.5	11.9±0.02	11.0	12.4-14.1	13.4±0.2	4.6
Distance P-V	24.8-26.7	25.8±0.03	24.8	27.9-30	29±0.3	2.8
Distance V-A	20.4-23.5	22.1±0.04	20.4	23-26.5	24.9±0.4	4.4

Table 3: Mean length (TL) and weight (W) of grass carp by age groups (Min – Max / Mean ± standard error)

	Age groups				
	I	II	III	IV	V
TL (cm)	16 - 58 25.8±1.0	36 – 63 53.5±0.57	58,8 – 85 76±1.6	80 – 89 85,75±1.32	93 – 109 99,75±2.23
SL (cm)	13.5 - 50 21.8±0.85	31 – 55 46,6±0.50	51 – 74 66.2±1.39	72 – 74 75.5±1.02	81-96 87,5±2.09
W (g)	58 - 2000 255,9±40.38	651 – 2514 1731,4±50.32	2500 – 6400 4888±247.82	5200 – 8300 68504224±529.7	9730 –17000 9730±1012.0
Fish number	59	75	21	8	8

Table 4: The mean calculated total length (cm) determined by back-calculation method according to age groups of grass carp (males and females combined)

Year class	Age group	Number fish	Back-calculated length according to age group				
			I	II	III	IV	V
2010	I	59	28,2				
2009	II	75	26,09	58,7			
2008	III	21	26,7	61,3	82,8		
2007	IV	8	26,2	54,4	78,5	94,3	
2006	V	8	26,1	45,9	75,9	94,4	109,1
Mean total length			***26,89***	***57,97***	***80,42***	***94,35***	***109,06***
Mean annual increment			***26,88***	***32,43***	***23,79***	***15,28***	***16,06***

Table 5: Growth of grass carp in different regions

Region	*	Mean length in each age (cm)									Authors
		I	II	III	IV	V	VI	VII	VIII	IX	
Lake, Florida, USA	***TL***	20	66.1	81.2	90	96.2					Shireman et al., 1980
Lake Guntersville, Alabama, USA	***TL***	33.4	62.7	76.8	85.2	89.6	89.5	92	96.7	97.3	Morrow & Kirk, 1995
River Amur, Russia	***SL***	8.4	16.8	23.6	29.6	35.8	42,4				Konstanti-nova, 1958
Kapchagay reservoir, Kazakhstan	***SL***	8.4	15.3	26.8	29.5	31.5					Dukravets, 1975
Lake Dengizkul, Uzbekistan	***SL***	17.9	25.1	41.0	45.9	59.4	65.4	70.0	17.9		Abdullaev & Khak-berdiev, 1989.
Tudakul reservoir, Uzbekistan	***TL***	26.9	58	80.4	94.4	109					This study
	SL	22.8	50.4	70.3	82.7	95.7					
* - ***TL*** – total length, ***l*** – length without70.3 tail											

Figure 1: Tudakul reservoir

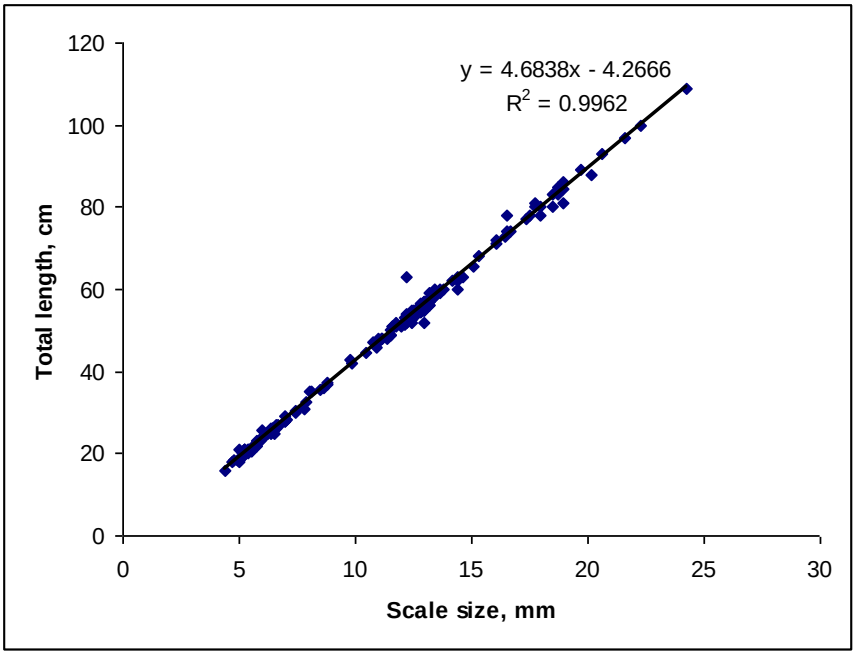

Figure 2: Scale (front and diagonal between lateral and front sectors radiuses) size – total length relationship of grass carp, Uzbekistan

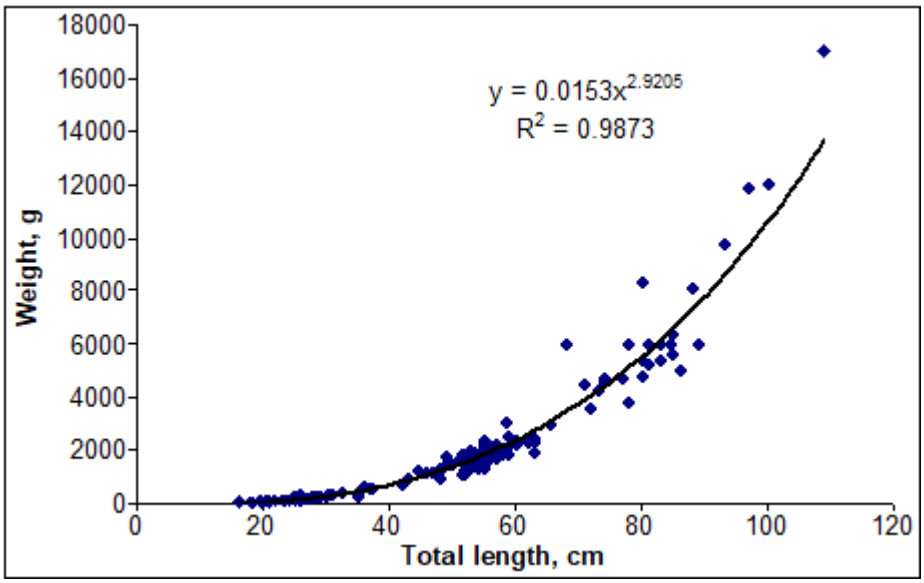

Figure 3: Total length – weight relationship of grass carp