AGE AND GROWTH OF MIRROR CARP (*CYPRINUS CARPIO* L.) AT SEROW FISH FARM

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INTRODUCTION

The mirror carp (*Cyprinus carpio* L.) is a native of central Europe, but it is now widely spread allover the world and lives successfully in nearly all tropical and subtropical countries. It is considered one of the most important fish used for culture.

In Egypt the common carp was first introduced from Indonesia in 1934 (Koura and El-Bolock, 1960). In 1949 it was decided to replace the Indonesian carp with the European common carp which was imported from Closio Farm, Cher Department, France. Since the introduction and successful acclimitization of carp, all the studies were restricted to experimental work at Barrage and Serow Fish Farms. These studies dealt with one aspect of the biology or the other and were carried out for limited periods and on small numbers of carp. (Koura and El-Bolock, 1960 ; Iman and Hashem, 1960 ; El-Bolock and Labib, 1968). All the previous studies are inadequate and complete knowledge of the biology of carp is greatly needed before planning any program on extensive fish culture in Egypt.

As a contribution of the knowledge of the general biology of carp the study of the age, growth, fecundity, reproduction, development, food and feeding habits were carried out. The present study is a part of a series of studies on the biology of carp. (Bishai and Labib, 1972, and Bishai et *alii*, 1972 a and b).

MATERIAL AND METHODS

Fish were collected from the rearing ponds at Serow Fish Farm in the Delta region of the Nile, where they were reared, and all of them were of a known age. Examination of 2150 fish was carried during 1966 — 1968. The fish ranged in length from 5 to 62 cm. total length, and an age from few months to six years old.

Random samples were taken from the catch of each pond. The length of the fish was recorded as the total length (T.L) to the nearest 0.5 cm. from the tip of the snout to the end of caudal fin. The weight was recorded with an accuracy of 0.1 gm., the sex and the stage of maturity was recorded. Scales were collected from below the dorsal fin from the left side. The head and portion of the anterior part of the vertebral column of each specimen were boiled in water for a short time. After boiling opercula, otoliths and vertebrae were cleaned and carefully washed with water, then dried for

three days. All these bony structures were examined, but it was found that the vertebrae were the most reliable for age determination of carp. It was found that the third vertebra is the most suitable one because the rings are clearly represented. These rings appear as alternate light and dark bands. In the light bands the rings are placed at greater intervals, while in dark bands the rings are closely placed. Measurements of the radius of each vertebra are made by placing an occular micrometer along the dorsal radius of the vertebra (posterior dorsal view) and the distance from the center of the centrum to each dark band to the top of the edge of each vertebra is recorded.

Validity of the Use of Vertebrae for Age Determination

The validity of the vertebral method in the present study was indicated by :—

(*a*) Good agreement of the determined age and actual age of fish as the fish being of known age, since they are reared in the fish farm.

(*b*) Increase in the average length with the increase in number of annuli.

(*c*) Good agreement of back-calculated lengths at the end of different years of life as computed from the vertebrae of the same or different age groups and year classes.

RESULTS

Length-Weight Relationship

The relationship between length and weight of carp is calculated by using the following formula :

$$\text{Log } W = \text{Log } c + n \text{ Log } L.$$

where :

W = weight in grams,

L = total length in centimetres.

c and n are constants.

The data of length and weight are presented in table 1 by grouping the fish by one centimeter total length interval, and computing the main total length and weight of the fish. It is found that there is no apparent differences between the weight of males and females, hence the average observed

weighs for both sexes combined were calculated. The average weights are then converted into logarithms, and the linear regression is used whose values are computed by the logarithms of total lengths and actual weights. The length-weight relationship can be expressed by the following formula :

$$\text{Log } W = -1.78056 + 3.02186 \text{ Log } L.$$

or

$$W = 0.01658\, L^{3.01186}$$

It is noticed that the weight increases at a rate equals to the cube of the length. The close agreement between empirical and calculated weights can be clearly seen in table 4 and fig. 1. In fig. 1 the smooth curve represents the calculated weights and the data represents the empirical ones. The difference between the calculated and empirical weights increases at the same rate with increase of length. The calculated weights are higher than the empirical weights for lengths up to 40 centimetres where the empirical weights exceed the calculated weights.

COEFFICIENT OF CONDITION "K"

Individual variation from the general length-weight relationship have usually been considered more interesting than the length-weight relationship itself and have been studied under the general term "condition". Changes in condition have usually been analysed by means of "condition factor", "coefficient of condition" or "pondral index" and has the symbol "K", which is calculated as a ratio between the observed weight and that expected from the observed length.

The value of the coefficient of condition "K" is expressed from the mathematical equation proposed by Fulton 1902.

$$K = \frac{W \times 100}{L^3}$$

where ;

W = weight of fish in grams.

L = total length of fish in centimetre.

The coefficient of condition "K" of mirror carp is represented in table 1, which shows a lower average value for fishes raning from 8 to 40 cm., being 1.56, as compared to fish more than 41 cm. which have a higher average value of 1.88. If all fish sizes are taken in consideration, the average value of K 1.7. It is noticed that carp from 5 to 7 centimetre total length have the highest value of K ranging from 2.08 to 3.06.

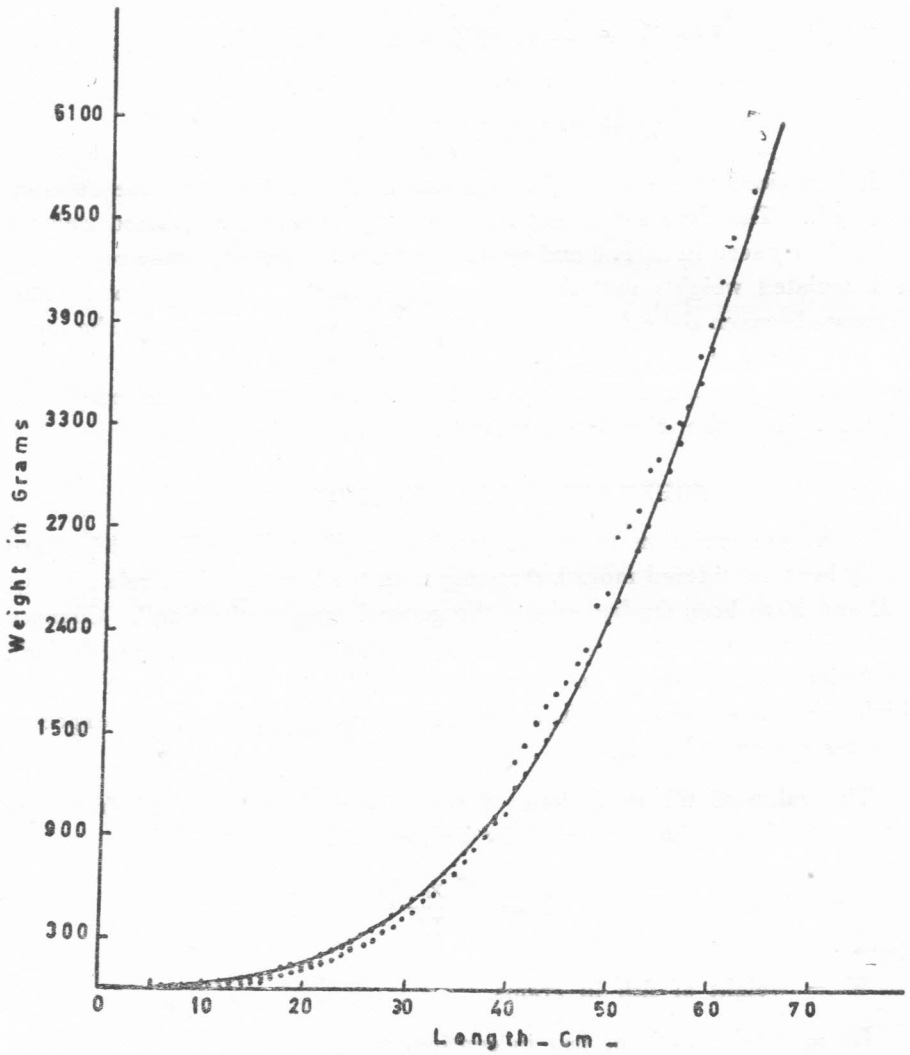

FIG. 1. The relationship between length and weight in the Mirror Carp (*Cyprinus carpio* L.) at Serow Fish Farm.

The increase of the value of the coefficient of condition at lengths more than 40 centimetres may be attributed to the better rate of growth of fish at this size. The study of growth shows that fish more than 41 cm. have higher empirical weights than those of calculated ones when computed from the length-weight relationship (Table 1).

BODY-VERTEBRA RELATIONSHIP

The relationship between the total length of fish and the radius of the vertebrae "V" ($\times$ 20) is determined for mirror carp and the data are represented in fig. 2. The results show that the relationship between the body length and the vertebral radius is represented by a straight line indicating a linear relationship, fitted by least squares to these data and applying the following equation :

$$L = a + b\,V.$$

where :

L = total length of fish in millimetres.

V = total vertebral radius (micrometer divisions).

a, and b are constants.

a is the intercept of the regression line which = 36, which is also a correction factor.

b is the slope and = 4.35.

The formula is found to be :

$$L = 36 + 4.35\,V$$

From this equation the calculated lengths are computed by the formula of Lee (1920) :

$$Ln = \frac{Vn}{V}\,(L - a) + a$$

$$Ln = \frac{Vn}{V}\,(L - 36) + 36$$

where :

Ln = calculated total length in millimetre at end of n years.

L = total length at capture in millimetre.

Vn = vertebra radius at annulus n.

V = total vertebral radius.

TABLE 1. Length-weight relationship and coefficient of condition "K" of mirror carp at Serow Fish Farm.

Number of fishes	Total Length (cm)	Average empirical weight (gm)	Calculated weight (gm)	"K"
12	5	3.8	2.1	3.06
6	6	5	4.6	2.31
15	7	7	5.8	2.08
22	8	9	8.7	1.75
14	9	12.5	12.4	1.70
21	10	15.6	17	1.56
41	11	21.7	22.7	1.62
58	12	25.4	29.5	1.47
87	13	33	37.5	1.50
120	14	41.4	46.9	1.51
114	15	51.7	57.7	1.53
110	16	63	70	1.53
113	17	78	84	1.55
142	18	90	100	1.54
98	19	109.3	117.8	1.59
87	20	124	137	1.55
51	21	141	159	1.52
54	22	161.7	183	1.52
42	23	183	2.9	1.50
37	24	216	238	1.50
51	25	242	269	1.50
57	26	272	303	1.54
50	27	294	339	1.49
69	28	342	379	1.55
70	29	366	420	1.50
59	30	417	466	1.54
36	31	452	514	1.51
37	32	512	566	1.57
35	33	558	621	1.55
33	34	638	679	1.62
29	35	685	741	1.59
28	36	756	807	1.62
34	37	821	876	1.62
20	38	900	950	1.64
14	39	996	1027	1066
23	40	1044	1109	1063
7	41	1350	1193	1.95
13	42	1439	1283	1.94
14	43	1571	1378	1.97

TABLE 1 (*Cont.*)

Number of fisnes	Total Length (cm.)	Average Empirical weight (gm)	Calculated weight (gm.)	"K"
15	44	1672	1477	1.96
12	45	1721	1580	1,88
12	46	1797	1689	1.48
13	47	1727	1801	1.85
28	48	2013	1918	1.82
25	49	2264	1042	2.00
18	50	2358	2170	1.88
9	51	2671	2303	2.01
18	52	2732	2442	1.94
14	53	2821	2586	1.89
10	54	3081	2736	1.95
11	55	3132	2892	1.88
8	56	3299	3053	1.87
10	57	3355	3221	1.81
7	58	3425	3312	1.75
10	59	3733	3574	1.81
7	60	3920	3759	1.81
1	61	4185	3959	1.84
2	62	4455	4150	1.86

The linear relationship between radius of verberae and body length indicates that the vertebrae radius and body length increase proportionally at least for carp varying in length from 100 to 360 mm. total length.

Time of Annulus Formation

Examination of the vertebrae of 650 mirror car during differe*nt* months of the year, showed that marginal annuli are formed during January to March. This coincides with the low temperature prevailing during this period in the rearing ponds. It is worth mentioning that the annuli are formed early or late in the season depending on the sudden drop of water temperature which in certain years is as early as December or as late as February and March. It seems that the low water temperature is accompanied by a decrease in the feeding rate which leads to a low rate of growth, and the formation of the dark narrow rings. Experimental studies on feeding of cary at Serow Fish Farm (Bishai et *alii*, 1972 a) showed a lowest rate during December and February in spite of the abundant artificial food given, as compared to other months of the year when carp was fed on the same amount and quality of food.

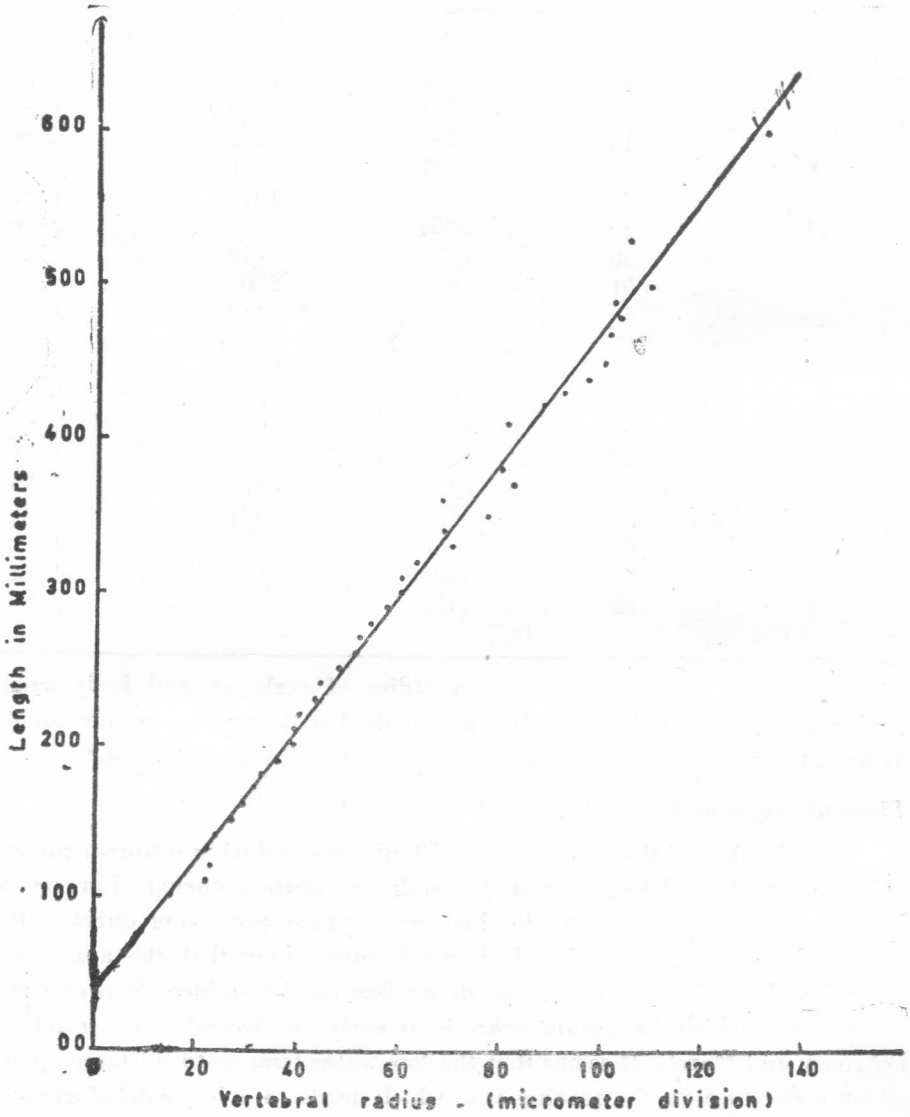

Fig. 2 Relationship between the total length and vertebral radius of *Cyprinus carpio* L, at Serow Fish Farm

GROWTH IN LENGTH

Table 3 shows the lengths at capture and those calculated at the end of each year of life of both sexes of mirror carp. The results indicate little differences between males and females in back calculated lengths at the end of each year of life (Fig. 4). The growth curve rises rapidly in the first year reaching an average of 135.4 mm. (Fig. 3). After the first year the average annual increment of length increases at the same rate ranging from 61 to 72.7 mm. (Table 2).

TABLE 2. The relationship between age, average total length at capture and calculated total length at the end of different years of life of *Cyprinus carpidl* L.

Age group	No. of fish	Average total length at capture mm.	Average calculated length at the end of each year of life (mm.)					
			1	2	3	4	5	6
I	332	190.6	145.9					
II	133	278.9	160.2	225.3				
III	73	351.0	158.0	225.7	288.6			
IV	20	239.0	160.6	224.3	297.1	364.2		
V	13	531.0	145.7	201.0	264.0	330.0	416.7	
VI	2	550.0	150.0	224.0	275.0	338.0	400.0	481.0
Grand Average	573	—	153.4	220.1	281.2	344.3	408.3	481.0
Increment of length . . .		—	153.4	66.7	61.1	63.1	64.0	72.7
% of annual increment	—	—	31.9	13.9	12.7	13.1	13.3	15.1

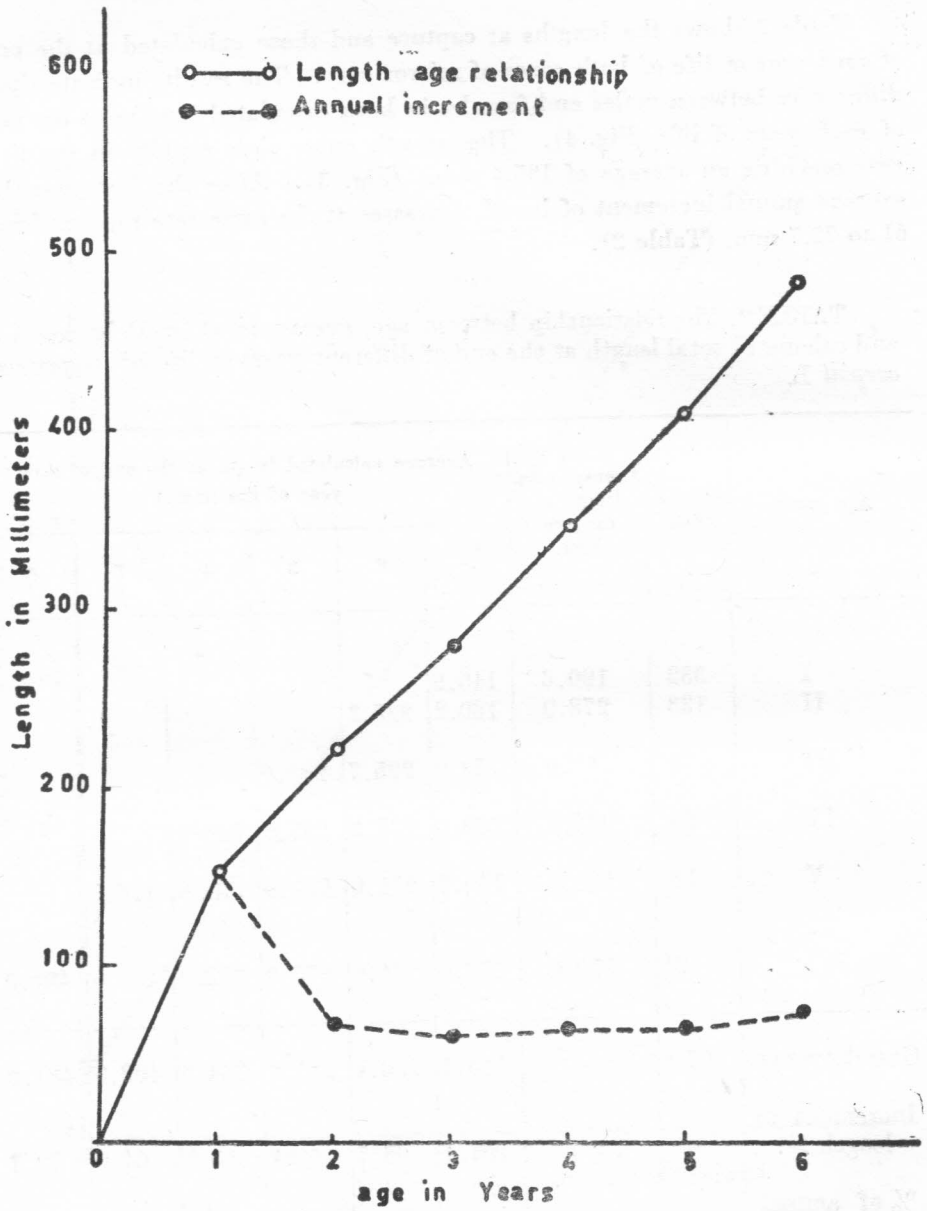

FIG. 3 Relation between average length and age of *Cyprinus carpio* L.

The low value of length as given by back calculation may be attributed to the fact that they indicate the length of fish when the annual ring is formed. The acutal length at capture is recorded irrespective of the position of the outermost annual ring whether it has a marginal or a deep marginal position i. e. either it is recently formed or it is formed a few months before.

After the first year it is evident that the growth in length of males is little more than that of the females (Fig. 4). It is concluded that the percentage increment in length of male and female mirror carp is greatest during the first year than in the following year being 31% and 32.8% respectively. From the second year the percentage increment ranges from 13.5 to 16.3% for males and 13.9 to 14.3% for females (Table 3).

It is evident that the growth rate in length of mirror carp at Serow Fish Farm reaches 153.4; 220.1; 281.2; 344.3; 408.3 and 481 mm. at the end of the first to the sixth years of life respectively for both sexes. The growth in length of carp in the first year of life is higher in Egypt, this may be attributed to the long period of higher temperature when optimal growth conditions prevail.

GROWTH IN WEIGHT

The calculated weights for different years of life of mirror carp are shown in Fig.5 which are derived by using the following length-weight equation :

$$\text{Log } W = -1.78056 + 3.01186 \log L.$$

It is evident that the growth in weight increases slowly during the first year, rapidly in the second and third years, and more rapidly in the forth and fifth years and reaches its maximum in the sixth year. The grand average calculated weights for mirror carp are : 62.1, 184.3, 385.6, 709.1, 1181, 1931 gms. for the 1st to the 6th years of life respectively. The percentage increment increases from 3.2% in the first year to 38.9% in the year in respect of the growth of 6th years (Table, 4).

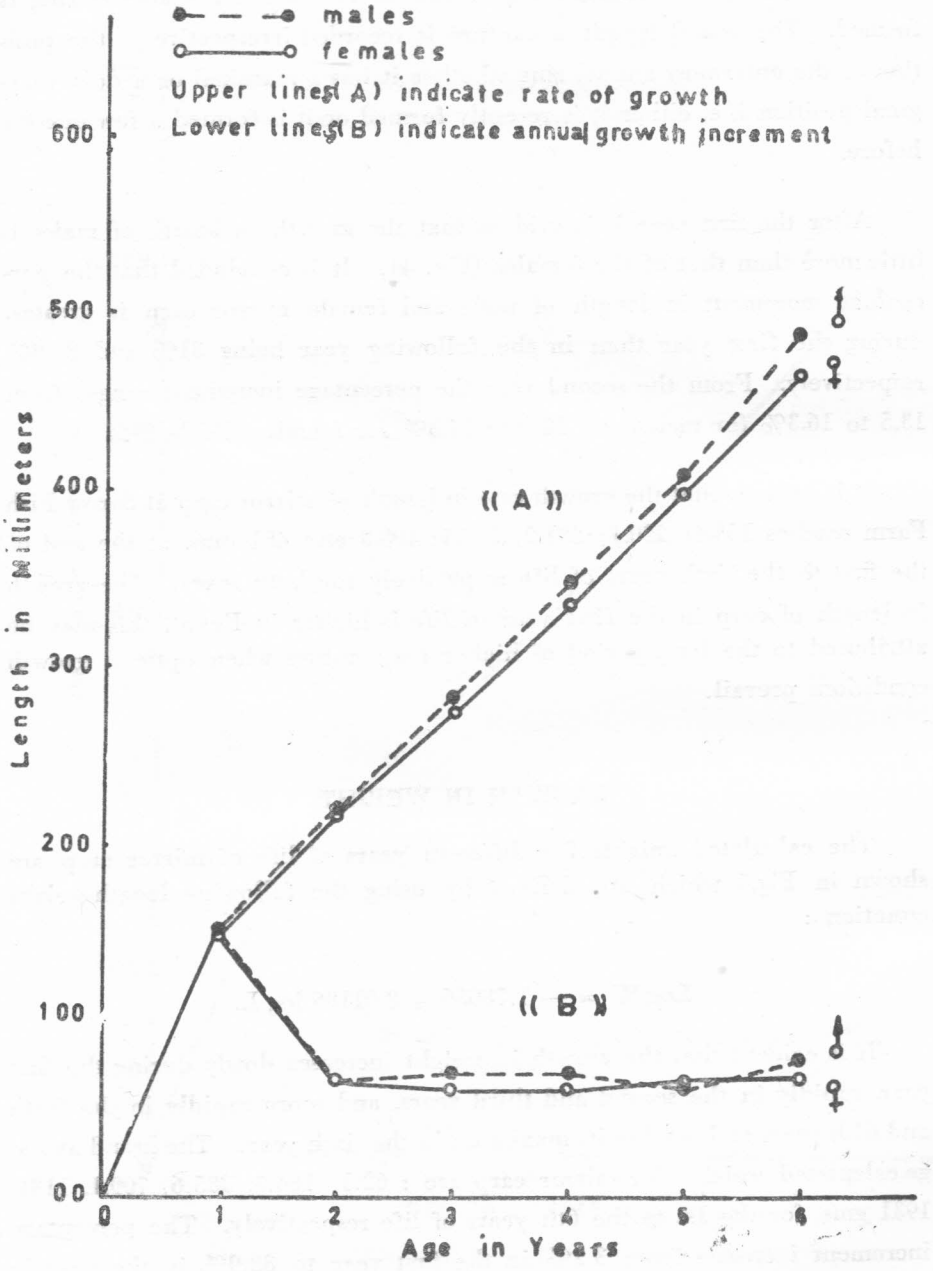

FIG. 4 Relation between length and age of female and male *Cyprinus carpio* L.

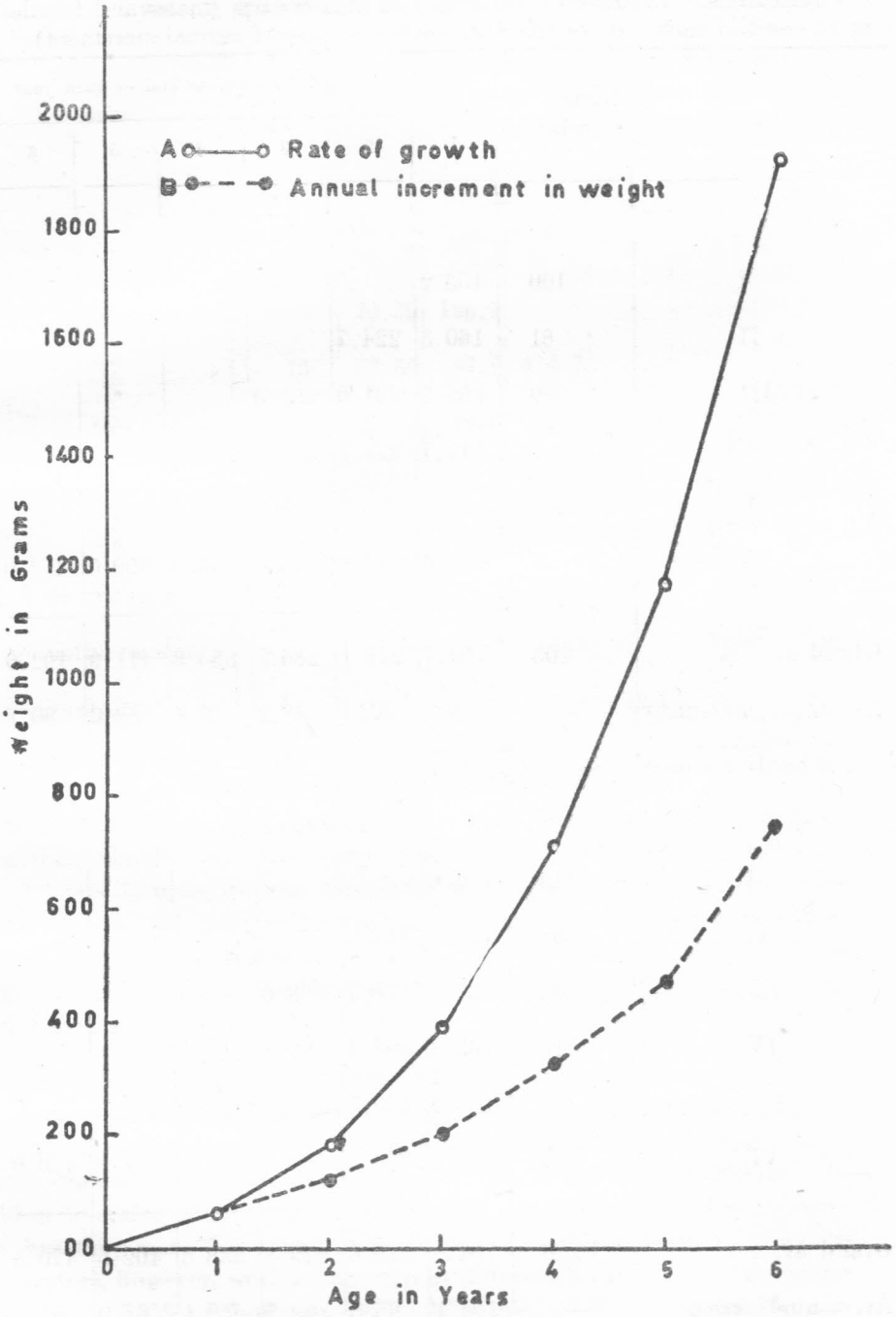

FIG. 5 Relation between weight and age of carp
(Cyprinus carpio L. *)*

TABLE 3.—Calculated total length of mirror carp (males and females at the end of each year of life and the percentage of annual increment).

Age group	Number of fishes	Galculated length in mm. at end of each year					
		1	2	3	4	5	6
				Males :			
I	100	155.2					
II	61	160.3	224.7				
III	29	152.9	221.0	281.0			
IV	4	147.7	221.3	319.7	380.4		
V	8	149.3	206.7	268.0	334.7	424.8	
VI	1	151.0	217.0	276.0	345.0	399.0	492.0
Grand av.	203	152.7	218.1	286.2	353.3	411.9	492.0
Av. anual increment	—	152.7	65.4	68.1	67.1	58.6	80.1
% of annual increment	—	31.0	13.3	13.9	13.6	11.9	16.3
				Females :			
I	142	152.6					
II	68	159.1	222.5				
III	44	161.5	228.7	293.6			
IV	16	163.8	225.1	291.4	360.0		
V	5	138.0	192.0	257.6	323.5	404.0	
VI	I	150.0	230.0	275.0	332.0	401.0	470.0
Grand av.	276	154.1	219.6	279.4	338.5	402.5	470.0
Av. annual increment	—	154.1	65.5	59.8	59.1	64.0	67.5
% of annual increment	—	32.8	13.9	12.7	12.6	13.6	14.4

TABLE 4.—Average calculated weights of mirror carp at the end of each year in grams, and the percentage of annual increment

Age group	No. of fishes	Av. calculated weights at the end of each year (geams)					
		1	2	3	4	5	6
I	332	53.15					
II	133	70.39	196.7				
III	73	67.56	197.8	414.7			
IV	20	70.92	194.0	452.5	834.8		
V	13	52.93	139.9	317.1	622.0	1253	
VI	2	57.76	193.0	358.1	670.5	1109	1931
Grand av. wt.	573	62.10	184.3	385.6	709.1	1181	1931
Av. annual increment .	—	62.10	122.2	201.9	323.5	471.9	750
% of annual increment	—	3.2	6.3	10.4	16.8	24.4	38.9

GROWTH IN WEIGHT AND SEX

It is evident from this study at Serow Fish Farm that male carp grow better than females after the second year of life and that the growth rate of both sexes is more or less, the same during the first and second years of life. In the 3rd. year males are heavier than females. The difference, however, between the two sexes is slight. In the 4th, 5th, and 6th years of life the difference in weight between both sexes is high, males being heavier than females (Fig. 6).

DISCUSSION

Studies on age determination of mirror carp at Serow Fish Farm showed that vertebrae are the most suitable bony structures for this purpose. Clear growth annual rings are found on both surfaces of the third vertebrae. In addition to scales other bony structures such as otoliths and opercula were used but they were not found suitable for age determination. Previous investigators, however, working on carp at different localities used the scales (Van Oosten, 1929 ; Schoffman, 1957 ; Walburg and Nelson, 1966), fin rays (Boyko, 1940) and opercula (Sigler, 1958).

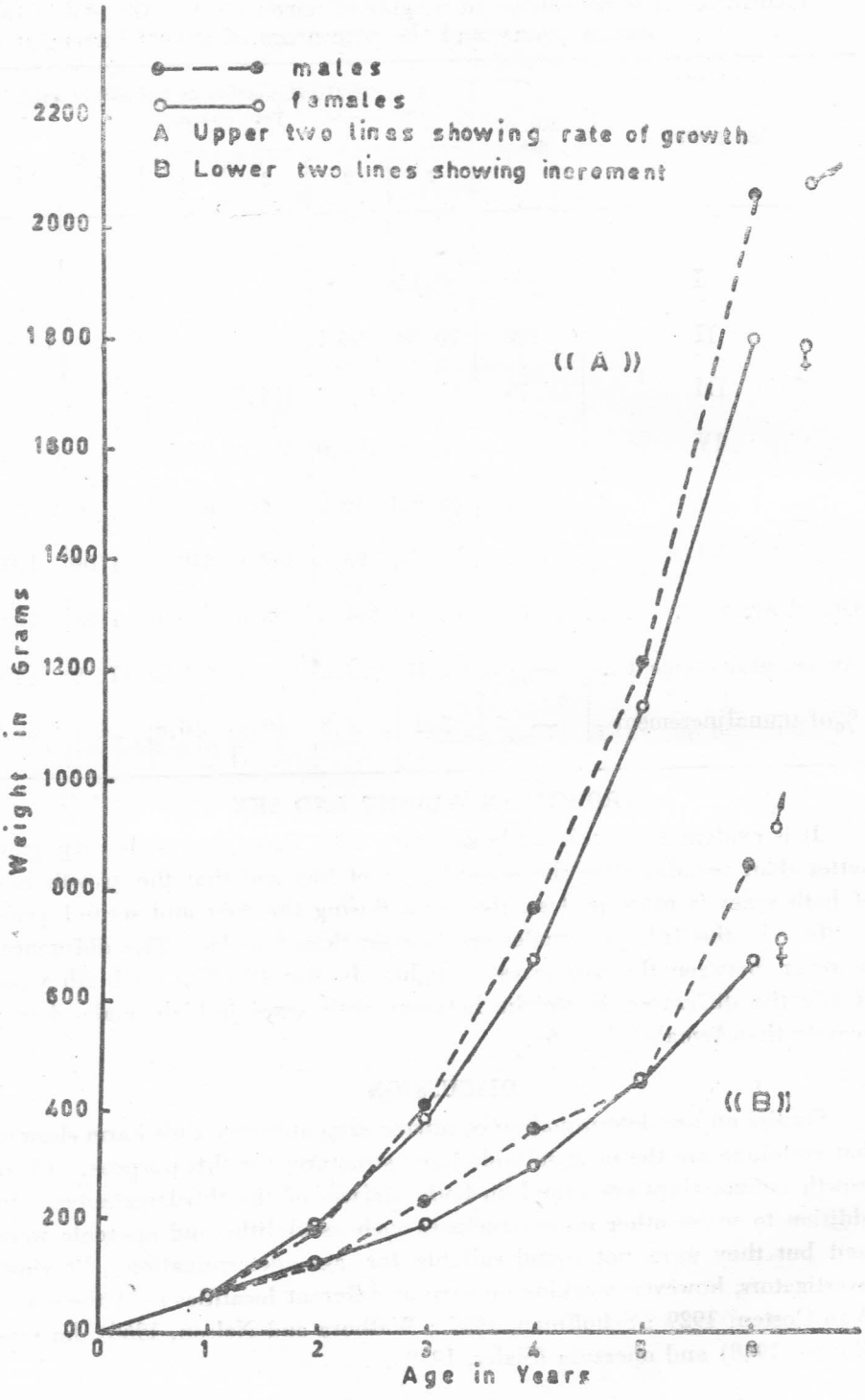

FIG. 6 Relationthip between age and average weight of female and male carp *(Cyprinus carpio* L.*)*

The age determination of fish living in subtropical and tropical regions is rather difficult on account of the slight fluctuation in the environmental conditions as compared to temperate zones where rings are formed as a result of the remarkable differences between winter and summer temperatures. In temperate regions growth is controlled by food supplies and temperature particularly the latter which has been shown to control the growth of fish in addition to internal factors. Various authors pointed out this difficulty in determining the age of tropical and subtropical fish, Chugonova, 1959; Lagler *et al.*, 1962 etc... Chugunova (1959) showed that in tropical regions where the winter is warm, the annuli develops as a results of cessation of growth during dry periods and in connection with gonad maturation.

The difficulty in determining the age of carp in Egyptian waters may be one of the reasons why previous investigators restricted their studies on growth and spawning etc. (Kaura and El-Bolock, 1960; Imam and Hashem, 1960) without the determination of age.

In the present investigation it is established that the vertebrae are the suitable bony structures for age determination. This is supported by the agreement between age determination from vertebrae and the actual age of fish reared in the ponds and from back calculation. The dark narrow rings are usually formed during January to March when the water temperature is comparatively low and the fish seems to feed little. These annuli may be formed earlier or late in the season depending on the onset of low temperature.

When considering the body-vertebra relationship of mirror carp it is found that this relationship can be expressed by Lea's equation (p. 401). This relationship is represented by a straight line and it is concluded that Lea's proportion can be used for growth calculation of mirror carp, as it gives the best fit for this relationship. The correction factor "a" which equals 36 means that the length of young fish when the vertebrae are first eppearing is 36 millimetres. Similar results were found by other investigators working on common carp but using the scales or opercles. English (1952) in his study of carp from Clear, Lake, Iowa used the body-opercle and body-scale relationship. In both cases he found that the straight line is sufficiently close to the actual relationship. Silger (1958) using the body-operculum relationship showed that the length-opercular relation is satisfactory represented by a straight line.

The results of the present study suggest that the greatest growth in length occurs during the first year of life and annual increment decreases in successive years ranging from 71 to 72 mm. Many authors pointed out that the period of rapid growth of many fishes is usually in the first year or two years of the (Frost and Smyly, 1952; Sigler, 1958; Nikolsky, 1963; Walburg and Nelson, 1966 etc...). Silger (1958) in his work on carp found that the average annual increment of growth from calculated lengths at the end of each year showed rapid rate of growth in the first two years, slowing up in the third year and a gradual leveling off up to the tenth year. He found that carp reaches an average length of 154.2, and 230 millimetres at the end of the first year in Bear Lake Refuge and Ogden Bay Refuge respectively.

At Serow Fish Farm, Egypt, mirror carp attains an average total length of 153.4 mm. at the end of the first year and 220 mm. at the end of the second year. The high growth rate of mirror carp in the first year agrees with the conclusions of Nikolsky (1963) who showed that the period of most rapid linear growth of carp usually occurs before the onset of maturity. The growth in length of male carp after the second year of life is sligthly higher than that of the female, and continues to be so till the 5th year. A similar observation was recorded by Sigler (1958) who found that in Ogden Bay Refuge, Utah male and female carp differ slightly in their length-weight relationship. He showed that plotted figures indicate that the differences favours the males that they are somewhat larger and heavier.

In contrast to the growth in length, the growth of mirror carp in weight is slow during the first year, rapid in the second and third years and more rapid in the fourth and fifth years and reaches its maximum in the sixth year. It seems that carp puts more weight as it grows older. A difference is recorded between the weights of male and female carp. Males seem to grow better than females after the second year of life. During the first and second years there is no high difference between the weights of male and female carp. This is in close agrement with the finding of previous investigators working on common carp at different localities (Wlodek, 1959; Krauper, 1964 ; Kempinska, 1968 etc...).

The growth rate of a fish is affected by many factors, such as enviromental conditions, genetic factors, low food supply, high rate of stocking in reared fish pond etc. If we consider the enviromental conditions at Serow Fish it is noticed that the temperature is high for most of the year ranging from 17.4 °C in March to 31.3 °C in August being within the optimal

temperature for carp. Hora and Pillay (1962) pointed out that the optimal water temperature for carp lies between 20 to 25°C. Water analysis showed that all other physicochemical characteristics are favourable for good growth, i.e. high oxygen content, nutrient content etc. Furthermore the natural and artificial food is abundant, the latter consists of rice bran and cotton seed cake which have a high nutritive value.

The low growth rate of mirror carp at Serow Fish Farm may be attributed to the high stocking rate of the experimental ponds being more than 3000 fry per faddan (a faddan = 4000 m^2). In addition it is noticed that in the experimental ponds where carp is reared other prolific fish are also found such as *Tilapia* spp. *Clarias* lazera. These fishes may account for the low growth rate of the mirror carp, especially *Tilapia* spp. which breeds thoughout the year and compete with carp for food and space. In order to obtain a high growth rate and yield of mirror carp in poinds it is recommended that :

(*a*) A comparatively low stocking rate (less than 3000 fry per feddan) should be adopted.

(*b*) Exclusion of other fish as much as possible (as *Tilapia* spp.) and if present it should be thinned out periodically, or a predator fish is introduced.

The study of length-weight relationship of fish is of great importance for fishery managment especially the length and weight may be determined with accuracy. Various authors emphasised the importance of this relationship and discussed its uses (Beckman), 1948 ; Le Cren, 1951 ; Rounsefell and Everhart 1953 ; ... etc). When considering the length-weight relationship of mirror carp at Serow Fish Farm it is found that this relationship can be expressed by the following formula :

$$W = 0.01658\ L^{3.01}$$

It can be seen that the weight increased at a rate equals to the cube of length. This growth rate is, however, higher than that found by Kaura and El-Bolock (1960), who worked on the same variety but at Barrage Fish Farm, Egypt. They suggested the following equation :

$$\text{Log } W = -3.8709 + 2.6404 \log L.$$

The value 2.6404 is an average, which is low for fishes less than 260 millimetre, being 2.3432, and high for fishes longer than 260 millimetre being 2.8915.

If a comparison is made between the present results on common carp at different localities, it is found that the present value of n (3.01) is nearly the same at that obtained by Sigler (1958) for carp at Bear and Clear Lake at Utah, U.S.A., but higher than that for other localities at Utah, and Lewis and Clark Lake, U.S.A. (Walburg and Nelson, 1966).

The coefficient of condition "K" is widely used as an indicator to give an idea about the degree of well-being of fish and its relative robustness, irrespective of the actual length-weight relations. It aids to detemine physical condition, suitability of habitat or spawning time. The present results show that the coefficient of condition (K value) for mirror carp ranging between 80 and 400 mm. is 1.56. For fish more than 410 mm. long it increases and has an average of 1.88. This is paralleled by high values of emperical weights of fish longer than 410 mm. as compared to the calculated ones when computed from the length weight relationship. Sc'aeperclaus (1933) found that the average value of "K" of normal Galic.an carp was 1.8 for lengths ranging from 5—25 cm. Sigler (1958) working n carp at five localities at Utah, gave different values of "K" ranging from 1.72 to 3.80.

SUMMARY

1.—This study is based on the examination of 3000 mirror carp collected from Serow Fish Farm during 1966—1968. The average length-weight equation derived from combined data of both sexes was :

$$W = 0.01658\ L^{3.01}$$

2.—The average value for the condition factor "K" was 1.7 for all length; being lower (K = 1.56) for fish 8—40 cm. long and higher (1.81) for carp 41—62 cm. long. Results show that carp longer than 40 cm. have better growth than smaller ones.

3.—The vertebrae are the most reliable skeletal structure used for age determination of carp in Egyptian water. They show dark and light rings. The dark rings are formed during January to March when the temperature is lowest and even if food is given in sufficient quantities.

4.—The relation between body length and vertebra radius was found to be a linear one and the equation representing this relationship is given for carp 10—56 cm. total length.

5.—The average lengths attained by carp during the 1st to 6th years of life are 153.4 ; 220.1 ; 281.2 ; 344.3 ; 408.3 and 481 mm. The percentage annual increment for male and female mirror carp ranges between 13.3 — 16.3% and 13.9—14.3% respectively.

6.—Mirror carp show slow annual increment in weight during the first year, a rapid increment in the second and third years of life and more rapid in the fourth to the sixth years. Carp attains 62.1; 184.3; 385.6; 709.1, 1181 and 1931 gm. during the 1st to 6th years of life.

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