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# Growth Conditions and Stock Analysis of the Carp (*Cyprinus carpio*, Linnaeus 1758) Population in Gölhisar Lake

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**Abstract:** In this study, growth in the carp population was investigated using samples caught with longline nets of different mesh sizes. Mortality rate and stock analysis were calculated by length frequency data taken from commercial fisheries.

The age composition of the samples was from I to VI. The fork lengths were between 10.5 and 49.4 cm, the total weights were found to be between 20.19 and 1922.20 g. and condition factors ranged from 1.298 to 2.388. The total mortality rate (Z) was found to be 1.36±0.10, the natural mortality rate (M) was 0.35 and the fishing mortality rate (F) was 1.01. The mean fish number longer than 28 cm in length in the population and the mean biomass were estimated as 26416 and 17564 kg, respectively. From simulations of the fishing mortality rates for each length group, it was determined that the Maximum Sustainable Yield (MSY) could be obtained with the present effort.

**Key Words:** Carp, Growth, Mortality rate, Stock.

## Gölhisar Gölü Sazan (*Cyprinus carpio* L., 1758) Populasyonunda Büyüme Özellikleri ve Stok Analizi

**Özet:** Bu çalışmada sazan populasyonundaki büyüme, değişik göz açıklığındaki ağlarla yakalanan örnekler üzerinde incelenmiştir. Ölüm oranları ve stok analizi ise balıkçıların avlamış olduğu üründen alınan boy frekans örnekleri üzerinde yapılmıştır.

Sazan örneklerinde yaş dağılımı I ile VI arasında değişmiştir. Çatal boylar 10.5 ile 49.4 cm, total ağırlıklar 20.1 ile 1922.2 g arasında, kondüsyon faktörleri ise 1.298 ile 2.388 arasında değişmiştir. Total mortalite oranı (Z) 1.36±0.10, doğal ölüm oranı (M) 0.35 ve balıkçılık ölüm oranı (F) 1.01 olarak bulunmuştur. Populasyonda 28 cm nin üzerindeki ortalama birey sayısı 26416, ortalama biomas ise 17564 kg olarak tahmin edilmiştir. Her boy grubunun karşısındaki balıkçılık ölüm oranlarının simülasyonu ile Sürdürülebilir Maksimum Ürünün mevcut av gücü ile alınabileceği tesbit edilmiştir.

**Anahtar Sözcükler:** Sazan, Büyüme, Ölüm oranı, Stok.

## Introduction

Fish populations are renewable source if they are exploited in a planned manner. Therefore, fisheries is one of the most important sources of revenue to the economy of a country. Also, it is an important food sector in human nutrition. People make use of this sector through commercial fishing, aquaculture and recreation.

To improve inland fisheries in the country, first of all, some studies must be carried out on stock assessment in lakes or reservoirs so the Maximum Sustainable Yield (MSY) and fishing effort in lakes can be determined. For this reason, in this study the maximum fishing effort and the potential yield of the carp stock in Gölhisar Lake were investigated. In order to achieve these objectives, growth parameters, mortality rates, and the population structure of the carp stock should be put forward. Therefore, in this study, growth characteristics, mortality rates, and a stock analysis of the carp population in Gölhisar Lake were investigated.

## Material and Methods

Gölhisar Lake is a small water body, located between Uylupınar and Yamadı Villages in Burdur Province (Figure 1). The area of the lake is about 400 ha, and the

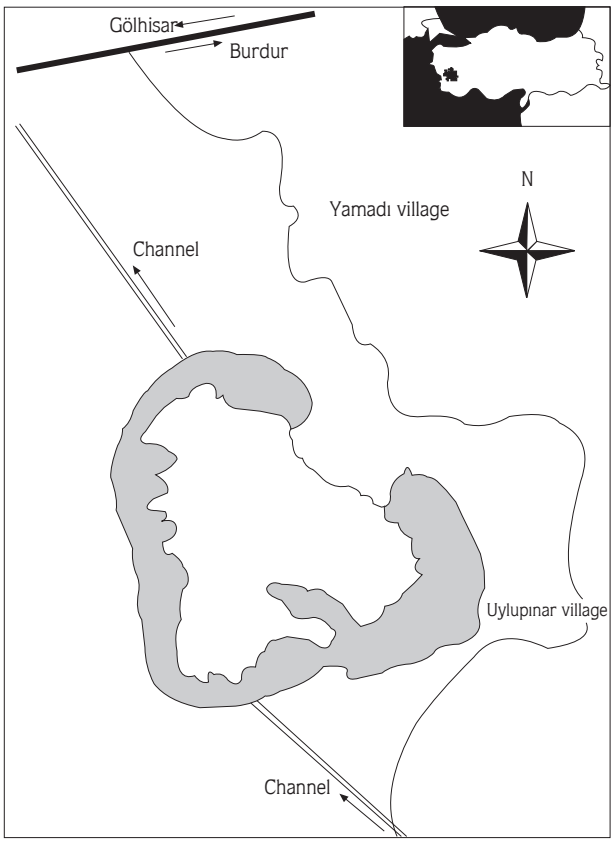


Figure 1. Map of Gölhisar Lake showing the study area.

maximum depth is 2 m. The ichthyofauna of the lake consists of fish species such as *Cyprinus carpio* L., 1758; *Stizostedion lucioperca* L., 1758; *Leuciscus borysthenicus* Kessler, 1859; *Silurus glanis* L.,1766 and *Gambusia affinis* Baird and Girard,1853. (1). There were 15 fishing boats with 6000 m long line nets operating in the lake in the 1994 fishing period.

The samples used in this study were caught with longline nets of different mesh sizes, and were obtained from the yield of the commercial fisheries. In catching fish samples for determining the growth characteristics, the mesh size ranged from 20 to 80 mm (20, 30, 40, 50, 60, 70, 80 mm). The scales of the fish samples were prepared in order to determine ages. The samples used for stock analysis were taken from the yield of commercial fisheries.

To investigate the growth of the carp population, the following equations were used (2,3,4,5):

$$L_{(t)} = L_{\infty} * [\, 1 - e^{(-K*(t-to))} \,]$$

$$W_{(t)} = W_{\infty} * [\, 1 - e^{(-K*(t-to))} \,]^{b}$$

$$W = a * L^{b}$$

Where;

$L_{(t)}$: fork length (cm) in "t" time; $L_{\infty}$: infinitive fork length (cm); K: Brody growth coefficient; t: time (age); $W_{(t)}$: Total weight (g) in "t" time; $W_{\infty}$: infinitive weight (g); and "a" and "b": constants.

Fulton's coefficient of condition factors (C) was computed by:

$$C = ( W / L^{3} ) * 100$$

Natural mortality rates in the population were calculated by the following equation (5,6,7):

$$\ln M = - 0.0152 - 0.279 * \ln L_{\infty} + 0.6543 * \ln K + 0.463 * \ln T$$

In the estimation of the total mortality rate, the Length-Based Linearized Catch Curve Method was used. In this method, the length values taken from commercial fisheries were noted, and the age of each length group was estimated using the von Bertalannfy Equation. Then, a linear regression analysis was applied for $y= \ln (C_{(L1,L2)} / \Delta t)$ , $x= t ( ( L_1 + L_2 )/ 2)$ and the slope (b) was found to be "Z" (7). The percentage of mortality in the exploited stock was found with the following equations:

$$S=e^{-Z}, \quad C= (F/Z)*(100-S), \quad D= (M/Z)*(100-S)$$

Where:

M: natural mortality rate; K: Brody growth coefficient; T: annual mean water temperature (ºC); Z: total mortality rate; S: the percentage of surviving fish in one year; C: the percentage the of catch; and D: the percentage of natural deaths.

In the stock analysis, the "Virtual Population Analaysis Method" was used. This method is based on determining the life circle of cohorts, and finding the mean fish number and mean biomass in the exploited stock. The virtual carp population in Gölhisar Lake was assessed by the following equations (7,8):

$$t_{(L1)} = t_{0} - (1/K) * \ln [1 - ( L_{1} / L_{\infty})]$$

$$\Delta t = t_{(L2)} - t_{(L1)} = (1/K) * \ln [(L_{\infty} - L_{1}) / (L_{\infty} - L_{2})]$$

$$H_{(L1, L2)} = e^{((M*\Delta t)/2))} = [(L_{\infty} - L_{1}) / ( L_{\infty} - L_{2})]^{M/2K}$$

$$F / Z = C_{(L1, L2)} / [N_{(L1)} - N_{(L2)}]$$

$$F = M * ( F / Z ) / ( 1- ( F / Z ) )$$

$Z = F + M$

$N_{(L1)} = [N_{(L2)} * H_{(L1, L2)} + C_{(L1, L2)}] * H_{(L1, L2)}$

Where:

$t_{(L1)}$: age of $L_1$; K: Brody growth coefficient; $\Delta t$: time interval; $H_{(L1,L2)}$: natural mortality factor; and Z, M, F: total, natural, and fishing mortality rates, respectively.

In determining the Maximum Sustainable Yield (MSY) of the carp stock in Gölhisar Lake, the bioeconomic stock analysis method was applied and the following equations were used ( 7 ) :

Length interval = $i = (L_i , L_{i+1})$

$Z_i = M + X * F_i$

$N_{(Li+1)} = N_{(Li)} * [ ( (1/H_i)-X*(F_i/Zi) )/(H_i -X*(F_i/Z_i) ) ]$

$C_i = [ N_{(Li)} - N_{(Li+1)} ] * X * F_i / Z_i$

$W_i = a [ ( L_i + L_{i+1} ) / 2 ]^b$

$Y_i = C_i * W_i$

$N_i * \Delta t_i = [ N_{(Li)} - N_{(Li+1)} ) ] / Z_i$

$B * \Delta t_i = N_i * ( ti * W_i )$

Where:

X: simulations factor (F-factor); C: catch number in the commercial fisheries; W: mean fish weight in annual yield; Y: yield;

## Results

### The Growth Characteristics

To investigate growth parameters in the carp population, during the study 13000 m longline nets were used and 693 carp samples were caught. Length groups and the number of fish caught are given in Table 1 according to the length and mesh size of the nets.

As it may be seen in Table 1, 189 of the 693 fish caught are longer than 28.5 cm. This was equal to 27.3% of the population. In the case of 1000 m longline nets, it was calculated that 287 fish were caught and 115 of these were longer than 28.5 cm. This ratio was equal to 40% of the population.

The fork lengths (LF) of the samples in the carp population ranged from 10.5 cm to 49.4 cm. The mean

Table 1. The number of fish caught and their length groups according to the length and mesh size of the nets.

| | Caught | | | | | | | | Calculated (Net lengths =1000 m) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Length interval | 20 3000 (m) | 30 3000 (m) | 40 3000 (m) | 50 1000 (m) | 60 1000 (m) | 70 1000 (m) | 80 1000 (m) | Σ | 20 | 30 | 40 | 50 | 60 | 70 | 80 | Σ |
| 10.5-13.5 | 8 | | | | | | | 8 | 3 | | | | | | | 3 |
| 13.5-16.5 | 9 | 27 | | | | | | 36 | 3 | 9 | | | | | | 12 |
| 16.5-19.5 | 35 | 37 | 6 | 1 | | | | 79 | 12 | 12 | 2 | 1 | | | | 27 |
| 19.5-22.5 | 29 | 51 | 16 | - | | | | 96 | 10 | 17 | 5 | - | | | | 32 |
| 22.5-25.5 | 24 | 74 | 49 | 1 | | | | 148 | 8 | 25 | 16 | 1 | | | | 50 |
| 25.5-28.5 | 9 | 45 | 79 | 3 | 1 | | | 137 | 3 | 15 | 26 | 3 | 1 | | | 48 |
| 28.5-31.5 | 4 | 35 | 43 | 9 | 3 | | | 94 | 1 | 12 | 14 | 9 | 3 | | | 39 |
| 31.5-34.5 | | 5 | 12 | 13 | 10 | 4 | | 44 | | 2 | 4 | 13 | 10 | 4 | | 33 |
| 34.5-37.5 | | 1 | 11 | 5 | 6 | 7 | | 30 | | 1 | 4 | 5 | 6 | 7 | | 23 |
| 37.5-40.5 | | | 2 | 1 | 3 | 6 | | 12 | | | 1 | 1 | 3 | 6 | | 11 |
| 40.5-43.5 | | | 1 | 1 | - | 2 | | 4 | | | 1 | 1 | - | 2 | | 4 |
| 43.5-46.5 | | | | | 1 | 1 | | 2 | | | | | 1 | 1 | | 2 |
| 46.5-49.5 | | | | | | 1 | 1 | 2 | | | | | | 1 | 1 | 2 |
| 49.5-52.5 | | | | | | | 1 | 1 | | | | | | | 1 | 1 |
| Total | 118 | 275 | 219 | 34 | 24 | 21 | 2 | 693 | 40 | 93 | 73 | 34 | 24 | 21 | 2 | 287 |

length (LF), minimum length, maximum length and standard deviation, confidence intervals in $t_{(0.05)}$, and the significance levels of the differences between females and males in the same age group are given in Table 2.

To estimate the length or age of a fish, "Von Bertalannfy Growth Equations" were used. Therefore, length based VBG equations of the carp population in Gölhisar Lake were as follows:

For females :

$L_t = 68.09 * [1 - e^{(-0.1995 * (t + 0.3174))}]$

$t_{L)} = - 0.3174 - [1 / 0.1995 ] * \ln [1 - ( L / 68.09)]$

For males :

$L_t = 76.72 * [1 - e^{(-0.1496 * (t + 0.6163))}]$

$t_{L)} = - 0.6163 - [1 / 0.1496 ] * \ln [1 - ( L / 76.72)]$

For females+males :

$L_t = 72.76 * [1 - e^{(-0.1723 * (t + 0.4456))}]$

$t_L = -0.4456 - [1 / 0.1723] * \ln [1- (L/ 72.76)]$

length-based growth diagram formed with the above equations can be seen in Figure 2.

The mean weight in the carp samples ranged from 20.1 g to 1922.2 g. The differences in weight between the females and males were statistically significant only in age groups II and V ( $P<0.05$). The mean weight with the minimum values, maximum values, standard deviations and confidence intervals with 95% for females and males of each age group are given in Table 3. Weight based on the von Bertalanffy Growth Equations were as follows:

For females:

$W_{(t)} = 4664.58 * [ 1 - e^{(-0.1995 * (t + 0.3174))} ]^{2.8676}$

For males:

$W_{(t)} = 6652.76 * [ 1 - e^{(-0.1496 * (t + 0.6163))} ]^{2.8847}$

For females+males:

$W_{(t)} = 5651.84 * [ 1 - e^{(-0.1723 * (t + 0.4456))} ]^{2.8739}$

The length-weight relationships were calculated by using the lengths and weights of the carp samples. These equations for females, males and combined sexes are given below:

For females: $W = 0.0258 * LF^{2.8676}$

For males: $W = 0.0243 * LF^{2.8874}$

For females+males: $W = 0.0252 * LF^{2.8739}$

The highest and lowest condition factors were found to be in age group I and in age group VI, respectively. The

Table 2. The length of the different age groups of the carp samples from Gölhisar Lake. ( N: Number of samples; LF: Mean fork length "cm"; Min: Minimum length; Max: Maximum length; SD: Standard Deviation; CI: Confidence Interval with 95 %; P: Significance level).

| | FEMALE | | | MALE | | | | FEMALE+MALE | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Age | N | LF± CI (Min-Max) | SD | N | LF± CI (Min-Max) | SD | | N | LF± CI (Min-Max) | SD |
| I | 132 | 16.74 ± 0.82 (10.5 - 28.5) | 4.751 | 121 | 16.95 ± 0.89 (10.5 -28.0) | 4.932 | P > 0.05 | 253 | 16.84 ± 0.60 (10.5 - 28.5) | 4.830 |
| II | 174 | 26.15 ± 0.62 (16.3 - 35.3) | 4.149 | 157 | 25.28 ± 0.65 (15.5 -35.9) | 4.117 | P > 0.05 | 331 | 25.74 ± 0.45 (15.5 - 35.9) | 4.150 |
| II | 32 | 32.06 ± 1.11 (26.5 - 43.5) | 3.060 | 34 | 31.45 ± 1.30 (24.0 -44.0) | 3.719 | P > 0.05 | 66 | 31.75 ± 0.84 (24.0 - 44.0) | 3.403 |
| IV | 15 | 40.19 ± 3.68 (25.0 -47.5) | 6.643 | 7 | 39.41 ± 2.84 (34.6 -46.0) | 3.075 | P > 0.05 | 22 | 39.95 ± 2.52 (25.0 -47.5) | 5.680 |
| V | 14 | 46.39 ± 0.84 (44.0 -48.5) | 1.451 | 5 | 43.88 ± 1.51 (43.0 -46.0) | 1.215 | P < 0.05 | 19 | 45.73 ± 0.85 (43.0 -48.5) | 1.772 |
| VI | 2 | 49.10± (48.8 - 49.4) | 0.424 | | | | | 2 | 49.10± (48.8 - 49.4) | 0.424 |

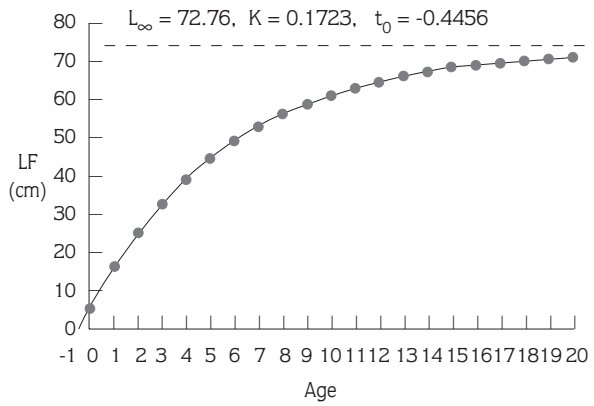


Figure 2. Growt in length of both sexes in the carp population of Gölhisar lake.

differences in the mean condition factors between female and males were statistically significant (P<0.05) only in age group V. For each age group, the minimum, maximum and mean condition factors are given in Table 4.

### Annual Mortality Rates

In determining the natural mortality rate, infinitive length, K and water temperature were used. The infinitive length and K values were determined in the previous section. Water temperature values for Gölhisar Lake are given in Table 5.

It was determined that the natural mortality rate (M) of the carp stock in Gölhisar Lake was 0.35. For the estimation of annual total mortality rates, the Length Based Linearized Catch Curve Method was used. More information and a mathematical explanation of mortality is given in Table 6.

The percentages of dead and surviving fish longer than 28 cm in length in the exploited stock were found to be as follows:

$S = e^{-1.36} * 100 = 25.67\ \%$

C= ( 1.01 / 1.36 ) * ( 100 - 25.67 ) = 55.20 %

D= ( 0.35 / 1.36 ) * (100 - 25.67 ) = 19.13 %

Total = 74.33 %

During one year, 74.33 % of the exploited carp population (over 28 cm in length) died, and 25.67 % of the exploited population survived.

### Stock Analysis

In the assessment of the exploited carp stock, the length samples were taken from the commercial fisheries in 1994 (the total yield was 15000 kg). Then, the corresponding frequency in each length group was arranged according to the total yield. The number of individuals caught in each length group is presented in Table 7. The exploited carp stock in Gölhisar Lake was

Table 3. Weights in the different age groups of the carp samples from Gölhisar Lake. (N: Number of samples; W: Mean weight "g"; Min: Minimum weight; Max: Maximum weight; SD: Standard Deviation; CI: Confidence Interval with 95 %; P: Significance level).

| | FEMALE | | | MALE | | | FEMALE + MALE | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | W ± CI (Min - Max ) | SD | N | W ± CI (Min - Max ) | SD | N | W ± CI (Min - Max ) | SD |
| I | 132 | 102.77 ± 15.56 (20.1-361.6) | 90.3 | 121 | 106.38 ± 16.72 ( 21.8 - 376.8 ) | 92.9 | 253 | 104.50 ±11. 33 ( 20.1 - 376.8 ) | 91.4 |
| II | 174 | 322.07± 20.01 (76.7-782.5) | 133.7 | 157 | 291.02 ± 18.69 (74.3 - 693.0) | 118.5 | 331 | 307.34± 13.78 (74.3 - 782.5) | 127.4 |
| III | 32 | 542.77 ± 58.75 (312.3- 1275.8) | 162.7 | 34 | 524.01 ± 70.51 (228.8- 1240.0) | 201.3 | 66 | 533.10± 44. 92 (312.3-1275.8) | 182.5 |
| IV | 15 | 1054.84±228.8 (254.0 -1624.0) | 407.7 | 7 | 996.16± 200.47 (678.0- 1409.0) | 216.8 | 22 | 1036.18±156.85 (254.0-624.0) | 353.7 |
| V | 14 | 1556.30±107.2 (1324.7-922.2) | 185.8 | 5 | 1210.40±149.9 (1084.6-212.5) | 120.8 | 19 | 1465.27±110.6 (1084.6-922.2) | 229.5 |
| VI | 2 | 1671.45 ± (1628.4-714.5) | 60.9 | | | | 2 | 1671.45± (1628.4-714.5) | 60.9 |

Table 4. The minimum, maximum and mean condition factor values and their Confidence Intervals and Standard Deviation according to age group of carp samples. (N: Number of samples; C: Mean condition factor; Min: Minimum condition factor; Max: Maximum condition factor; SD: Standard Deviation; CI: Confidence Interval with the 95 %; P: Significance level).

| | FEMALE | | | MALE | | | | FEMALE+MALE | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Age | N | C± CI (Min-Max) | SD | N | C± CI (Min-Max) | SD | | N | C± CI (Min-Max) | SD |
| I | 132 | 1.791±0.027 (1.394-2.208) | 0.154 | 121 | 1.757±0.022 (1.443-2.109) | 0.122 | P > 0.05 | 253 | 1.775±0.017 (1.394-2.208) | 0.140 |
| II | 174 | 1.689±0.019 (1.432-2.388) | 0.126 | 157 | 1.693± 0.018 (1.396-2.221) | 0.117 | P > 0.05 | 331 | 1.691±0.013 (1.396-2.221) | 0.122 |
| III | 32 | 1.613±0.035 (1.478-1.956) | 0.096 | 34 | 1.627±0.032 (1.456-1.852) | 0.092 | P > 0.05 | 66 | 1.621±0.023 (1.456-1.956) | 0.094 |
| IV | 15 | 1.539±0.073 (1.298-1.754) | 0.131 | 7 | 1.609±0.111 (1.440-1.759) | 0.120 | P > 0.05 | 22 | 1.561±0.058 (1.298-1.759) | 0.129 |
| V | 14 | 1.553±0.047 (1.444-1.738) | 0.081 | 5 | 1.430±0.083 (1.345-1.525) | 0.067 | P < 0.05 | 19 | 1.520±0.045 (1.345-1.738) | 0.094 |
| VI | 2 | 1.412± (1.401-1.422) | 0.015 | | | | | 2 | 1.412± (1.401-1.422) | 0.015 |

Table 5. Water temperature values (°C) in Gölhisar Lake.

| Jan. | Feb. | Mar. | Apr. | May | Jun. | Jly. | Aug | Sep. | Oct. | Nov. | Dec. | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 9 | 12 | 18 | 20 | 24 | 27 | 26 | 20 | 16 | 14 | 10 | 17 |

Table 6. Estimation of total mortality rate with the linearized catch curve based on length composition data collected from commercial fisheries.

| Length $L_1$ - $L_2$ | N C(L1,L2) | Age T(L1) | Δt | T (L1+L2)/2 (x) | Ln ((CL1, L2))/Δt) (y) |
|---|---|---|---|---|---|
| 28-30 | 70 | 2.374 | 0.265 | 2.507 | 5.577 |
| 30-32 | 62 | 2.640 | 0.278 | 2.779 | 5.407 |
| 32-34 | 35 | 2.918 | 0.292 | 3.064 | 4.786 |
| 34-36 | 27 | 3.210 | 0.307 | 3.364 | 4.477 |
| 36-38 | 15 | 3.517 | 0.325 | 3.680 | 3.832 |
| 38-40 | 9 | 3.842 | 0.344 | 4.014 | 3.264 |
| 40-42 | 8 | 4.186 | 0.366 | 4.369 | 3.085 |
| 42-44 | 5 | 4.551 | 0.390 | 4.746 | 2.551 |
| 44-46 | 3 | 4.941 | 0.418 | 5.151 | 1.971 |
| 46-48 | 2 | 5.360 | 0.451 | 5.586 | 1.489 |
| 48-∞ | 3 | 5.811 | - | - | |

| N | b (Z) | Sy | Sx | $Sb^2$ | sb | $t_{n-2}$ | Z±CI |
|---|---|---|---|---|---|---|---|
| 10 | - 1.36 | 1.413 | 1.032 | 0.002 | 0.045 | 2.31 | 1.36± 0.10 |

$Sb^2 = 1 / (n-2) * ((sy / sx)^2 - b^2)$, CI = tn-2 * sb

Table 7. Distrubition of the length groups of the carp in the annual yield, converted into age intervals and natural mortality factors ($H_{L1,L2}$).

| Length interval $L_1$ - $L_2$ | Age $t_{(L1)}$ | Δt | W (kg) | Sample N | In Yield (15000 kg) N | H |
|---|---|---|---|---|---|---|
| 28 - 30 | 2.374 | 0.265 | 0.40196 | 70 | 7182 | 1.0475 |
| 30 - 32 | 2.640 | 0.278 | 0.48688 | 62 | 6352 | 1.0499 |
| 32 - 34 | 2.918 | 0.292 | 0.58272 | 35 | 3591 | 1.0524 |
| 34 - 36 | 3.210 | 0.307 | 0.69008 | 27 | 2770 | 1.0553 |
| 36 - 38 | 3.517 | 0.325 | 0.80957 | 15 | 1539 | 1.0585 |
| 38 - 40 | 3.842 | 0.344 | 0.94181 | 9 | 923 | 1.0620 |
| 40 - 42 | 4.186 | 0.366 | 1.08738 | 8 | 821 | 1.0661 |
| 42 - 44 | 4.551 | 0.390 | 1.24688 | 5 | 513 | 1.0707 |
| 44 - 46 | 4.941 | 0.418 | 1.42092 | 3 | 334 | 1.0760 |
| 46 - 48 | 5.360 | 0.451 | 1.61006 | 2 | 205 | 1.0821 |
| 48 - ∞ | 5.811 | - | 1.81491 | 3 | 308 | - |

assessed, using the number of individuals in each length group, by Virtual Population Analysis (Table 8). As it may be seen in Table 8, a cohort (a batch of fish of approximately the same age) was recruited to the exploited stock when they were over 28 cm in length.

33787 fish were recruited to the exploited stock when they were 28 cm in length. When this cohort reached 30 cm in length, 23936 fish survived, and, when they reached 40 cm in length, 3390 fish survived (Table 8, Figure 3).

Adding of the mean values in each class interval gives the mean number and mean biomass of the cohort. The mean number of fish over 28 cm in length was 26416 and the mean biomass was 17564 kg.

### Bioeconomic Analysis of the Stock

In the carp stock, future yields and stock biomass levels can be predicted by simulations of the VPA results. In the VPA Table the F value for each length group was the present effort for fishing mortality rates. At different levels of fishing effort (the present effort in Table 8 is

Table 8. Length-based Virtual Population Analysis (Cohort Analysis) of the carp population in Gölhisar Lake. (*assumed to be known in advance).

| Length interval L1 - L2 | Catch (L1, L2) | Survivor N (L1) | Explo. rate F/Z | Fishing mortality F | Total mortality Z | Mean N * Δt N(L1, L2)*Δt | Mean Biom*Δt kg B * Δt |
|---|---|---|---|---|---|---|---|
| 28 - 30 | 7182 | 33787 | 0.729 | 0.942 | 1.292 | 7625 | 3065 |
| 30 - 32 | 6352 | 23936 | 0.768 | 1.159 | 1.509 | 5481 | 2669 |
| 32 - 34 | 3591 | 15665 | 0.728 | 0.937 | 1.287 | 3833 | 2234 |
| 34 - 36 | 2770 | 10732 | 0.745 | 1.023 | 1.373 | 2709 | 1869 |
| 36 - 38 | 1539 | 7012 | 0.697 | 0.805 | 1.155 | 1912 | 1548 |
| 38 - 40 | 923 | 4804 | 0.653 | 0.659 | 1.009 | 1401 | 1319 |
| 40 - 42 | 821 | 3390 | 0.698 | 0.809 | 1.159 | 1016 | 1105 |
| 42 - 44 | 513 | 2213 | 0.673 | 0.720 | 1.070 | 712 | 888 |
| 44 - 46 | 334 | 1451 | 0.657 | 0.670 | 1.020 | 498 | 708 |
| 46 - 48 | 205 | 943 | 0.627 | 0.588 | 0.938 | 349 | 562 |
| 48 - ∞ | 308 | 616 | 0.500* | 0.350 | 0.700 | 880 | 1597 |
| | | | | | Total | 26416 | 17564 |

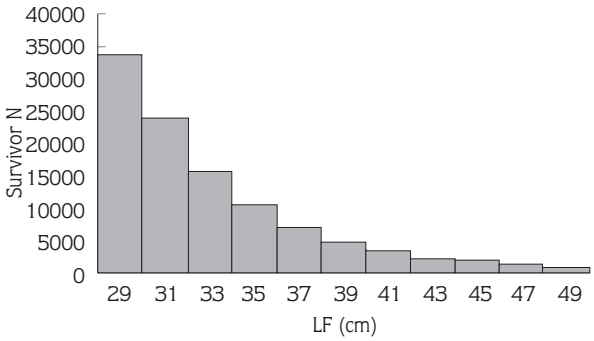


Figure 3. Cohort dynamics of the carp population in Gölhisar Lake according to VPA.

100 % or 1), future yields and biomass were predicted. As it may be seen in Tables 9,10 and 11 the present F values in Table 8 were multiplied by different F-factors (0, 0.4, and 1.2), and the new F values were found for each length groups. Then, yield and stock biomass were predicted using the new F values for the new F- factors. The yield would be 0 kg if the fishing effort decreased 100%, and it would be 12570 kg if the fishing effort decreased 60 %. In turn, it would be 14960 kg if the effort increased by 20%. In addition, the number of survivors for different F- factors are given in Figure 4. The simulated results for 0; 0.2; 0.4; 0.6;...3 F- factors are given in Table 12 and Figure 5.

15000 kg yield obtained by present fishing effort. That showed us that in the case of lower fishing effort the exploitation of the stock would be insufficient. Otherwise, in the case of higher fishing effort there would be negative effects on the carp stock, resulting in low yield.

## Discussion

In order to investigate the growth in the carp population of Gölhisar Lake, 13000 m longline nets with different mesh sizes were used and 693 carp samples were caught. 70% (9000 m) of the longline nets used had mesh sizes of 20, 30 and 40 mm. The nets of 50 mm and above were only 4000 m and 30% of the total of longline nets. Although the age composition ranged from I to VI , most of the 693 samples were in the I-II age groups and the proportion of samples above 28.5 cm in length was 27%. However, in the case of 1000 m length nets of each mesh size, total of 287 samples would be caught and 40% of these samples would be longer than 28.5 cm.

The age composition in previous studies of carp populations was as follows: İznik Lake carp, I-IX (9); Mogan Lake, I-XIII (10); Eğirdir Lake's I-XI, Beyşehir Lake, I-XIII (11); Gölcük Lake, I-XIII (12); Bafra Lake, I-VIII (13); and Altınkaya Dam Lake carp, I-VII (14).

Table 9. Predicted yield and biomass if the fishing effort decreased 100 % (F- factor =X =0).

| Length Interval (L1-L2) | H | W (kg) | F1 | X | F | N | C | Yield (kg) | Mean N*Δt | Mean B. (kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 28-30 | 1.0475 | 0.40196 | 0.942 | 0 | 0 | 33787 | 0 | 0 | 8556 | 3440 |
| 30-32 | 1.0499 | 0.48688 | 1.159 | 0 | 0 | 30792 | 0 | 0 | 8164 | 3974 |
| 32-34 | 1.0524 | 0.58272 | 0.937 | 0 | 0 | 27935 | 0 | 0 | 7750 | 4517 |
| 34-36 | 1.0553 | 0.69008 | 1.023 | 0 | 0 | 25222 | 0 | 0 | 7355 | 5075 |
| 36-38 | 1.0585 | 0.80957 | 0.805 | 0 | 0 | 22648 | 0 | 0 | 6955 | 5630 |
| 38-40 | 1.0620 | 0.94181 | 0.659 | 0 | 0 | 20214 | 0 | 0 | 6547 | 6165 |
| 40-42 | 1.0661 | 1.08738 | 0.809 | 0 | 0 | 17923 | 0 | 0 | 6153 | 6692 |
| 42-44 | 1.0707 | 1.24688 | 0.720 | 0 | 0 | 15769 | 0 | 0 | 5754 | 7175 |
| 44-46 | 1.0760 | 1.42092 | 0.670 | 0 | 0 | 13755 | 0 | 0 | 5356 | 7608 |
| 46-48 | 1.0821 | 1.61006 | 0.588 | 0 | 0 | 11881 | 0 | 0 | 4956 | 7977 |
| 48-- | | 1.81491 | 0.350 | 0 | 0 | 10147 | 0 | 0 | 28990 | 52617 |
| | | | | | | | 0 | 0 | 96354 | 110870 |

Table 10. Predicted yield and biomass if the fishing effort decreased 60 %. (F- factor =X =0.4).

| Length Interval (L1-L2) | H | W (kg) | F1 | X | F | N | C | Yield (kg) | Mean N*Δt | Mean B. (kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 28-30 | 1.0475 | 0.40196 | 0.942 | 0.4 | 0.377 | 33787 | 3076 | 1236 | 8158 | 3279 |
| 30-32 | 1.0499 | 0.48688 | 1.159 | 0.4 | 0.464 | 27856 | 3224 | 1570 | 6949 | 3383 |
| 32-34 | 1.0524 | 0.58272 | 0.937 | 0.4 | 0.375 | 22200 | 2193 | 1278 | 5848 | 3407 |
| 34-36 | 1.0553 | 0.69008 | 1.023 | 0.4 | 0.409 | 17961 | 2019 | 1393 | 4936 | 3406 |
| 36-38 | 1.0585 | 0.80957 | 0.805 | 0.4 | 0.322 | 14215 | 1337 | 1082 | 4155 | 3362 |
| 38-40 | 1.0620 | 0.94181 | 0.659 | 0.4 | 0.264 | 11424 | 936 | 882 | 3545 | 3338 |
| 40-42 | 1.0661 | 1.08738 | 0.809 | 0.4 | 0.324 | 9248 | 973 | 1058 | 3004 | 3265 |
| 42-44 | 1.0707 | 1.24688 | 0.720 | 0.4 | 0.288 | 7224 | 720 | 898 | 2501 | 3117 |
| 44-46 | 1.0760 | 1.42092 | 0.670 | 0.4 | 0.268 | 5629 | 557 | 791 | 2080 | 2955 |
| 46-48 | 1.0821 | 1.61006 | 0.588 | 0.4 | 0.235 | 4344 | 405 | 652 | 1725 | 2777 |
| 48-- | | 1.81491 | 0.350 | 0.4 | 0.140 | 3335 | 953 | 1730 | 6810 | 12352 |
| | | | | | | | | 12570 | | 44641 |

Table 11. Predicted yield and biomass if the fishing effort increased 20 %. (F- factor =X =1.2).

| Length Interval (L1-L2) | H | W (kg) | F1 | X | F | N | C | Yield (kg) | Mean N*Δt | Mean B. (kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 28-30 | 1.0475 | 0.40196 | 0.942 | 1.2 | 1.130 | 33787 | 8434 | 3390 | 7463 | 3000 |
| 30-32 | 1.0499 | 0.48688 | 1.159 | 1.2 | 1.391 | 22741 | 7054 | 3435 | 5071 | 2469 |
| 32-34 | 1.0524 | 0.58272 | 0.937 | 1.2 | 1.124 | 13912 | 3740 | 2179 | 3327 | 1939 |
| 34-36 | 1.0553 | 0.69008 | 1.023 | 1.2 | 1.228 | 9007 | 2724 | 1880 | 2218 | 1531 |
| 36-38 | 1.0585 | 0.80957 | 0.805 | 1.2 | 0.966 | 5506 | 1417 | 1147 | 1467 | 1188 |
| 38-40 | 1.0620 | 0.94181 | 0.659 | 1.2 | 0.791 | 3575 | 809 | 762 | 1023 | 963 |
| 40-42 | 1.0661 | 1.08738 | 0.809 | 1.2 | 0.971 | 2408 | 685 | 745 | 706 | 767 |
| 42-44 | 1.0707 | 1.24688 | 0.720 | 1.2 | 0.864 | 1476 | 400 | 499 | 463 | 577 |
| 44-46 | 1.0760 | 1.42092 | 0.670 | 1.2 | 0.804 | 914 | 246 | 350 | 306 | 435 |
| 46-48 | 1.0821 | 1.61006 | 0.588 | 1.2 | 0.706 | 561 | 143 | 230 | 203 | 326 |
| 48-- | | 1.81491 | 0.350 | 1.2 | 0.420 | 347 | 189 | 343 | 450 | 818 |
| | | | | | | | | 14960 | | 14013 |

Table 12. Yield and stock biomass for various efforts in Gölhisar Lake carp stock.

| F- Factor | Yield (kg) | Biomass (kg) | F - Factor | Yield (kg) | Biomass (kg) |
|---|---|---|---|---|---|
| 0 ( 0 Boat) | 0 | 110.870 | 1.6 (24 Boats ) | 14.688 | 9.767 |
| 0.2 (3 Boats ) | 8.679 | 69.255 | 1.8 ( 27 Boats ) | 14.536 | 8.438 |
| 0.4 (6 Boats) | 12.570 | 44.641 | 2.0 ( 30 Boats ) | 14.388 | 7.420 |
| 0.6 ( 9 Boats ) | 14.196 | 31.128 | 2.2 ( 33 Boats ) | 14.253 | 6.618 |
| 0.8 ( 12 Boats ) | 14.821 | 22.849 | 2.4 ( 36 Boats ) | 14.130 | 5.975 |
| 1.0* (15 Boats)* | 15.000* | 17.564* | 2.6 ( 39 Boats ) | 14.020 | 5.446 |
| 1.2 ( 18 Boats ) | 14.960 | 14.013 | 2.8 ( 42 Boats ) | 13.907 | 5.004 |
| 1.4 ( 21 Boats ) | 14.839 | 11.543 | 3.0 ( 45 Boats ) | 13.832 | 4.632 |

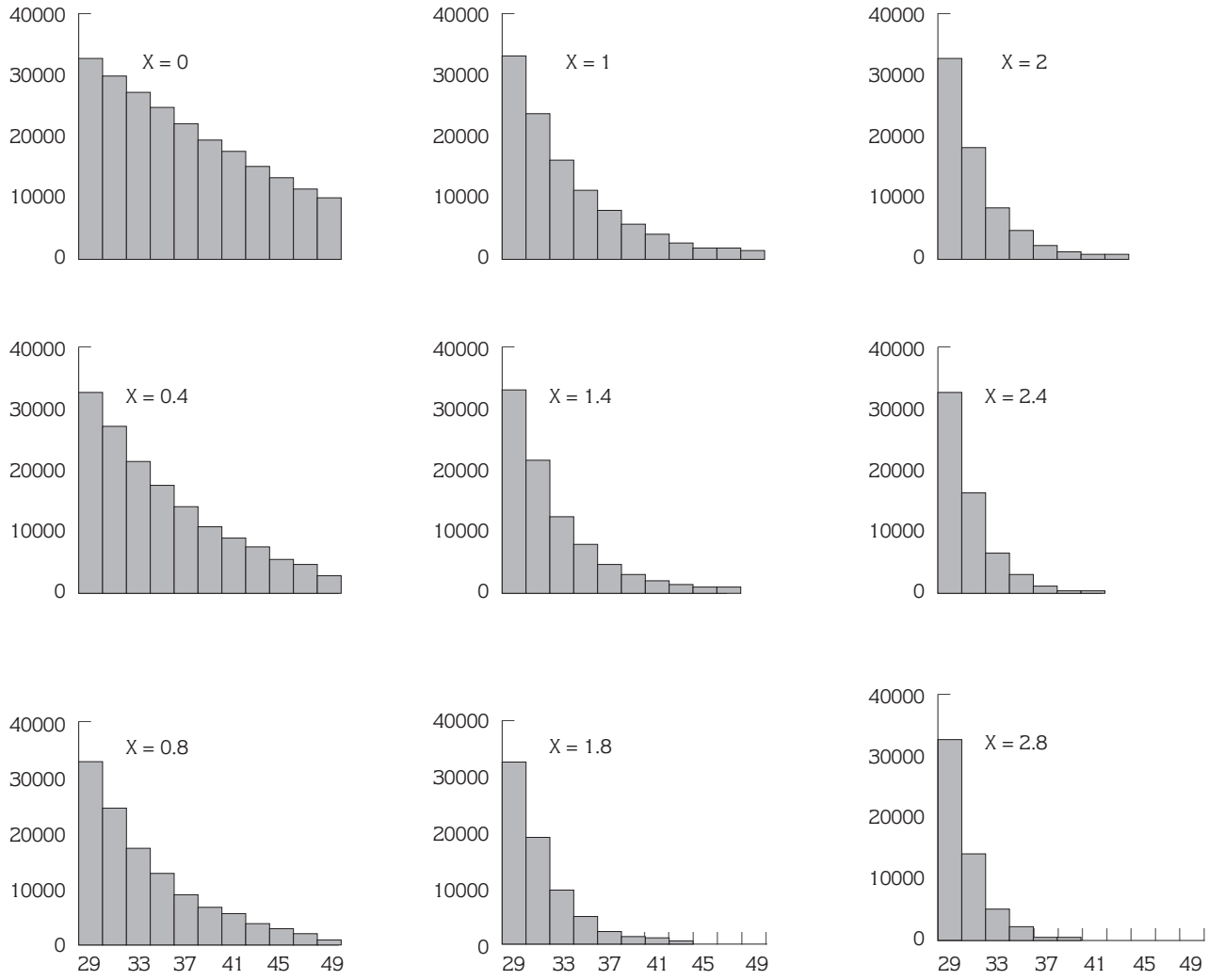


Figure 4. Survivor numbers for some different X factors in length groups. (x= LF, y= Survivor number).

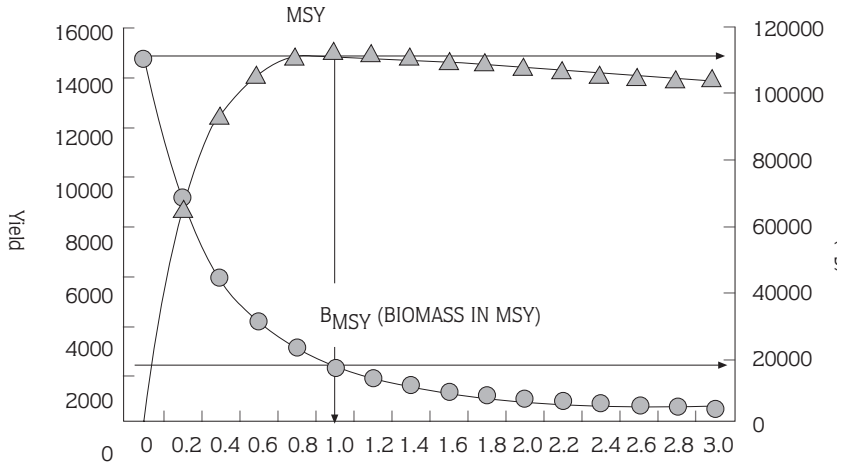


Figure 5. The relationship of Effort -Yield and Biomass in the carp stock.

These differences in the age distribution of the populations may be due to gill net selectivity, fishing activity, feeding habits and the ecological characteristics of the lakes.

In this study, the fork lengths of the carp population ranged from 10.5 cm to 49.4 cm. A comparison of the lengths in each age groups of this study with some previous works is given in Table 13. This shows that the highest length value was obtained from Marmara Lake carp (15), and the lowest length value was obtained from Gölcük Lake carp (12). The differences in mean length in populations containing the same species but in different regions may be due to differences in the climatical and ecological conditions of the regions. In addition, carp populations increase quickly in warm regions which have no shortage of food.

In this study, differences in the lengths of the females and males in carp population were significant only for age group V ($P<0.05$). Female fish seemed to be larger than the males above age group III. This may be due to the age of sexual maturity age.

The total weight of the carp population in Gölhisar Lake ranged from 20.1 g to 1922.2 g and the total weights for ages I,II,III,IV,V and VI were 104.50, 307.34, 533.10, 1036.18, 1465.27, and 1671.45 g,

Table 13. The reported length values in each age group for various carp populations in Turkey.

| Researcher | | Lake | AGES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | I | II | III | IV | V | VI | VII | VIII | IX | X |
| Numan | (9) | Akşehir | 22.3 | 36.2 | 46.1 | 52.2 | 56.4 | 59.9 | | | | |
| | | Beyşehir | 9.5 | 17.9 | 24.6 | 31.1 | 35.5 | | | | | |
| | | Eğirdir | 10.9 | 19.8 | 26.2 | 31.1 | 35.2 | | | | | |
| | | İznik | 12.0 | 21.1 | 28.9 | 36.8 | 43.1 | 48.2 | 51.7 | 55.4 | 57.7 | |
| | | Marmara | 14.4 | 29.2 | 37.5 | 41.8 | 43.0 | | | | | |
| | | Manyas | 9.0 | 16.2 | 22.7 | 28.6 | 33.2 | | | | | |
| | | Süleyman | 10.2 | 19.3 | 28.2 | 33.3 | 37.0 | | | | | |
| Düzgüneş | (10) | Mogan | 21.3 | 27.3 | 34.1 | 38.4 | 42.1 | 48.6 | 56.8 | 60.1 | 62.4 | 65.4 |
| Erdem | (11) | Çavuşcu | 16.3 | 23.9 | 30.1 | 36.5 | 41.5 | 46.5 | 50.6 | 56.7 | 60.6 | |
| Balık, Ustaoğlu | (12) | Gölcük | 7.7 | 10.3 | 13.6 | 16.3 | 17.2 | 19.2 | 20.9 | 23.2 | 25.6 | 27.4 |
| Demirkalp | (13) | Bafra | 16.6 | 26.8 | 32.0 | 36.6 | 44.2 | 51.6 | 53.5 | 63.0 | | |
| Bircan ,Erdem | (14) | Altınkaya | 19.9 | 26.8 | 35.5 | 40.3 | 47.2 | 51.9 | 61.6 | | | |
| Alpbaz,Hoşsucu | (15) | Marmara | 25.2 | 41.6 | 51.3 | 57.8 | 64.0 | 80.0 | | | | |
| Karabatak | 16) | Hirfanlı | 18.1 | 27.1 | 31.8 | 35.0 | 38.6 | 43.6 | 48.7 | | | |
| Tanyolaç | (17) | Eymir | - | 24.9 | 31.9 | 38.0 | 42.4 | 43.6 | 49.3 | 53.3 | 56.9 | |
| Tanyolaç,Karabatak | (18) | Mogan | - | 27.4 | 34.3 | 37.3 | 40.0 | 43.3 | 48.2 | 54.3 | 61.5 | |
| Erdem | (19) | Akşehir | - | - | 33.2 | 40.1 | 47.0 | 53.1 | 59.5 | 64.3 | | |
| | (20) | Eber | 16.3 | 25.1 | 34.1 | 38.0 | 44.9 | 51.1 | 56.5 | 61.8 | 66.6 | 70.7 |
| | | Eğirdir | 14.1 | 23.2 | 31.4 | 36.1 | 40.0 | 44.1 | 50.1 | 54.5 | 58.8 | 64.0 |
| | | Beyşehir | 13.1 | 28.2 | 31.0 | 35.6 | 40.4 | 45.9 | 50.0 | 55.6 | 60.9 | 65.2 |
| | (21) | Beyşehir | 15.3 | 23.2 | 31.8 | 35.9 | 41.3 | 46.1 | 50.6 | 55.6 | 60.9 | 64.7 |
| | (22) | Apa | 14.2 | 23.2 | 32.2 | 36.5 | 42.2 | 46.9 | 51.1 | 57.1 | | |
| | (23) | Tödürge | 11.3 | 17.8 | 23.9 | 28.2 | 30.8 | 34.0 | 37.8 | | | |
| Akyurt | (24) | Almus | - | 20.4 | 23.6 | 31.0 | 33.7 | 37.0 | | | | |
| Cengizler,Erdem | (25) | Hafik | 12.8 | 18.5 | 23.9 | 26.9 | 30.5 | 33.2 | 36.6 | | | |
| İkiz | (26) | Mamasın | 16.6 | 24.5 | 32.4 | 39.6 | 45.6 | 51.2 | 54.5 | 59.7 | 62.0 | 65.0 |
| Atalay | (27) | Beytepe | 17.2 | 21.2 | 24.3 | 29.2 | 34.0 | | | | | |
| Yerli | (28) | Köyceğiz | 22.4 | 30.8 | 35.8 | 41.6 | 47.5 | 54.7 | 60.0 | | | |
| Çetinkaya | (29) | Akşehir | 14.3 | 18.0 | 21.7 | 23.8 | 25.9 | 28.2 | 31.6 | 38.1 | | |
| Present study | | Gölhisar | 16.8 | 25.7 | 31.8 | 40.0 | 45.7 | 49.1 | | | | |

respectively. These results showed that the size of the Gölhisar Lake carp population was greater than that of Mogan Lake (10), Beytepe Lake ( 27) and Akşehir Lake (29).

The parameters used in von Bertelanffy Growth Equations were found to be $L_\infty$ = 72.76 cm. ; $W_\infty$ = 5651.84 g. ; K = 0.1723; $t_0$ = - 0.4456; and b = 2.8739. The "K" value known as the "Brody Growth Coefficient" was higher than for most carp populations. According to Munro and Pauly (30), "K" values of the same species in different ecosystems give us an indication of the growth performance of that species. They developed an equation that is known as the "Phi Prime Index". The mathematical explanation of Phi Prime is: Phi Prime= ln K +2* ln $L_\infty$. In this study the Phi Prime Index of the carp population was found to be 6.816. Other indices for carp populations in Turkey are given in Table 14. The calculated Phi Prime Index showed that the highest growth performances Eber Lake (20), Mamasın Lake (26) and Gölhisar Lake. As it may be seen in Table 14, the "K" value alone is insufficient to determine the growth performance. Although the highest "K" value was obtained from Gölhisar Lake carp, the highest Phi Prime Index was obtained from Eber Lake carp (20). This shows that growth performance was not only related to "K" values, but also to $L_\infty$ values.

In this study, the condition factors calculated for females and males were found to be similar. The differences between the condition factors of the females and males were only significant ($P<0.05$) in age group V. The minimum and maximum condition factors of both sexes combined were found to be 1.298 and 2.388. This fluctuation may largely be attributed to filling gonads and to feeding opportunities. It seems that the condition factors of the carp population in Gölhisar Lake were greater higher than those of the Akşehir (29) and Gölcük Lake (12) carp populations.

The mortality rates of Gölhisar Lake carp were found to be Z= 1.36 ± 0.10; the natural mortality rate, M= 0.35; and the fishing mortality rate, F= 1.01. It can be seen that the mortality in the population was due to natural events (19.13%) and fishery activities (55.20%). These mortality rates may be rather high and seem a threat to the population in future. However, because of the decrease in lake area between the years 1990 and 1994, there was a negative effect on the number of recruits. In this period, it was assessed that 33787 fish were recruited to the exploited stock when they were 28 cm in length. For the future, in the case of enlargement of the lake, it was estimated that the number of recruits would be high and mortality rates would be low. Similar research was carried out on the Mogan Lake carp population (10), and the total mortality, fisheries mortality and natural mortality were reported to be 52%, 8.18% and 43.82 % respectively. However in that research, tagging and recapture method was used.

In this study, the number and mean biomass of the exploited stock of Gölhisar Lake carp were calculated as 26416 and 17564 kg, respectively. Individually, the average weight of the exploitable stock in Gölhisar Lake was calculated as 665 g / fish found by dividing the mean biomass by the mean number. It was determined that the 30 -32 cm length group experienced the highest pressure from fisheries. The number of exploited carp in Mogan Lake was reported to be 9410 and 57% of this stock was more than 1000 g (10). The difference between the two results was due to the higher fisheries mortality in Gölhisar Lake than in Mogan Lake. In this study, the

Table 14. Comparison of growth performance of various carp population in Turkey using Phi prime test.

| Researcher | | Lake | $L_\infty$ | K | Phi Prime Index |
|---|---|---|---|---|---|
| Düzgüneş | (10) | Mogan | 101.94 | 0.0867 | 6.803 |
| Erdem | (20) | Eber | 109.76 | 0.09956 | 7.090 |
| Erdem | (23) | Tödürge | 80.71 | 0.10987 | 6.573 |
| Cengizler , Erdem | (25) | Hafik | 54.53 | 0.13959 | 6.028 |
| İkiz | (26) | Mamasın. | 85.17 | 0.134 | 6.897 |
| Çetinkaya | (29) | Akşehir | 79.95 | 0.0535 | 5.827 |
| Present study | | Gölhisar | 72.76 | 0.1723 | 6.816 |

Maximum Sustainable Yield (MSY) was calculated as 15000 kg with a maximum of 15 boats using simulations of fishing mortality rates against each length group. It was simulated that in the case of no fishing effort (zero boats), there would be no commercial yield (angling was ignored), and mean biomass would be 110870 kg. In addition to this, if the present effort were decreased 60% (six boats) the total yield and mean biomass would be 12570 kg and 44641 kg, respectively. And, if the present effort doubled (30 boats), total yield and mean biomass would be 14388 kg and 7420 kg, respectively. It appeared that the maximum sustainable yield would be obtained by the maintenence of the present effort. But this available yield will depend on the number of recruited fish. Thus, the available yield will be higher by increasing the number of recruited fish in coming years.

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