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Population Dynamics and Stock Assessment of *Capoeta umbla* (Heckel, 1843) in Lake Hazar, Elazığ, Turkey

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Abstract

Population parameters such as growth, mortality rates, annual catch and stock size of *Capoeta umbla* (Heckel, 1843) population in Lake Hazar were investigated. Length and weight relationships of the population was $W= 0.070xTL^{2.39}$ (n= 364; $R^2 = 0.95$) and von Bertalanffy Growth Parameters were estimated as $L\infty= 53.77$ cm; K=0.16; t_0=-1.84 and $W\infty$=957.38 g. Natural mortality rate (M) was 0.363 while fishing mortality (F) and total mortality rate (Z) were 0.349 and 0.712, respectively. Annual catch was 25721 kg (107544 individuals) and mean fish size was 28.7 cm (239.4 g). Estimated stock size based on mark and recapture method was 91601 kg ($CI_{(95\%)}$: 85163-99061 kg) and 382627 individuals ($CI_{(95\%)}$: 355736-413916 individuals). Stock size was also assessed by using length-based cohort analysis and was found to be 95256 kg ($CI_{(95\%)}$:55079-263225 kg) and 358105 individuals ($CI_{(95\%)}$: 240251-868729 individuals). According to yield-biomass relationships, estimated maximum sustainable yield (MSY) was 27070 kg.

Keywords: Lake Hazar, *Capoeta umbla*, growth parameters, mortality rates, stock assessment

Elazığ Hazar Gölü'nde Yaşayan Capoeta umbla (Heckel, 1843)'nın Stok Tahmini ve Populasyon Dinamiği

Özet

Elazığ Hazar Gölü'ndeki *Capoeta umbla* (Heckel, 1843) populasyonunun av miktarları, boy frekansları, büyüme parametreleri ve ölüm oranları gibi populasyon parametreleri ve stok büyüklüğü incelendi. Populasyona ait boy ağırlık ilişkisi $W= 0.070xTL^{2,39}$ (n= 364; $R^2 = 0.95$) ve von Bertalanffy büyüme parametreleri ise; $L\infty$=53.77 cm; K=0.16; t_0=-1.84 ve $W\infty$=957.38 g olarak hesaplandı. *C. umbla* populasyonunda doğal ölüm oranı M=0.363; balıkçılık ölüm oranı F=0.349 ve total ölüm oranı Z=0.712 olarak bulundu. Yıllık avlanan ürün miktarı 25721 kg (107544 adet) olup avlanan balıkların ortalama büyüklüğü 28.7 cm (239.4 g) olarak hesaplandı. Markalama yöntemine göre stok büyüklüğü bioymas olarak 91601 kg ($CI_{(\%95)}$: 85163-99091 kg) ve sayısal olarak ise 382627 adet ($CI_{(\%95)}$: 355736-413916 adet) olarak hesaplandı. Boya dayalı cohort analizine göre ise ortalama biyomas 95256 kg ($CI_{(\%95)}$: 55079-263225 kg) ve sayısal olarak ise 358105 adet ($CI_{(\%95)}$: 240251-868729 adet) olarak tahmin edildi. Ürün-Biyomas ilişkisine göre sürdürülebilir maksimum ürün (MSY) 27070 kg olarak hesaplandı.

Anahtar Kelimeler: Hazar Gölü, *Capoeta umbla*, büyüme parametreleri, ölüm oranları, stok tahmini.

Introduction

The genus *Capoeta* of Cyprinids is distributed in southern China, northern India, Turkmenistan, Lake Aral, the Middle East and Anatolia (Türkmen *et al*., 2002). The individuals of this genus occurs in lentic systems as well as lotic systems (Alp *et al*., 2005), and it was reported in the Ceyhan (Kara *et al*., 2010), Aşağı Gökdere, Köprüçay, Asi, Göksu, Seyhan, Büyükmenderes, Dalaman, Karasu, Seyitler (Turan, 2008), Euphrates (Gül *et al*., 1996), Tigris (Yılmaz and Solak, 1999) rivers and Hirfanlı (Yılmaz *et al*., 2010), Menzelet (Alp *et al*., 2005) Sarıyer (Ekmekçi, 1996a; Ekmekçi, 1996b), Aslantaş - Mehmetli (Başusta and Erdem, 1996), Almus (Cengizler and Erdem, 1994) and Kalecik (Şen, 1988) reservoirs and in Hazar (Özdemir, 1982), Nazik (Şen *et al*., 1999) and Çıldır (Canbolat *et al*., 1999) lakes in Turkey. This genus is represented by 18 species (*C. angorae, C. antalyensis, C. baliki, C. banarescui, C. barroisi, C. bergamae, C. caelestis, C. damascina, C. ekmekciae, C. erhani, C. kosswigi, C. mauricii, C. pestai, C. sieboldi, C. tinca, C. trutta, C. turani*, and *C. umbla*) and 1 subspecies (*C.c. capoeta*) (Küçük

and Güçlü, 2006; Turan *et al*., 2006; Geldiay and Balık, 2007; Turan *et al*., 2008; Froese and Pauly, 2012; Levin *et al*., 2012).

Capoeta umbla (Heckel, 1843), Transcaucasian barb, inhabits Euphrates-Tigris river systems. It is also known as "lake fish or stream fish" locally and it is the most commercially valued fish for the local people around Lake Hazar. A large number of studies have been carried out on this species in Lake Hazar as well as in different regions of the country (Ekingen and Sarıeyyüpoğlu, 1981; Canpolat and Çalta, 2001; Aydın and Şen, 2002; Türkmen *et al*., 2002; Yüksel, 2002; Yüce and Şen, 2003; Bayır *et al*., 2007; Çoban and Şen, 2011). Nevertheless, there is no study about its stock size and population parameters.

In order to apply an effective fisheries management and biological conservation, stocks sizes should be assessed and then maximum sustainable yield and fishing efforts should be determined for each fish population.

In this study population dynamics and stock size of *C. umbla* in Lake Hazar were studied. Information from this study may be used to design commercial fisheries management strategies for the lake, including the regulation of fishery pressure on *C. umbla* population in Lake Hazar. Accordingly, the aim of the study were to estimate 1) growth parameters 2) mortality rates 3) stock size 4) maximum sustainable yield and optimum fishing effort for the *C. umbla* population in Lake Hazar.

Materials and Methods

Lake Hazar

Lake Hazar located at 25 km south of Elazığ is a tectonic lake and its surface area is about 86 km^2. It is located at the latitude of 38° 29' N, longitude of 39° 24' E and altitude of 1248 m (Figure 1). The average length of Lake Hazar is about 20 km and its width 4.5 km. The maximum depth of the lake was reported as 219 m (Anonymous, 1995). Lake Hazar has brackish and alkaline water (NaCl=728.6 mg/l; Na_2CO_3=726.10 mg/l; $CaCO_3$=628 mg/l and pH=8.8) and has an oligotrophic character (Cici, 1995).

The main fish species of the lake are *C. umbla* (Heckel, 1843), *Alburnus heckeli* Batalgil, 1943, *Oxynoemacheilus eregliensis* (Banarescu and Nalbant, 1978), *Cyprinus carpio* Linnaeus, 1758 and *Aphanius asquamatus* (Sözer, 1942). A total of 7 commercial fishing boats are present and they are not independent from any cooperatives or special organization present in the lake. Lake Hazar is an important recreational area for Elazığ province and a lot of restaurants and summer houses are found around the lake. Thus the domestic pollution threatens the lake in future.

Fish Samples

This study was conducted on *C. umbla* (Heckel, 1843) individuals caught from Hazar Lake in Elazığ province between September 2008 and August 2009. In this study, fish samples were obtained in two ways:

1. In order to determine length-weight relationship and growth parameters, fishes were obtained by researchers by fishing in the lake once a month and a total of 364 fish (237 females and 127 males) were sampled. The fish samples were collected using the 10 trammel and gill nets (each net was 100 m in length) with mesh sizes between 20 and 120 mm. These nets were also used for fisheries activities in the lake by fishermen.

2. In order to determine the amount of the annual catch, length frequency distributions and stock assessment, fishes were obtained by fishermen for one day in a week early morning (every week during the nine months). The length and weight of all fish caught by at least 5 of fishing boats (total of 7 fishermen) were determined.

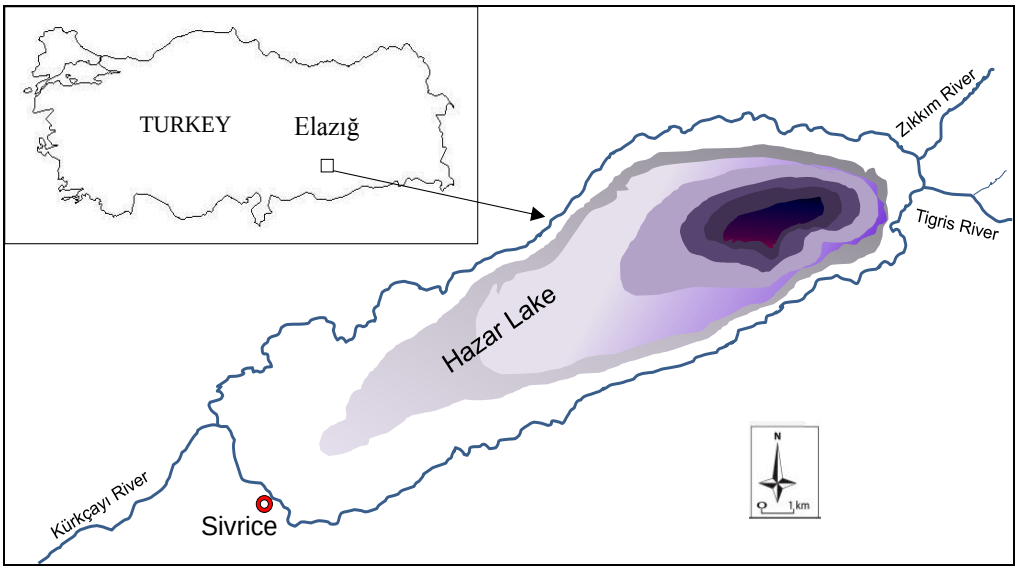

Figure 1. The map of Lake Hazar and study area.

Growth Parameters

In the laboratory, total length and weight of the each fish sample were measured and then its sex was noted. Ages of fish were determined by using otoliths (Ekingen and Polat, 1987; Öztürk *et al*., 2000; Aydın and Şen, 2002).

The length-weight relationship was determined from $W= a*L^b$ equation, where, W is total fish weight (g) and L is total length (cm). The a and b are the parameters describing the length-weight relationship (Sparre and Venema, 1998). Length-weight relationships of fishes and standard error (SE) of a and b values were estimated with SPSS 16.0 statistical software (SPSS Inc.).

In the investigation of the growth of the *C. umbla* population, the von Bertalanffy growth equations were used (Sparre and Venema, 1998):

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

Where, L_t= Length of the fish at age t, $L\infty$= Asymptotic length, K= Brody growth coefficient, t_0= Age of the fish at 0 cm length, $W\infty$= Asymptotic weight. VBGF parameters ($L\infty$, K and t_0) and their SE were calculated from the age-length data using the non-linear regression (Marquard's algorithm) implemented in the FAO-ICLARM FiSAT II package (Gayanilo *et al*., 2005). The confidence interval ($CI_{(95\%)}$) values of the VBGF parameters were calculated from $CI=SE*t_{(n-1)}$ equation, where, SE is the standard error of parameters, t_{n-1} is the critical value of the theoreatical t-distribution for n-1 degrees of freedom (Sparre and Venema, 1998).

Mortality Rates

In order to estimate the total mortality rate (Z), the Length-Based Linearized Catch Curve Method (Sparre and Venema, 1998) was used. In this method, the length values taken from commercial fisheries were used (107544 individuals), and the age of each length group was estimated by using the inverse von Bertalannfy growth equation (Sparre and Venema, 1998). Then, a linear regression analysis was applied for $y= \ln(C_{(L1,L2)}/\Delta t(L1,L2))$, $x= t((L1+L2)/2)$. The slope (b) of this regression is considered to be an estimator of "Z" (Sparre and Venema, 1998). Natural mortality rate (M) was calculated by Pauly's (1980) empirical equation;

$$\ln M = -0.0152–0.279 * \ln L_\infty + 0.6543 * \ln K + 0.4630 * \ln T$$

where; M is the natural mortality rate and T is the annual mean water temperature (°C).

Fishing mortality (F) was calculated from the equation of F=Z-M. Percentage survival rate was estimated from the equation; $\%S=e^{(-Z)}*100$. The percentage of deaths due to fishing (%C) and to natural reasons (%D) were also estimated with the equations; %C= (F/Z)*(100-S) and %D= (M/Z)*(100-S), respectively (Sparre and Venema, 1998; Alp and Balık, 2000).

Stock Assessment

Stock size was assessed by two different methods: mark and recapture method and length based cohort analysis.

Mark and Recapture Method

Multiple marking and recapturing method developed by Schnabel (1938) were applied in order to assess of the stock size of *C. umbla* in Hazar Lake. For this purpose, tagging was done weekly at the selected stations. The nets were set in the evening hours and collected in the morning hours on the following day. After the lengths and weights of the fish were measured, they were tagged with the T-Bar anchor tags by using Mark III Fine Fabric Tagging gun. The abbreviation of the institution (ESUAE), telephone number and fish number were printed on the mentioned tags. Totally, 2825 individuals were marked and released, and 175 marked fish were recaptured between 20 October 2008 and 24 August 2009. The following mathematical equation, the Schnabel Method was used in order to assess population size (Schnabel, 1938).

$$N_0 = \frac{\sum_{i=1}^{k}(C_i M_i)}{\sum_{i=1}^{k} R_i}$$

Where; N_0= The unknown size of the population just prior to the first sample; k= The total number of samples in the entire study (i.e., i=1...k); C_i= The number of fish captured in the *i*th sample; M_i= The number of marked fish in the population just prior to the *i*th sample $M_1=0$; R_i= The number of marked fish in the *i*th sample, $R_1=0$.

Ricker (1975) and Krebs (1998) suggested two possible methods for constructing confidence intervals for N_0 the Schnabel method. First, if ΣM_i is small (i.e., <50) then a Poisson approximation for constructing a confidence interval for ΣM_i is used. Alternatively, when ΣM_i is large, then a confidence interval is constructed for $\frac{1}{N}$ by employing the standard methods using the standard error

$$SE_{\frac{1}{N_0}} = \sqrt{\frac{\sum_{i=1}^{k} R_i}{(\sum_{i=1}^{k} C_i M_i)^2}}$$

with df = n − 2. In the present study, second method was used to estimate confidence interval for N_0 since, ΣM_i was larger than 50.

Length Based Cohort Analysis

As the second method for the stock analysis of *C. umbla*, the length-based cohort analysis was applied. For this purpose, the annual catch and length frequencies were used and the population size in the beginning of the season was assessed by using the number of fish caught from each length class during one-year fishing season and the estimated mortality rates of *C. umbla* in Lake Hazar (Sparre and Venema, 1998; Alp and Balık, 2000; Çubuk *et al*., 2005). In order to determine annual yield of *C. umbla* in Lake Hazar, the data obtained from fishermen were used. From these data, mean values for daily, weekly, monthly and annual yields were obtained. In addition, length frequencies were also prepared monthly. Length groups were formed by 2 cm intervals (such as 12-14, 14-16, 16-18……).

Yield-Biomass Relations and Maximum Sustainable Yield

In order to assess of the yield-biomass relations and maximum sustainable yield (MSY) of *C. umbla* population, the length based Thompson and Bell method was applied (Sparre and Venema, 1998; Alp and Balık, 2000; Çubuk *et al*., 2005).

Results

Growth

A total of 364 *C. umbla* (237 female and 127 male) were collected and examined in order to determine the growth parameters. The total lengths (and weights) of the females varied between 12.3 cm (28.6 g) to 47.6 cm (894.0 g) and those of the males varied between 11.0 (27.0 g) and 44.8 cm (874.0 g). The ages of the fish were between 1 and 10 years old (Table 1).

The equations of the length-weight relationships were as follows:

Females : $W = 0.056*TL^{2.466}$ (n= 237; $R^2 = 0.95$; $SE_a = 0.006$; $SE_b = 0.033$)
Males : $W = 0.104*TL^{2.267}$ (n= 127; $R^2 = 0.93$; $SE_a = 0.017$; $SE_b = 0.051$)
Combined sexes : $W = 0.070*TL^{2.390}$ (n= 364; $R^2 = 0.95$; $SE_a = 0.007$; $SE_b = 0.029$)

The von Bertalanffy growth parameters and their confidence limits ($CL_{(95\%)}$) of *C. umbla* were calculated for females, males and combined sexes (Table 2).

Mortality Rates

The growth parameters of combined sex were used to estimate mortality rates. The natural mortality

Table 1. Total length (cm) and total weight (g) values *of C. umbla* populations inhabiting Lake Hazar (M: Male; F: Female)

Age group	Sex	N	*TL*	Range	SE	*W*	Range	SE
I	F	7	14.31	12.3-16.5	1.43	43.98	28.6-53.1	3.25
	M	11	13.71	11.0-16.1	0.50	42.07	27.0-55.1	2.61
	F+M	18	13.95	11.0-16.5	0.37	42.81	27.0-55.1	1.99
II	F	24	23.55	17.1-26.1	0.36	127.41	58.0-16.0	4.76
	M	22	22.47	17.3-24.8	0.33	106.22	58.0-132.0	3.50
	F+M	46	23.03	17.1-26.1	0.26	117.28	58.0-160.0	3.35
III	F	52	26.61	20.5-33.8	0.44	183.23	96.0-306.0	8.19
	M	39	25.44	21.0-33.5	0.54	160.46	98.0-290.0	9.04
	F+M	91	26.11	20.5-33.8	0.34	173.47	96.0-306.0	6.16
IV	F	65	28.68	23.5-34.2	0.43	227.26	112.0-376.0	9.09
	M	24	28.06	22.7-35.8	0.67	210.20	120.0-356.0	13.55
	F+M	89	28.51	22.7-35.8	0.36	222.69	112.0-376.0	7.58
V	F	38	31.14	22.9-39.8	0.78	270.28	134.0-390.0	14.03
	M	9	30.80	25.3-37.8	1.24	253.77	170.0-360.0	24.58
	F+M	47	31.08	22.9-39.8	0.67	267.12	134.0-390.0	12.20
VI	F	23	32.43	24.2-37.5	0.97	309.13	142.0-432.0	21.61
	M	10	33.17	26.5-40.0	1.28	289.10	211.0-385.0	22.35
	F+M	33	32.65	24.2-40.0	0.77	303.06	142.0-432.0	16.40
VII	F	16	33.65	26.2-39.8	1.19	346.31	172.0-476.0	25.98
	M	7	35.41	32.2-41.3	1.09	340.71	276.0-458.0	26.85
	F+M	23	34.18	26.2-41.3	0.89	344.60	172.0-476.0	19.50
VIII	F	5	34.82	31.1-37.5	1.08	383.40	277.0-486.0	38.42
	M	4	38.07	33.0-43.3	2.10	411.75	361.0-485.0	26.48
	F+M	9	36.26	31.1-43.3	1.18	396.00	277.0-486.0	23.49
IX	F	3	37.36	32.8-43.3	3.10	478.33	316.0-602.0	84.79
	M	-	-	-	-	-	-	-
	F+M	3	37.36	32.8-43.3	3.10	478.33	316.0-602.0	84.79
X	F	4	44.65	41.0-47.6	3.10	736.25	602.0-894.0	60.17
	M	1	44.80	-	-	874.00	-	-
	F+M	5	44.68	41.0-47.6	1.19	763.80	602.0-894.0	54.14

rate on *C. umbla* population in Lake Hazar was estimated as M=0.363 using by L∞=53.77, K=0.16 and T =16°C. On the other hand, commercial fishing data were used to estimate the total mortality rate (Z). According to linearized catch curve method, the total mortality rate was estimated as Z=0.712 (Figure 2).Fishing mortality rate was also estimated as F=0.349 by subtracting the natural mortality from the total mortality (F=Z-M).

The percentage survival (%S) was estimated as 49%. Thus, the percentage of total deaths occurred in the stock in the fisheries season was 51%, when this figure was divided according to causes, 25% was due to fisheries activities (%C) and the remaining 26% was from natural reasons (%D). The exploitation rate (E) was found to be 0.49.

Annual Catch and Length Frequencies

The total annual catch of *C. umbla* in Lake Hazar during the 2008-2009 fishing season consisted of 107544 individuals and amounted to 25721 kg. The average length and average weight of these fish were calculated as 28.7 cm and 239.4 g, respectively. While the highest yields were obtained in September, October and November, the lowest yield was obtained in February. The lengths of the fish caught varied from 12 cm to 45 cm and the great majority of the annual catch was composed of the individuals from 25 cm to 27 cm (Figure 3).

Stock Assessment

Stock Assessment with Mark and Recapture Method

A total of 2825 individuals (M) were marked by using the multiple marking methods in order to assess the stock size (Table 3). Totally, 69808 individuals (Ct) were controlled in the commercial catch and research materials caught between 20 October 2008 and 24 August 2009. Altogether 175 marked fish (Rt) were recaptured (Table 3).

According to the mark and recapture method, the stock size in numbers (No) was estimated as 382627 individual fish ($CI_{(95\%)}$: 355736-413916). This corresponded to an estimated biomass of 91601 kg ($CI_{(95\%)}$: 85163-99061 kg).

Stock Assessment with the Length-bAsed Cohort Analysis

A cohort analysis was applied by using the length frequencies obtained from the total commercial catch. The number of the individuals larger than 12 cm was estimated to be 367219 at the beginning of the cohort (Table 4). This cohort showed an exponential decay and only 246 individuals survived bigger than 44 cm in length (Figure 4) and older than 10.38 years old.

Stock size (mean N) of *C. umbla* based on length based cohort analysis was estimated at 367219 individual fish ($CI_{(95\%)}$: 240521-868729 fish), and

Table 2. The VBGF parameters of *C. umbla* populations inhabiting Lake Hazar

	Female	Male	Combined sexes
L∞	49.22	56.17	53.77
$CL_{(95\%)}$	45.7-52.74	53.12-59.22	49.53-58.00
K	0.20	0.13	0.16
$CL_{(95\%)}$	0.17-0.23	0.04-0.22	0.05-0.28
t_0	-1.88	-1.62	-1.84
$CL_{(95\%)}$	-2.39- -1.37	-3.16- -0.08	-2.23- -1.45

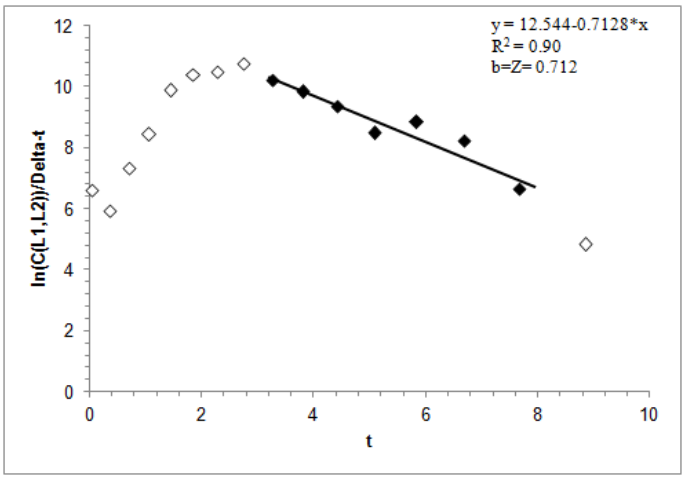

Figure 2. Total mortality (Z) of *C. umbla* in Lake Hazar using by linearized catch curve method.

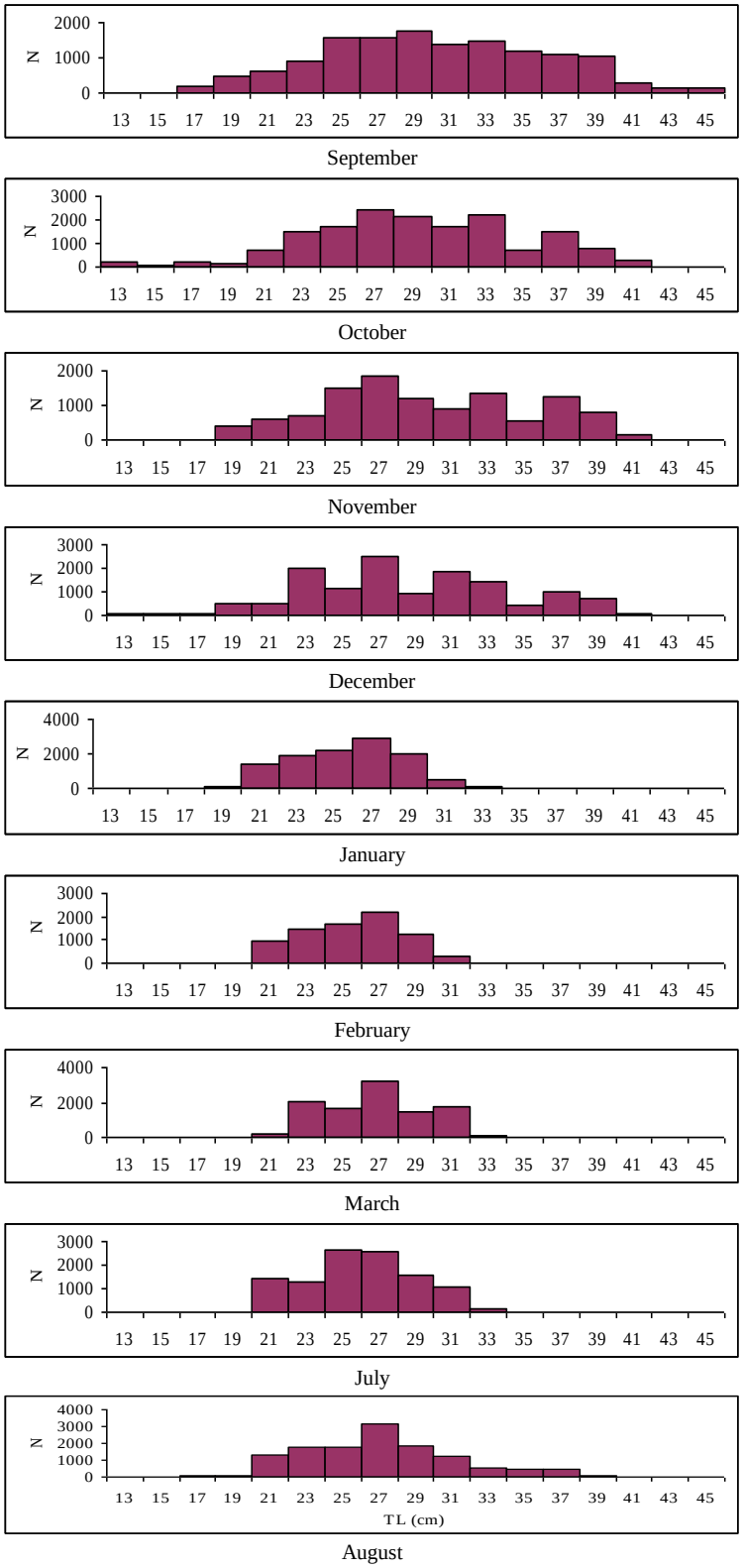

Figure 3. Length frequency of *C. umbla* catched in the 2008-2009 fishing season from Hazar Lake, according to months.

95256 kg ($CI_{(95\%)}$:55079-263225 kg) as biomass (Table 4). Length based cohort analysis was applied with the using of growth parameters for combined sex ($L\infty$= 53.77, K= 0.16 and t_o= -1.84). Stock size of *C. umbla* was estimated to be between 55079 and 263225 kg with 95% confidence limits (Table 2).

Assessment of the Maximum Sustainable Yield (MSY)

With the simulation of the fishing mortality and fishing effort maximum sustainable yield (MSY) was assessed as 27070 kg with an increase of 2.4 times of

Table 3. Mark and recapture program for *C. umbla* in Lake Hazar. (Ct: total number of fish captured in sample t, Rt: number of fish already marked in sample t, M: The number of new marked fish, Mt: total number of fish marked in population in sample t)

Date		Ct	Rt	M	Mt	Mt*Ct
20.10.2008	26.10.2008	2152	0	12	0	0
27.10.2008	02.11.2008	2037	0	3	12	24444
03.11.2008	09.11.2008	1813	0	22	15	27195
10.11.2008	16.11.2008	1896	2	13	37	70152
17.11.2008	23.11.2008	2055	0	16	50	102750
24.11.2008	30.11.2008	3920	2	1	66	258720
01.12.2008	07.12.2008	1509	1	15	67	101103
08.12.2008	14.12.2008	48	2	9	82	3936
15.12.2008	21.12.2008	1540	2	13	91	140140
22.12.2008	28.12.2008	1954	3	10	104	203216
29.12.2008	04.01.2009	3366	3	0	114	383724
05.01.2009	11.01.2009	1716	2	2	114	195624
12.01.2009	18.01.2009	1395	2	5	116	161820
19.01.2009	25.01.2009	1698	1	5	121	205458
26.01.2009	01.02.2009	1668	2	6	126	210168
02.02.2009	08.02.2009	1100	1	0	132	145200
09.02.2009	15.02.2009	986	2	0	132	130152
16.02.2009	22.02.2009	1157	0	0	132	152724
23.02.2009	01.03.2009	1135	0	0	132	149820
02.03.2009	08.03.2009	1135	0	0	132	149820
09.03.2009	15.03.2009	1245	0	0	132	164340
16.03.2009	22.03.2009	1707	0	0	132	225324
23.03.2009	29.03.2009	1571	0	0	132	207372
30.03.2009	05.04.2009	2248	1	115	132	296736
06.04.2009	12.04.2009	295	3	64	247	72865
13.04.2009	19.04.2009	673	1	152	311	209303
20.04.2009	26.04.2009	1316	4	295	463	609308
27.04.2009	03.05.2009	862	5	191	758	653396
04.05.2009	10.05.2009	409	2	91	949	388141
11.05.2009	17.05.2009	510	9	107	1040	530400
18.05.2009	24.05.2009	444	2	99	1147	509268
25.05.2009	31.05.2009	598	2	134	1246	745108
01.06.2009	07.06.2009	1417	8	314	1380	1955460
08.06.2009	14.06.2009	1624	10	359	1694	2751056
15.06.2009	21.06.2009	708	8	153	2053	1453524
22.06.2009	28.06.2009	964	3	216	2206	2126584
29.06.2009	05.07.2009	2138	12	112	2422	5178236
06.07.2009	12.07.2009	1940	16	60	2534	4915960
13.07.2009	19.07.2009	2077	14	105	2594	5387738
20.07.2009	26.07.2009	1791	13	56	2699	4833909
27.07.2009	02.08.2009	1747	10	70	2755	4812985
03.08.2009	09.08.2009	1861	2	0	2825	5257325
10.08.2009	16.08.2009	2037	8	0	2825	5754525
17.08.2009	23.08.2009	1575	10	0	2825	4449375
24.08.2009	31.08.2009	3771	7	0	2825	10653075
Total		69808	175	2825		66957479

the present fishing effort. This is close to the present yield (25721 kg). So it can be seen that the maximum sustainable yield (MSY) may be obtained with an increase of 2.4 times of the present fishing effort (Figure 5). There are 7 commercial fishing boats in the lake now and if there were 17 boats (2.4 times of the present fishing boats), the maximum sustainable yield would be obtained.

Discussion

The oldest *C. umbla* reported in the literature was 13 years old and 47.20 cm in length (Şen and Aydın, 2000). Age distributions and asymptotic length (L_∞) distributions of the different populations were between 1 and 13 years old and 41.11-73.41 cm for combined sex (Şen and Aydın, 2000; Türkmen *et al*., 2002; Yüksel, 2002; Yılmaz *et al*., 2003; Güneş 2007; Çoban and Şen 2011) and the ages and $L\infty$ values of the present study were consistent with the previous studies (Table 5).

The exponent "b" in the length and weight relationships of *C. umbla* varied from 2.459 to 3.199 (for combined sex) (Şen and Aydın, 2000; Türkmen *et al*., 2002; Yüksel, 2002; Yılmaz *et al*., 2003; Güneş 2007; Çoban and Şen 2011) (Table 5).

Table 4. Length based cohort analysis of *C. umbla* in Lake Hazar ($L\infty$=53.77; K=0.16; t_0= -1.84; M=0.363)

L1-L2	$T_{(L1)}$	Δt	H	C	$N_{(L1)}$	F/Z	F	Z	Mean N	Mean B (kg)	Yield (kg)
12-14	0.02	0.30	1.057	228	390151	0.006	0.002	0.365	113179	3551	7
14-16	0.04	0.32	1.060	123	348839	0.003	0.001	0.364	106131	4850	5
16-18	0.36	0.34	1.064	528	310190	0.014	0.005	0.368	99129	6274	33
18-20	0.70	0.36	1.067	1687	273678	0.048	0.018	0.381	91961	7759	142
20-22	1.06	0.38	1.072	7617	238610	0.201	0.091	0.454	83609	9122	831
22-24	1.44	0.41	1.077	13549	200642	0.338	0.185	0.548	73148	10070	1865
24-26	1.85	0.43	1.082	15904	160541	0.417	0.260	0.623	61224	10422	2707
26-28	2.28	0.47	1.088	22387	122413	0.564	0.470	0.833	47582	9847	4633
28-30	2.75	0.50	1.096	14104	82753	0.528	0.406	0.769	34772	8622	3497
30-32	3.26	0.55	1.105	10689	56027	0.540	0.426	0.789	25106	7367	3136
32-34	3.81	0.60	1.116	7372	36224	0.537	0.421	0.784	17493	6008	2532
34-36	4.41	0.67	1.129	3393	22503	0.433	0.277	0.640	12257	4881	1351
36-38	5.08	0.75	1.145	5445	14660	0.661	0.709	1.072	7683	3517	2493
38-40	5.82	0.85	1.166	3419	6426	0.738	1.022	1.385	3345	1748	1786
40-42	6.67	0.98	1.195	816	1793	0.669	0.733	1.096	1113	659	483
42-44	7.65	1.16	1.124	160	573	0.489	0.348	0.711	460	307	107
44-∞	8.81			123	246	0.500	0.363	0.726	339	253	92
							Total yield and biomass			95257	25703

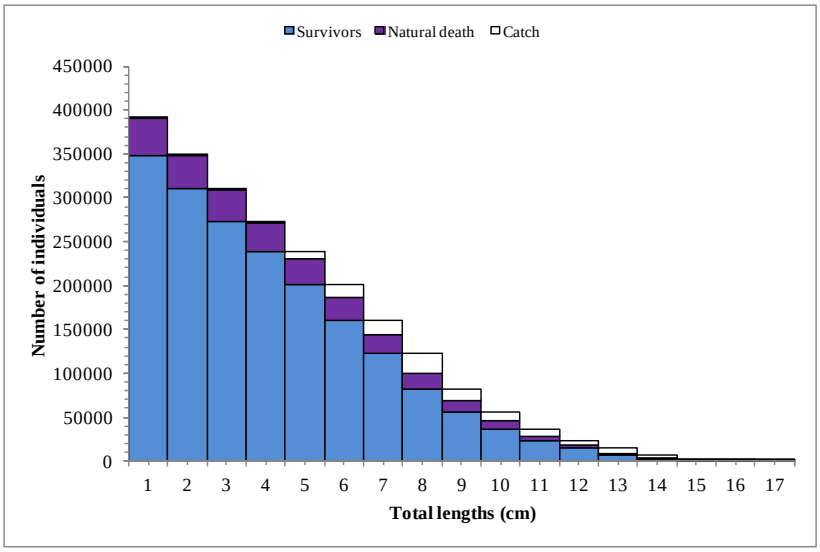

Figure 4. The length based cohort analysis of *C. umbla* in Lake Hazar.

In the present study, the exponent "b" was estimated as 2.466 for females, 2.267 for male and 2.390 for combined sex and these were lower than those of the previous studies. Length and weight relationships in the present study were estimated by using the total lengths and total weights. However, the same exponents in the previous studies were estimated from the fork lengths and total weights. In addition to sampling methods and times were different. So, the differences between our estimates and the previous results may have resulted from the different nature of data.

The total mortality rate of *C. umbla* population in Lake Hazar was found to be Z=0.712 and fishing mortality rate (F) was 0.349 and natural mortality rate (M) was 0.363. Approximately 51% of the stock died during the fisheries season, and 25% was due to the fisheries activities and 26% was because of natural reasons. The optimum exploitation rate (E) is assumed to be 0.50 for sustainable fishery and it was estimated as 0.49. This situation shows that mortality rates in Lake Hazar were suitable for sustainable fisheries.

In the present study, the stock size of *C. umbla* was assessed with two independent methods; first by mark and recapture method and second by length based cohort analysis. Mean stock sizes and lower and higher stock sizes with their confidence intervals were estimated as 91601 kg ($CI_{(95\%)}$: 85163-99061 kg) and 382627 individuals ($CI_{(95\%)}$: 355736-413916 individuals) with mark and recapture method and they were 95256 kg ($CI_{(95\%)}$:55079-263225 kg) and 367219 individuals ($CI_{(95\%)}$: 240521-868729 individuals) with length based cohort analysis. The results obtained

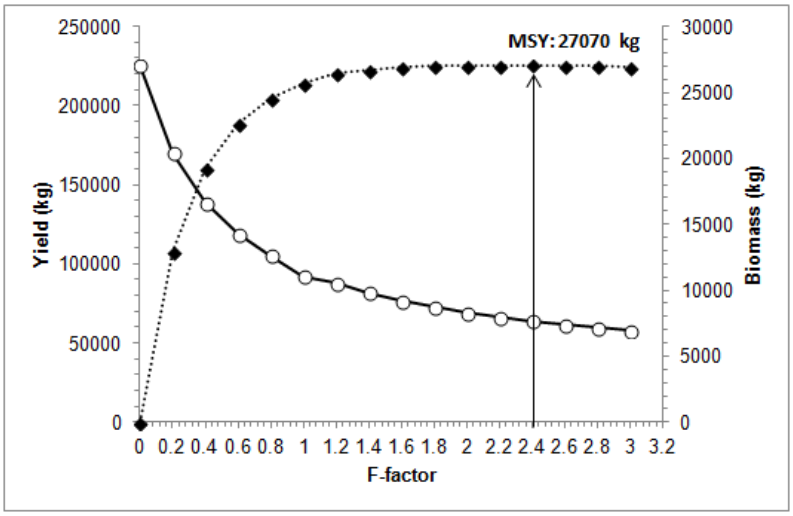

Figure 5. Yield–Biomass relationships and maximum sustainable yield (MSY) of *C. umbla* in Lake Hazar.

Table 5. Population characteristics of *C. umbla* presented in different studies and their comparison with the results of the present study. (F: Female, M: Male, C: Combined sex)

Population	Sex	N	Age	b	L∞	K	t_0	L (Range)	W (Range)	Ref.
Lake Hazar	F	180	2-13	3.006	68.61	0.076	-2.04	18.70-47.20	55.50-902.00	
	M	164	2-13	3.097	71.49	0.064	-2.63	19.50-46.00	57.00-900.50	1
	C	346*	1-13	3.186	68.62	0.074	-2.20	18.70-47.20	55.50-902.00	
Lake Hazar	F	53	2-7	3.204	-	-	-	19.96-36.25	67.33-419.00	
	M	48	1-7	3.263	-	-	-	12.35-34.25	13.62-405.50	2
	C	101	1-7	3.199	-	-	-	12.35-35.25	13.62-412.25	
Lake Hazar	F	96	2-7	2.746	72.24	0.064	-2.53	18.62-38.30	56.41-527.10	
	M	132	2-7	2.690	64.73	0.061	-3.65	19.21-32.05	68.48-327.50	3
	C	228	2-7	2.704	68.62	0.062	-3.04	19.00-34.13	64.03-394.03	
Lake Hazar	F	237	1-10	2.466	49.22	0.20	-1.88	14.31-44.65	43.98-736.25	
	M	127	1-10	2.262	56.17	0.13	-1.62	13.71-44.80	42.07-874.00	4
	C	364	1-10	2.390	53.77	0.16	-1.84	13.95-44.68	42.81-763.80	
Keban	F	109	2-7	2.772	75.68	0.050	-6.91	26.68-37.06	172.71-547.68	
Reservoir	M	123	2-7	2.678	69.42	0.073	-4.49	25.48-37.10	178.81-519.40	3
	C	232	2-7	2.727	73.41	0.059	-5.67	25.98-37.06	176.27-542.96	
Tercan	F	165	1-6	2.321	41.64	0.196	-0.69	11.62-31.84	21.91-346.18	
Reservoir	M	158	1-6	2.485	40.60	0.219	-0.29	12.35-31.06	26.70-327.61	5
	C	323	1-6	2.674	41.11	0.201	-0.54	12.00-31.65	24.43-341.54	
Tuzla	F	146	1-6	2.400	54.17	0.124	-1.54	12.11-32.67	23.99-330.96	
Stream	M	161	1-6	2.532	46.08	0.151	-1.34	12.67-31.00	28.65-277.31	5
	C	307	1-6	2.459	52.15	0.137	-1.35	12.42-32.34	26.54-320.23	
Euphrates	F	260	1-7	2.955	-	-		7.52-27.85	4.80230.60	
River	M	276	1-7	2.979	-	-		7.76-29.26	5.40-261.30	6
	C	536	1-7	2.962	-	-		7.63-28.79	5.18-2.962	
Karasu	F	506	1-12	2.936	45.70	0.139	-0.83	10.40-34.20	15.00-557.00	7
River	M	665	1-10	2.991	42.30	0.146	-0.98	10.90-32.30	18.00-428.00	

Ref: (1) Şen and Aydın (2000) *two individual is juvenile; (2) Yüksel (2002); (3) Çoban and Şen (2011); **(4) Present study**; (5) Güneş (2007) ; (6) Yılmaz *et al*. (2003); (7) Türkmen *et al*. (2002).

with two methods are close to each other, however, statistically, mark and recapture method provide more accurate results than those of the length based cohort analysis because of its lower standard errors and narrower confidence intervals. The mark and recapture method was applied for carp (*C. carpio*) population in Lake Mogan (Düzgüneş, 1985) and pike perch (*Stizostedion lucioperca* (Linnaeus, 1758)) population in Lake Eğirdir (Erk'akan and Bayrak, 1992). However, fin cutting was applied as marking method instead of external tagging such as T-Bar anchor tags. Fin cutting has some disadvantage because it may become invisible in time. Length based cohort analysis was applied for carp population in Lake Gölhisar (Alp and Balık, 2000), pike perch population in Lake Eğirdir (Balık *et al*., 2004) and for northern pike (*Esox lucius* Linnaeus, 1758) population in Lake Karamık (Çubuk *et al*., 2005) in Turkey.

It was predicted that if the fishing effort was

increased 2.4 times the maximum sustainable yield (MSY) would have been obtained from the stock. This means that the current number fishing boats (7 boats) in the lake should be increased to 17. This is not consistent with the present estimates of mortality rates and stock exploitation rate (E). Because, in order to ensure a sustainable fisheries, the exploitation rate (E) should be around 0.50 and it was estimated to be 0.49 in the present study. In addition, the present yield (25721 kg) and predicted maximum sustainable yield (27070 kg) are very close to each other. Thus, it is advisable to sustain the fishing effort in Lake Hazar at its current level.

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