Age and growth of bigeye kilka (*Clupeonella grimmi* Kessler, 1877) in Iranian waters of the Caspian Sea

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Abstract

Age and growth of Bigeye Kilka, *Clupeonella grimmi*, were studied in Iranian waters of the Caspian Sea from early May 2006 to April 2007. The sagitta otoliths were removed for each 5 mm length interval up to a total number of 262 fish. Fork length and weight ranged from 92.5 to 142.5 mm and 4.2 g to 23.4 g, respectively. The largest length-groups was observed from December to February and the lowest in April, which was coincided with spawning period and feeding during wintering, respectively. The overall sex ratio (male:female) was 0.33:1 which differed significantly from the expected ratio of 1:1. The length-weight regression was $W= 0.0000744\ FL^{3.14}$ for females and $W=0.0000341FL^{3.16}$ for males, indicating the Caspian Bigeye grew isometrically for both sexes. Age determination based on otoliths readings showed that the population was composed of six- groups from 2 to 7 years old which observed a rapidly growth during the second year. In the age compositions, the four years old specimens with a mean fork length and weight 115.5±7.8 mm and 11.9 ± 2.8 g were the most abundant age group and accounted for 40.1%. The condition factor was 0.7-0.8 which varied in difference months and coincided to the gonad development. Age-at-length data were used to determine von Bertalanffy growth parameters for this population in both sexes, indicating that K value and L_∞ of females was more than that of males. The results showed that *C. grimmi* is a rapidly-growing species in the southern parts of the Caspian Sea.

Keywords: Age, Growth, *Clupeonella grimmi*, Caspian Sea, Iran

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Introduction

Age and growth studies constitute an extremely important field of commercial fishery biology, providing the knowledge which is required for the solution problems of population dynamics, assessment of fishing ground, and fishery management techniques (Matisa, 1992; Mohd Nsir, 1994). The most abundant fishes of the Caspian Sea are three small clupeids known as "Kilka" which are anchovy Kilka (*Clupeonella engrauliformis* Svetovidov, 1941), common Kilka (*C. cultriventris caspia* Bordin, 1904), and bigeye Kilka (*C. grimmi* Kessler, 1877) (Svetovidov, 1963).

Bigeye Kilka comprised about 1-7 percent of the total catch Kilka in the Iranian waters (Besharat and Khatib, 1993; Fazli *et al*., 2006). This species inhabits the relatively deeper areas of the central and southern Caspian Sea. Bigeye differs from the two other species of Kilka in their distinctive adaptation to deeper parts of the water bodies (Prikhod'ko, 1981). For instance, they have bigger eyes, structural difference in their retinas and greater transparency of the tissues (Prikhod'ko, 1981). The larvae of bigeye Kilka remain further offshore in depths exceeding 70 m, compared to the anchovy kilka. They are stenohaline and live in the lower water temperature (Prikhod'ko, 1981). This species has a life span of 8 years in the southern Caspian Sea with males and females attaining sexual maturity between 65 mm and 75 mm, respectively (Prikhod'ko, 1981). Bigeye Kilka, mainly, have been recorded as native species in the Iranian waters of the Caspian Sea and rarely found in other regions of the Sea (Prikhod'ko, 1981).

Some studies were carried out previously on bigeye Kilka in Iranian waters regarding to Kilka distribution - (Svetovidov 1963; Besharat and Khatib, 1993; Rezvani *et al*., 1993; Naderi *et al*., 1997), stock assessment methods by hydroacoustic during 1994-1996 (Pourgholam *et al*., 1996; Fazli and Besharat, 1998) before entrance of Ctenophorea to the Caspian Sea. Other studies were on the age, growth and biomass (Mamedov, 2006; Fazli *et al*., 2009) and population dynamics (Parafkandeh, 2009).

Despite the economic and ecological importance of *C. grimmi* in the Caspian Sea, there is limited information available regarding its age, growth and condition factor in Iranian waters of the Caspian Sea after observing the jellyfish (Ctenophora, *Mnemiopsis leidyi*). Such information is especially important because of the ecological changes that are occurring in the Sea at present due to the appearance of Ctenophorea, in 1999 (Shiganova *et al*., 2001). In the 1980s, this species was reported in the Black Sea devastating affected the whole ecosystem (Vinogradov *et al*., 1989). The present study aimed to investigate the biology, population structure, age, growth and von Bertalanffy population parameters of *C.grimmi* compared with before observing the Ctenophora *M. leidyi* in Iranian waters of the Caspian Sea.

Materials and methods

This study was conducted in the Iranian waters of the Caspian Sea between May 2006 and April 2007. The commercial catches of Kilka fish is commenced at this time of the year excepted from May to June that catch of Kilka fish is banned. It should be noted that this species is caught only in the colder months (from December 2006 to April 2007). Fresh samples of *C. grimmi* were collected using a conical liftnets mobilized with 1500w underwater electric lights to attract the fish in Babolsar, Amirabad and Anzali stations in Mazandaran and Guilan provinces, respectively (Fig.1). The diameter of the hoop of a conical liftnet was 2.5 to 3 m and the length of the net bag was at least 1.25 times greater than the diameter of the hoop (Ben- Yami, 1976). The mesh size between two knots of the net is 7-8 mm. Age was determined using otolith reading. For each sex we collect 5-10 otoliths from each 5 mm size class. In this study, 151 otoliths were removed. To enhance contrast and facilitate reading and interpretation of growth marks, the whole otoliths were put in the glycerin solution for 24 hours and then observed with black background under reflected light through a microscope (Fig.2).

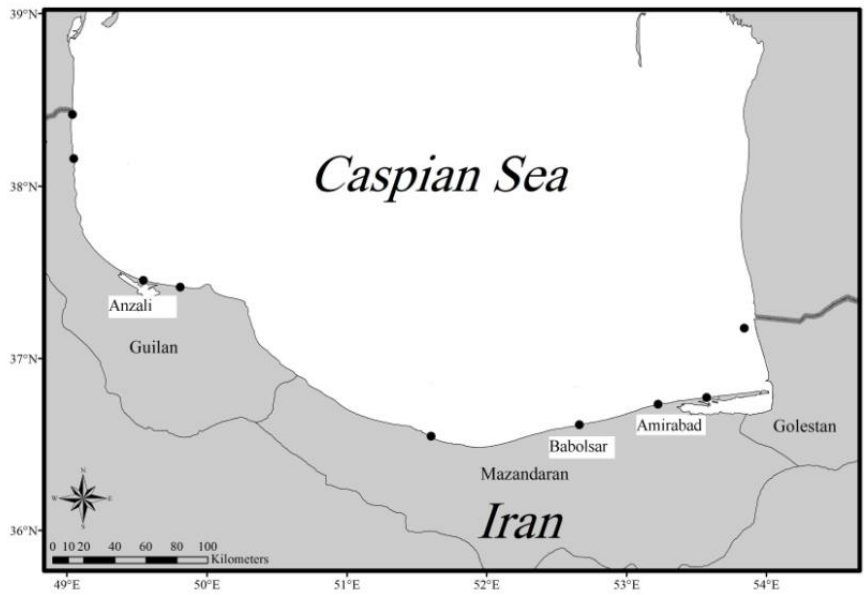

Figure 1: The landing places of kilka in Iranian waters (Amirabad-Babolsar and Anzali harbors) of the Caspian Sea.

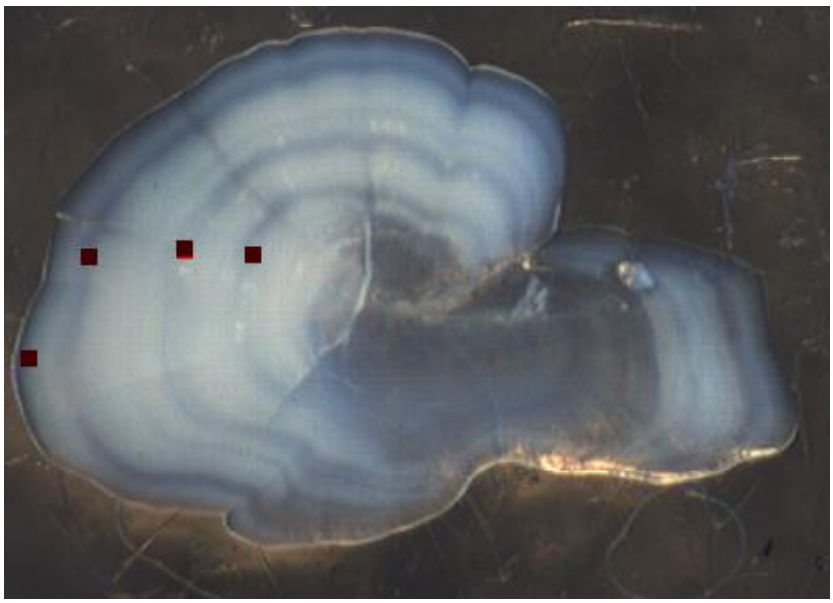

Figure 2: Age determination of *Clupeonella grimmi* with otolith (annual rings in 4 years old)

After transferred specimens to the laboratory, up to 200 specimens for Bigeye Kilka were randomly selected and then biological parameter as fork length, weight and age were studied. Fork length and weight of captured fish were measured to mm and g, respectively.

The relationship between weight and length was calculated using the exponential regression:

$$W = a \times L^b$$

where W is the total weight (g), L is the fork length (mm); a is the regression constant (intercept) and b is the regression coefficient (slope) (Ricker, 1975).

The Fulton condition factor (CF) was determined for each fish using the following equation (Bagenal, 1978):

$$CF = \frac{W}{L^b} \times 100$$

where W is the total weight (g) and L is fork length (mm). Length-at-age data were fitted to the von Bertalanffy growth model (Ricker, 1975) using non-linear least-squares regression:

$$L_t = L_\infty (1 - e^{-k(t-t_0)})$$

where L_t is the length of the fish at age t, L_∞ is the asymptotic length, K is a growth rate per unit of time, and t_0 is the theoretical age at which the fish would have length zero. Overall growth performance index (Φ') of species can be interpreted by the growth index (Munro and Pauly, 1983):

$$\Phi = \log_{10}^{K} + 2\log_{10}^{L\infty}$$

Length-at-age data analysis was used to FiSAT software proposes. Chi-squared analysis was used to examine a significant difference from an expected 1:1 sex ratio for all fish.

Results

Length and weight relationship

Six hundred and twenty six specimens of *C. grimmi* were totally collected and used for this study. One hundred and fifty five specimens were males and 471 were females. The overall sex ratio (males: females) in this study was 0.33:1 for adult bigeye Kilka which differed significantly from the expected 1:1 ratio (λ^2 = 159.5, p<0.05, Table 1). Females were generally more abundant and significant difference was observed between males and females throughout the year (p<0.05; Fig. 3), except in January, there was no significant difference between males and females (χ^2 =2.8, p=0.096). Males were most abundant in all the size classes lower than 102.5 mm (p<0.001). Females predominated in the size classes greater than 102.5 mm (p<0.001; Fig. 4).

Table 1: Chi-square monthly test for *Clupeonella grimmi* sex ratio in the Iranian waters of the Caspian Sea.

Month	Males	Females	Total	χ^2	p
Dec.	14	113	127	77.2	0.001
Jan.	56	75	131	2.8	0.096
Feb.	64	189	253	61.8	0.001
Mar.	8	37	45	18.7	0.001
Apr.	13	57	70	27.7	0.001
Total	155	471	626	159.5	0.001

Fork length and weight ranged from 92.5 to 142.5 mm and 4.2 to 23.4 g (average 119.8±7.9 mm, 13.1±2.8 g, n=471) for females and from 92.5 to 132.5 mm and 5.2 to 18.5 g (average 113.90±8.8 mm, 11.2±2.8 g, n=155) for males. A significant difference was observed in length and weight relationship between males and females in various months (ANOVA, F = 89.676, p<0.05). For both sexes of all individuals, the relationship between total length and somatic weight was described as: $W = 0.00000572\ FL^3$ (r^2 = 0.91, n = 626);

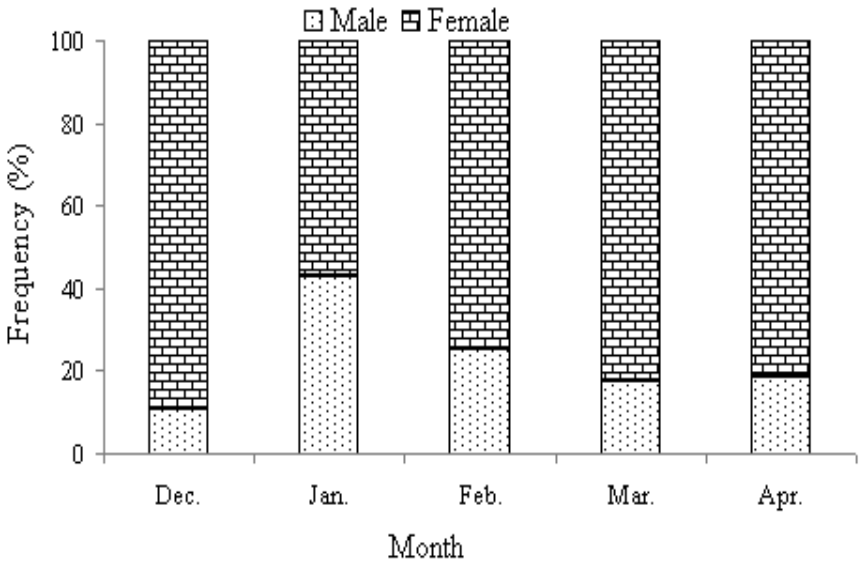

Figure 3: Monthly variations in sex ratio of *Clupeonella grimmi* in the Iranian waters of the Caspian Sea.

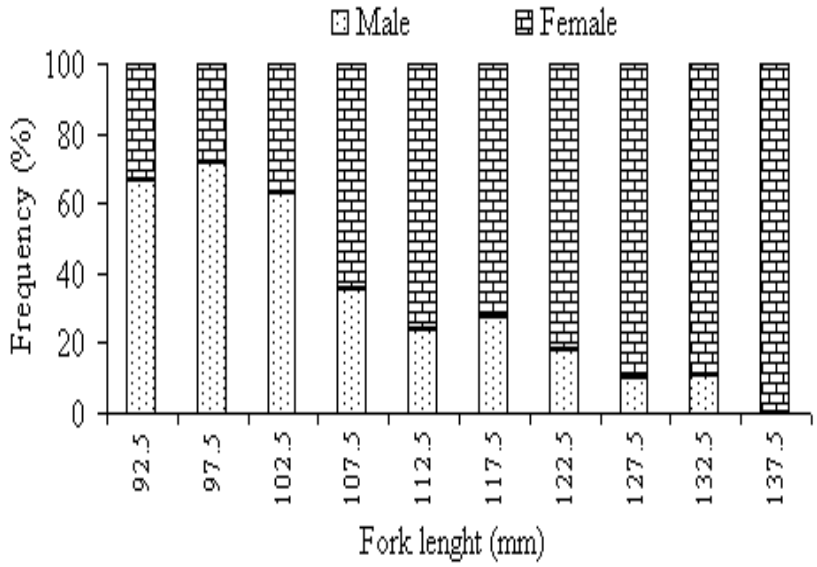

Figure 4: Sex composition of bigeye kilka *Clupeonella grimmi* in the Iranian waters of the Caspian Sea.

for females: W= 0.000007441 $FL^{3.159}$ (r^2=0.89, n=471); and for males: W=0.0000034 FL^3 (r^2=94, n=155). There were significant difference between sexes in the slopes (b) of length–weight relationship (t-test, t=38.736.102, p <0.05).

Length frequency

Fork length frequency of *C. grimmi* samples varied between 92.5 and 142.5 mm. The largest length groups (from 92.5 to 142.5 m) was observed during December to February and the smallest in April (from 97.5 to 127.5 mm) which was coincided with spawning period and feeding during wintering, respectively (Fig. 5). After a relatively low fork length from the average 120.4 mm in December to 117.7 mm in January, an increase in fork length was recorded (up to the average of 119.6 mm) in March. In April,

the fork length started to decrease steadily to the average of 114.4 mm.

Condition factor

The Fulton's condition factor (CF) varied from March (0.70) to December (0.79). There was a decrease in growth rate from December to March (0.79 to 0.7), an increase in April (0.78), which was coincided with development of gonads (Fig. 6). Condition factor was 0.75 (Fig. 7).

Von Bertalanffy age-at-length catch curve

Age of 262 fish was determined using the otoliths. The fish of the youngest group was two years and the oldest was seven years old. Totally, there were six age-groups (2 to 7 years old) (Fig. 8). The mean age was 4±1 yr. Totally, there were six age-groups (six age-groups for females with mean 4.1±1yr and also five age-groups for males with mean 3.9±1.2 yr). In the age compositions, the four years old specimens with a mean fork length and weight 115.5±7.8 mm and 11.9±2.8 g were the most abundant age group and accounted for 40.1% (40% for males and 41% for females; Table 2). There was a significant difference in age between males and females (t-test, t=9.566, $p<0.05$). The highest fork length growth increments were 133 mm/yr for males and 144 mm/yr for females at four years old. The von Bertalanffy growth parameters were: L_∞ = 148 mm, K = 0.29 year^{-1}, t_0 =-1.123 years for both sexes (Fig. 9). These parameters were as follows: L_∞=144 mm, K=0.31 year^{-1} for females; and L_∞=132 mm, K = 0.27 year^{-1},

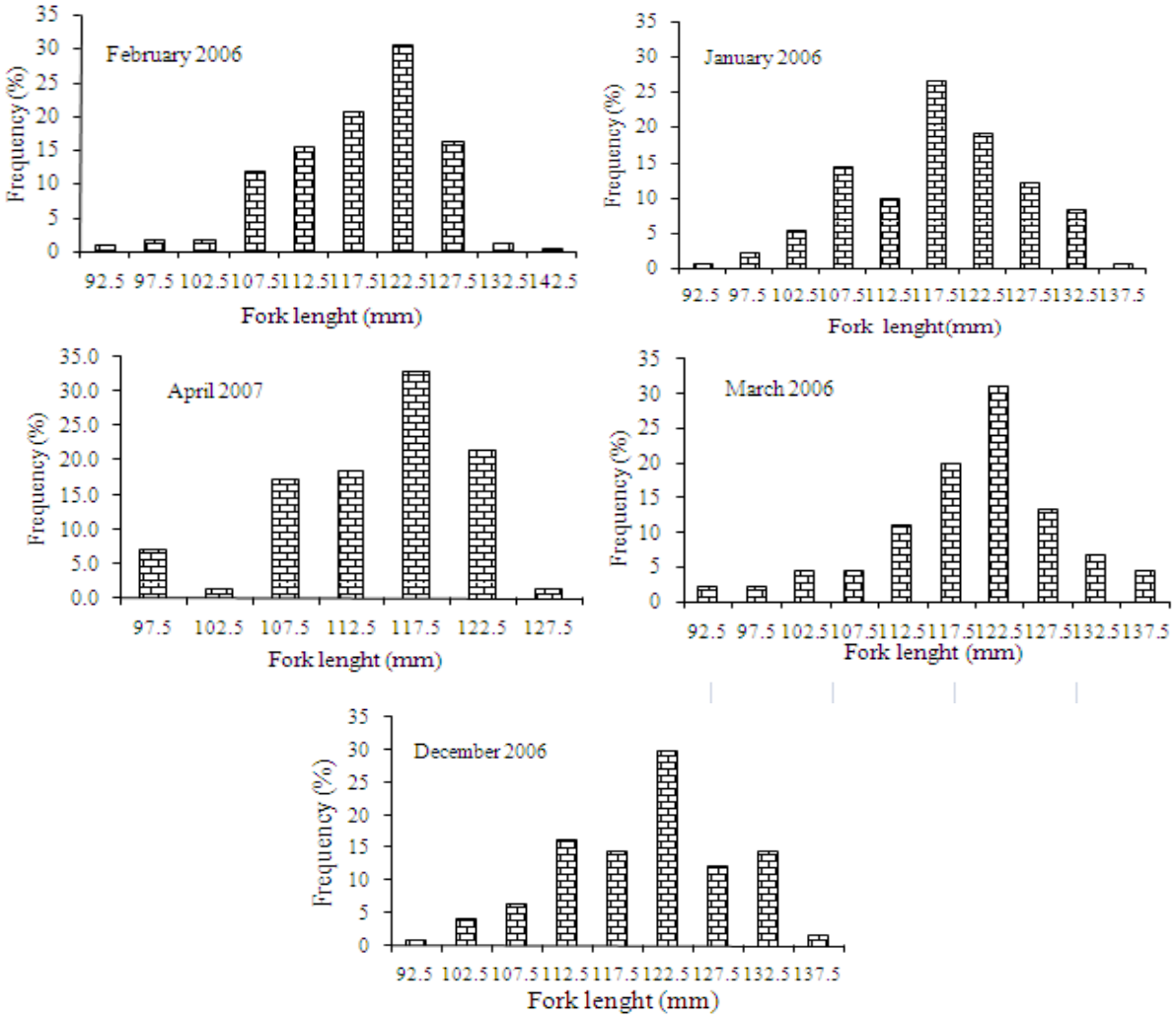

Figure 5: Monthly length-frequency distribution of *Clupeonella grimmi* in the Iranian waters of the Caspian Sea.

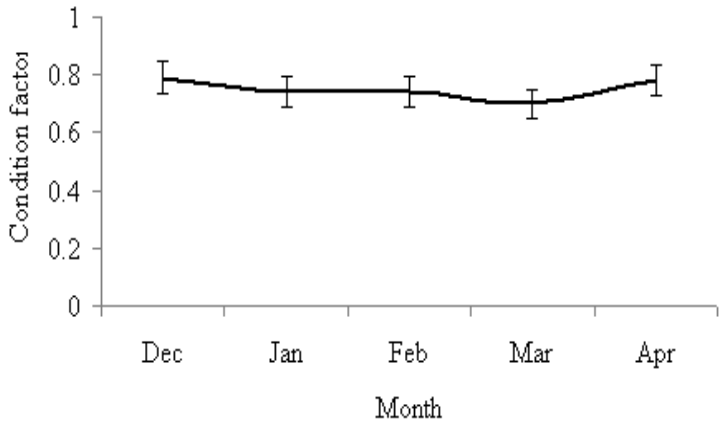

Figure 6: Mean (± S.E) of the condition factor of *Clupeonella grimmi* in the Iranian waters of the Caspian Sea.

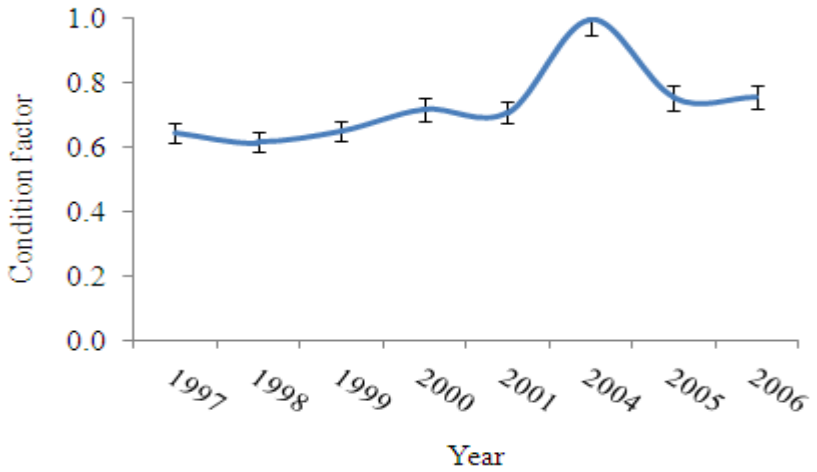

Figure 7: Annually changes of condition factor (mean ± S.E) of *Clupeonella grimmi* in the Iranian waters of the Caspian Sea.

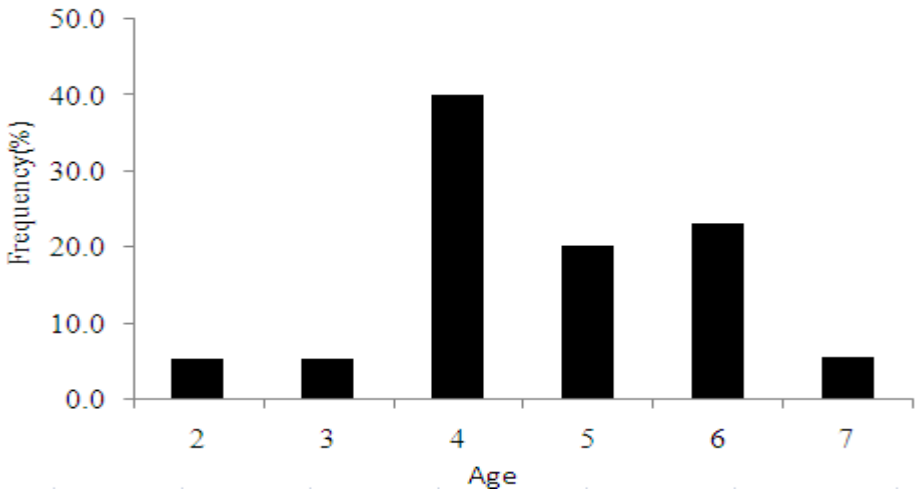

Figure 8: Age composition of *Clupeonella grimmi* in Iranian waters of the Caspian Sea.

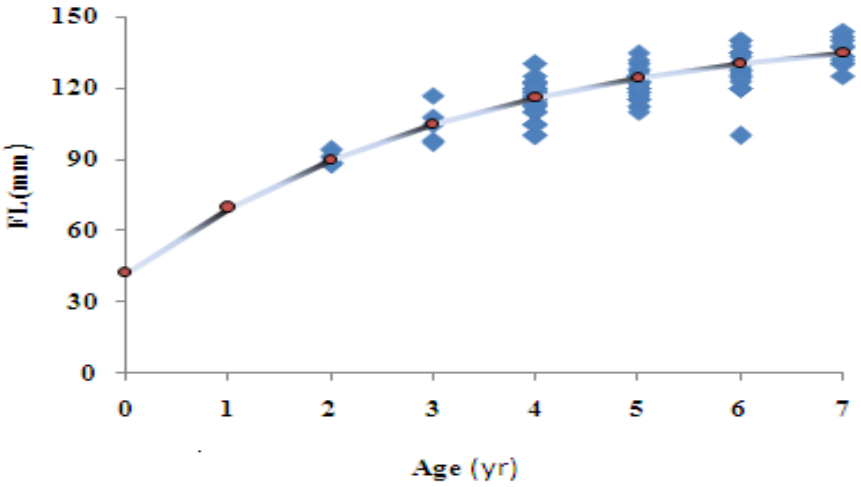

Figure 9: Theoretical growth curve for fork length of *Clupeonella grimmi* in Iranian waters of the Caspian Sea.

for males (Table 3). The growth performance index (Φ') was 3.688 for both sexes. The *K* value and L_∞ of females was more than that of males.

Table 2: Fork length (mm) means of *Clupeonella grimmi* in Iranian waters of the Caspian Sea.

Fork length (mm)	Age groups					
	2	**3**	**4**	**5**	**6**	**7**
Female	91±2.91	104±4.3	114.5±7.8	125.8±4.5	130±5.9	134.9±5.8
N	10	6	90	44	55	15
Male	90±1.5	105.5±6.3	110.8±5.7	120.3±5.5	128±11.6	
N	4	8	15	9	6	
Total	90.2±1.4	105±8.7	110.2±7.8	124.4±9	130.5±8.4	135±8.4
N	14	14	105	53	61	15

Table 3: Von Bertalanffy Parameters of growth equation *C. grimmi* from various localities and at different times.

Area	L_∞	K	t_0	Reference
Iranian waters	125.5	0.467	0.33	Pourgholam,1996
Azerbaijan waters	123.8	0.414	0.41	Mamedov, 2006
Iranian waters	143.6	0.267	1.74	Parafkandeh, 2009
Iranian waters	142	0.280	1.39	Fazli *et al*., 2009
Iranian waters	148	0.290	1.12	Present study

Discussion

In the present study, the exponent (*b*) of length-weight relationship for both sexes was 3.16. Bagenal (1978) indicated that the exponent usually ranges from 2.30 to 5.50 and it is generally more than 3. The relationship between fork length and body weight was calculated for each sex. Values of the isometric coefficient (*b*) were 3.14 and 3.16 for females and males, respectively, which were not significantly different from 3, indicating that the growth of *C. grimmi* is isometric. Similar isometric growth was reported by Mamedov (2006), but with over b (3.56) in Azerbaijan off waters. In contrast, Fazli *et al*. (2009) reported a lower exponent of the Von Bertalanffy equation (*b* = 2.89) and also less than that (2.61) reported by Parafkandeh (2009). It is thus difficult to compare the values of previous studies with those in the literature, as the recent reported data are insufficient; especially new data in the southern part of the Caspian Sea is needed.

Length can vary with geographical location that is probably related to some factors such as climate, trophic status and diet, destruction of natural habitats, unsuccessful natural breeding, fishing pressure (Koliev, 1997). During surveys along the central Caspian off Azerbaijan between 1995-2004, the fork length and weight means were 91 mm and 8.5 g

(Mamedov, 2006). Pourgholam (1996) in hydroacoustic project reported that fork length and weight means of *C. grimmi* were 108 mm and 9.5 g in Iranian waters. During the years between 1995-2001, fork length and weight means of *C. grimmi* were 103.6 mm and 7.6 g, respectively, in Iranian waters (Fazli *et al*., 2009). Parafkandeh reported that fork length means were 117.5 mm and most of them were in range of 120-130 mm, while the majority of the fish were 87 to 107 mm in 1997 (Fazli, 2002). In this study, the average fork length and weight of *C. grimmi* obtained as 118 mm and 12.7 g. Therefore, at the present study an increase in fork length and weight means of *C. grimmi* was observed than the previous years. This is due to the abundance of fish less than 90 mm severe and even reached zero and despite of big fish, the average length increased. Comparing these data suggest that the length range of the species is more limited and most of the larger fish are caught.

The length- frequency distribution has the largest span in December to February and then span changes from February to April from maximum 142.5 to 127.5 mm. This could be due to migration of females and males to these areas for spawning.

Generally, the highest values of condition factor were observed in December and April. The increase condition factor in December and April could be due to gonadal development and feeding activity. Condition factor decreased in winter (January) because of decreased food intake and low temperature. Similar fluctuation in condition factor was reported by Fazli *et al*. (2009). In addition condition factor increased to the highest levels in 2004 to 2006 rather than to previous years. After *Mnemiopsis* appeared in 1999 in the Caspian Sea (Ivanov *et al*., 2001), they fed aggressively zooplankton, fish eggs and fish larvae (Mutlu, 1999) and particularly on zooplankton, which is the food for zooplanktivorous kilka (Kideys *et al*., 2001; 2005). According to Fazli *et al*. (2007a), the biomass of the most abundant species of Kilka, anchovy, and bigeye Kilka decreased during 2000-2004. They found that the trends for biomass and condition factor were opposite, therefore prior to the stock collapse, the species may have been food-limited. Subsequent to the collapse, perhaps reduced inter and intra-specific competitions may have led to increased availability of zooplankton for the diminished Kilka stocks in which their condition increased.

Data on sex-ratio in different sizes showed absence of males above 102 mm. Females were the dominant sex and also were dominant in length class above 102 mm. This indicates that females grow to a larger size than males. The overall ratio of males to females (male:female) was 0.33:1, significantly different from 1:1, and there was a month difference in sex ratios except for January. This estimate differs from the ratio of 2.12:1 that reported by Besharat and Khatib (1993) who collected samples from 1990-1991 using a conical lift net with underwater electric lights. During hydro-acoustic biomass assessments which conducted in 1996 and 1997, some samples were

collected by mid-water trawl in the Iranian waters of the Caspian Sea (Fazli and Besharat, 1998). In the shallow waters, males were most abundant but in the deep waters females predominated in all seasons. These results confirm that the behavior of females changed with respect to underwater electric lights during the year. Ben-Yami (1976) reported that fish display different behaviors as they respond to light. A key hypothesis is that fish are attracted to light to feed. With the development of the gonads, females appeared to be less attracted to light. As they approached to the spawning time, they ceased feeding and disappeared from the catches. In case of males, they continued to feed during spawning and it seemed that their response to light remained unchanged (Ben-Yami, 1976). Dominance of female may be attributed to anyone or more the following factors as reported by Del-Zarka and Sedfy (1970): (a) segregation of the sexes through various periods of the year including segregation resulting from sex differences in age and size at maturity, (b) gear selectivity in relation to sex differences in morphology and in physiological activity and (c) differences in natural and fishing mortalities between sexes and (d) greater activity which in turn increase changes of being caught. As the bigeye Kilka biomass collapsed due to the combined effects of fishing mortality and the decline in available prey species (Fazli *et al*., 2007), dominant females in the *C. grimmi* population, probably a reaction to declining fish stocks of the struggle for survival through the spawning and reproduction more.

Negative values of the t_0 are frequent among species with rapid growth during the 1st year and reduced growth rates in subsequent year (Peres and Haimovic, 2004). Difference in length-at age and growth were observed between the males and females of *C. grimmi* in the southern of the Caspian Sea. Female fish often attains greater size than males, usually through a faster growth rate (Paker, 1992). At the present study for the age group of 2-3 yr, the rate increments were 13 mm/yr (20%) for females and 15.5 mm/yr (20%) for males. Subsequently, growth rate (length) in females and males trended to decrease and the growth rate differed significantly between sexes (about 5 mm/y (10 %). Females of *C. grimmi* grow fast in the second-third year of the life but, after that, grow more slowly than females. Several factors might be responsible for this growth different between males and females, for example, physiological changes influenced by temperature changes, feeding regimes and productive cycles (Utagawa and Taniuchi, 1999). There are few papers from previous studies about growth parameters in *C. grimmi* for comparing with the results of present study in the southern of the Caspian Sea. However, Table 3 gives some comparison between previous and present studies. Branstetter (1987) categorized *K* value as 0.05-0.10/yr for slowly growing species, 0.10-0.20/yr for species with average growth, and 0.20-0.50/yr for rapidly growing species. The results showed that *C. grimmi* in the

southern Caspian Sea have a rapid growth rate. This could be due to available food resources, optimum temperature (temperate area) and salinity. Hong-Jing and Cong-Xin (2008) reported that there are several factors affecting growth rate such as shortage of food, deprivation caused by migration and changes of temperatures. The *K* and $L\infty$ ratio are important parameters in the growth patterns used by Pauly *et al*. (1988). In this study, The *K* value and L_∞ of females of *C. grimmi* had relatively more than that of males.

Consequently, the finding on age and growth of *C. grimmi* from this research will help to elucidate the distribution with age of fish and their sustainable management. Moreover, further research is needed to complete the studies on age and growth during annual cycle.

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