Effects of fishing and natural factors on the population of the fish *Clupeonella grimmi* (Clupeiformes: Clupeidae) in southern waters of the Caspian Sea

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ABSTRACT: The present study aimed to investigate the changes of bigeye kilka *Clupeonella grimmi* population caused by human and natural factors in southern waters of the Caspian Sea. This study was conducted in 2009 and 2010 during which Length, weight and age were studied. The annual survival rate, natural and fishing mortality in 2009 were estimated 0.305 yr^{-1}, 0.448 yr^{-1} and 0.736 yr^{-1}, and in 2010 were 0.309 yr^{-1}, 0.419 yr^{-1} and 0.775 yr^{-1}, respectively. Accordingly, total mortality in 2009 and 2010 was 1.184 yr^{-1} and 1.174 yr^{-1} and the exploitation rate was calculated 0.621 and 0.660, respectively. Bigeye kilka appropriated 4.5% and 4.2% of total kilka catch in Mazandaran Province in 2009 and 2010, respectively. Results showed that bigeye kilka catch amount has decreased and its population is under over-fishing and natural pressure.

KEY WORDS: *Clupeonella grimmi*, mortality, survival rate, exploitation rate.

RESUMEN: Efecto de la pesca y los parámetros naturales en la población de Clu*peonella grimmi* (Clupeiformes: Clupeidae) en las aguas meridionales del Mar caspio. En este estudio investigamos los cambios en la población *Clupeonella grimmi* a causa de factores humanos y naturales en las aguas meridionales del Mar Caspio. El estudió se realizó entre el 2009 y 2010 donde se registró largo, peso y edad. La tasa de sobreviviencia annual y de mortalidad por pesca en 2009 se estimó en 0.305, 0.448 y 0.736 annual, y en el 2010 fue de 0.309, 0.419 y 0.775 respectivamente. De igual forma, la mortalidad total en el 2009 y 2010 fue de 1.184 y 1.174 annual y la tasa de explotación se calculó en 0.621 y 0.660 respectivamente. El total de captura en Mazandaran en 2009 y 2010 fue de 4.5% y 4.2%, respectivamente. Los resultados muestras que la captura ha disminuido y que su población se encuentra bajo la presión natural y pesquera.

Palabras clave: *Clupeonella grimmi*, mortalidad, tasa de supervivencia, tasa de explotación.

In the Caspian Sea, three kilka species including common (*Clupeonella caspia* Svetovidov, 1941), anchovy (*C. engrauliformis* Borodin, 1904) and bigeye kilka (*C. grimmi* Kessler, 1877) are found. These three pelagic species are the primary planktivores in the Caspian Sea (Mamedov, 2006) and are prey species for key predators (Pourgholam et al., 1996), so, these species are important in ecosystem function of the Caspian sea and are important to the economies of coastal areas.

Bigeye kilka can be distinguished from other kilkas by their bigger eye and greater number of vertebra (Berg, 1948). This species is distributed in the central and southern Caspian and extends farther from shore than the two other kilka species. It is found primarily at depths greater than 50-70 m with low light. This species is less tolerant to high temperature and salinity than anchovy and common kilka (Prikhodko, 1981). Bigeye kilka can spawn throughout the year, but most spawning occurs between November and April in the southern Caspian Sea (Fazli et al., 2004; Aliasghari et al., 2011).

Kilka fishing is conducted during nighttime using under-water light and funnel nets. Recently catch composition of kilkas has changed and now common kilka is dominant in the catch (Karimzadeh et al., 2010). Kilka stocks have been decreasing, which threatens jobs and industries with the potential for subsequent social and economic problems (Esmaeili Sari et al., 2002). Potential causes of the decline of kilka populations include invasion of ctenophore *Mnemiopsis leidyi* into the Caspian Sea (Ivanov et al., 2000), kilka population changes (Esmaeili Sari et al., 2002, Daskalov and Mamedov, 2007, Roohi et al., 2008), environmental changes, pollution, and overfishing (Paritskii et al., 2001, Fazli, 2011).

Although there have been studies of bigeye kilka biology (Fazli et al., 2004; Karimzadeh et al., 2010; Aliasghari et al., 2011) and stock assessment (Pourgholam et al., 1996; Fazli and Rouhi, 2001; Fazli, 2011) in the southern Caspian Sea, there is little attention has been paid to changes in the bigeye kilka population over time in the southern Caspian. The aim of the present study was to determine the population structure, mortality, survival, and exploitation rate of *C. grimmi* in southern waters of the Caspian Sea in order to assess the current status of the population and variation during recent years for stock management and constant exploitation of kilkas via optimum fishing management.

MATHERIALS AND METHODS

Sampling area: The sampling areas were in Iranian waters of the southern Caspian in Mazandaran province with the vessels of Babolsar Harbor (Fig. 1) in 52° 55″ E and 36° 51″N. These vessels were equipped with cone nets and underwater electric lights. This research was conducted during a two-year period from January 2009 to December 2010 at depths of 70 to 100 meters and 2027 samples were collected. Species identification was aided using Macroscopic and morphologic characteristics key (Berg, 1948; Svetovidov, 1963).

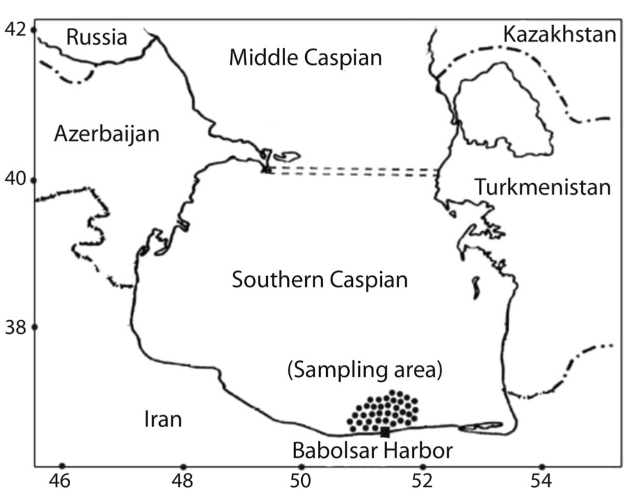

Fig. 1. Sampling areas (spotted region) in southern Caspian Sea.

Sample analysis: In the laboratory, fork length (mm) was measured with a measuring board and body weight was measured using digital balance (nearest 0.1 g).

For age determination, sagittal otoliths of fish were used. Otoliths were put in glycerin and age was determined using a stereomicroscope with a top-projected light and a black background (Francis&Campana, 2004).

The length-weight relationship was calculated as following:

$$W = a\,L^{b}$$

where W is the fish weight (g), L is the fork length (mm), *a* is constant and *b* is the regression trend line slope (Bagenal, 1978).

Determining the growth pattern via t-test, the b amount was evaluated using the following formula (Morey et al., 2003):

$$t = \frac{b - 3}{Sb}$$

where b is the regression trend line slope and Sb is the standard deviation of b.

Von Bertalanffy growth parameters were calculated using a non-linear estimation method (Pauly et al., 1992) as:

$$Lt = L_{\infty}\,[1\text{-}exp^{\,-k(t-t_0)}]$$

where t is age in years, L_t is fish length at age t, t_0 is length at 0, L_{∞} is L-infinity and k is the growth coefficient.

Natural mortality coefficient (M) was estimated from Pauly's equation (Pauly, 1999).

$$\log(M) = -0.0066 - 0.279\log(L_{\infty}) + 0.6543\log(K) + 0.4634\log(T)$$

where T is the annual average water temperature of fish habitat which was estimated 12°C in a former study (Karimzadeh et al., 2010).

Survival rate (S) was calculated using the catch curve method (Ricker, 1975). Total mortality (Z) was transformed from the survival rate as:

$$Z = -\ln S$$

Total mortality (Z) is sum of the two sources of mortality (M and F) together (Prakarn, 2002); so, the coefficient of fishing mortality (F) was calculated as the coefficient of total mortality (Z) minus the coefficient of natural mortality (M) using the equation:

TABLE 1
Length and weight data of bigeye kilka in 2009 and 2010 in southern Caspian

Year	M/F	Weight (g)				Fork length (mm)				
		Average	SD	Min	Max	Average	SD	Min	Max	N
2009	Male	14.06	5.31	4.69	28.94	118.51	12.03	81	139	438
	Female	15.43	5.22	5.81	28.73	122.11	10.72	84	148	546
	Total	14.91	5.28	4.69	28.94	120.06	11.95	81	148	984
2010	Male	14.11	5.21	4.85	28.91	117.72	12.54	82	141	413
	Female	15.87	5.17	5.90	28.69	121.08	12.32	85	147	630
	Total	15.17	5.24	4.85	28.91	119.12	13.42	82	147	1043

$$Z = M + F \rightarrow F = Z - M$$

Exploitation rate was calculated from the fishing mortality divided by the total mortality as (Sparre & Venema, 1989):

$$E = \frac{F}{F + M}$$

Statistical analysis software: The software applications *Microsoft Office Excel 2003*, *SPSS 10.0,* and *FISAT* were used for statistical analysis.

RESULTS

During 2009, the total catch of common kilka, anchovy, and bigeye kilka was 20,741 tons (5121 VN), of which common kilka had the highest catch proportion (88.3%). The proportion of anchovy and bigeye kilka were 7.2% and 4.5%, respectively. In 2010, total kilka catch was 21,216 tons (5544 VN), of which common kilka had the highest catch (86.2%), followed by anchovy (9.6%) and big eye kilka (4.2%).

Average fork lengths of bigeye kilka in 2009 and 2010 were 120.06±11.95 and 119.12±13.42 mm and average weights were 14.91±5.28 and 15.17±5.24 g, respectively (Table 1).

The fork length and body weight relationship in bigeye Kilka (2010) was $W = 0.000006\, E^{3.07}$ and the regression correlation was R^2=0.834 (Fig. 2). The calculated b was significantly more than 3 and t-test showed the positive allometric growth pattern ($p<0.05$).

Age composition of bigeye kilka catch included 6 age groups, 2-7 years (both females and males). Age 3 was the largest age group, composing 34.82% and 33.56% of the catch in 2009 and 2010, respectively. Average age during these two years was 3.97±0.88 and 3.90±1.22 yr, respectively.

Von Bertalanffy growth parameters were similar both years with no significant difference. In 2009, bigeye kilka parameters were: L_∞=145.1mm, k=0.37yr^{-1}, t_0=-0.63yr

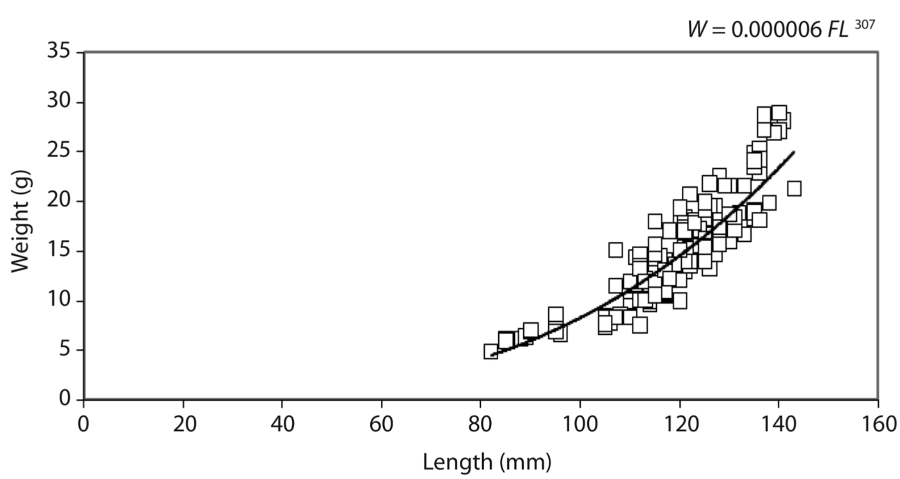

Fig. 2. Length-Weight relationship for bigeye kilka in 2010.

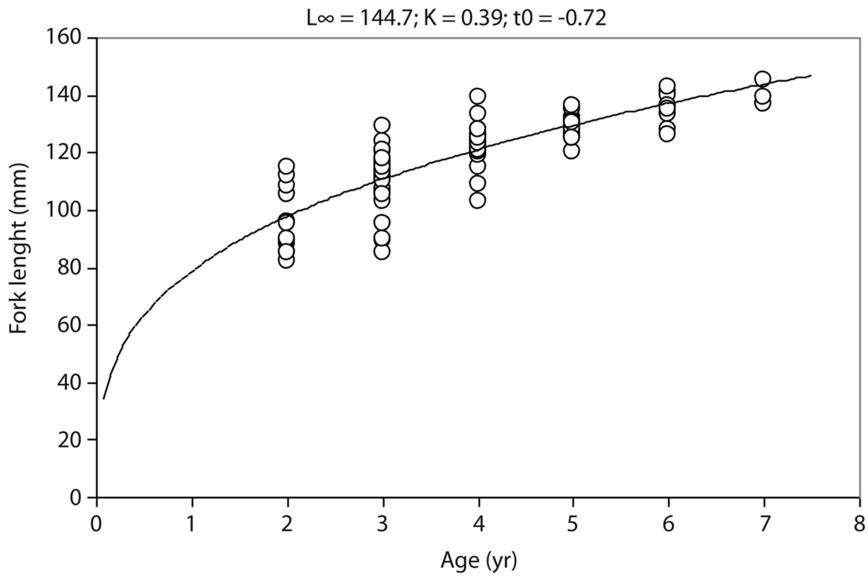

Fig. 3. Von Bertalanffy growth curve for bigeye kilka in 2010.

with the growth equation: L_t = 145.1[1-exp $^{-0.37(t+0.63)}$]. Parameters in 2010 were: L_∞=144.7mm, k=0.39yr^{-1}, t_0=-0.72yr (L_t = 144.7[1-exp $^{-0.39(t+0.72)}$]) (Fig. 3).

The coefficient of natural mortality (M) in 2009 and 2010 was 0.448yr^{-1} and 0.419 yr^{-1}, respectively. Using catch curves, the annual survival rate (S) was estimated 0.305 yr^{-1} in 2009 and 0.309 yr^{-1} in 2010. According to the survival rate, the instantaneous coefficient of total mortality (Z) in 2009 and 2010 was estimated 1.184 yr^{-1} and 1.174 yr^{-1}, respectively. Instantaneous coefficients of fishing mortality (F) were 0.736 yr^{-1} and 0.775 yr^{-1} in 2009 and 2010, respectively. In these years, the exploitation rate (E) of bigeye kilka was estimated 0.621 and 0.660, respectively.

DISCUSSION

Studies of fish population dynamics are essential for understanding human and natural effects on fish populations and for devising effective management plans. Pelagic species are vulnerable to environmental variations; thus, environmental factors should be considered in stock assessment (Zhang and Lee, 2001). During the past years, the Caspian Sea environment has changed significantly in response to impacts of human and natural factors such as pollution, fluctuations of sea water level as well as invasive species (Salmanov, 1999; Ivanov, 2000; Rouhi et al., 2008).

Bigeye catch proportion in 1996 was 22.1% of total kilka catch (Pourgholam et al., 1996), in 1997 was 12.6% afterwards decreased to 6.2% in 2001 (Fazli et al., 2002) then reached 4.2% in 2010. Decreasing process in bigeye catch amount can be due to over fishing or increasing life depth (out of reach for fishing vessels) because of the pressure of natural factors such as *M. leidyi* as well as two other kilka species on bigeye niche.

Average weight and fork length of bigeye kilka in southern Caspian increased continuously from 1997 to 2008 (Fazli et al., 2009; Karimzadeh et al., 2010); afterwards average weight increased continuously but fork length had an inconsiderable decline in 2009 continuing to 2010. Relative increasing size in catch is perhaps because of over fishing, decreasing the reproduction rate or standardization of net meshes. On the other hand, increasing average weight simultaneous with decreasing length shows relatively good feeding sources for this species in high depth.

Calculated b in present study was as b>3 indicating this species has a positive allometric growth pattern ($p<0.05$) and agree with the previous studies in which b was more than 3 (Belyaeva et al., 1989, Fazli et al., 2004, Mamedov, 2006; Karimzadeh et al., 2010). Reported b amounts show that bigeye kilka has relative good environmental and feeding conditions perhaps because of its deep life area which is less affected by human and natural factors.

Age study showed that 4-years old fish were dominant in bigeye kilka population in 2001 (Fazli et al., 2009). Afterwards, age 3 and 4 had the most catch proportion in 2008 (Karimzadeh et al., 2010) and in present study age 3 was dominant. Dropping process of average catch age can be due to the bigeye habitat affected by natural factors and environmental changes. Considering the standardization of kilka fishing net mesh, decreasing the average age of bigeye kilka in recent years can show the increasing growth rate which caused this species to be catched in lower age. Considering the growth coefficient of slow-growing species $k \leq 0.1$ (Jennings et al., 2001), k amount in bigeye kilka is more than this given, so this species is a fast-growing aquatic. Study on k shows that this coefficient decreased from 1989 to 2004 (Belyaeva et al., 1989; Fazli, 2007) but increased again to 2010. High k amounts can reflect the high natural mortality (Holt, 1965); in other words, fast-growing species will tolerate high natural mortality. According to Gulland (1969), species with high M amount have high k amount as: $1 \leq M/k \leq 2$. On the other hand, L_∞ for bigeye has increased from 1989 (Belyaeva et al., 1989) to 2004 (Mamedov, 2006), until present study. Increased L_∞ amount in 2010 in comparison with 1989 indicates this species tries to decline the natural mortality because bigger fish will have fewer predators (Sparre & Venema, 1998); in other words, natural mortality has an inverse relation with L_∞. Changes in k and L_∞ of bigeye in recent years indicates that its habitat has been affected by the Caspian Sea ecological changes due to the ctenophore *M. leidyi* and also the pressure of two other kilka species to bigeye habitat. Bigeye Kilka with feeding on its own feed sources in deeper waters tries perhaps compensating the pressure of natural competitors by enlarging as a way against predators.

Natural mortality of bigeye kilka has decreased since 1995 to 2001 (Fazli et al., 2009) till 2009 and 2010 in present study; inversely the fishing mortality had an increasing process during this period. Decreasing M in recent years can be resulted of changes in life depth of bigeye kilka to deeper waters as well as enlarging the body size; and increasing F perhaps is due to recent increasing fishing depth by vessels (from 40-50m to more about 100m in depth) and approaching bigeye habitat in depth more than 70 m (Prikhodko, 1981). On the other hand, over fishing is an adverse pressure on this species. Using standard fishing gear, timely seasonal limitation of fishing and reducing the catch amount in fishing program can decrease the fishing mortality. The exploitation rate (E) of bigeye kilka in 2009 and 2010 was more than the desirable amount ($E \approx 0.5$) suggested by Gulland (1983) as the theoretical exploitation rate that could maximize the harvest. Thus, bigeye kilka stock was under over-fishing. There is a direct relation between the exploitation rate and fishing mortality (Beverton&Holt, 1959); thus, the increasing of both exploitation rate and fishing mortality occurs simultaneously.

It is noticeable that the increasing catch of common kilka was simultaneous with decreasing the proportion of two other kilka species, anchovy and bigeye, in catch composition (Fazli, 2011). These can be resulted of human and natural factors such as over-fishing and the invader ctenophore *M. leidyi* which are the main causes for decreasing kilka biomass in southeastern Caspian. In fact, the most likely primary cause of decreased kilka stock is the invasion and spread of *M. leidyi* in Caspian (Daskalov and Mamedov, 2007). This ctenophore transported with ballast water from the Black Sea and appeared in the Caspian Sea in 1999 (Ivanov et al., 2000) and feeds on zooplankton, fish eggs and larvae (Kideys and Moghim, 2003). *M. leidyi* has a high reproduction rate because of suitable environmental conditions; so, it can be potential threat for the Caspian Sea habitants (Esmaeili Sari et al., 2002).

During the last decade, kilka fishing in Mazandaran waters (southern Caspian) was conducted in depth more than 40 m (Fazli and Rouhi, 2001); but now in deeper waters more than 70 m up to 100 m; indicating changes in kilka life depth as well as fishing depth. During previous years, bigeye kilka has not significantly been affected by the Caspian Sea pelagic changes due to inhabiting in deep regions (*Aliasghari et al.,* 2011); but the adverse competition on feeding and ecological niche between *M. leidyi* and kilka, specially common and anchovy kilka, can lead to unilateral intercept with the ctenophore dominance (Esmaeili Sari et al., 2002) which will certainly influence bigeye population. Penetrating common kilka to depth more than 30-40 m, will dislodge anchovy kilka population from its habitat (Fazli *et al*., 2005). As a result of common kilka force, anchovy kilka population went to deeper parts of the sea and make pressure on bigeye population. Moreover, feeding competition can be one reason of the stock decrease of pelagic fishes such as kilka in the Caspian Sea. Continuing this process, no recovery could be expected in pelagic fishery (Finenko et al., 2006). Thus, monitoring vertical movements of kilka population, effecting factors and changes of its niche and feeding sources, *M. leidyi* spread specially in water column and controlling it with biological methods is essential for constant catch of Kilka in Caspian.

This study showed that bigeye kilka has affected by human and natural factors, *M. leidyi* and over fishing. In recent years, the Caspian Sea ecosystem and kilka population incurred damage because of invader ctenophore. Moreover, the exploitation rate of bigeye kilka is more than the acceptable level. Regarding to the importance of kilka fishes in food chain and human usage, continuing such process leads to destruction of the kilka population and thereupon the Caspian ecosystem. So, it is necessary to exert a hard surveillance on the Caspian Sea in the case of *M. leidyi* controlling and kilka fishing programming.

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