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Full Length Research Paper

Study of the natural and fishing mortality and exploitation rates of bigeye kilka (*Clupeonella grimmi)* in the southeast part of the Caspian Sea (Babolsar)

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The natural, fishing and total mortality survival and exploitation rates of bigeye kilka were studied. The survival rate and natural mortality were calculated using catch curve and Pauly methods, respectively. Natural and fishing mortality have been estimated up to 0.881 and 0.309 yr^{-1}, respectively. According to the catch curve method, the annual survival rate of bigeye kilka has been estimated to be 0.304 yr^{-1}. Owning to this survival rate, the instantaneous coefficient of the total mortality of bigeye kilka has been estimated up to 1.19 yr^{-1}, while the exploitation rate of bigeye kilka has been estimated up to 0.260. The catch amounts of bigeye kilka decreased gradually mainly due to overfishing, predators and ecological disturbances which occurred in the Caspian Sea. Using the conclusion of this study and the previous studies of other researchers, it is suggested that the population of bigeye kilka were overexploited in the past years and were vulnerable to their natural predators.

Key words: *Clupeonella.grimmi,* natural mortality, fishing mortality, total mortality, survival rate, exploitation rate.

INTRODUCTION

Kilka fishes belong to the family of Clupeidae. Three species of clupeids including anchovy kilka (*Clupeonella engrauliformis*, Svetovidov, 1941), bigeye kilka (*Clupeonella grimmi*, Kessler, 1877) and common kilka (*Clupeonella cultriventris caspia*, Bordin, 1904) exist in the Caspian Sea. These species are pelagic fishes, and are one of the most abundant fishes that live gregariously in the Caspian Sea because of zooplankton feeding, and as such, are considered as Caspian Sea bread (because other aquatic animals feed on them). All three kilka species exist in the commercial catch using underwater electrical lights and lift net or fish pumps (Nikonorov, 1964). Bigeye kilka live in depths of more than 50 to 70 m and are rarely caught in depths between 20 and 40 m, although they do not exist in depths less than 20 m. This fish never enters the northern part of the Caspian Sea, but lives (in deep parts) in the middle of the southern part of the Caspian Sea. It has different adaptation from two other species including: bigger eyes, body tissue with more transparency and is a steno-biotic species (Svetovidov, 1963; Kaspnirkh, 1978; Abdoli and Naderi, 2009).

Kilka fishing is an important source of income and protein for Iranians inhabiting in the Caspian Sea's coastal regions. The collapse of kilka fisheries has adverse effects on both the economy and regional protein consumption. Previous studies about the population characteristics of kilka in Iranian waters of the Caspian Sea were based on their distribution (Besharat and Khatib, 1993) and stock assessment and biology (Fazli and Besharat, 1998; Pourgholam et al., 1996; Fazli et al., 2007a, b). Quantitative assessments are necessary for the management and effective exploitation of this stock. The information such as sex, growth and mortality has special importance because of the ecological changes occurring in the Caspian Sea at present. Moreover, invader Ctenophore *Mnemiopsis leidyi* which appeared in 1999 (Ivanov et al., 2000) has effects on all ecosystem components used by kilka. The aim of the present study is to fill the information gaps of kilka species population biology, thereby catching its assessment and creating a base for the effective and optimum management of kilka catch in the Caspian Sea in Mazandaran zone with a longitude of 52° 55′ and latitude of 36° 51′.

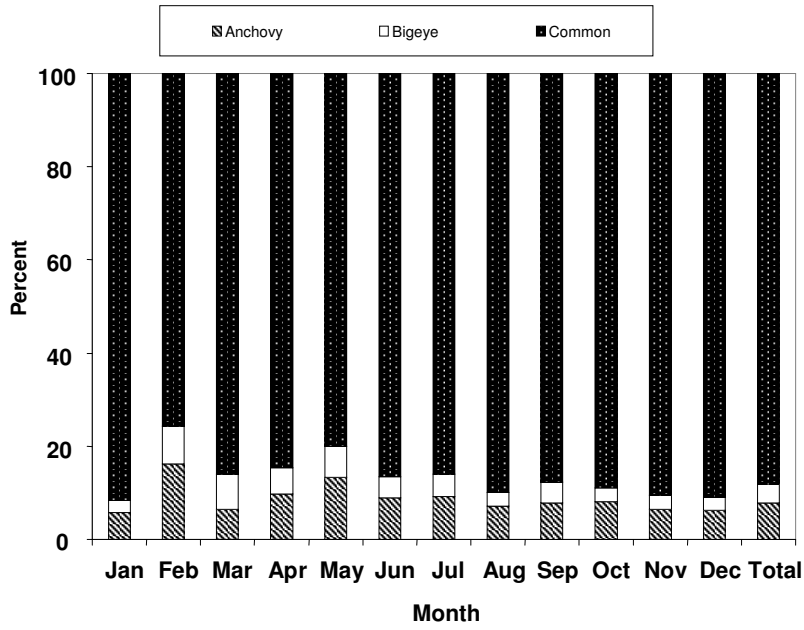

Figure 1. Species composition of three kilka species in Mazandaran zone of the Caspian Sea in 2008.

MATERIALS AND METHODS

The samples were provided from the fishing landing site (Babolsar port) in the province of Mazandaran. The samples examined in this study were caught at depths ranging from 40 to 100 m by conical lift nets equipped with underwater electric lights. The catch amount, fishing effort and CPUE were considered. The sampling has been done in Babolsar landing from January to December 2008. After sampling, 150 to 200 kilka fishes were randomly selected every fortnight in the port (the catch evacuating site) for measurements and determining the species composition. In the laboratory, species identification has been done according to identification key by Berg (1948). The samples were transported to the laboratory for measurement and were initially sorted into size bins according to 5 mm (fork) length intervals. Then, the total weight (to the nearest 0.1 g) and sex were also determined. Age determination of kilka fishes was done using otoliths. Otoliths were provided in each biometry stage of each length class (10% fishes, male and female, 100 specimens) and were put in a special plate containing glycerin. Their age determination was done using stereomicroscope in terms of the light that glinted from top, and as such, its background was black (Chilton et al., 1982).

Survival rate (*S*) was calculated using the catch curve method (Ricker, 1975). In the catch curve method, the linear relation between the age and Ln of the second part of the fish abundance curve in catch-number is in the right part of the curve (declining part). In this relation, EXP (b) is equal to the S amount, whereas the instantaneous coefficient of total mortality (*Z*) was transformed from the survival rate as:

$Z = -\ln S$.

The natural mortality coefficient (M) was estimated from the tentative Pauly formula (Pauly, 1999):

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

Where T is the annual water average temperature of the fish habitat. In this study, T was 12° C.

Fishing mortality coefficient (F) was calculated using the formula:

$Z = M + F$

Exploitation rate was calculated using the formula (Sparre and Venema, 1992):

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

Where F is the fishing mortality coefficient and M is the natural mortality coefficient.

RESULTS

In the year 2008, the catch of kilka (common, anchovy and bigeye) and the fishing effort of the fishing boats were estimated to be 11451.9 tons and 5045 VN (vessel × night), respectively. From 2770 kilka specimens collected during January to December in 2008, 2171 common kilka, 338 anchovy kilka and 261 bigeye kilka have been studied. The most abundant belonged to the common kilka (87.38%), while the least abundant belonged to the bigeye kilka (4.29%). However, anchovy kilka abundance was 8.33%. Fundamentally, the common kilka was dominant in catch in all months of the year, and it was found to be most abundant in January at about 91.67% and least abundant in February at about 75.68% (Figure 1).

Table 1. Monthly catch, effort and CPUE of bigeye kilka in Mazandaran region of the Caspian Sea in 2008.

Month	Catch (ton)	Effort	CPUE (ton)
Jan	9.8	327	0.03
Feb	129.6	681	0.19
Mar	61.4	417	0.147
Apr	4.7	125	0.038
May	0	0	0
Jun	2.6	51	0.052
Jul	47.8	643	0.074
Aug	68	828	0.082
Sep	40.7	453	0.09
Oct	9.2	218	0.042
Nov	63	523	0.12
Dec	54.1	779	0.069
Total	490.8	5045	0.097

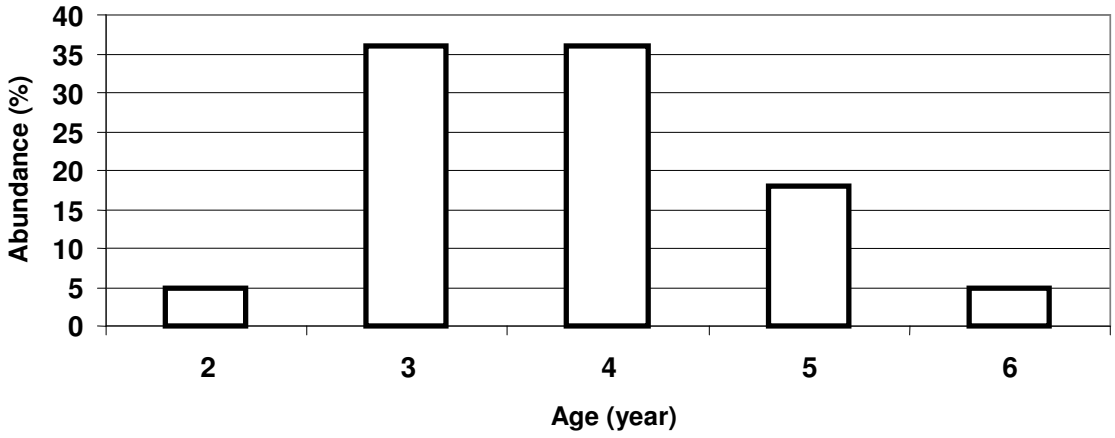

Figure 2. Age abundance percent of bigeye kilka in Mazandaran region of the Caspian Sea in 2008.

Table 2. Average fork length and weight of bigeye kilka in the Mazandaran region of the Caspian Sea in 2008.

Average weight ± SD (g)	14.42 ± 4.11
Average length ± SD (mm)	122.75 ± 10.67
N	261

The catch amount of bigeye kilka during this year was 490.8 tons, and the most abundant of its catch was in February with about 129.6 tons and the least amount was in June with about 2.6 tons. The highest fishing effort was in August (828 vessels per night = VN) and the lowest effort was in June (51 vessels per night). The maximum CPUE (Catch per unit of effort) amount for bigeye kilka was about 0.19 tons per vessel for each night in February, while its minimum was about 0.03 tons per vessel for each night in January. Overall, catch and CPUE amount for anchovy kilka in the studied zone in 2008 were 490.8 and 0.097 tons per vessel for each night, respectively (Table 1).

Age composition of the bigeye kilka catch comprised 5 age groups including the 2 to 6 years group. Age 4 and 3 was the largest age group and it appropriated 72% of the catch (Figure 2). For females and males, age averages were 4.194 ± 0.571 (2 to 6 years range) and 3.347 ± 0.917 (2 to 6 years range), respectively. However, the average age of bigeye kilka population in 2008 was 3.8 years old.

Average fork length for bigeye kilka was 122.75 ± 10.67 mm, and it ranged from 85 to 152 mm. About 39% of its length abundance belonged to the 120 to 130 mm length classes, whereas the average weight of this fish was 14.42 ± 4.11 g. The minimum and maximum weight were 4.86 and 32.34 g, respectively (N = 261) and about 55% of the weight abundance belonged to the 11 to 17.2 g weight classes (Table 2).

According to the catch curve method, the annual survival rate of bigeye kilka has been estimated as 0.304 yr^{-1}. Owning to this survival rate, the instantaneous coefficient of the total mortality (Z) for bigeye kilka was estimated as 1.19 yr^{-1}. The instantaneous coefficient of the natural mortality (M) of bigeye kilka, which has been estimated from tentative Pauly method, was 0.881 yr^{-1}, while the instantaneous coefficient of the fishing mortality (F) was 0.309 yr^{-1}. Therefore, the exploitation rate (E) of bigeye kilka was estimated as 0.260.

DISCUSSION

It is necessary to constantly exploit fish biology and population dynamics data, as well as fishing management responsibly. Population dynamics is related to the continuous process of time generation, thereby replacing its production which is, in fact, growth and death. General models can help to better predict the fishing effect on fish population, and this is possible when various factors (ecology and exploitation) and effects on population can be recognized certainly (Biswas, 1993).

One of the purposes of the catch and biology study is to recognize the human and natural effective factors on fish population in order for it to have a profitable continuity for a long time (Ball and Rao, 1984). The catch amount of Kilka in Mazandaran zone (southeast of the Caspian Sea) decreased from 38 thousands tons in 1999 to 8.025 thousands tons in 2003, and then increased and reached 13.859 thousands tons in 2005 (Mazandaran fisheries statistic annals, Fisheries organization archive, 2005). According to the results of the study on catch and CPUE amount, it is revealed that the relative abundance of the common kilka population has shown an increasing process in relative abundance recently in comparison with previous years. This is because of increasing fishing effort and fish habitat expansion and changes in living depths. Anchovy and bigeye kilka population showed a decreased process in 2008 in comparison with previous years, which was mainly due to overfishing and natural factors, thus, the stock showed a decreasing process in its population. Similar results were also reported by Fazli et al. (2002, 2004a, 2004b, 2005, 2007a, 2007b) in the Iranian region of the Caspian Sea during 1995 to 2004. Fork length average of bigeye kilka in southeast Caspian was 92.9 mm in 1997. This value increased continually (Fazli et al., 2007 a, b) until it reached 122.7 mm in 2008. Weight average of bigeye kilka in 1997 was 5 gr and had continually increased during subsequent years (Fazli et al., 2007a, b) until it reached 14.4 gr in 2008. When the changes in the process study of the average length and weight of bigeye kilka were compared with that of previous studies, it showed that the length, weight and age of this species population continuously had an increasing process during the 1997 to 2008 period.

Bigeye kilka population comprised 5 age groups including the 2 to 6 years group. In bigeye kilka, the 4 and 3 years age group appropriates 72% of the total abundance to itself and thus, forms the dominant population. According to the results of the age study, the 4 and 3 years old bigeye kilka were dominant in the catch. Thus, we can say that in recent years, young fish population has mainly decreased in catch and older fish has gradually been dominant in the catch due to the use of nets with standard mesh (during recent years, after kilka stock decreasing), increase of overfishing (during last years) and change in the living depth (Fazli et al., 2007 a, b).

Invader ctenophore Mnemiopsis leidyi entered the Caspian Sea through balance water of ships, feeds extensively on zooplankton, fish eggs and larvae (Kideys and Moghim, 2003; Mutlu, 1993; Tsikhon-Lukanina et al., 1999). Invader ctenophore consumes voraciously zooplankton, which is the food resource of zooplanktivore fishes such as kilka fishes (Kideys et al., 2001b). The main feeding of kilka fishes is on zooplankton, while the feeding competition of M. leidyi with kilka is perhaps an important factor in the rigorous decrease of pelagic fishes stocks such as anchovy kilka in Caspian Sea (Bagheri and Sabkara, 2003). Before the invasion of Mnemiopsis leidyi into the Caspian Sea, common kilka fishing has only been done in spring and summer; but after the invasion, a relative increasing abundance of the catch was observed in all months of the year (Valovik, 2000). Kilka fishing in cold seasons occurs in depths more than 60 m, while common kilka lives in depths of 10 to 60 m in all parts of the Caspian Sea (Pourgholam et al., 1996). Thus, it seems that this species has penetrated the anchovy kilka habitat, which lives mainly in depths more than 30 to 40 m, and had pushed this species to the deeper areas. Studies, with funnel-shaped net and underwater light, show that CPUE and catch amount decreases severely in regions with high relative abundance of common kilka (Besharat and Khatib, 1993). Therefore, the damage of anchovy kilka stock occurred after the invasion of Mnemiopsis leidyi (Fazli et al., 2002); moreover, the presence of common kilka in depths more than 60 m leads to the pushing and replacement of common kilka by anchovy kilka and a decrease in catch.

During recent years, in Mazandaran zone, the catch amounts of bigeye kilka fishes in the Caspian Sea had decreased, but the common kilka catch was still more than two other species (anchovy and bigeye), perhaps due to the catch decrease in the levels of anchovy and bigeye species habitat. So, the fishermen have invaded the levels of the common kilka habitat in order to attain more catch (that is, change in fishing depth). Thus, regardless of the bigeye kilka fishes catch amounts decrease, common kilka fishing has had an increasing process. Consequently, it can be said that the increasing fishing effort, overfishing and human and natural factors are the main reasons for decreasing kilka fishes in the

southeast Caspian Sea in Mazandaran zone. Also, similar results were reported by Fazli et al. (2004a, 2004b, 2005, 2007a, 2007b) and Karpyuk et al. (2004).
In this study, the exploitation rate of bigeye kilka has been estimated to be 0.260, which shows the desirable exploitation amount (E 0.5). In 2008, the natural mortality of bigeye kilka was estimated to be 0.881yr-1, while the fishing mortality was estimated as 0.309yr-1. Therefore, it was revealed that natural mortality was higher than fishing mortality, suggesting the high vulnerability of this species to natural predators. Results also showed that natural factors had played a significant role in the catch frequencies of bigeye kilka. The results suggest that the stocks of bigeye kilka were overexploited in the past years and as such, they have also showed high vulnerability to natural predators.

Conclusions

The catch amounts of bigeye kilka decreased gradually mainly due to overfishing, predators and ecological disturbances which occurred in the Caspian Sea. The present study revealed that natural mortality was higher than fishing mortality, suggesting the high vulnerability of this species to natural predators. The results suggest that the population of bigeye kilka were overexploited in the past years and were vulnerable to their natural predators.

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