Population dynamics and biological characteristics of kilka species (Pisces: Clupeidae) in the southeastern coast of the Caspian Sea

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Abstract

The aim of the present study was to investigate the age structure, length-weight relationship, sex ratio, sexual maturity stages, growth parameters, natural and fishing mortality coefficients of three species of kilka, including common, anchovy and bigeye kilka. The fork length–weight relationship of common, anchovy and bigeye kilka were calculated as $W=0.000153\ FL^{2.37}$, $W=0.000349\ FL^{2.18}$ and $W=0.00160\ FL^{2.97}$, respectively. The parameters of the von Bertalanffy growth curve for length were L_∞ = 143.5 mm, K = 0.30 yr^{-1} and t_0 = -1.02 yr for common kilka; L_∞ = 151.9 mm, K = 0.28 yr^{-1} and t_0 = -1.12 yr for anchovy kilka and L_∞ = 148.6 mm, K = 0.46 yr^{-1} and t_0 = -0.18 yr for bigeye kilka. The instantaneous coefficient of natural mortality of common, anchovy and bigeye kilka were estimated as 0.671, 0.633 and 0.881 yr^{-1}, respectively. The current exploitation rates of three species were estimated as 0.55, 0.41 and 0.26 for common, anchovy and bigeye kilka, respectively. The results suggest that common kilka stock is under over-fishing now.

Keywords: *Clupeonella cultriventris caspia, C. engrauliformis, C. grimmi*, Growth, Sexual maturity stage.

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Introduction

Kilka fishes belong to the family Clupeidae with three species including anchovy kilka (*Clupeonella engrauliformis* Svetovidov, 1941), bigeye kilka (*C. grimmi* Kessler, 1877) and common kilka (*C. cultriventris caspia* Bordin, 1904). Kilka fishes are pelagic fishes which live in gregarious and are one of the most abundant fishes in the Caspian Sea. They are considered as the Caspian Sea bread, due to being fed by other aquatic animals in higher levels of the food chain.

Common kilka inhabits in the coastal zone with depth less than 50-70 m (Prikhodko, 1981; Pourgholam et al., 1996; Fazli and Besharat, 1998). This euryhaline species has a wide distribution and is found in high and low water temperatures and in freshwater and in salinity more than 36 ppt. Common kilka spawns in spring (Prikhodko, 1981).

Anchovy kilka was forming almost 80-90 percent of total kilka catch in the Caspian Sea. Anchovy kilka inhabits in the middle and southern Caspian Sea which forms dense populations in depth 30 m in this region. Anchovy kilka spends a wintering period in southern Caspian and afterwards, has a spring migration to middle Caspian and a summer feeding period often in the middle and southern Caspian and after spawning, has an autumn migration to the southern Caspian Sea. Anchovy kilka tolerates 8-14 ppt salinity fluctuations but most of them are limited to salinities between 10 ppt and 12 ppt.

Bigeye kilka lives in depths of more than 50-70 meters and is rarely caught in depths between 20-40 meters. It does not exist in depths less than 20 m. This fish never enters the northern Caspian Sea and lives in deep parts of the middle and southern Caspian and has a different adaptation from two other species, including: bigger eyes, body tissue with more transparency and is a stenobiotic species (Svetovidov, 1963; Annonymous, 1978).

Kilka fishing is an important source of income and protein supplement for many people living in the Caspian Sea coastal regions. The collapse of kilka fisheries can have adverse effects on both the economy and regional protein consumption. Previous studies on population characteristics of kilka in the Iranian waters of the Caspian Sea were focused on distribution (Besharat and Khatib, 1993), stock assessment and biology (Pourgholam et al., 1996; Fazli and Besharat, 1998; Fazli, et al., 2007a,b; Fatemi et al., 2009) of these fish. Quantitative assessments are necessary for management and effective exploitation of stock. Information such as sex ratio, growth factors, and mortality due to ecological changes occurring in the Caspian Sea are of particular importance. Moreover, the invader Ctenophore *Mnemiopsis leidyi* which appeared in 1999 (Ivanov et al., 2000) had a great impact on all ecosystem components used by kilka.

The aim of the present study was to fill the gaps in our knowledge on population biology, and catch assessment of kilka species and to create a base for effective and optimum management of kilka catch in the Caspian Sea in Mazandaran waters, Babolsar.

Materials and methods

The samples were provided from fish landing site (Babolsar harbor) in the province of Mazandaran, from January to December 2008. The samples examined in this study were caught at depths ranging from 25 to 100 meters by conical lift nets equipped with underwater electric lights. 150-200 kilka fishes were randomly selected fortnightly and transported to the laboratory for measurement. The samples were initially sorted into size bins according to 5 mm (fork) length intervals. Then, the total weight (to the nearest 0.1 g), sex and maturity stages of ovary were also determined. Sexual maturity classification was carried out based on six stages in ovarian development as defined by Biswas (1993).

Age was determined using otoliths which were isolated in each biometry stage of each length class (10% fishes, male and female, 607 specimens), put in a plate containing glycerin and were examined under stereomicroscope (Chilton et al., 1982). 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 and b are the parameters (Bagenal, 1978). Van Bertalanffy growth parameters were estimated using a non-linear estimation method (Pauly, 1984):

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

where t: age, Lt: fish length in age of t, t_0: age virtual assay in length of 0, L∞: asymptotic length or mean length of oldest fishes and k: growth coefficient. Survival rate (S) was calculated using the catch curve method (Ricker, 1975). The instantaneous coefficient of total mortality (Z) was transformed from the survival rate as $Z=-\ln S$.

The instantaneous coefficient of natural mortality coefficient (M) was estimated from 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 water annual average temperature of fish habitat. In this study, T was 12^0C. Fishing mortality coefficient (F) was calculated using the below formula:

Z = M + F.

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

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

In order to determine the spawning time, the gonadosomatic index (GSI) was used (Bagenal, 1978):

$$GSI = \frac{w}{W} \times 100 ,$$

where w is gonad weight (g) and W is body weight (g).

Results

In the Year of 2008, catch of kilka (three species: common, anchovy and bigeye kilka) and fishing effort were estimated to be 11451.9 tons and 5045 VN (vessel×night). The most abundance belonged to common kilka (87.38%) and the least abundance belonged to bigeye kilka (4.29%). Anchovy kilka abundance was 8.33%. Minimum and maximum of fishing efforts were 51 (in June) and 828 VN (in August), respectively. Minimum and maximum of CPUE were 0.56 (in April) and 3.668 tons per VN (November) for common kilka; 0.07 (in April) and 0.38

(in February) for anchovy kilka; 0.03 (in January) and 0.19 tons per VN (in February) for bigeye kilka, respectively. Average fork length of common kilka was 99.26±10.09 mm, ranged from 65 to 140 mm. About 67% of length abundance belonged to 95-105 mm length classes. Average weight of common kilka was 9.61±3.11 g (2.95-25.14 g). The average of fork length and weight of anchovy kilka were 116.44±13.49 mm (70-140 mm) and 11.4±3 g (3.29-23.90 g), respectively. The average of fork length and weight of bigeye kilka were 122.75±10.67 mm (85-152 mm) and 14.42±4.11 g (4.86-32.34 g), respectively (Table 1).

Table 1: Average fork length and weight of three kilka species

	Common kilka	Anchovy	Bigeye kilka
Average weight ± SD (g)	9.61±3.11	11.47±3.07	14.42±4.11
Average length ± SD (mm)	99.26±10.09	116.44±13.49	122.75±10.67
N	2171	338	261

Growth parameters (**L∞, k, t$_0$**) for common, anchovy and bigeye kilka were estimated according to length and age data. So, growth equations were: $L_t = 143.51[1-\exp^{-0.30(t+1.02)}]$ for common kilka (Fig. 1), $L_t = 151.9[1-\exp^{-0.28(t+1.12)}]$ for anchovy kilka (Fig. 2) and $L_t = 148.6[1-\exp^{-0.46(t+0.18)}]$ for bigeye kilka, respectively (Fig. 3). The fork length and weight regression of common kilka and Anchovy were $W = 0.000153\,FL^{2.37}$ (R^2=0.81; n= 2171) and $W = 0.000349\,FL^{2.18}$ (R^2=0.824; n=338), respectively. The values of "*b*" for common and anchovy kilka were 2.37 and 2.18, respectively, which were significantly different from 3.0, indicating an allometric growth. The fork length and weight regression of bigeye kilka was $W = 0.00160\,FL^{2.97}$ (R^2=0.756; n=261). Dissimilar to the two former species, the value of "*b*" for bigeye kilka was not significantly different from 3.0, indicating an isometric growth.

The sex ratio of male: female were 0.819:1, 0.508:1 and 0.434:1 for common, anchovy and bigeye kilka, respectively, in which females were dominant. Monthly sex ratio of three kilka species showed that males were dominant in March and November; September and October; September, October and November, for common, anchovy and bigeye kilka, respectively (Table 2). Monthly variation of ovarian maturity stages of the main species, common kilka, showed that the proportion of maturity stages of 4 and 5 increased in February and March and peaked in April (Table 3). The GSI value peaked (8.83) in May and declined to the lowest level (0.80) in September (Fig. 4). Therefore, the reproduction of common kilka ended in September. For anchovy kilka, the proportion of maturity stages of 4 and 5 increased in April and May and peaked December but the GSI value showed two peaks in June and December (Fig. 4). Dissimilar to the two former species, the reproduction of bigeye kilka occurred throughout the year (Table 3). The proportion of maturity stages of 4 and 5 and GSI showed two peaks in April-May and September-October (Table 3 and Fig. 4).

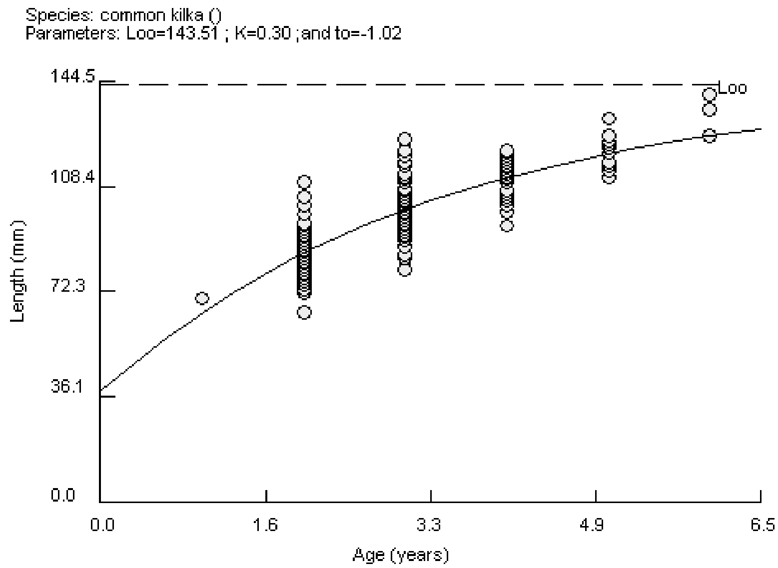

Figure 1: Theoretical growth curve for fork length of common kilka

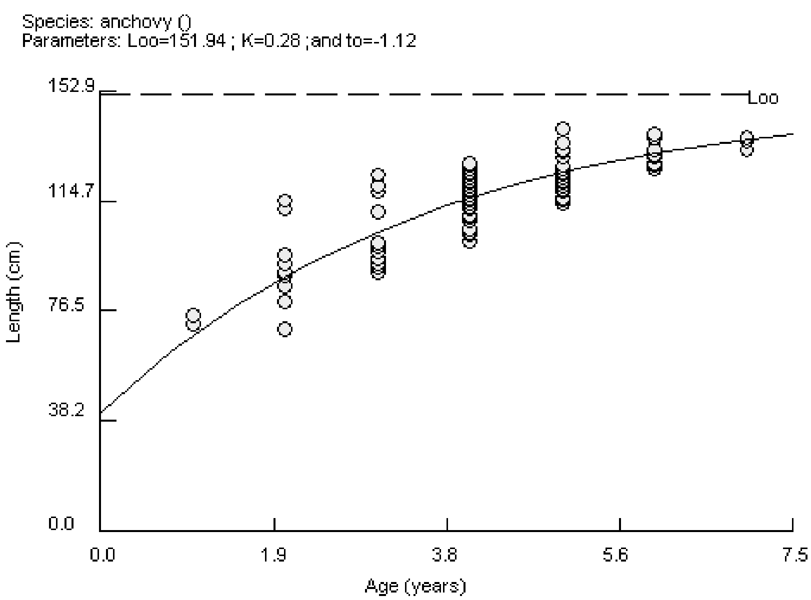

Figure 2: Theoretical growth curve for fork length of anchovy kilka in the present study

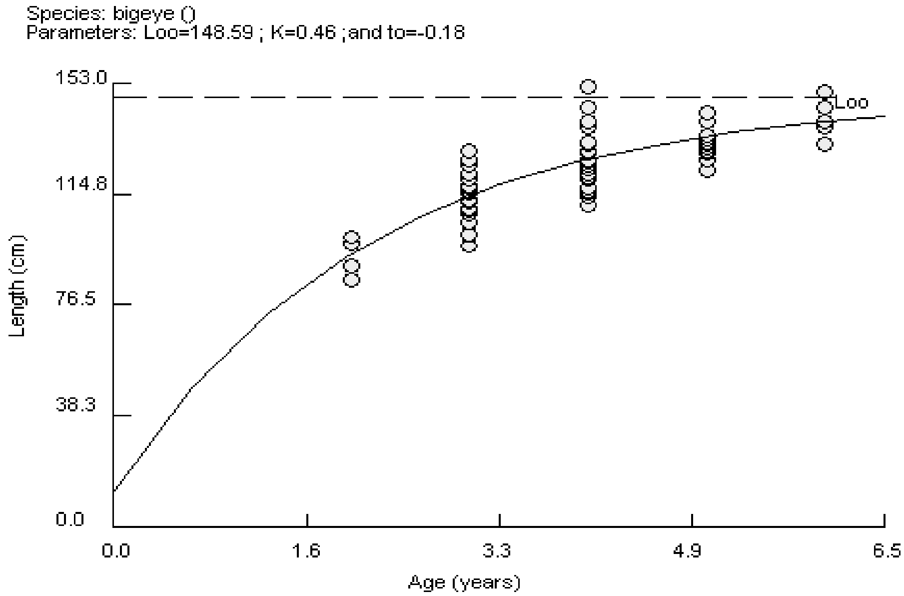

Figure 3: Theoretical growth curve for fork length of bigeye kilka in the present study

Table 2: Sex ratio (percent) of three kilka species in the present study

month	common		anchovy		bigeye	
	male	female	male	female	male	female
Jan	43	57	26	74	16	84
Feb	48	52	28	72	20	80
Mar	63	37	22	78	45	55
Apr	44	56	32	68	36	64
May	34	66	35	65	27	73
Jun	48	52	29	71	33	67
Jul	41	59	35	65	45	55
Aug	47	53	42	58	57	43
Sep	43	57	56	44	40	60
Oct	40	60	53	47	60	40
Nov	52	48	44	56	60	40
Dec	47	53	22	78	50	50

Table 3: Monthly proportion (percent) of sexual maturity stages of three kilka species (common, anchovy, bigeye)

Month	common				anchovy				Bigeye			
	Stage 2	**stage 3**	**stage 4**	**stage 5**	**stage 2**	**stage 3**	**stage 4**	**stage 5**	**stage 2**	**stage 3**	**stage 4**	**stage 5**
Jan	56	29	11	4	67	17	16	0	0	0	100	0
Feb	37	47	16	0	63	37	0	0	7	27	33	33
Mar	28	37	35	0	72	24	2	2	0	7	86	7
Apr	0	8	77	15	59	14	27	0	0	0	73	27
May	0	23	50	27	54	23	23	0	0	23	44	33
Jun	11	43	39	7	30	47	23	0	27	18	37	18
Jul	46	26	27	1	33	41	26	0	35	35	30	0
Aug	74	15	11	0	39	31	30	0	9	28	54	9
Sep	85	14	1	0	14	72	14	0	0	0	67	33
Oct	95	4	1	0	40	10	50	0	0	0	75	25
Nov	97	2	1	0	26	26	43	5	16	28	28	28
Dec	93	3	4	0	0	0	100	0	0	0	50	50

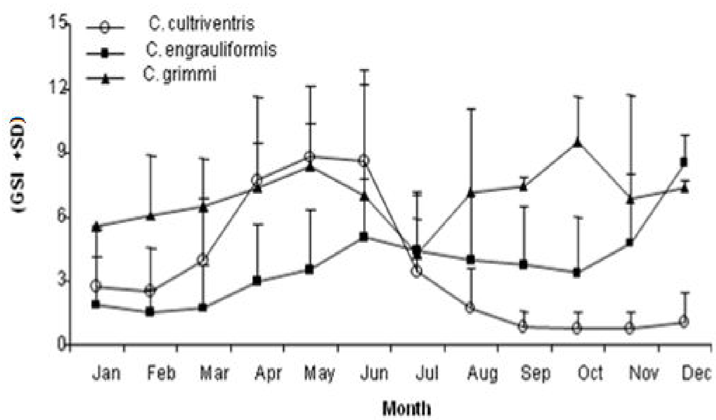

Figure 4: Monthly GSI mean (+SD) of three kilka species in the present study

Age composition of catch of common kilka was constituted of 6 age groups, including 1-6 years. Age 3 was the largest age group, composing 42.70% of the catch (Table 4). For females and males, age average was 3.12±0.34 (ranged 2-6 years) and 2.85±0.59 (ranged 1-6 years), respectively. The age of anchovy kilka ranged 1-7 years, with 4-years age group being predominated (40.97%) (Table 4). For females and males age average was 4.23±0.76 (ranged 2-7 years) and 3.87±0.75 (ranged 1-7 years), respectively. In bigeye kilka, age was ranged 2-6 years, with ages 3 and 4 being the largest groups composing 72% of the catch (Table 4). Mean age of females and males were 4.19±0.57 (ranged 2-6 years) and 3.35±0.92 (ranged 2-6 years), respectively. According to catch curve method, the

Table 4: Catch at age of three kilka species (common, anchovy and bigeye)

Species	parameter	Age group (year)							Total
		1	2	3	4	5	6	7	
common kilka	n (percent)	2 (0.55)	114 (31.40)	155 (42.70)	76 (20.94)	12 (3.31)	4 (1.10)	-	363 (100)
anchovy kilka	n (percent)	2 (1.39)	19 (13.19)	16 (11.11)	59 (40.97)	29 (20.14)	16 (11.11)	3 (2.08)	144 (100)
bigeye kilka	n (percent)	-	5 (5.00)	36 (36.00)	36 (36.00)	18 (18.00)	5 (5.00)	-	100 (100)
common kilka	Catch (ton)	55.14	3142.78	4273.07	2095.18	330.82	110.27	-	10007.2
anchovy kilka	Catch (ton)	13.25	125.87	106.00	390.86	192.12	106.00	19.87	953.9
bigeye kilka	Catch (ton)	-	24.54	176.68	176.68	88.34	24.54	-	490.8
Total (ton)									11451.9

annual survival rate of common kilka was estimated up to 0.218 yr^{-1}. With owning this survival rate, the instantaneous coefficient of total mortality (Z) of common kilka was estimated up to 1.52 yr^{-1}. The instantaneous coefficient of natural mortality (M) of common kilka, estimated from tentative Pauly method was 0.671yr^{-1}. The instantaneous coefficient of fishing mortality (F) was 0.849 yr^{-1}. Therefore, the exploitation rate (E) of common kilka was estimated up to 0.55.

The annual survival rate, the instantaneous coefficient of total, natural and fishing mortality of anchovy kilka were 0.343, 1.07, 0.633 and 0.437 yr^{-1}, respectively. The exploitation rate of anchovy kilka has been estimated up to 0.41.

The annual survival rate, the instantaneous coefficient of total, natural and fishing mortality of bigeye kilka were 0.304, 1.19, 0.881 and 0.309 yr^{-1}, respectively. The exploitation rate of bigeye kilka has been estimated up to 0.26.

Discussion

One of the purposes of catch and biology studies is to recognize the human and natural effective factors on fish population in order to its profitableness continuity in a long time (Ball and Rao, 1984). The annual catch of kilka decreased from 38 thousands tons in 1999 to 8.025 thousands tons in 2003 and then increased and reached to 13.859 thousands tons in Mazandaran province in 2005. Our results showed that relative abundance of common kilka has an increasing trend during last decade. This is because of increasing fishing effort and habitat expansion and changes in living depths. The catch and CPUE of anchovy and bigeye kilka showed a decreased process in 2008 in comparison with the previous years which is mainly due to overfishing and natural factors, thus, the stock showed a decreasing trend in the population. Similar results were reported by Fazli et al., (2002; 2004a,b; 2005 and 2007a,b) in the Iranian coasts of the Caspian Sea, during 1995-2004. Fork length average in common kilka in the Iranian waters of the Caspian Sea in 1997 was 103.5 mm. It decreased during 1998, 1999 and 2000 and reached to 80.8 mm and increased again after 2001 (Fazli et al., 2007b) reaching to 99.26 mm in 2008, suggesting that the population of common kilka is younger than 1997 to 2000, but older than 2001 to 2008. During 2001 to 2008, the fork length of anchovy and big kilka increased. The exponent of length-weight relationship for common and anchovy kilka (b=2.37 and b=2.18, respectively) showed that growth is not isometric. In contrast, Fazli et al. (2007a,b) reported a higher, different b for common and anchovy kilka (b=2.76 and b=2.87, respectively). The male: female ratio of common kilka was 0.819:1. This ratio was also estimated during 1997-2005 which females were dominant in all of these years with a relatively high abundance and were formed about 70-80% of population (Fazli et al., 2007b). For anchovy and bigeye kilka the ratios were 0.508:1 and 0.434:1. But during 1997 to 2004 males of both species were dominant in the Iranian waters of the Caspian Sea (Fazli et al., 2007a). The present study showed that reproduction of common kilka peaked in April-May. Similar results were reported by other authors (Prikhodko, 1981; Abtahi et al. 2002; Fazli et al., 2007b). Spawning of anchovy kilka has more extension than common kilka. They exist from May to October in depths of 50-200 m gregariously in southern part of the Caspian Sea in autumn (Berg, 1948; Annonymous. 1978; Sedov and Rychagova, 1984) which is similar to the result of the present study. Dissimilar to the two former species, the reproduction of bigeye kilka occurred throughout the year. Some previous studies reported similar results (Kazanchev, 1963; Annonymous, 1978; Fazli et al., 2009). According to Kazanchev (1963) and Annonymous (1978) spawning of bigeye kilka is longer than the two other species. The bigeye kilka spawns after January throughout September intensively during spring and autumn. According to the age study, 3-years old fish have appropriated 42.70% of total abundance in common kilka, 4-years old fish have appropriated 40.97% of total abundance in anchovy kilka, 3 and 4-years old fish have appropriated 72% (each 36%) of the total abundance in bigeye kilka. Therefore, in age structure study in 2008, kilka fishes with high age classes (3 and 4 years old) were dominant. Thus, it can be concluded that in recent years, young fish population has been decreased in catch mainly due to using nets with standard mesh and overfishing. Before *Mnemiopsis leidyi* invasion to the Caspian Sea, (the ctenophora transported with ballast water from the Black Sea and appeared in the Caspian Sea in 1999, Ivanov et al., 2000) common kilka fishing has only been carried out in spring and summer; but after invading of this ctenophore, a relative increasing abundance was observed in the catch in all months o year(Valovik, 2000; Fazli et al., 2004b). Kilka fishing in cold seasons occurred in depths more than 60 m while common kilka lives in all parts of the Caspian Sea in depths 10-60 m (Pourgholam et al., 1996). Studies with funnel-shaped net with underwater light showed that catch and CPUE of anchovy kilka decreases severely in regions with high relative abundance of common kilka (Besharat and Khatib, 1993). Therefore, it seems that common kilka has penetrated to anchovy kilka habitat, which lives mainly in depths more than 30-40 m (Pourgholam et al., 1996), and pushed this species to the deeper areas. The results showed that, in 2008 the exploitation ratio of common, anchovy and bigeye kilka were 0.55, 0.41 and 0.26. For common kilka the ratio is higher than 0.5, suggested by Gulland (1983), as the theoretical exploitation rate that could maximize harvest. In most instances, this theoretical rate has proved to be high, and not sustainable. It is concluded that the stock of common kilka was being over-fished in 2008. Overall, changes in the composition and abundance of kilka fishes population in comparison with the recent 10 years has been mainly due to the invader (*Mnemiopsis leidyi*), increase of fishing effort, over fishing and unsuitable management on kilka stocks. Experience in Iran and many other countries with high dependence on natural resources indicates that practicable effective control of fishing is very difficult, thus this leads to an increase of over fishing and decrease of aquatic stocks.

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