Fishery and biological aspects of anchovy Kilka (*Clupeonella engrauliformis*) in the southern Caspian Sea

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Abstract

This paper aimed to investigate the fishery and biological characteristics of anchovy Kilka in Iranian waters of the Caspian Sea from 2005-2007, including length and age structure ,Von Bertalanffy growth parameters, length and age at first capture, condition factor, sex ratio, natural and fishing mortality. The examination of catch data approved that Kilka population in the Caspian Sea have been declined a few years ago following entrance jellyfish Ctenophora M*nemiopsis leidyi*. The greatest destruction of anchovy kilka catch was occurred while the catch of anchovy from 4250 tonnes in 2005 reached to 924 tonnes in 2007. The results showed that *K* value and L_∞ calculated 0.375/year, 131.7mm, respectively. The instantaneous coefficient of natural mortality was estimated 0.49/year.The instantaneous coefficient of fishing mortality and total mortality was 0.51 /year and 1/year, respectively. The Exploitation rate was calculated as 0.51. The length and age ranges restricted comparison to last decade and sharply decreased recruitment. In the past few years, the main reasons of disintegrates among anchovy Kilka stocks in the Caspian Sea were synchronized overfishing competitive anchovy Kilka with *M. leidyi*.

Keywords: Caspian Sea, *Clupeonella engrauliformis*, Age, Growth, Sex ratio, Overfishing

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Introduction

Kilka, a pelagic fishes feeding on zooplankton, is the most abundant fish in the Caspian Sea. There are three species of Kilka in the Caspian Sea including anchovy (*Clupeonella engrauliformis* Svetovidov, 1941), bigeye (*C.grimmi* Kessler, 1877) and common kilka (*C.cultriventris* Bordin, 1904) (Svetovidove, 1963). Kilka were important commercially and more than 80 % of the total catch, so being a vital role in the food chain specially seals and sturgeon, ecosystem health and fisheries management of the Caspian Sea (Salmanov, 1999 ; Ivanov, 2000). Anchovy kilka exists the central and southern Caspian Sea, with depth more than 30 m and endurance waters with 10-12 % salinity fluctuations (Prikhod'ko, 1981). It has different migration: has a spring feeding migration (to the central Caspian), an autumn spawning migration and third migration is vertical which has coincided with *Eyrytemora* spp (zooplankton) migration for feeding (Sedov, and Rychagova, 1983). previous studies on the fishery structure and population biology parameters of anchovy kilka in Iranian waters were performed by hydroacoustic method in Iranian waters during 1994-1996 , that were contered on distribution , stock assessment and biology (Fazli and Besharat, 1998; Poorgholam et al., 1996) of these fish. The another study on anchovy kilka were allocated to estimation population ecological parameters in Iranian waters (Fazli et al., 2007) and in Azerbaijan waters (Mamedov, 2006) during 1995-2004. Despite of the economic and ecological importance of anchovy kilka as one of the major commercial species in the Caspian Sea, insufficient information is available about the fishery and population dynamics of this fish in Iranian waters. In addition to, comb jelly *Mnemiopsis leidyi* which appeared in 1999, had already severely damage impact and ecological changes on the pelagic ecosystem, particularly the trophic chain in the central and southern Caspian Sea (Mamedov, 2006).

The aim of this study was statement catch and biological characteristics changes, including the length and age structure, growth parameters, natural and fishing mortality and prepared the way for impressive management and permanent exploitation of Anchovy kilka in the Iranian waters.

Materials and methods

Kilka fishing vessel used to survey the resource along the coast of Iranian waters in the Caspian Sea from 2005 to 2007. Kilka catch were made at night in the traditional commercial method, using a funnel lift net mobilized with 1500 w underwater electric lights to attract the fish (Fazli et al., 2007). Sampling was carried out at 3 stations along the coast at depth of Kilka fishing vessel used to survey the resource along the coast of Iranian waters in the Caspian Sea from 2005 to 2007. Kilka catch were made at night in the traditional commercial method, using a funnel lift net mobilized with 1500 w underwater electric lights to attract the fish (Fazli et al., 2007). Sampling was carried out at 3 stations along the coast at depth of

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ranging 30-100 m, including Babolsar and Amirabad (Mazandaran province) and Anzali (Guilan province) harbors (Fig.1). After transferring the specimens to the laboratory, 200 specimens of anchovy kilka were randomly selected every each 10 days and then biological parameter including fork length, weight, age and sexuality were studied (Table 1). The sample initially classification to 5 mm fork length interval, then weight was measured using a scale digital to the gram. Three otoliths (lapillus, asteriscus and sagitta) present in the inner ear of fishes, the sagittal otolith is used for age determination of some fishes. It is composed of a number of concentric shells or ring with different radii. Deoending on the amount of organic material in each shell ring or zone, its appearance varies from extremely opaque to completely transparent or translucent (hyaline). Sagital otoliths were put in the glycerin solution for 24 hours and then observed with black background under reflected light through a stereo-microscope (Fazli et al., 2007). Generally the opaque zone is formed during summer and the hyaline zone during winter, and one opaque zone and one hyaline zone together constitute one-year growth of the fish (Vivekanandan, 2005) (Fig. 2). The catch per unit of effort (CPUE), was calculated as the catch of a vessel per night or VN (Sparre and Venema, 1992). The Length –weight relationship and condition factor (CF) were estimated by following equations (Bagenal, 1978):

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

Where W is the total weight (g), L is the fork length (mm), a is constant and b is the slop of length –weight relationship.

The Von Bertalanffy growth curve was fitted to size at age data (male and female) using FISAT package the formulation of the growth in length curve is by following equation:

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

where L_t is the fork length at age t, L_∞ is maximum asymptotic length attainable and K is a the curvature parameter and t_0 is the age at which fish would have had length zero (Sparre and Venema, 1992). Along with standard Von Bertalanffy growth equation, the index of Pauly and Munro (1984) was used to investigation the annual growth (Φ) dynamics of the resource.

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

Table 1: Biological material analysed in this study

Parameter	Number
Length	3114
Weight	3114
Age	283
Condition factor	3114
Sex	3114

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Survival rate (S) was calculated using the Chapman and Robson method to estimate terminal fishing mortalities (Chapman and Robson, 1960). The instantaneous coefficient of total mortality (Z) was transformed from the survival rate as:

$$Z = -\ln S$$

The estimated natural mortality with the empirical formula of Pauly (1980):

$$M = 0.8\exp(0.279 - 0.0152 - LnL\infty 0.6543 + LnK\ 1.463 + LnT)$$

where M is the rate of natural mortality and T is the average annual water temperature of the Caspian Sea (17.5- 18 ° C).

The exploitation ratio (E) estimated by:

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

Age at first captur (t_c) and length at first capture (L_c) were calculated by using linearised length – converted catch curve method (pauly, 1984).

Results

Catch, CPUE and relative abundance

The overall of relative abundance anchovy Kilka trend considerable decreased during the past three years so that the abundance were 18.8, 8.5 and 6 percent in 2005, 2006 and 2007, respectively (Fig. 3). The catch of anchovy Kilka declined from about 4250 tonnes in 2005 to 1896 and 924 tonnes in 2006 and 2007, respectively. In addition, the CPUE (catch per unit effort) had fluctuation and dropped from 0.3 in 2005 to 0.1 tonnes/VN during 2006 – 2007, at the same period (Fig. 4).

Growth parameter

During surveys along the coast of Iranian waters, the fork length and weight range of anchovy kilka were between 85 to145 mm and 3.3 to19.2g with averaged 116.8±5.5 mm and 10.7±1.5g, respectively (Table 2). The fork length and weight mean females and males observe separately (Table 3). Average size of fish has been significant differenced (either females or males) in 2005-2007.

Table 2: Annually fluctuations of average for fork length (mm), weight (g) of Clupeonella engrauliformes of the Caspian Sea during 2005-2007

		Fork length (mm)		Weight (g)		Reference
Year	N	Mean±SD	Min-Max	Mean±SD	Min- Max	
2005	1377	113.2±38.7	85-130	10.0±1.2	3.3-18.6	Present study
2006	1264	118±5.90	85-150	11.0±1.7	5.3-26.4	
2007	473	120.9±5.7	100-145	11.3±1.3	7.1-19.2	
Total	3114	116.8±5.5	85-145	10.7±1.5	3.3-19.3	

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Table 3: The average fork length (mm), weight (g) for female and male *Clupeonella engrauliformes* of the Caspian Sea during 2005-2007

		Fork length ± SD		Weight ± SD	
Year	N	Females	Males	Females	Males
2005	1377	115.5±5.1	110 ± 4.5	10.3±1.4	9.8 ± 1
2006	1264	119±5.9	115.7±5.6	11.3±1.8	10.6±1.4
2007	473	121.8±5.4	116.4±4.9	11.5±1.3	10.3 ±1

More than 86% of the catch was of fish 107-118 mm in 2005, 86% of the catch 112-123 mm in 2006 and 93.1% of the catch 112-128 mm in 2007. The Length distribution peak changed to right side and juvenile fishes gradually decreased or have been neglected (Fig. 5). The males caught were slightly smaller than females.

$W = 0.000163L^{2.382}$ Length – weight relationships for anchovy kilka was (R^2=0.86, N=3138)

Analysis of the age composition reveals that anchovy kilka were from 2 - 7 years old in the commercial catch the period 2005 – 2007 (Table 4), but the bulk of the catch was 4-5 years old (87.8%) in 2005, 4-6 years old (85.4%) in 2006 and 4-6 years old (87.7%) in 2007 and increased the frequency 6 years old .There aren't below 2 years old at all (Fig. 6).

Table 4: Mean Fork length and weigh at age of Kilka anchovy in 2005-2007

Age	7	6	5	4	3	2
FL(mm)±SD	124.8±7.2	121.3±6	116.7±5.2	111.4±4.8	100.3±9.5	90±7
W(g)	12.4	11.7	11.2	10.2	7.7	7.4

The Von Bertalanffy growth parameters K, L_∞ and t_0 were calculated 0.375/year,131.7 mm and -1.243/year, respectively (Fig. 7).

$$L_t = 131.7(1 - e^{-0.375(t+1.243)})$$

The growth performance index (Φ) of anchovy kilka calculated 3.814. The instantaneous coefficient of total mortality (Z) based on catch curve was 1.year^{-1}. The natural mortality using with catch curve and the empirical formula of Pauly and fishing mortality were 0.49/year and 0.51/year, respectively. The annual survival rates (S) of anchovy kilka was 0.36/year. The Exploitation ratio (E) was calculated as 0.51. The age at first capture (t_c) of anchovy kilka was calculated 3.289 years. The juvenile fish are not fully exploited or not fully recruited, it is usually necessary to discard the left hand side of the curve (Fig. 8). The result of the regression analysis is:

$$\ln(N / \Delta t) = 10.217 - t$$

The result of the regression analysis is shown that the first length group (the length at first capture) under full exploitation is between 105-110 mm (105 mm).The condition factor of anchovy kilka decreased from 2005 to 2007. There is a Significant different among the years from 2005 to 2007 (P= 0.0001).

Overall the sex ratios (male to female) was 1.34:1 and significantly different (χ^2=34.2, P = 0.001); 2:1(χ^2=157.4, P=0.001) and 4.9:1 (χ^2=209.8, P=0.001) in 2005, 2006 and 2007 respectively. The females were dominated (Table 5).

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Table 5: Annual variation in sex ratio for anchovy kilka the Iranian waters of the Caspian Sea

P	χ^2	df	Female:Male	Total(N)	Male(N)	Female (N)	Year
0.001	034.2	1	1.40:1	1377	580	797	2005
0.001	157.4	1	2.10:1	1264	409	855	2006
0.001	209.8	1	5.00:1	473	79	394	2007

Discussion

Anchovy Kilka was commonly the most abundant fish species in the Caspian Sea, approximately 80-90% of the total catch of Kilka (Sedov and Rychagova, 1983; Fazli and Besharat, 1988). The level of the Caspian Sea has risen, following the generally distribution of the three kilka species has clearly changed from what it was some years ago (Prikhod ko, 1975). As a result, situation undesirable for anchovy kilka (Sedov et al..1998). This could be due to the main part of the population Anchovy kilka is restricted to waters with salinity between 10~12% (Prikhod ko, 1981).

The important commercial species, anchovy Kilka, is apparently unable to recruitment regeneration in 2001, when 10-40% of the stock died due to a natural event (Tarasov, 2001). According to Katunin et al. (2002), Erartquak, hydrovolcanic events and gas blowout the local Absheron led to hydrogen sulphid and methane rose from the depths and depositein their intestine and tissue and this probably result to mortality in 2001. Since Anchovy has different migration (from the south to the central) and on the contrary (Sedov and Rychagova, 1983), it can effect on stock Anchovy kilka in Iranian waters.

In the Mamedove (2006) study, the exploitation ratio was calculated of 0.69 for Anchovy Kilka in Azerbaijan coastal. During years 1998-2004, the exploitation ratio of anchovy Kilka varied between 0.562-0.803 (Fazli et al., 2007). In most instances, this fishing ratio was proven to be high, and not sustainable. In the present study, the exploitation ratio obtained 0.51. This ratio is higher than the 0.4 suggested by Patterson (1992) as fishing rate satisfying optimal of stock or maximum harvest. So, the Anchovy kilka stocks have been overfishing and damaged severely.

As Gasturin et al. (2005) reported a decreased trend catch, although they did not describe their assessment method, the catch of kilka in the central and south Caspian Sea dropped from 4384 number per effort in 2000 to 598 number in 2004. Between 2000 and 2004 years, the catch of Azerbaijan alone decreased from, 18500 tonnes to 5100 tonnes (Mamedov, 2006). The catch and CPUE of anchovy Kilka showed a decreased process in 2006 in comparison with the previous years which is mainly due to overfishing and natural factors, thus, the stock showed a drcreasing trend in the population (Fazli et al., 2002, 2003,2004, 2006; Karimzadeh et al., 2010). Our analyses show similar trend, the abundant of anchovy decreased from 18.8% in 2005 to 6% in 2007 (Fig. 3). The annual catches of anchovy Kilka decreased sharply from 67500 tonnes in

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1999 to 5200 tonnes in 2004 (Fazli et al., 2007) and then it declined 924 tonnes in 2007 (Fig. 4). The CPUE of anchovy Kilka decreased sharply from 3.1 in 1999 to 0.4 tonnes per VN (vessel × night) in 2004 (Fazli et al., 2007) and then it declined 0.1 tonnes in 2007 (Fig. 4).

During surveys along the coastal of Azerbaijan (1995-2004), the length of anchovy Kilka ranged 63-130 mm, with an average of 100 mm and weight between 3-16g, with an average 7.4g (Mamedov, 2006). In contrast, Fazli et al. (2007) reported, the length of anchovy Kilka ranged 40-140 mm, with an average 94 mm and weight between 0.4-18.4g, with an average 5.7g in Iranian waters of the Caspian Sea. According to Gasturin et al.(2004), the length ,weight and age mean increased in Central and South Caspian Sea during 1996-2004 as length mean from 86 mm to 102 mm , weight mean from 5.7g to 9 g . Our results showed that, the mean of length and weight increased. The length of anchovy Kilka ranged 85-145 mm, with an average 116.8 mm and weight between 3.3 - 26.4 with an average 10.7g. Age structure also similar trend to fork length of the species were found. According to Fazli et al. (2007), the composition age of anchovy Kilka showed seven age groups from 1–7 years in 1995-2004. Our analysis of age composition showed six age group from 2-7 years and aren't below 2 years old at all. This could be due to reduced stock rehabilitation Anchovy kilka. The past few years, the catch of anchovy kilka no juveniles (0.2-0.6%) due to unable recruitment and also decrease average rate of capture of 1900 fish to just 20 anchovy kilka per funnel lift net in 2004 (Sedov et al., 2004).

At the present study, estimation of the L_∞ and K values of anchovy Kilka were smaller than those reported (Mamedov, 2006 and Fazli et al., 2007), to be diminished length group (>131mm) might be overfishing during years ago but K values also in conformity with the earlier (Table 6).

Table 6: Parameter growth of Anchovy Kilka in the Caspian Sea

Area	L_∞	K	t_0	References
Caspian Sea (Iranian waters)	134	0.324	-0.757	Fazli, 1998
Caspian Sea (Azerbaijan waters)	140	0.159	3.387-	Mamedov, 2006
Caspian Sea (Iranian waters)	148	0.238	-1.340	Fazli et al., 2007
Caspian Sea (Iranian waters)	131	0.375	-1.243	Present study

A wide variation in the observed growth parameter estimates such as incorrect former estimates, varying environmental condition and high correlation between L∞ and K (Niamaimandi et al., 2008). The growth fish to influence outer and inner factor and it varied in different environments. The most important outer causes contained temperature, food availability and population densities (Royce, 1984). Mean condition factor of anchovy declined to its lowest level in 1998 and 2001 in Iran and Azerbaijan coastal respectively, but increased specially from 2002 again (Mamedov, 2006 and Fazli et al., 2007; Parafkandeh Haghihi & Kaymaram, 2012). The present study, we found out condition dropped from 2005 to 2007. These changes take placed coincide to the ctenophore

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Mnemiopsis leidyi bloom in the Caspian Sea. In the late 1990s, *M. leidyi* was transported into the Caspian Sea possibly with ballast water from Black Sea and spread throughout the Caspian Sea within a few years (Kideys et al., 2005). *M. leidyi* is a greatly reproduction comb jelly feeding severely on zooplankton. The diet of *M.leidyi* in the southwestern Caspian includes cladoceras(*Polyphemus exiguus and Pleopis polyphemoides*), copepods (*Calanipeda aquae dulcis, Eurytemora grimmi,E. minor, Halicyclops sarsi, Acartia tonsa*), Bivalve, Crab, and Balanus larvae. *Eurytemora, A. tonsa*, and Bivalve larvae dominate the food, the other species accounting for some 11% of the total (Kasymov, 2001). Following the *M. leidyi* expansion into the Caspian Sea in 2000, food items such as *E. grimmi* and *E. minor*, the favoured prey of kilka, virtually disappeared (Tinenkova and Petrenko, 2004). On the other hand, the dominant zooplankton species of the diet of anchovy kilka is *E. grimmi* (>70 % annuall) (Prikhod'ko, 1975 and Sedove and Paritsky, 2001). Therefore, feeding competitive *M. leidyi* caused shortage food of Anchovy.

As a result, two causes are important for reduction and collapse population of *C. engrauliformes* in the Caspian Sea consist of appearance of *M.leidyi* and overfishing. It can be recommended that fishing effort and number of vessels reduce in the southern Caspian Sea.

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