Research Article

Risk of stock extinction in two species of kilkas (Clupeonella engrauliformis and C. grimmi) from the Caspian Sea

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Abstract: The present study aimed to update and describe the current stock status and to provide quantitative methods for assessing vulnerability extinction of two main pelagic species i.e. Clupeonella engrauliformis and C. grimmi in Iranian waters of the Caspian Sea during 1995-2017. The biomass of C. engrauliformis and C. grimmi were collapsed from more than 180,000 and 47,000 mt in 1996 to 520 and 448 mt in 2017, respectively. The proportional rate of population mature biomass of C. engrauliformis and C. grimmi were declined from about 105,000 and 32,000 mt in 1998 to less than 490 and 440 mt in 2017, respectively. The generation length of both species was estimated five years. Base on IUCN criterion A, the proportional rates of population mature biomass of both kilka species show an exponential reduction and are Critically Endangered. The stocks of two kilka species are being shared among all bordering countries of the Caspian Sea. Therefore, it is suggested a coordinated regional effort between surrounding countries of the Caspian Sea to perform a proper management of kilka fishes’ resources.

Keywords: Catch, Biomass, Stock extinction, Anchovy kilka, Bigeye kilka, Caspian Sea.

Introduction

Three small pelagic fish species of the genus Clupeonella including common kilka (C. caspia Svetovidov 1941), anchovy kilka (C. engrauliformis, Bordin 1904), and bigeye kilka (C. grimmi Kessler, 1877) are found in Iranian waters of the Caspian Sea (Fazli et al. 2007; Amiri et al. 2017a, b; Esmaeili et al. 2018). Mamedov (2006) and Karimzadeh et al. (2010) described that these small fishes are as integral part of the food chain and important indices in ecological health of the sea basin. In year 1970, annual catch of kilka was about 423 thousand mt, accounting for about 70% of the total fish catch in the Caspian Sea (Ivanov 2000).

Prikhod’ko (1981) explained that anchovy and bigeye kilka are endemic and stenohaline species concentrating in the central and southern Caspian Sea. Bigeye kilka tolerates salinity and temperature changes less than two others. In contrast, common kilka is a euryhaline and Ponto-Caspian endemic which inhabits the Black Sea, the Sea of Azov, and the Caspian Sea (CABI 2019).

Over the past three decades, various environmental, biological and anthropogenic factors have significantly affected the environment of the Caspian Sea (Salmanov 1999; Ivanov 2000; Ganjian et al. 2010; Roohi et al. 2010), particularly entering an exotic species, Mnemiopsis leidyi, first reported in 1999 (Ivanov et al., 2000). Due to this invasion, the kilka stocks declined and communities, habitats, and ecosystem functioning of the Caspian Sea shifted into an unusual condition (Pourang et al. 2016). Anchovy and bigeye kilka comprise about 80-88 percent and more than 10 percent of the total kilka catch in...
Iranian waters of the Caspian Sea, respectively (Fazli et al. 2009). According to Janbaz (2018), due to *M. leidyi*, the catch of anchovy and bigeye kilka collapsed less than 2 percent and in contrast, common kilka comprised about 98 percent of total kilka catch in 2017. D’Elia & McCarthy (2010) described that to evaluate the migration impacts and prevent the loss of biodiversity, understanding species vulnerability to extinction is a major goal of conservation biology. Therefore, the central objectives of this study were: (1) to update and describe the current stock status, and (2) to provide quantitative methods for assessing vulnerability extinction of two main kilka species (anchovy and bigeye kilka) in Iranian waters of the Caspian Sea during 1995-2017.

**Materials and Methods**

Sampling areas for kilka were located in the fishing grounds of the Iranian two provinces of Mazandaran and Guilan. Total catches of kilkas by each vessel were collected by the Iranian Fisheries Organization (Mazandaran and Guilan branches) during the years of 1995-2017 are used as input data in this study. The catch data of three kilka species is shown in Figure 1.

The population biological parameters and instantaneous coefficient of natural mortality estimated were used based on Fazli et al. (2007, 2009) (Table 1). To estimate catch-at-age, age compositions were derived from length composition data collected from the conical lift net during 1995-2017, and age-length key in Iranian waters were used as input data (Fazli et al. 2007, 2009; Janbaz 2018). The instantaneous coefficient of fishing terminal mortality \((F_t)\) was calculated as:

\[
F_t = Z - M
\]

Where \(Z\) is the total mortality and \(M\) = the natural mortality. A biomass-based cohort analysis (Zhang & Sullivan 1988) was used to estimate biomass and instantaneous fishing mortality at age and by year according to the following model equations, assuming that catch is taken instantaneously at mid-year.

To assess the extinction risk of anchovy and bigeye kilka, the IUCN Red List categories and criteria were applied (IUCN 2017). There are nine IUCN Red List categories: Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD) and Not Evaluated (NE). Species are classed as threatened if they fall within the categories CR, EN or VU. To classify as threatened, there are

**Table 1.** Parameter estimates used in stock biomass analysis for anchovy and bigeye kilka in the Caspian Sea.

<table>
<thead>
<tr>
<th>Species</th>
<th>K (yr(^{-1}))</th>
<th>L(_\infty) (mm)</th>
<th>t(_0) (yr)</th>
<th>a</th>
<th>b</th>
<th>M (yr(^{-1}))</th>
<th>Z (yr(^{-1}))</th>
<th>reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchovy</td>
<td>0.238</td>
<td>148</td>
<td>-1.34</td>
<td>1.2\times10(^{-4})</td>
<td>2.868</td>
<td>0.473</td>
<td>1.14</td>
<td>Fazli et al. (2007)</td>
</tr>
<tr>
<td>Bigeye</td>
<td>0.280</td>
<td>144</td>
<td>-1.39</td>
<td>8.3\times10(^{-6})</td>
<td>2.894</td>
<td>0.460</td>
<td>1.21</td>
<td>Fazli et al. (2009)</td>
</tr>
</tbody>
</table>
five quantitative criteria (A–E) related to population reduction (criterion A), geographic range (criterion B), population size and decline (criterion C), very small or restricted population (criterion D), and probability of extinction (criterion E) which, in the present study, criteria A is examined for both kilka species.

In marine fish species, the reproductive potential is closely related to body size. As biomass is 'an index of abundance' (IUCN 2017); therefore, the biomass of mature individuals was used to apply criterion A. The proportions of the mature female of anchovy kilka are 0.04, 0.52 and 0.80 for ages 1, 2 and 3, respectively, while for bigeye kilka are 0.03, 0.36, 0.90 and 1.00, respectively. Age 4 was the age of full maturity of both species (Fazli et al. 2007). The proportional rate of population mature biomass declines \((\text{Reduction} = R)\) was calculated as:

\[
R = 1 - \left(\frac{OB}{OP}\right)^{3g}
\]

Where OB is the ratio of the second biomass of mature individuals to the first biomass of mature individuals, \(OB\) is the ratio of the second biomass of mature individuals to the first biomass of mature individuals, \(OB\) is the ratio of the second biomass of mature individuals to the first biomass of mature individuals, \(OP\) is the number of years between the first and last observations years, and \(g\) is generation length. The generation length (the average age of parents of the current cohort) was calculated according to the following equations:

\[
G = \sum x l_x m_x / \sum l_x m_x
\]

Where the summations are from age \((x)\) 0 to the last age of reproduction, \(m_x\) is (proportional to) the fecundity at age \(x\), and \(l_x\) is survivorship up to age \(x\); and (IUCN, 2017):

\[
G = \frac{1}{AM} + AFC
\]

Where the \(AM\) is adult mortality = \(M\) and \(AFC\) is the age at first reproduction, \(AFC = 2\) years for both species (Fazli et al. 2007, 2009). The Excel 2013 software was used to estimate biomass, instantaneous fishing mortality, generation length, and stock reduction.
Results
The total biomass of anchovy kilka ranged from ~170000 to 185000 mt during 1995-1998, decreasing rapidly to less than 11000 mt in 2007, and then declined to 520 mt in 2017. In this period, the average biomass of ages 1-3 represented the highest proportion of total biomass at 83.1%. In contrast, the average biomass of ages 5-7 comprised more than 84.5% of total biomass in the last three years (Fig. 2). The proportional rate of population mature biomass of anchovy kilka collapsed from about 105000 mt to less than 490 mt in 2017.

Similar to anchovy kilka, the biomass of bigeye kilka varied between about 36000-52000 mt during 1995-1998, reaching its minimum of ~3700 mt in 2002, then deceased to the lowest level in 2017 (448 mt). In the years 1995-1998, the average biomass of ages 1-3 was 86%, and in the last three years, the average biomass of ages 5-7 comprised more than 85% of total biomass (Fig. 3). The proportional rate of population mature biomass of bigeye kilka declined from about 32000 mt in 1998 to less than 440 mt in 2017.

The generation length of both species (anchovy and bigeye kilka) using the average age of parents was estimated 5 years whereas using adult mortality and age at first reproduction was 4 years. Based on IUCN criterion A, during 1998-2017, the proportional rate of population mature biomass of both kilka species showed an exponential reduction (Figs. 4-5; Table 2). Under criterion A1, A2, A3 and A4, the reduction rate was more than 96% indicated both species are Critically Endangered (Table 2).

Discussion
Ball & Rao (1984) stated that the main purposes of catch and biology studies are to recognize the human and natural effective factors on fish population for their profitableness continuity in a long period. Moreover, earlier publications (Daskalov & Mamedov 2007; Fazli et al. 2007, 2009; Karimzadeh et al. 2010; Roohi et al. 2010; Pourang et al. 2016) showed that catch, CPUE, and biomass of bigeye and anchovy kilka dropped to their lowest level since 2002 and 2007, respectively. In contrast, the results showed that the relative abundance, catch, CPUE and biomass of common kilka have increasing trends during the last two decades and its habitat changed to deeper depths. Fazli (2011), on the other hand, reported that in pre-invasion period (1997-1999),
common kilka was often observed in spring and summer, and bigeye kilka was frequently recorded in autumn and winter, predominated in February-March and anchovy kilka predominated during other months. In the post-invasion period (2001-2009), common kilka had a higher frequency during the whole year and dominated catches. During the last decade, this species comprised more than 95% in all months (Janbaz 2018). During 1995-1998, anchovy and bigeye kilka stocks showed an average biomass of ages 1-3 (more than 83%), whereas, in the last three years, these stocks showed an average biomass of ages 5-7, comprising more than 84% of total biomass, confirming that the population of both species are getting too old.

According to Nasrollahzadeh et al. (2012), the

Fig.4. The population mature biomass and exponential reduction of anchovy kilka in Iranian waters of the Caspian Sea during 1995-2017.

Fig.5. The population mature biomass and exponential reduction of bigeye kilka in Iranian waters of the Caspian Sea during 1995-2017.
southern Caspian Sea is more suitable for the growth and reproduction of the comb jelly compared to the north and central areas. Previous studies showed that the *M. leidy* caused variations in nutrients, transparency, pH, dissolved oxygen (Nasrollahzadeh et al. 2008), as well as TOM in the Caspian Sea (Roohi et al. 2010). Also, Pourang et al. (2016), by assessing the *M. leidy* impacts on the Caspian Sea ecosystem using the biopollution level (BPL) index, showed that this species impacts on native species, communities, habitats and ecosystem functioning. The BPL for the years 2001-2010 was relatively stable at the greatest impact level. Also, the effects of the ctenophore on habitat increased gradually from no impact (H0) in 2001 to the massive level (H4) in 2006. Therefore, due to the pelagic fish habitats severely damaged, the catch and biomass of anchovy and big-eye kilka did not recover and declined to the lowest level in 2017.

Kilka species are the main food items for top predators (sturgeons and seal) in the Caspian Sea (Prikhod’ko 1979). These predators consumed about 590,000 mt of the three kilka species (Badalov 1972). Before the expansion of the ctenophore (year 2001), the abundance and diversity of the zooplankton species were relatively high and three species of Kilka fish fed them (Pourang et al. 2016). During the expansion period (2002-2009), due to food competition of two species of kilka i.e. anchovy and bigeye with *M. leidy*, their stocks decreased sharply. Tavakoli et al. (2019) concluded that one of the reasons for sturgeon stocks reduction is related to ecosystem change and reduction of food resources (kilka species stocks) in the Caspian Sea.

Kiabi et al. (1999) classified 65 native taxa fish species under IUCN Red List Categories based on data collected in the south Caspian Sea basin of Iran. They reported that four anadromous taxa are critically endangered due to overfishing, deterioration of their spawning grounds, and restricted habitat. They also showed that 24 taxa including three kilka species are in the category of least concern. We found that the two main kilka species (anchovy and bigeye kilka) are critically endangered. Moreover, it is also evident that most commercial endemic and native fish species such as anchovy and bigeye kilka, five species of sturgeons (CITES & UNEP 2017), except Caspian kutum (*Rutilus kutum*) are vulnerable or critically endangered in Iranian waters of the Caspian Sea. Abdolhay et al. (2011) suggested that the landings of Caspian kutum had increased during the last three decades due to the stock enhancement program, consistent with those results reported by Fazli et al. (2012). In this period, they found a significant correlation between released fingerlings and recruitments of Caspian kutum in Iranian waters of the Caspian Sea. Most of the commercial fish species, especially stocks of anchovy and bigeye kilka shared among all bordering countries of the Caspian Sea. Therefore, a coordinated regional effort between border countries of the Caspian Sea is required for wise management of fish resources and invader species of the ecosystem.

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**References**


مقاله پژوهشی
خطر انقراض دو گونه از کیلکا ماهیان (C. grimmi و Clupeonella engrauliformis) در دریای خزر
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چکیده: هدف از این مطالعه بررسی و توصیف وضع فعلی ذخایر و ارائه روش‌های کمی برای ارزیابی خطر انقراض دو گونه ماهی پلاژیک Clupeonella grisomi و C. grimmi می‌باشد. در سال‌های 1374 تا 1396 هیأت حاکمیت و توانمندی در سواحل ایرانی دریای خزر می‌باشد. میزان ذخایر این دو گونه بحرانی بوده و کاهش یافته‌اند. در سال 1375 به سال 1376 میزان ذخایر این دو گونه در اندازه‌هایی بین 100000 و 32000 تن در سال 1375 به 500 و 400 تن در سال 1376 کاهش یافته‌است.

کلمات کلیدی: صید، انقراض، ذخایر، کیلکا آنجویی، کیلکا معمولی، دریای خزر.